CHALMERS

Development of a Future Hood Concept Facilitating Daily Maintenance and Increased Perceived Quality

Master of Science Thesis

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Abstract

The hood of a car today gives the impression of being a simple solution. With increased complexity on hinges and lock mechanisms, the hood opening mechanism is not that simple. Opening and closing the hood also demands a gap between the hood and the body wide enough to avoid clash. These aspects lead to issues in achieving good looking lines between the surface components, and therefore issues regarding the perceived quality of the car. With more complicated technology as electronics and Xenon lights, the degree of which customers can perform service themselves decrease for every car model that is released. Soon the complexity in the engine room might be so high that there is no need to open the engine hood.

This master thesis is conducted at the attribute of Perceived Quality at Volvo Car Corporation. Volvo Cars Corporation is currently putting effort in achieving a name as a premium brand within the automotive industry. An important step is to assure high perceived quality to low cost. It has been identified that one way to grant higher perceived quality for the front part of the car is to develop a hood solution which will not require the traditional hood opening.

This thesis project investigates how a new hood design can be carried out and explores the possibilities to increase the perceived quality concerning the hood. By using proven and recognized product development tools taught at Chalmers University of Technology, a new concept for the hood is developed, in order to obtain higher perceived quality than the current solution and eliminate the need for the customers to open the hood, for daily maintenance. The product development tools and methods are also described and customized to fit this type of development project. The thesis also describes what profits that can be obtained by the new hood solution. By an extensive market research, analyzes have been made regarding how consumers will perceive the new solution, and how the new solution can be of value for Volvo customers. Furthermore this thesis describes the potential for weight and cost reduction. The new hood concept is demonstrated as CAD model in CATIA V5 and also a virtual prototype in Showcase.

The final concept have a hood that open to a service position, primarily facilitating filling of washer fluid and engine oil, but also opens the opportunity for filling of other fluids. From the service position, the hood is able to be removed to give access to the engine room. By using this solution, split-lines between hood and fender can be changed to fit perceived quality's requirements.

Keywords: *Perceived quality, cosmetic quality, craftsmanship, hood, engine room, bonnet, product development.*

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Nomenclature

A2mac1 - Automotive benchmarking website

Allians test - Test performed to set insurance rates

CAD - Computer Aided Design

CATIA V5 - Computer Aided Three-dimensional Interactive Application by Dassault Systemes

Euro-NCAP - European New Car Assessment Programme

Plenum - The section at the back of the engine room

PQ - Perceived Quality

Showcase - 3D presentation software by Autodesk

SUV - Sport Utility Vehicle

TMU - Time Measured Unit

VCC - Volvo Cars Corporation

1. Introduction

This master thesis is conducted at the attribute of Perceived Quality at Volvo Car Corporation. Volvo's new brand strategy, Scandinavian Luxury, aims to put Volvo in the premium segment within the automotive industry. One important step in this direction is to assure high perceived quality to low cost. Developing a new solution for the hood opening has been identified as one way to grant higher perceived quality for the front part of the car.

1.1.Background

In order to refill oil and washer fluid in cars today, it is required to open the hood. Opening the hood also allows fast access to the engine in order to perform controls and repairs. Customers often open the hood when purchasing a car in order to check that everything looks good. This is common even if the customers do not know what to look for and is considered as a part of the overall impression when deciding whether to buy the car or not, *see chapter 4.1.2*.

Opening and closing the hood demands a gap between the hood and the body wide enough to avoid clash. In order for the hood lock to lock in place, the solution needs to be designed to allow the hood to move past its locked position. These aspects lead to issues in achieving good looking split-lines between the surface components, and therefore issues regarding the perceived quality of the car. This calls for advanced and expensive geometry systems in order to calculate and predict the gap and deviation in height between the surface components. In order to reduce these issues, one alternative is to disable the opening function of the hood for consumers. As this would lock the hood and not allow opening and closing. Bump stops preventing the hood from hitting the car body will not be necessary, resulting in improved nominal dimensions and variation of the appearance of the lines between the surface components. In the same time this could reduce the number of parts and therefore reduced weight and cost.

1.2.Purpose

VCC is currently putting effort in achieving a name as a premium brand within the automotive industry. In order to accomplish this, effort needs to be put into assuring high perceived quality for future car models. An issue regarding the perceived quality for the car is the split-lines around the hood, *Figure 1*. The purpose for this thesis project is to investigate how and if a new hood design can increase the perceived quality concerning the hood.

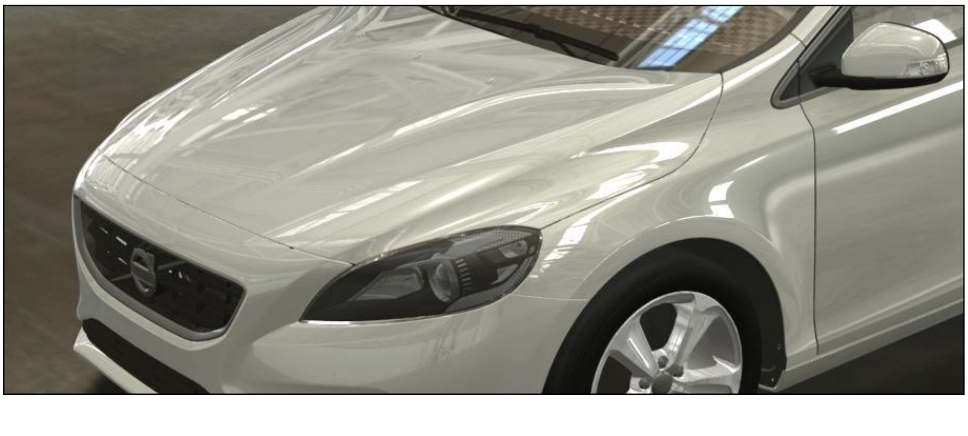


Figure 1: Current split-line.

1.3.Goals

This thesis new concept is focused on designing a new hood solution in order to obtain higher perceived quality. By looking outside of today's standards and traditions, a new solution with higher perceived quality is to be obtained without compromising the quality and reliability. The new hood concept is to be presented as CAD model in CATIA V5 and also a virtual prototype.

Questions to be answered within the thesis project are:

- What profits can be obtained from a new hood concept?
- What will the consumers gain from the concept?
- How will consumers perceive the new hood concept?
- What departments at Volvo can gain from this project?
- How much cost and weight can be reduced?
- How is refilling of fluids solved?
- Are there possibilities to merge parts to eliminate number of parts?

1.4.Limitations

During the initial phase of the master thesis, following limitations were established:

- Parts related to pedestrian safety, *see chapter 2.1.3*, will not be changed during the project although they will be considered in the engineering design of the new hood concept by discussions with the department for pedestrian safety.

- The project is only to focus on the next generation car models, older models will not be evaluated for design changes. However a current model will be used to be able to demonstrate the concept.

- Only one car model will be taken under consideration for concept development and design.

1.5.Volvo Car Corporation

Volvo Car Corporation is a Swedish car manufacturer founded in 1927 in Gothenburg, Sweden. The Volvo cars are known for their safety and reliability. VCC's new brand strategy, Scandinavian luxury, is aiming to put Volvo on the premium car segment. Since 1999, VCC is not a part of Volvo Group. VCC was first bought by Ford in 1999 and in 2010, the Chinese company Zhejiang Geely Holding Group bought VCC. VCC sold 449 255 cars in 2011 which was an increase by 20.3% in comparison to previous year. (Volvo Cars, 2012)

In today's competitive market, car manufacturers are putting in a lot of effort in establishing a brand name standing for high quality and reliability. In order to enter the premium segment in the automotive industry, one of the most important characteristics is having a high perceived quality in the cars.

This master thesis is conducted at the attribute of Perceived Quality at Volvo Car Corporation. The Perceived Quality attribute is in charge of setting up requirements and increasing the perceived quality of products. The attribute consists of four sub attributes: Appearance & Geometrical Quality, Material Quality, Illumination and Paint & Finish. This master thesis was performed in the sub attribute of Appearance & Geometrical Quality. In this sub attribute, requirements are specified regarding geometrical relations between components that are visible for customers. By working with increasing the perceived quality and user friendliness for the next generation Volvo cars, this master thesis aims to further enhance the Scandinavian Luxury profile, which is Volvo's new brand strategy.

2. Theory

This chapter describes the tools and methods used during the product development process. Also important terms and areas for this project are described.

2.1. Automotive theory

The main areas of automotive theory discussed in this report consider perceived quality and pedestrian crash safety.

2.1.1. Perceived quality

There is no overall definition used describing perceived quality, as different branches and organizations all have their own definition of what perceived quality is. Perceived quality is a word used at VCC. Other words commonly used to describe the same attribute are craftsmanship, design or cosmetic quality, (Wagersten et al., 2009). Aspects taken into consideration are most often material, sound, gloss, and feeling when touched. High perceived quality has always been an indication of good craftsmanship thus being a criterion for premium products. Perceived quality is the impression of the quality of a product, it has no direct connection to the real quality of the product, but is rather an impression experienced through the customers senses. In the automotive industry, perceived quality is regarded to have a high connection to the split-lines of the car, (Wagersten, 2011). In order to obtain split-lines which will give the impression of high quality; gap size, flush, parallelism and symmetry of visible split-lines must be controlled. (Wagersten et al., 2011) In this report perceived quality refers to the split-lines of the car.

The aspects of perceived quality that will be mentioned and taken into account in this report are, Over-slam, split-lines, gap and flush.

Over-slam

Over-slam is the movement needed for the lock mechanism to function for the hood, it refers to that the engine hood needs to move past the front in order to lock the engine hood in place.

Split-lines

Split-lines refer to the space between components that are assembled, *see Figure 2*. Often the components are not allowed to have contact with each other in order to fulfill certain functions. An example of this are the doors or engine hood on a car, these must have split-lines wide enough between the different components in order to avoid clash when closing and opening them. (Wagersten, 2011)

Figure 2: Split-line between the hood and the fender.

A lot of car models today have a split-line between the hood and fender that run through a surface that has two curvatures. This split-line that runs over a double-curved surface will be referred as an s-curve, Figure 3.

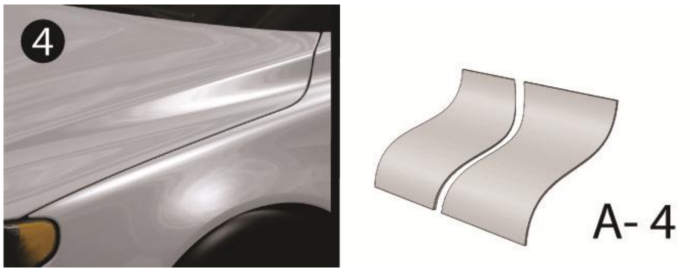


Figure 3: S-curve.

Gap

Gap is the distance between the surfaces, Figure 4. The width of the gap is determined of the space needed in order to assure that the opening and closing function is not compromised. Due to variation that can occur, in production and assembly and required over-slam, the gap size for moving components often need to be wider than for split-lines between nonmoving components. Variation can cause uneven or very large gaps that lower the perceived quality of a car. (Wagersten, 2011)

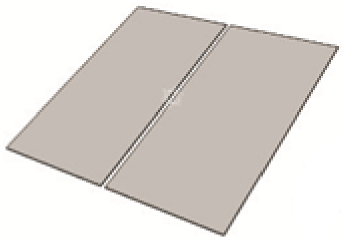


Figure 4: Example of a gap between two surfaces.

Flush

Flush refers to the deviation in height in the split-lines between two components that are assembled. This mainly originates from variation in production, and is more sensitive for double-curved surfaces.

2.1.2. How perceived quality is predicted

In order to define and control split-lines in the early stages of the development process, split-lines are regulated by aesthetical geometrical requirements. These can be for example maximum and minimum gap or flush-size. There are a lot of factors affecting the final appearance of the split-lines, *see Figure 5*. These need to be taken into account when deciding of the split-lines and working for high perceived quality. (Wagersten, 2011)

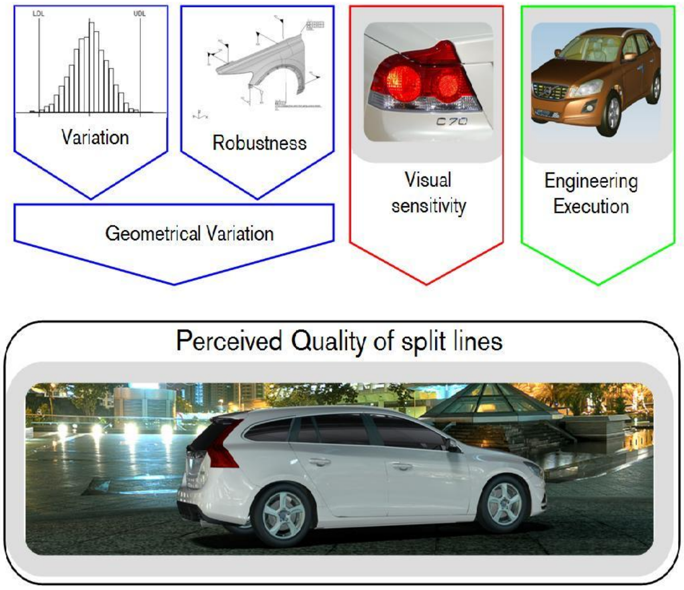


Figure 5: Contributing factors to Perceived Quality of split-lines. (Wickman et al., 2010)

In order to control the perceived quality, measurements of gap and flush are made. These are shown in standard deviation diagrams. Furthermore visualizations are a common way to control the split-lines. This can be done with tolerance management in RD&T in order to simulate the deviation between parts that occur in production and also visualize how it would look in the final product. Evaluation of perceived quality focuses on different objectives. These range from supporting the aesthetical requirements, analyzing detail execution of split-lines by focusing on visible details and also evaluating the visual robustness of a concept. (Wagersten, 2011)

2.1.3. Pedestrian safety

Volvo works actively to keep people safe around their vehicles which include both passive and active safety, intent to protect pedestrians. To try to prevent serious injuries, the bumper, hood, windshield and a-pillars are designed to absorb the collision between the car and pedestrian. When accidents occur, the most fatal impact is when the pedestrian hits the car as opposed to the impact to the ground. (Crandall et al., 2002) The most common injury in moderate accidents is fractures to knees and legs. In severe injuries leading to death, brain damage caused by the impact between head and either engine hood or wind screen represent four out of five cases.

To prevent injuries, different kinds of cars use different safety systems. Higher cars such as SUVs might meet safety regulations without the help of active systems. Smaller, lower cars use active systems to meet safety regulations. Pop-up hoods which make the back of the hood pop up, triggered by sensors in the front, create a softer area for the pedestrians, avoiding direct contact between i.e. engine block and pedestrian body. Active safety systems as airbags hidden in plenum can be used to protect pedestrians from the a-pillars and the wind screen. Also passive safety systems are used such as a softnose, which is the front part of the car, manufactured in a softer material to better absorb the pedestrian body in case of an accident.

2.1.4. Legislations

To receive the highest rating in Euro-NCAP, a cooperation between countries and car manufacturers intent to create a safer traffic environment, the pedestrian safety system needs to meet several test criteria. (Euro-NCAP, 2011) The tests are designed to evaluate impact to the pedestrian's different body parts. *As seen in Figure 6*, adults as well as children have to be taken into consideration. (Crandall et al., 2002) European Union has set a demand that by 2015, all pedestrian involved in an accident with a car moving 40kph or less must survive. (Schwoerer, 2007)

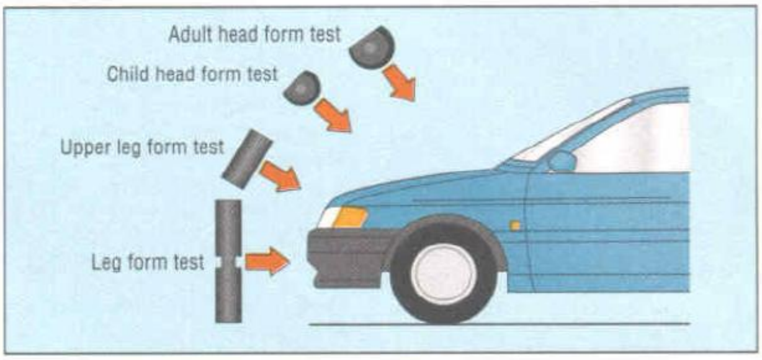


Figure 6: Pedestrian safety tests (Crandall et al., 2002)

2.2. Product development methods

Product development, aims to achieve creativity by using structured methods. This chapter describes the theory about the product development methods used from product planning and market research, to concept generation and selection and final design. The methods used and the order they are used in can be seen in Figure 7.

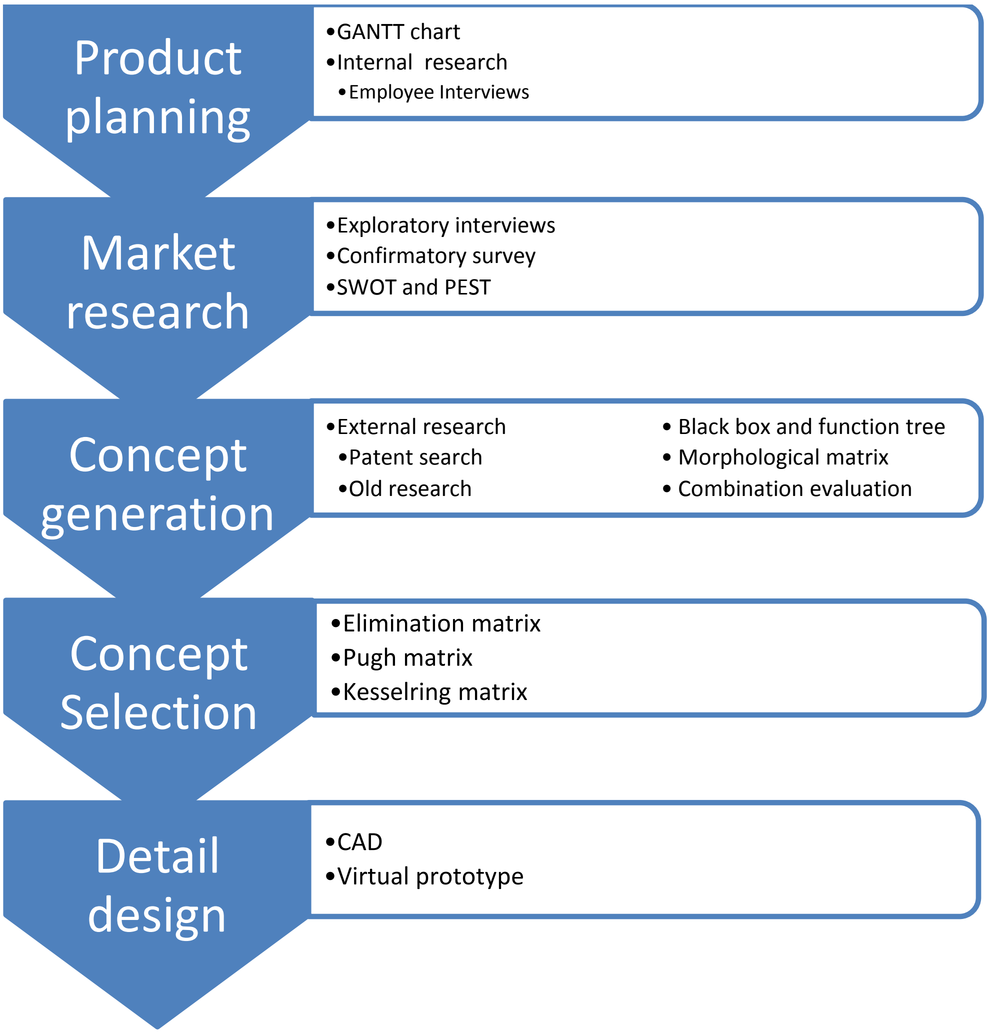


Figure 7: Process steps for product development as described in this master thesis.

2.2.1. SWOT-analysis

To determine the position of a new product in relation to its competitors, a SWOT analysis is commonly used. The analysis is based on four criteria, Strengths, Weaknesses, Opportunities and Threats, (Karlsson, 2010). The first two criteria (strength and weakness) are seen from an internal point of view, the last two (opportunities and threats) are seen from an external point of view. The criteria strength and opportunities are regarded as helpful, weaknesses and threats are regarded as harmful. The SWOT analysis is a good way to categorize the position of a product in an early stage in a project.

2.2.2. PEST-analysis

The PEST analysis is a method used to identify and list the Political, Economic, Social and Technological forces affecting a business, (Karlsson, 2010). The purpose is to support in the search and analysis of the surrounding environment with regards to all four market forces. The pest analysis is used in order to obtain a holistic view of the market at its current state and an attempt to predict future trends regarding the four market forces. The PEST analysis is a complement for the SWOT analysis and is used for further studying the external factors affecting the business and a new potential product.

2.2.3. Surveys and Interviews

Surveys and interviews are question-based data collection methods. Interviews are often carried out in explorative purpose and are used in order to identify customer needs and trends. The focus is on gathering in depth information and explanations by probing and being open and flexible. As a complement, surveys are more commonly used in confirmatory purpose. Surveys focus on gathering information for statistical analysis by comparisons and repetition. (Kvale and Brinkmann, 2009)

Interviews can be, structured, semi-structured and unstructured, (Kvale and Brinkmann, 2009). A structured interview has questions that are formulated and listed in a certain order in advanced. Semi-structured interviews have pre formulated questions in order to assure that certain topics are covered, however the exact formulation and order can vary between different interview sessions. A semi structure interview allows more flexibility and can give a greater depth to the interview. An unstructured interview is more focused on the interviewee, the interviewer has a more passive role during this type of interview. This type of interview is commonly not recommended to be used in a product development purpose. (Kvale and Brinkmann, 2009)

2.2.4. KJ method

The KJ (Kawakita Jiro) method is a tool that is used in order to analyze qualitative data. Statements gathered from interviews and surveys are typically written on post-it notes and put on a wall, (Bergman and Klefsjö, 2001). The first step to take, once all statements are put on the wall, is to remove redundant statements. The second step is to cluster statements regarding the same topic close to each other. The final step is to choose a label that describes all of the needs in the group, each label describes the theme for the related statements. The final result from the KJ-method is used as input for the requirement specification. This will assure that the information from the customer research is used correctly and that no statement of importance is missed when establishing the customer oriented product requirements. (Bergman and Klefsjö, 2001)

2.2.5. Black-box and function tree

In product development, a black-box represents a box working as a transforming function. This creates the effects that transform the input; material, energy, signals or information, to the output demanded. A black box should contain a verb and a noun describing the main transformation function, *see Figure 8* . (Johannesson et al., 2005)

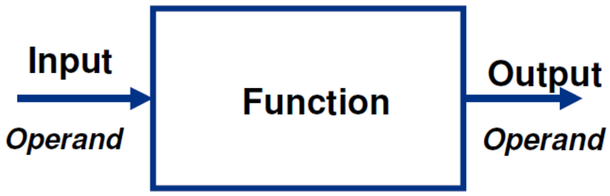


Figure 8: Example of black box (Johannesson, 2011)

After defining the main transformation, the black box is divided into sub functions that describe the different problems to be solved. The deviation of the black box into sub function will build up the function tree. These sub functions need to be solved in order for the product to produce the desired outcome, (Ulrich and Eppinger, 2008). Once this is done, it should be considered if the sub function can be divided into even simpler sub functions, this should be done until all function are simple enough to be easy to handle and solve. The function tree should only contain the functions that need to be solved, and not suggest how a specific function is solved with a technical solution.

2.2.6. Morphological matrix

The morphological matrix is a tool used for systematic concept generation, (Ulrich and Eppinger, 2008). The matrix consists of columns for each sub function that needs to be solved in order to obtain the main function of a product. Each sub-function can have several solutions, these build up the rows of the matrix. By combining one fragment from each column in the matrix, potential solutions for the overall product are generated. The combination of the sub-function solutions does not automatically lead to a complete solution for the product. Each set of combinations need to be further developed and refined before they can be considered as complete product concepts. The refinement can lead to more than one solution for a combination of solutions, (Ulrich and Eppinger, 2008). See Figure 9 for an example of a morphological matrix.

Sub-function	Alternative 1	Alternative 2	Alternative ……	Alternative (n-1)	Alternative n
Heat bread	 Heating system	Sketch + text description	Sketch + text description	Sketch + text description	Sketch + text description
Handle bread	 Load/Eject system	Sketch + text description	Sketch + text description	Sketch + text description	Sketch + text description
Carry parts	 Chassis	Sketch + text description	Sketch + text description	Sketch + text description	Sketch + text description

Figure 9: Example of morphological matrix describing a toaster, (Johannesson, 2011).

2.2.7. Elimination matrix

The elimination matrix is a tool to make a first rough screening of concepts generated in the concept generation phase. The selection is to be based on if the alternatives (Johannesson, 2011):

- Solve the "main problem"
- Fulfill all demands in the requirement specification
- Are compatible/"realizable"
- Have reasonable cost
- Are safe
- Fit into the product portfolio

The alternatives can either, fulfill the criteria, not fulfill the criteria, need more information or need to be checked with the requirement specification. If an alternative fulfill all criteria the alternative can move on to the next stage of the concept screening. If it does not fulfill the criteria it gets removed. In some cases there is not enough information to make a decision, in these situations the decision should be postponed until enough information is gathered in order to make a decision. (Johannesson, 2011)

2.2.8. Pugh matrix

The purpose of the Pugh matrix is to screen out the number of concepts and improve the concepts. This step in the product development process is often referred to as concept screening. When performing this, all concepts need to be portrayed graphically and with supporting text. (Ulrich and Eppinger, 2008) The selection criteria in the Pugh matrix are based on wishes and demands in the requirement specification that assure that the product fulfills more than what is required. (Johannesson et al., 2005) When performing the concept screening, a concept is selected as a reference concept. The other concepts are rated against this concept by evaluating if it fulfills criteria "better than", "same as" or "worse than" the reference concept in the matrix.

Once the rating for each concept has been done for all criteria, the concepts are ranked. After the ranking, the concepts are combined or improved in order to eliminate the "worse than" ratings of a concept. Once this is done the new concepts should be put in the Pugh matrix for a second round. The Pugh matrix should at least be performed twice before moving on to the next step of the development process. (Ulrich and Eppinger, 2008)

2.2.9. Kesselring matrix

The Kesselring matrix, *Figure 10*, is the second phase of the elimination process. This step works similarly to the Pugh matrix. The Kesselring matrix weighs every criterion in order to get a fairer and more exact evaluation of every concept. The method is therefore more time consuming than the Pugh matrix. On the other hand the results reflect a more fair comparison. The Kesselring matrix has the advantage to eliminate unrealizable concepts that the Pugh matrix was not able to, (Ulrich and Eppinger, 2008).

Criterion		Solution alternative									
		Ideal		1		2		3		4	
	w	v	t	v	t	v	t	v	t	v	t
Wish A	2	5	10	2	4	2	4	3	6	2	4
Wish B	4	5	20	3	12	4	16	4	16	2	8
Wish C	5	5	25	2	10	4	20	3	15	3	15
Wish D	3	5	15	3	9	4	12	3	9	1	3
Wish E	1	5	5	3	3	2	2	3	3	3	3
Wish F	4	5	20	2	8	4	16	1	4	3	12
$T = \sum t_j$		95		46		70		53		33	
T/T_{max}		1.00		0.48		0.74		0.56		0.35	
Ranking		-		3		1		2		4	

Figure 10: Example of a Kesselering matrix, (Johannesson, 2011).

Each criterion is given a weight factor to stress the level of importance and every concept is rated with a rating score. The weight factor and the rating score are multiplied and the sum of all products is the score of a concept. The sums of all concepts are then compared to each other to select a winner. The winning concept still has to be verified as a better solution than the current by tests or evaluations, (Ulrich and Eppinger, 2008).

3. Methodology

This chapter describes the methods by which the project has been performed, *see Figure 11*. The methods used are recognized methods in product development and span from product planning and market research to concept generation and complete product and prototype.

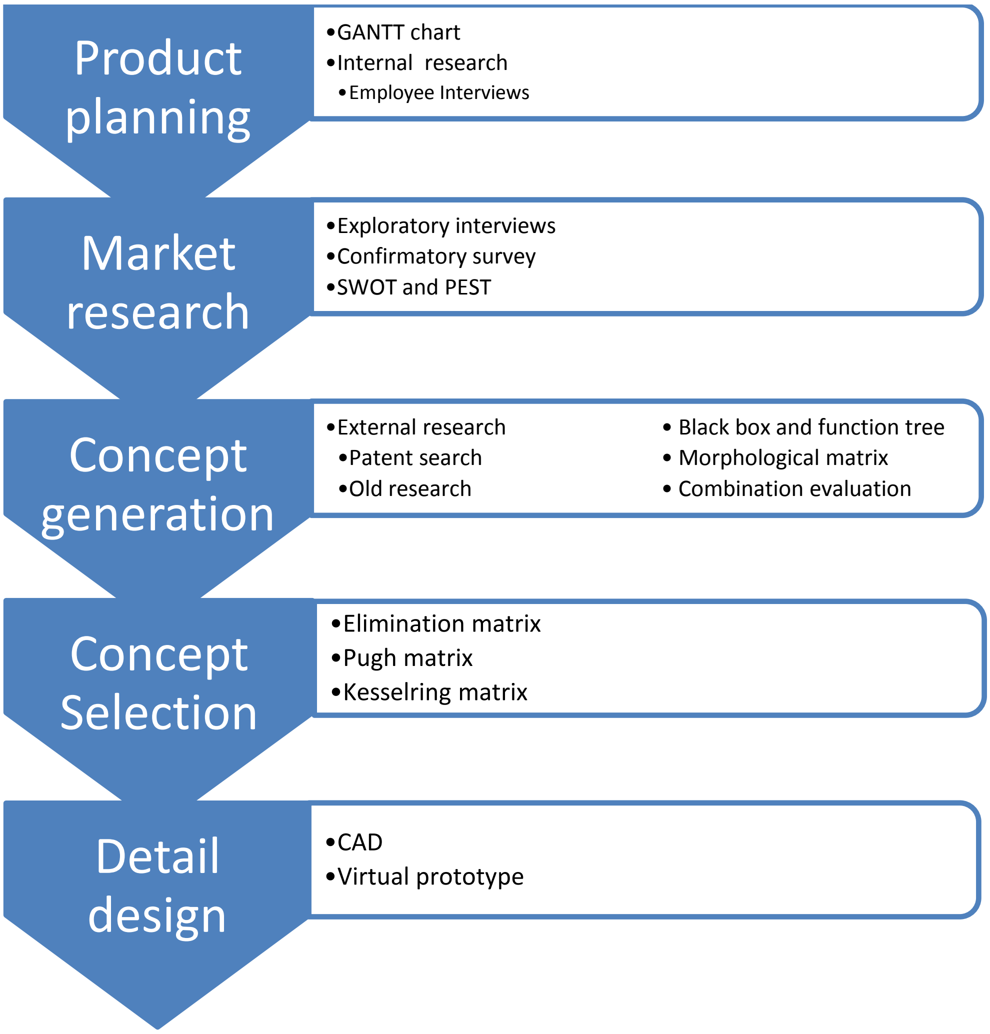


Figure 11: Process steps for product development.

3.1. Product planning and market research

To assure success for the project and reduce the risk for the product development process and the final product, the project started by formulating the strategy for the development process. In order to fully describe and reflect on the vital steps of the development process, a Gantt chart was established, *see appendix A*, describing the different steps of the project and the time in which they were expected to be performed. In order to establish a view of where the new product concept stands on the market a market research was performed, containing a SWOT analysis was supported by a PEST analysis. This was performed by analyzing the internal capabilities and the surrounding market. During this stage, previous projects regarding closing of the hood were studied and discussions with co-workers at VCC were carried out.

3.1.1. SWOT and PEST analysis

In order to identify the new concepts position on the market in beginning of the project, a SWOT analysis was made. It was discovered that opportunities needed further investigation. This was considered an important area in order to achieve a customer oriented new concept.

In order to fully understand the market, a PEST analysis was conducted. This was used as support for the SWOT analysis when deciding how to conduct the customer research and planning of the development process. The complete SWOT and PEST analyses were also used as references when establishing the first requirement specification.

3.1.2. Identifying customer needs

In order to assure a customer oriented final product, research was performed identifying the needs of the customers. Also customer values, past, current and future trends were investigated. This was done by conducting a customer survey where salesmen at retailers for BMW, Audi, Mercedes and Volvo were interviewed using a semi-structure interview form. These brands were chosen in order to obtain answers from and about customers driving cars from the premium brand segment. A total of 13 salesmen were interviewed, the time for each interview ranged from 10 to 20 minutes. In order to broaden the answer base, interviews were also conducted with potential customers. This group consisted of individuals in the ages from 20 to 60 years. These interviews were structured and were performed by telephone or face to face at the automotive retailers mentioned. A total of 10 persons were interviewed. The answers from all interviews were written on paper during the interviews, and later listed and analyzed using the KJ method.

Simultaneously as the interviews were being conducted with potential customers, meetings were held internally at Volvo Cars Corporation. These meetings were conducted with representatives from different departments that were regarded to have a connection to the master thesis project. The departments were: pedestrian safety, ergonomics, painting, engine, engine cover, service and front lights.

Each department contributed with requirements that were important for the project seen from their area of work. The requirements that were considered as crucial requirements for the master thesis project were put into the requirement specification. By using the KJ method, the comments from the interviews were interpreted to requirements, and also they were put into the requirements specification.

When the interviews were finished and knowledge had been built up considering the customer behaviors regarding the engine hood, an internet survey was made. This was done with collaboration with Chalmers University of Technology in Gothenburg Sweden. The survey was distributed by email and was also put up on the internet. In order to cover a broad base of potential customers, different forums were used to distribute the survey. These ranged from social networks to automotive forums and family forums. The targeted countries were Sweden, Germany, Kina and USA. The web pages that the survey link was put up on were:

Facebook (World)
Motor-talk (Germany)
Familjeliv (Sweden)
Garaget (Sweden)

Sweclockers (Sweden)
Zatzy (Sweden)
Xcar (China)

3.2. Concept generation

The concept generation was made in four steps supported by *Product Design and Development* by Karl, T. U & Steven D. E. The first step was to clarify the problem followed by external research. The final steps were to explore systematically and reflect on the solutions.

3.2.1. Clarifying the problem

In order to concept generate systematically, the problem was divided into smaller sub problems. The first step in this was to establish a black box describing the main transformation function. The input for establishing the black box was the knowledge gained from the internal meetings. An understanding around what needed to be solved during the master thesis had at this point been established. Several versions of the black box were made and discussed. However no complete black box was made as discussed in *Product Design and Development* (Ulrich and Eppinger, 2008). When a transformation box was established that described the main function that needed to be solved, it was considered enough to move on with establishing a function tree. Therefore no input or output was defined for the transforming function.

Before starting to divide the black box into a function tree, the Volvo V40 was examined considering hood and engine room. This model was chosen because it is the newest Volvo released on the market. A function tree was established on how this model solves the main transformation function of the black box. This worked as a foundation for establishing the new function tree for the master thesis project. The first step was to rearrange the sub functions in the V40 function tree to fit the project. Once this was done the functions that were considered to be outside of the project were marked with dashed lines to and around the sub functions. The sub functions that were to be solved during the master thesis project were rewritten to be solution independent.

3.2.2. External research

There had not been a project at Volvo Cars Corporation fully exploring the concept of changing the current hood solution. This meant that the internal research that was carried out during the project consisted of knowledge gained from meetings with experts regarding pedestrian safety, ergonomics, painting, engine, engine cover, service and front lights. More effort was then put into external research.

During the external research, the webpage www.a2mac1.com was used in order to search for solutions within the automotive industry. Furthermore furniture manufacturers, airplanes and other heavy machinery were investigated in order to find inspiration for solutions for the sub functions. The external research consisted of searching for solutions for hinges and other opening mechanisms. Also re-filament of fluids into different devices was looked upon.

A patent search was performed to investigate the existing solutions for inspiration, evaluate possible upcoming obstacles and to scan the market for solutions to evaluate newsworthiness.

3.2.3. Generating concepts

When enough information had been gained from the external research, this information was used when generating concepts. These concepts were to solve the sub functions in the function tree. The guidelines during the concept generation were the output from the customer research and the first version of the requirement specification. External research was being conducted during the complete concept generation process as inspiration in order to boost the creative thinking.

Once sufficient amount of solutions had been generated to each sub function, the solutions were reviewed. Solutions that had potential were refined and put into the morphological matrix. Concepts that were impossible to work further with were canceled.

In order to combine the solutions in the morphological matrix systematically, a concept weighting method was used. Every sub function was evaluated on how well they fulfilled the criteria: design, customer service, usability, safety, manufacturing and workshop service by using the requirement specification as guideline. All the combinations were graded according to the following grading system:

Adds great value
Fits well
Does not add value
Conflict

If a solution conflict with another, the combination was canceled and a new combination was chosen. See *appendix F* for examples of solution combinations from the morphological matrix.

The concepts that resulted from the morphological matrix were drawn up as new sketches describing the whole concepts. These were evaluated and discussed regarding if they could be improved and if sufficient amount of different concepts had been generated. When it was considered that enough different concepts had been generated that covered a broad base of different solutions, the concept evaluation and elimination process started.

3.3. Concept evaluation and elimination

The concept evaluation and elimination consisted of three main steps; elimination matrix, Pugh matrix and Kesselring matrix. When conducting the elimination matrix (Figure 30), all concepts that had been generated from the morphological matrix were evaluated individually to check if they fulfilled the criteria's in the elimination matrix. The concepts that did not fulfill the criteria's in the elimination matrix were eliminated. Concepts that needed more information were revised and controlled if they could be improved. The improved versions were then inserted in the elimination matrix for a second evaluation.

The next step in the concept evaluation and elimination process was the Pugh matrix. In this step, 14 concepts were evaluated regarding nine selection criteria. Two iterations were made of the Pugh matrix using two different concepts as datum. The selection criteria used covered the aspects PQ/Design, service and usability, manufacturing and safety. See Figure 31 and Figure 32 for the two versions of the Pugh matrix.

All concepts were graded regarding how well they fulfill the selection criteria compared to the datum concept. If a concept fulfilled the criteria better than the datum it got the grade (+), if it was the same a (0) was given and if it fulfilled the criteria worse than the datum it was given a (-). The score of the concept was obtained by adding all the grades. From this the concepts were ranked, the concepts that got the highest rank were moved on to the next step of the concept elimination process. In order to verify the results from the Pugh matrix, an iteration was made using a different concept as datum. When the Pugh had been iterated twice, the designated concepts moved on to the next step. The concepts that had a similar rank or were very close to each other in the design were considered if they could be merged to one concept. Four concepts made it through the Pugh matrix.

The final four concepts were further worked on in order to refine all to a level where an evaluation could be made by using the Kesselring matrix. In the Kesselring matrix four selection criterions were used for the evaluation. These are PQ/Design, Service and usability, manufacturing and safety, all of the criterions have a number of sub criterions in order to make a more detailed evaluation. See Figure 37 for the results of the Kesselring matrix.

3.4.Final Concept design

When the final concept was chosen the work continued with final design and development. It was decided that the new hood solution would be designed towards the Volvo V40 due to this being the newest Volvo model on the market. The initial step was to decide exactly how the solutions would work and look. Different solutions of new split-lines were discussed. When this was done the solution was drawn up in the CAD program CATIA V5. Changes were made to a design model of the V40 hood and fender. First the old split-line between the hood and fender was merged to one surface, also the split-line between the a-pillar and fender was merged. Once this was done, the new split-lines were made. In order to demonstrate how the concept would work, simple hinges were drawn to illustrate the movement of the hood and also illustrate how the new hinges could look in principle. Also the engine oil and washer fluid filling caps were drawn. All new components were drawn in CATIA V5 and assembled into a complete product in order to verify the movement of the hood would work and all the components would fit together.

Once the final concept had been drawn in CATIA V5 and all parts were complete, the parts were exported to Showcase in order to make a realistic visualization of the concept. The parts made in CATIA V5 were imported to an already made complete model of the V40. The old hood, fender and plenum area was removed and replaced by the components made during this thesis project. In showcase the parts were given the correct materials and color. Images were made showing the split-lines, the oil and washer fluid filling and how the movement of the hood would look. Also an animation was made in order to further illustrate the new hood concept. See chapter 4.4 for the results of the final design.

4. Results

This chapter describes the results from the different steps in the product development process that were made during the thesis project.

4.1. Market research

The initial market research was done by conducting a SWOT and PEST analysis. From this it was evident what areas that needed to be further investigated. Furthermore customer interviews and surveys were performed, as well as internal discussions at VCC. The input from the market research was used in establishing a requirement specification and worked as support for the entire product development process.

4.1.1. SWOT and PEST analysis

The SWOT analysis shows the strengths, weaknesses, opportunities and threats that were defined early in the market research phase. Early in the project, the internal strengths were well defined. Points as weight and cost reduction, higher design freedom and better gap and flush possibilities were topics that had been discussed at VCC before the start of the master thesis project. Weaknesses had not yet been as thoroughly investigated. This is clear in the SWOT-analysis, *see Figure 12*, as there are not many weaknesses listed. It was decided that discussions were needed with departments with connections to the new hood concept. This was made to further clarify the weaknesses to take into consideration when designing the new concept.

The opportunities and threats listed in the SWOT analysis were listed from early discussions with regarded departments at VCC, *see* Figure 12. It was considered, when the SWOT-analysis had been made, that both these areas need further investigation. This investigation should be in form of external and internal research in order to be fully confirmed. The opportunities and threats were used as guidelines when designing the customer research.

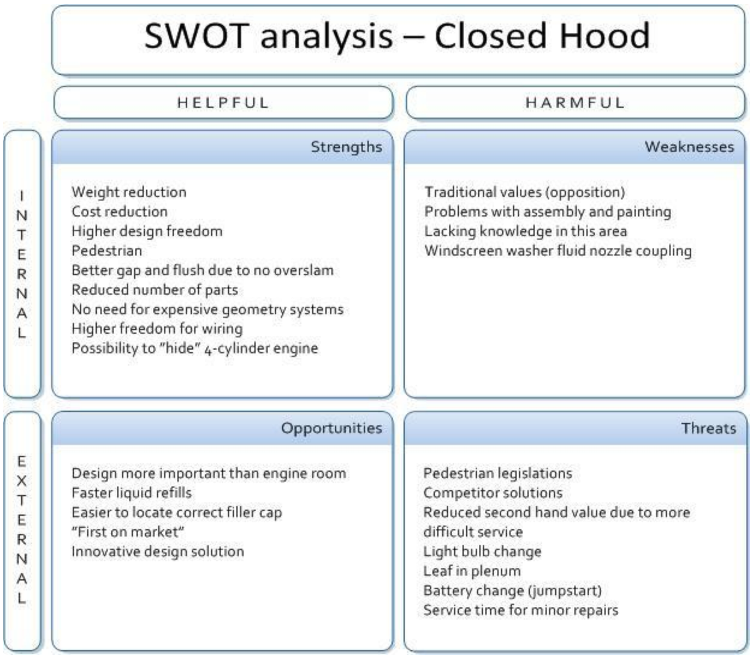


Figure 12: SWOT analysis

As a support to the SWOT, a PEST analysis was made, see Figure 13. This gave an understanding on how the market looks regarding political, economic, social and technological trends on the market. The PEST analysis was not considered crucial for the project, it was rather to build up a perspective and discussion regarding the market trends, effort was not put into investigating these questions further.

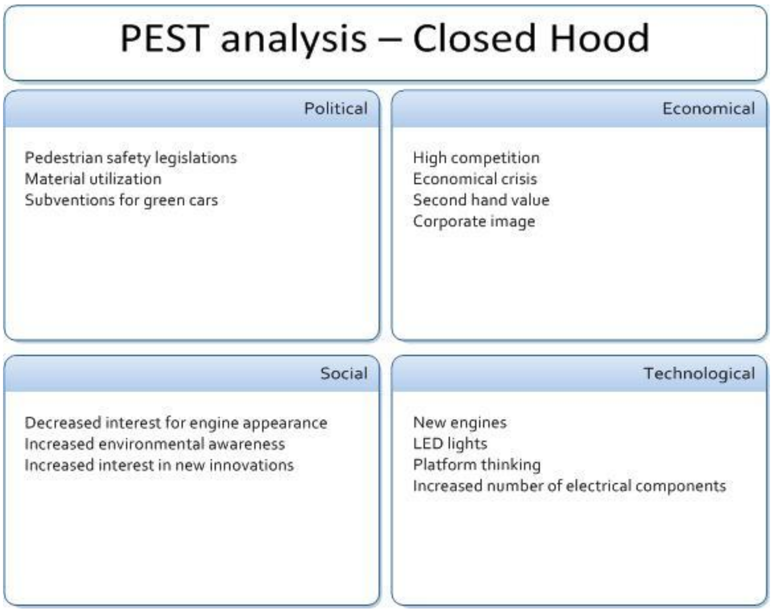


Figure 13: PEST analysis

4.1.2. Customer research

A total of 23 persons were interviewed during this master thesis. 13 of the interviewees were salesmen at different car retailers and 10 were customers interviewed either by phone or face to face. The interviews were semi structured and between 10 to 20 minutes long. The information gathered in the interviews were organized and analyzed using the KJ-method, see appendix B for results of the KJ-method. The answers and knowledge gained from the interviews were used to establish the first version of the requirement specification. The results from the interviews were also used as guideline when designing an internet survey. An example from the question workflow can be *seen in Figure 14* and the complete question workflow can be *seen in Appendix D Hood Master thesis survey*.

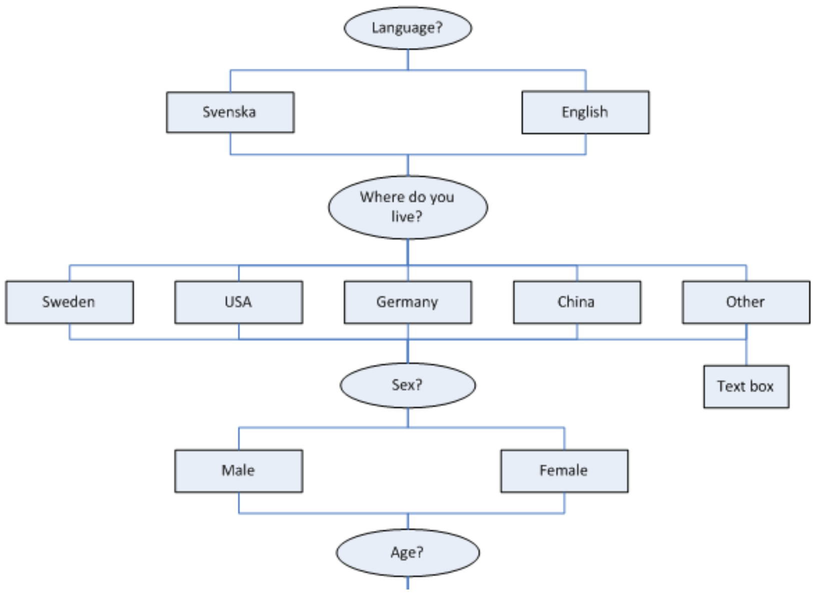


Figure 14: Example of the question workflow in the internet survey

The internet survey was sent out, a total of 1041 respondents started the survey, 76.6% followed through to the last question. 86.6% of them men and 13.4% women. 942 of the answers obtained were from respondents living in Sweden, 8 respondents were from USA, 21 from Germany and 31 from China. The rest of the respondents were from various countries. The majority of the respondents, 67.4% were in the age group 18-29. The internet survey results were compiled in four documents, showing an overview of the results, and also showing answers from automotive forums, non-automotive forums and also based on the countries of the respondents. See *appendix D* for all the answers from the internet survey. It is also listed here the amount of answers obtained for each question.

As an outcome from the survey, 74.8% of the respondents open the hood to inspect when buying a new car, *see Figure 15*. If the motor forum answers are disregarded, the number of people who inspect under the hood when buying a new car decrease to 65.3%. In the comment field for the same question, the most common answers are "curious how it looks", "to see where the fluids go" or "to see how easy the service is".

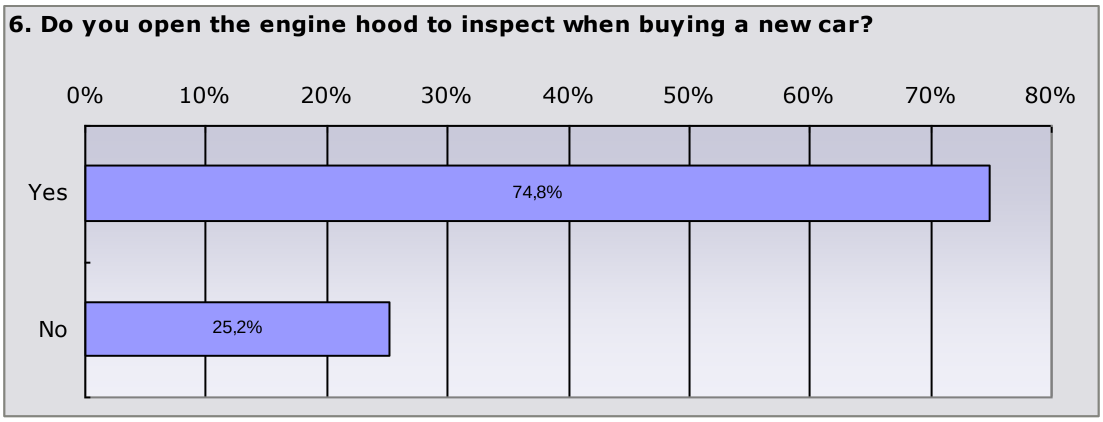


Figure 15: Answers for question 6, “Do you open the engine hood to inspect when buying a new car?”

The internet survey showed that most people open the hood of their car once a month or once a week, *see Figure 16*. If the answers from the motor forums were disregarded, the frequency of how often people open their hood decrease to between once a month and once every half year. The most common reasons for opening the hood are refilling washer fluid and checking the oil, *see Figure 17*. This was true regardless of which group or country that was analyzed. Filling of engine oil was the third most common reason to opening the hood. This was assumed early in the project and was confirmed by the survey. 33% answered that they had another reason to open the hood. A lot of these respondents have answered that they performed a general control of the engine room in order to assure that everything looks in order.

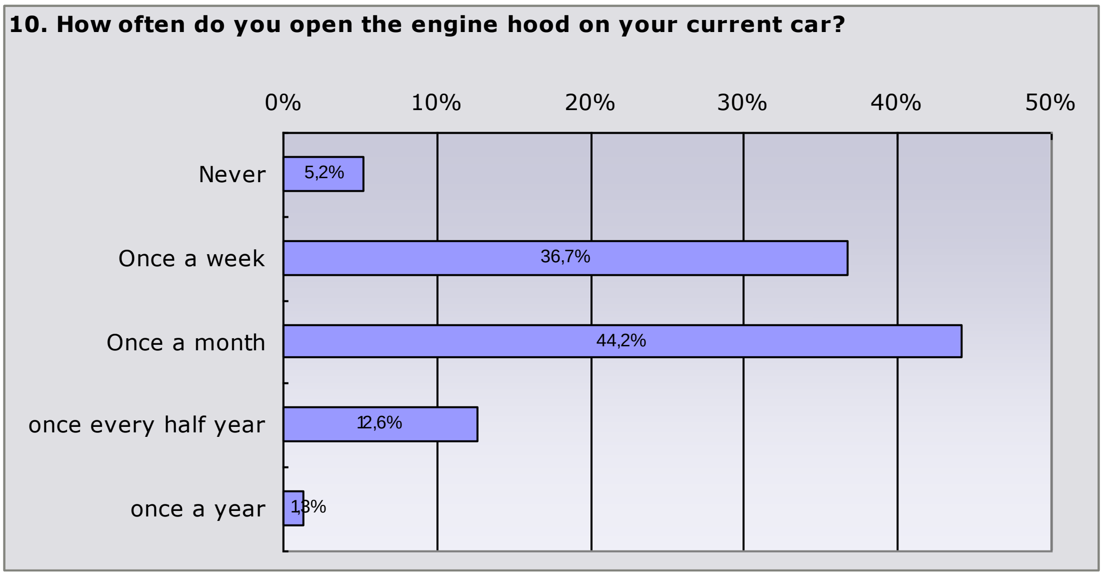


Figure 16: Answers for question 10, "How often do you open the engine hood on your current car?"

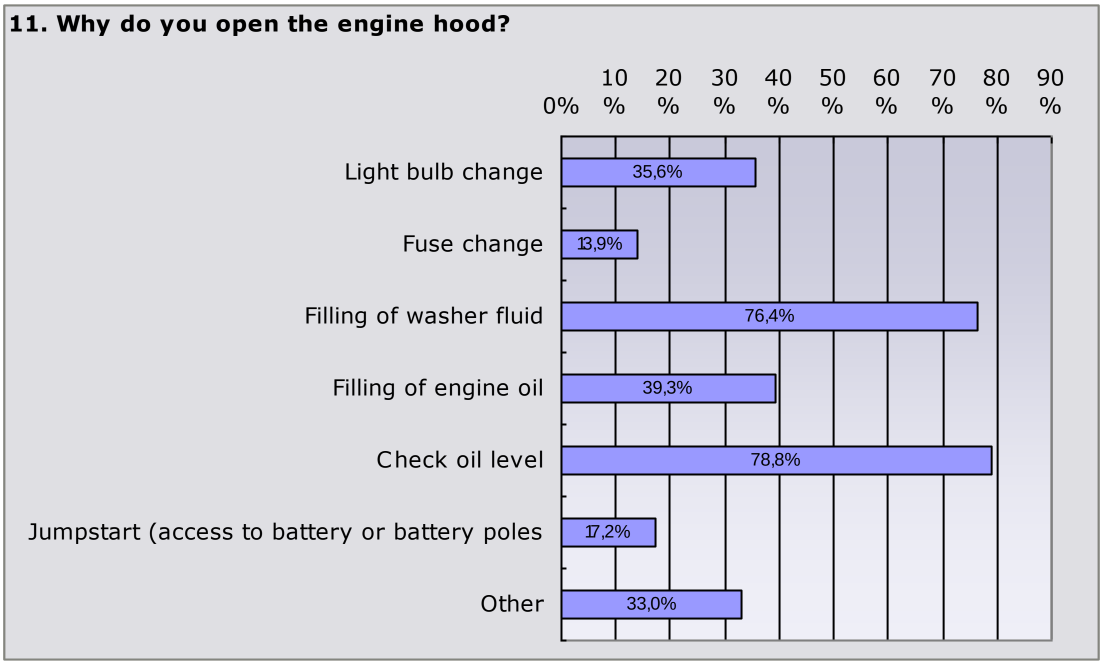


Figure 17: Answers from question 11, "Why do you open the engine hood?"

The general opinion on the respondent's perception of opening the hood is that it is easy and can be made by nearly anyone, *see Figure 18*. But even though 88.2% found it easy to open the hood, the comments for this question revealed a large number who either experienced the hood lever hard to locate or complained about getting dirty. The perception from question 13, "How would your reaction be about an engine hood that you only need to open in service workshops? Refilling of oil and washer fluid is performed in some other way.", is that more than half of the respondents perceive the concept as negative, *see Figure 19*. Commentaries show that people make assumptions from the question that the engine hood cannot be opened at home. When comparing regular people with people from the motor forums, regular people have a more positive approach to these two questions. The main concern is not being able to perform small services as light bulb changes and to be deprived the opportunity to inspect your own engine.

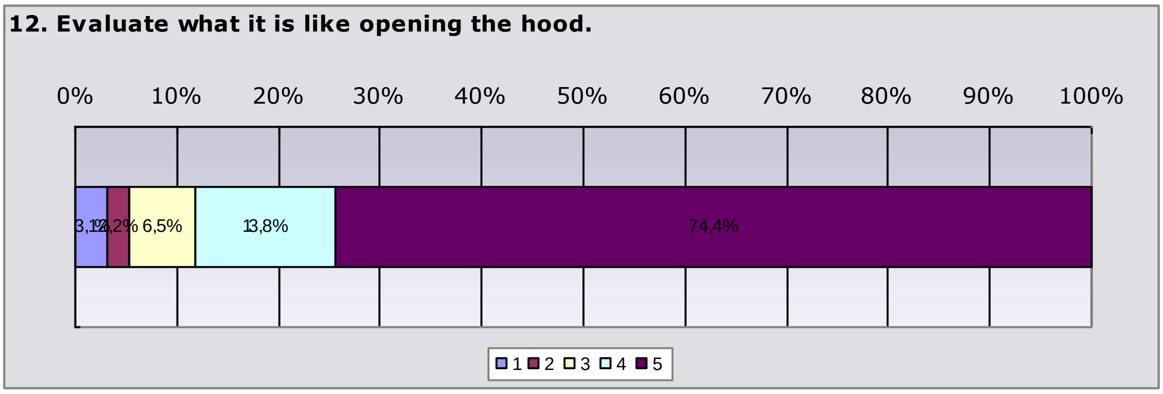


Figure 18: Answers from question 12, "Evaluate what it is like opening the hood." where 1 is hard and 5 is easy.

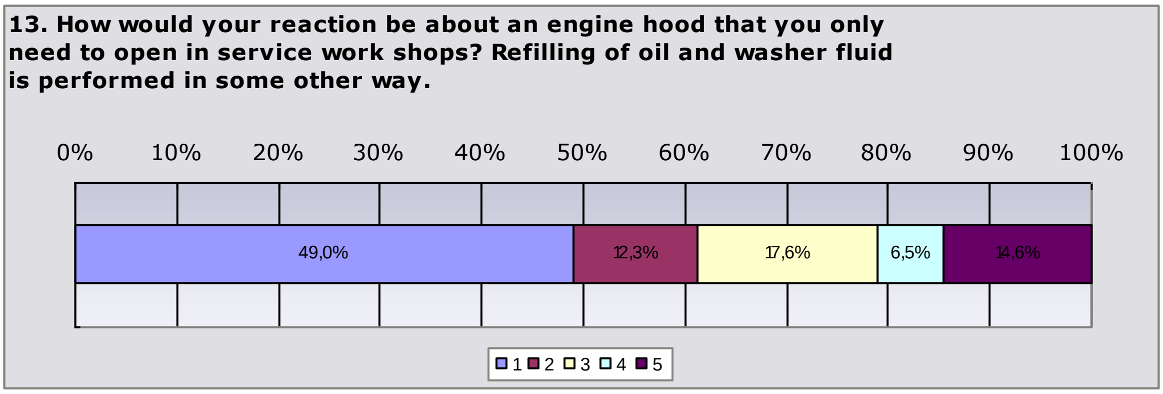


Figure 19: Answers from question 13, "How would your reaction be about an engine hood that you only need to open in service workshops? Refilling of oil and washer fluid is performed in some other way." where 1 is negative and 5 is positive.

An unexpected result was the fact that it was apparent that more than half of the respondents keep leaving their cars to workshops for service even after the warranty on the car has expired, *see Figure 20*. The most common reasons mentioned to keep leaving the car to a workshop was to get valid stamps in the service book in order to keep the value of the car. Those who answered that they did not leave their car to a workshop after the warranty expired motivated it with that they either were car mechanics themselves, had a big interest in fixing their own car or knew somebody that could fix their car for them. It was also obvious that those who did not leave their car to a workshop have older cars than those who leave their car to a workshop. The results from the survey were used when making the weighting criteria in the Kesselring matrix and also during the detail design in order to assure a customer focused final solution.

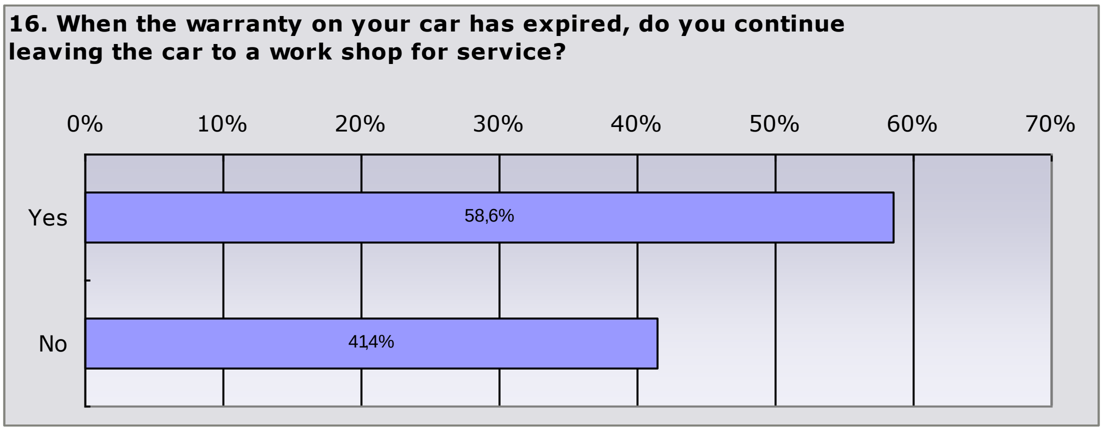


Figure 20: Answers from question 16, "When the warranty on your car has expired, do you continue leaving the car to a workshop for service?"

4.1.3. The requirement specification

The first version of the requirement specification was based on the results from the exploratory customer survey that was compiled in the KJ method. Also requirements from discussions with experts regarding pedestrian safety, ergonomics, painting, engine, engine hood, service and front lights are covered in the specification. In the first version, 38 requirements were listed, however the requirement specification was updated during the development process and several revisions were made. See appendix C for the final version of the requirement specification.

4.2. Concept generation

The concept generation resulted in a black box and a function tree describing the main functions that needed to be solved. Also a morphological matrix containing all generated concepts for the sub functions was created. Furthermore the concept generation resulted in an elimination matrix, Pugh matrix and Kesselring matrix. Ultimately the concept generation process resulted in the final concept that was moved on to the detail design phase.

4.2.1. Black box and function tree

The black box generation resulted in a defined main problem that need to be solved, that describe the main box in the project. The problem was not suitable for defining a black box around it, however the process resulted in a fruitful discussion. The hood and the area around it contained too many inputs and outputs to keep a simple black box.

Even though the black box turned out to be troublesome defining, the analysis effort was sufficient to formulate a foundation for the function tree. The initial function tree, Figure 22, based on a Volvo model was analyzed for improvements. To create a function tree that facilitate the daily service tasks, the sub-functions had to be raised outside of the "Open hood" box in the hierarchy to be able to concept generate each sub-function for itself. The washer fluid, oil and battery pole access were reformulated to allow a more free generation of solutions for the different sub-problems. The function tree now resulted in 4 sub-functions that must be solved in order to develop a fully functional solution, Figure 21.

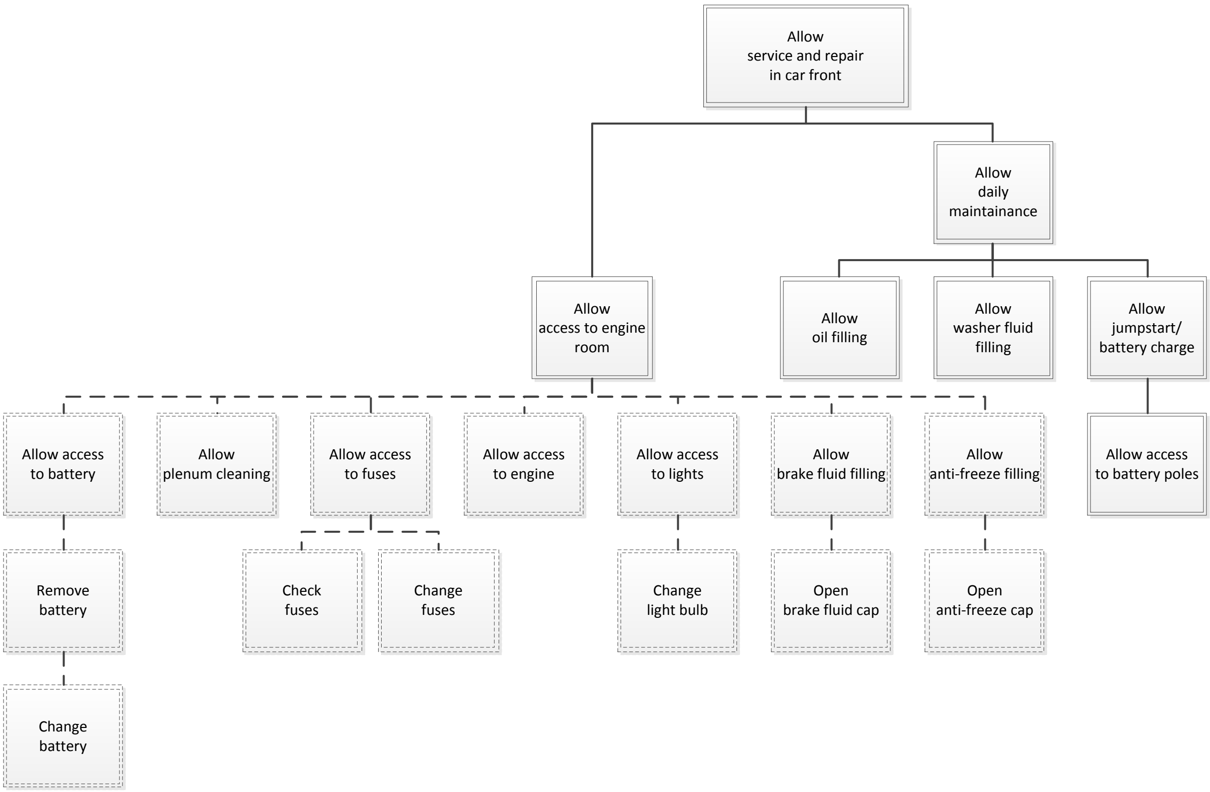


Figure 21: Function tree describing the function that needed to be solved for the master thesis.

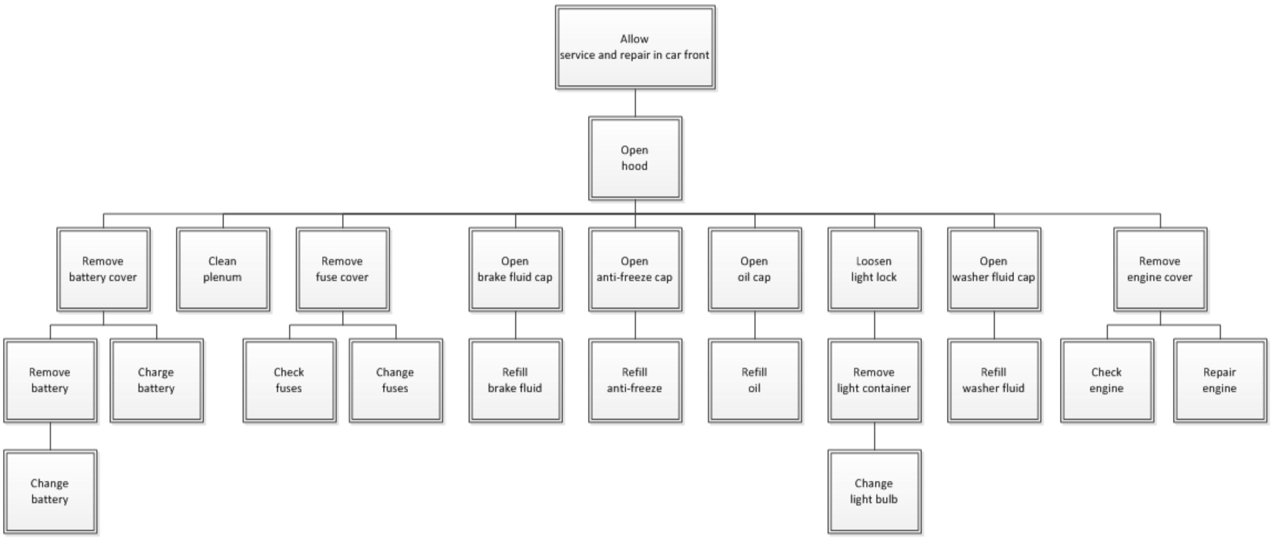


Figure 22: Function tree describing service in engine room

4.2.2. External research

The external research consisted of benchmarking and a patent search.

Benchmarking:

By looking closer to the only solution on the market with similar mindset, the Audi A2 (Figure 23), conclusions were drawn that to be able to lift a hood of a larger car would require two persons. The

A2 has the fluid refills hidden behind the grill, which might cause problems in Allians tests and for fire hazard reasons.

Figure 23: Audi A2, (Dayerses 2012)

One of the most important problems related to perceived quality is the s-curve in the split-line. Two car models from Audi with a similar solution were found, the A1 and R8. The split line is here drawn straight back from the front lights to the front door, see Figure 24. To avoid clash between hood and front fender, a double pivot hinge must be used. The double pivot hinge provides worse tolerances. The result is eliminated s-curve at the expense for slightly worse gap and flush.

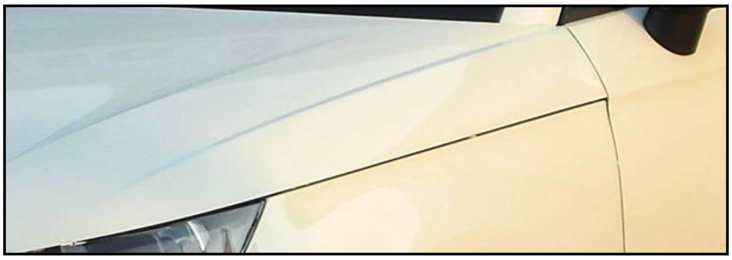


Figure 24: Audi A1 split-line

To expand the benchmarking, products and solutions not related to the automotive industry was investigated. Inspiration was obtained from kitchen drawers, with a push on a drawer, a sprint mechanism is activated that moves the drawer out. A similar mechanism might be implemented in a sliding hood solution. A second opening system seen on buses is the door opening system where the door is parallel to the bus all the way through the opening. This might be used to give access to a service area.

4.2.3. Patent search:

The patent search indicates interest in solutions related to the problem of this project. The search resulted in a large amount of patents. Several of the patents were solutions for filling of washer fluid and oil but only a few patents regarding the opening of the hood. Three of the patents were more relevant to the project. Although, the patents will not be a problem for this project, the solutions are too unlike to become an obstacle.

One patent, owned by Opel, described a motor vehicle with a service area placed at the foot of the windscreen, Figure 25. The patent does not explain whether the service area is always visible or if the hood is pushed forward to reveal the service area. This patent was approved in 2009 and is active in Germany until 2023. In discussion with a Patent Engineer at VCC, this patent will not constitute a problem.

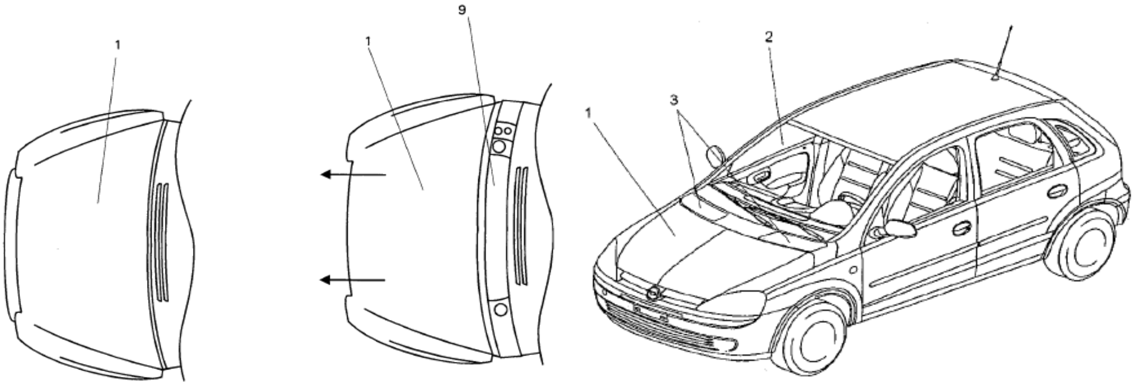


Figure 25: Patent DE10336847, (Espacenet, 2012)

Renault owns a patent where the filling of washer fluid is performed through a hinged lid in the wing, similar to the petrol filling lid, Figure 26. The tank is placed inside the engine room and the filling accessible without opening the hood. This patent is only active in France.

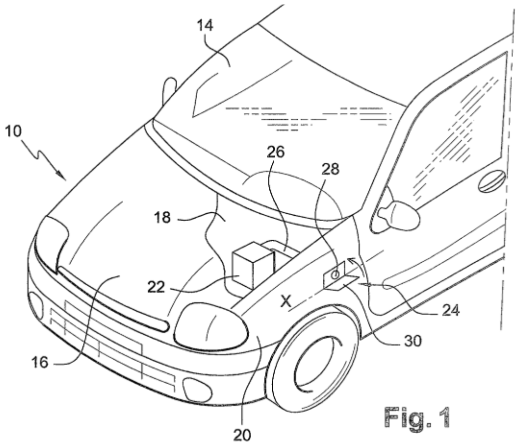


Figure 26: Patent FR2895357, (Espacenet, 2012)

Figure 27 shows the only document found that actually was produced in a mass production car, the Audi A2. The solution is based in a fixed hood mounted with two hooks and two screws. The fillings of washer fluid and engine oil are made through the grill which opens as a hinged hatch. To be able to get access to the engine room, the fixed hood needs to be screwed and lift off. The patent is active until 2017.

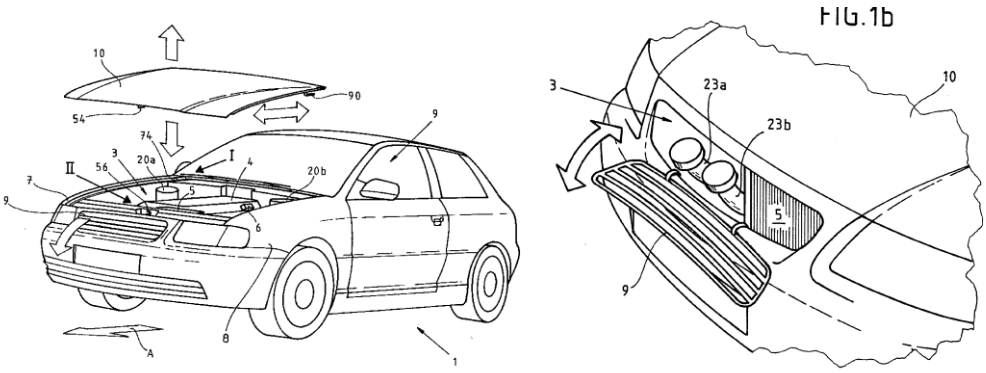
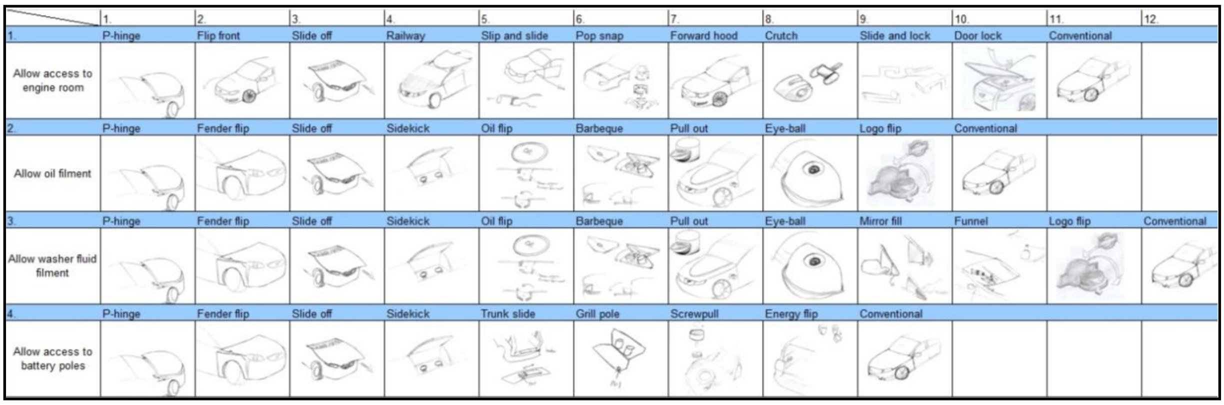


Figure 27: Patent DE19718594, (Espacenet 2012)

4.2.4. Morphological matrix

The morphological matrix, Figure 28, contains the different solutions for the sub-functions allow access to the engine room, allow oil filament, allow washer fluid filament and allow access to battery poles. The solutions that could solve more than one sub-function are put in to all the sub-functions that they can solve. The sub-functions that were to be solved are listed on the left side of the matrix and the solutions are listed from left to right in the top of the matrix. The solutions are listed with a picture describing the solution as well as the name of the solution. See appendix D for a full view of the morphological matrix.



	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	P-hinge	Flip front	Slide off	Railway	Slip and slide	Pop snap	Forward hood	Crutch	Slide and lock	Door lock	Conventional	
Allow access to engine room												
2.	P-hinge	Fender flip	Slide off	Sidekick	Oil flip	Barbeque	Pull out	Eye-ball	Logo flip	Conventional		
Allow oil filment												
3.	P-hinge	Fender flip	Slide off	Sidekick	Oil flip	Barbeque	Pull out	Eye-ball	Mirror fill	Funnel	Logo flip	Conventional
Allow washer fluid filment												
4.	P-hinge	Fender flip	Slide off	Sidekick	Trunk slide	Grill pole	Screwpull	Energy flip	Conventional			
Allow access to battery poles												

Figure 28: Morphological matrix containing all generated solutions.

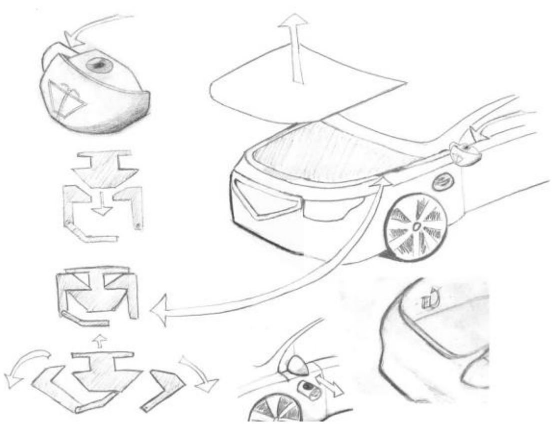


Figure 29: Concept generated by combination of the solutions 1.6 Pop snap, 2.7 Pull out, 3.8 Eye ball and 4.8 Energy flip from the morphological matrix.

4.2.5. Elimination matrix

In the elimination matrix all 25 generated concepts are evaluated. Before moving on to this step, all concepts were named in order to easily tell them apart. The concepts that got a (+) as the decision were moved on to the Pugh matrix. When the elimination matrix had been conducted, 13 concepts were to be put in directly in the Pugh matrix. Six concepts got question marks in the matrix, these were revised and modified, resulting in additional three concept. In the end, 15 concepts made it past the elimination matrix, and were moved on to the Pugh matrix. Nine concepts got the decision (-) and were eliminated. See Figure 30 for the elimination matrix.

Elimination matrix			Garage opening hood					120402
Selection criteria			Decision					
+	Yes		+	Pursue solution				
-	No		-	Eliminate solution				
?	Lack of information		?	Collect information				
!	Check req. speq.		!	Check req. speq. for changes				
Version 1.0	Concepts							
Selection criteria	Solve the "main problem"	Fulfill requiremen t	Are compatible /"realizable	Have reasonable cost	Safe	Fit into the product portfolio	Remarks	**Decision**
P-house	+	+	+	+	+	+	Replace grillpole by P-hinge/trunk	+
Squidgybo	+	+	?	?	+	+	Revision regarding oil filment and cost	?→-
A1 classic hood	+	+	+	+	+	-	Does not fit desired future portfolio	-
Mordor	+	+	?	?	+	+	Revision regarding oil filment, change oil filment to conventional	?→+
Fordor	+	+	+	?	+	-	Unnecessary complicated, high cost	-
Flip front	+	+	+	+	+	+	Can be hard to fit in product portfolio	+
Mecka-nizm	-						Solutions does not match	-
BBQ king	+	+	+	+	+	+	Similar to existing solution (A2)	+
LIFT DA ROOF	+	+	+	+	+	+	Evaluate battery pole position	+
Rail flip	+	+	?	?	+	+	Revision regarding oil filment	?→-
Pop eye	+	+	+	+	+	+	Clean solution, evaluate oil filment	+
BBQ queen	+	+	+	+	+	+	Everything in grill, check patent	+
Hingeless	+	+	+	+	+	+	Just a variant on hingess	+
Crutch funnel	+	+	+	+	+	+	Simple solution	+
SAAB	+	+	+	?	+	?	Revision on oilfilment and hood, change oil filment to conventional	?→+
Slide kick	+	+	+	+	?	?	Risk for pedestrian? Visible hatch.	?→-
Slide	+	+	+	-			Movin the whole front is expensive	-
Kicki	+	+	+	+	-		Risk for fluids on battery pole	-
Bettan	+	+	+	+	+	-	Two moving components close	-
Old man	+	+	+	?	+	?	Can be expencive	?→-
Logo door	+	+	+	+	+	+	Innovative	+
L8	+	+	+	+	+	+	Simple solution	+
Convie crutch	+	+	+	+	+	+	Simple solution	+
Bob	+	+	+	+	+	+	Innovative	+
Let it slide	+	+	+	+	+	+	Check patent	+

Figure 30: Elimination matrix containing all 25 concepts.

4.2.6. Pugh matrix

There were 14 concepts that where put into the Pugh matrix for evaluation. Each concept is evaluated compared to a datum concept. The Pugh matrix was made in two iterations, with different datum, in order to verify the results from the first version. See Figure 31 and Figure 32 for the two versions of the Pugh matrix. The result of the Pugh matrix was four concepts that were to be worked on to a level in order to in order to be able to evaluate them in the Kesselring matrix.

Version 1.0	Concepts													
Selection criteria	Concept 1 P-	Concept 6 Lift da	Concept 10 Flip	Concept 13 BBQ	Concept 16 Pop	Concept 17 BBQ	Concept 18	Concept 19 Crutch	Concept 21 SAAB	Concept 27 Logo	Concept 28 L8	Concept 29 Convie	Concept 30 Bob-O	Concept 31 Let it
Potential for smaller gap and	+	+	+	+	+	+	D	0	0	0	0	-1	0	+
Time to access engine room	-	-	-	-	-	-		0	0	0	0	0	0	0
Pedestrian safety	+	+	-	0	+	0	A	0	0	0	0	0	0	+
Manufacturing	0	0	-	-	0	-		-	-	-	-	-	-	0
Steps to allow refilling of	+	+	-	+	+	+	T	+	+	+	+	+	+	+
Steps to allow refilling of	+	-	-	+	-	+		0	0	0	0	0	0	+
Workshop service	0	0	0	0	0	0	U	0	0	0	0	0	0	0
Few parts	0	-	0	-	-	-		-	-	-	-	-	-	0
Innovative	+	0	0	0	+	0	M	0	0	+	+	+	+	0
Sum +'s	5	3	1	3	4	3		1	1	2	2	2	2	4
Sum 0's	3	3	3	3	2	3		6	6	5	5	4	5	5
Sum -'s	1	3	5	3	3	3		2	2	2	2	3	2	0
Net score	4	0	-4	0	1	0		-1	-1	0	0	-1	0	4
Rank														
Continue?														

Figure 31: Pugh matrix version 1.

Version 2.0	Concepts													
Selection criteria	Concept 1 P- house	Concept 6 Lift da Mordor	Concept 10 Flip front	Concept 13 BBQ king	Concept 16 Pop eye	Concept 17 BBQ queen	Concept 18 Hingeles s	Concept 19 Crutch funnel	Concept 21 SAAB	Concept 27 Logo door	Concept 28 L8	Concept 29 Convie crutch	Concept 30 Bob-O	Concept 31 Let it slide
Potential for smaller gap and	-	0	+	+	+	+	0	0	0	D	0			
Time to access engine room	0	0	+	-	+	+	0	0	0		0			
Pedestrian safety	+	0	-	-	+	-	0	0	0	A	0			
Manufacturing	-	0	-	0	-	-	0	0	-		0			
Steps to allow refilling of	+	0	-	-	0	0	-	+	0	T	0			
Steps to allow refilling of	0	0	+	+	+	+	0	0	0		0			
Workshop service	0	0	-	0	+	+	0	0	-	U	0			
Few parts	+	0	+	-	-	-	+	0	-		0			
Innovative	+	0	-	0	+	0	0	0	0	M	+	+	+	0
Sum +'s	4	0	4	2	6	4	1	1	0		1			
Sum 0's	3	9	0	3	0	2	7	8	6		8			
Sum -'s	2	0	5	4	2	3	1	0	3		0			
Net score	2	0	-1	-2	4	1	0	1	-3		1			
Rank														
Continue?														

Figure 32: Pugh matrix version 2.

4.2.7. The final four concepts

When the Pugh matrix had been conducted, four concepts made it through the process. The final concepts were Pop eye, Slider, Logo and Funnel. Following is a description of these concepts. All of the concepts were further developed before the elimination, leading to the final concept.

Pop Eye

This concept is built on a hood which needs to be lifted off when access to the engine room is desired, see Figure 33. The oil filling is located under the hood, on the top of the engine as the current solution. The washer fluid filling is placed in the side rear mirror, permitting refilling of washer fluid without the need to open the hood. The battery pole is placed in the trunk of the car.

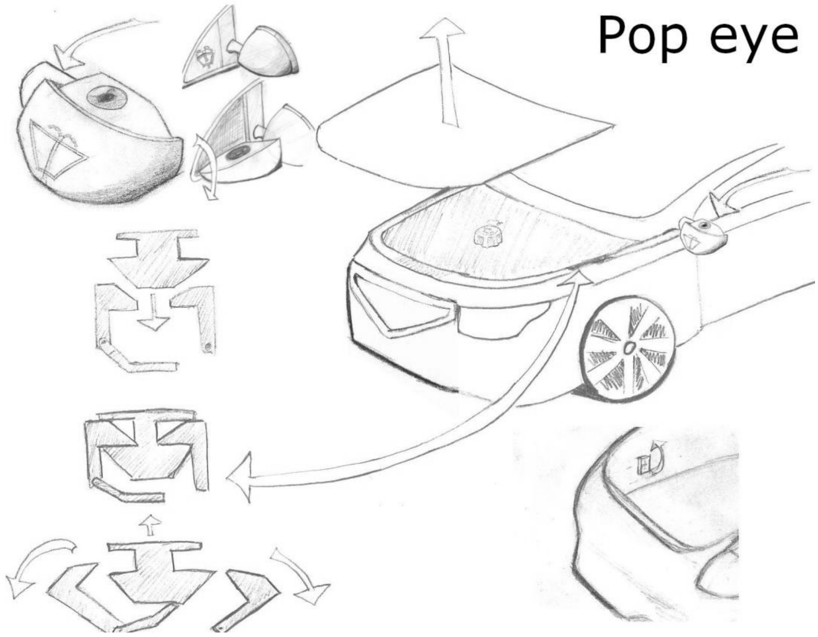


Figure 33: Concept Pop eye

Slider

Slider has a hood that moves up and forward into a service position where filing of oil and washer fluid is possible in the plenum area, see Figure 34. The battery pole is to be places in the plenum area or in the trunk. In order to access the engine room, the hood can be opened conventionally from the service position or alternatively lifted off if desired.

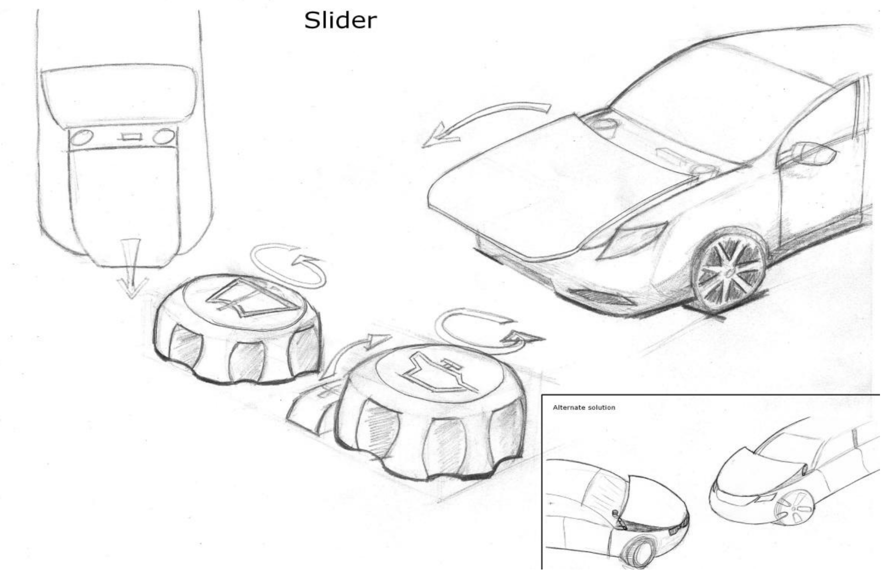


Figure 34: Concept Slider

Logo

The hood is attached with a bracket, tracking the hood into the right position. It can be open a few degrees in a mechanism similar to a hinge, but for service of the engine, the hood needs to be lifted off. The concept has a conventional oil filling. The washer fluid filling is performed through a hatch camouflaged by a logo on the side or the side blinkers, see Figure 35. An alternative solution is to fill the washer fluid through the front logo in the grill. The battery pole is placed in the trunk.

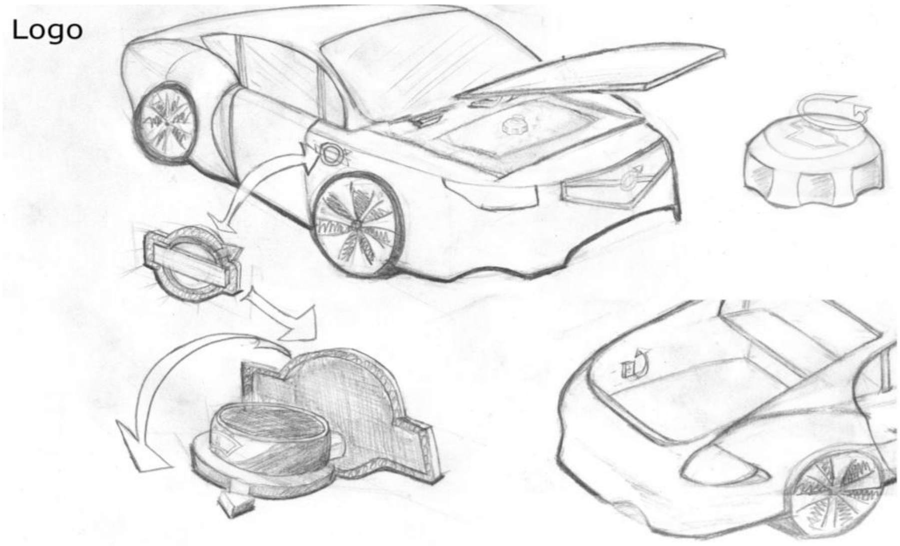


Figure 35: Concept Logo

Funnel

The hood solution has a snap on hinge principle, see Figure 36. This solution can be opened similar to regular hinges. For service in the engine room the hood is lifted off. The concept has conventional oil filling. The washer fluid is to be refilled at the wind screen. Battery pole is placed in the trunk.

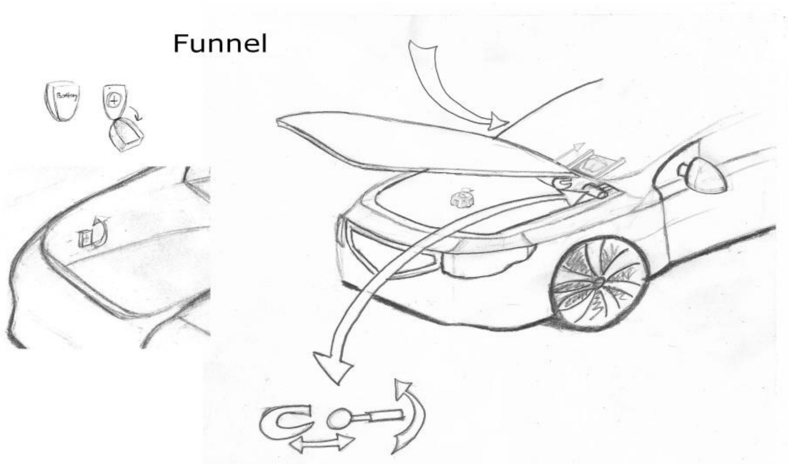


Figure 36: Concept Funnel

4.2.8. Kesselring matrix

Pop eye was the concept with the highest score regarding the criteria PQ/Design, see Figure 37. However the concept that made it through the Kesselring matrix with the overall highest score was the concept Slider. This concept was then chosen as the final concept and the work continued with final design and development of this concept. The remaining two concepts Funnel and Logo got low PQ score due to the fact that the opening mechanism restricted the degrees of freedom for split line placement.

Kesselring Matrix v1.1		Slider		Funnel		Pop eye		Logo	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
PQ/Design	50								
Potential for smaller gap and flush	12	6	72	3	36	8	96	3	36
Overslam	12	8	96	6	72	9	108	6	72
Independence of split lines	12	8	96	4	48	8	96	4	48
Independence of geometry	4	8	32	5	20	4	16	5	20
Few parts	6	5	30	7	42	4	24	7	42
Innovation	4	6	24	5	20	8	32	5	20
Service and usability	30								
Time to access engine room	5	5	25	4	20	3	15	4	20
Persons to lift hood	4	5	20	4	16	3	12	4	16
Workshop service	4	5	20	4	16	4	16	4	16
Prerequired tools	2	5	10	4	8	3	6	5	10
Refilling of washer fluid	9	7	63	8	72	9	81	9	81
Refilling of engine oil	6	7	42	4	24	3	18	4	24
Manufacturing	8								
Painting	4	5	20	5	20	3	12	5	20
Assembly	4	4	16	6	24	6	24	6	24
Safety	12								
Pedestrian safety	7	6	42	5	35	6	42	5	35
Allians test	5	4	20	5	25	4	20	5	25
Total Score	100		628		498		618		509
Rank		**1**		**4**		**2**		**3**	

Figure 37: Kesselring matrix

4.3. Potentials for cost reduction

Creating a new hood solution creates opportunities in several areas related to the engine area. An investigation was carried out to evaluate possible savings. Cost and weight reduction propositions were made on the Volvo V40. The investigation is made based on components with potential for removal or changes. To be added are components based on the new concept. The calculations also include time measurement units, to include possible time and cost reductions built on manufacturing time and fine tuning.

The components were selected and discussed with responsible departments. Components may vary between different engine alternatives. The engine chosen for the investigation is the DRIVe, a common engine choice.

Some parts are not possible to remove, but instead modified for better performance. The engine cover is needed for noise and vibration dampening. The engine cover is designed to look aesthetically good, if the engine cover is not seen by the costumer anymore, possibilities emerge for redesigning the cover to optimize noise and vibration dampening. Wiring in the engine room is now performed for the customer not to see. Wiring in a future car could be made in the shortest and cheapest way.

Volvo V40 DRIVe							
Component	**Amount**	**Cost**	**Sum [SEK]**	**Weight [g]**	**Sum [g]**	**TMU**	**SEK**
Reinforcement striker	2						
Safety catch	1						
Bonnet latch lh	1						
Fict fastener latch	6						
Bonnet latch rh	1						
Bonnet lever control	1						
Hood release cable front	1						
Hood release cable rear	1						
Reinforcement hood hinge rh	1						
Reinforcement hood hinge lh	1						
Bonnet hinge rh	1						
Bonnet hinge lh	1						
Reinf. Gas spring anchorage	1						
Gas spring Y555	1						
Bracket gas spring hood assy	1						
Engine shield	1						
Bump stop	2						
Adjustable z-support	2						
Boellhoff - Snaploc D10	1						
			325,2		5549	8305	65

[1]Blank boxes censored by Volvo Cars Corporation

4.4. Final design

The concept chosen to be the final concept for further development is the concept that in previous steps was named Slider. The purpose with this concept is that it has a service position in which the hood can move in order to allow access to washer fluid and engine oil filling. The oil and washer fluid filling is made in the plenum area through the oil and washer fluid caps placed on each side of the plenum area. Due to the movement from completely closed, to the service position, a greater freedom is achieved in deciding how the split-lines can be drawn between the hood and fender. The design freedom for the split-lines is due to the fact that the hood moves up and forward. This movement does not require an s-curve in order to function. Shown in Figure 38 is a CATIA V5 assembly of the Volvo V40, with new split-lines between the hood and fender. The CAD models were the first step in the process to illustrate the new concept.

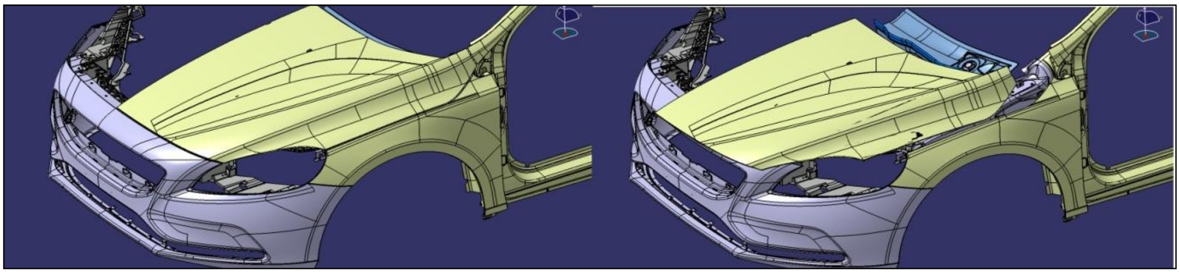


Figure 38: CAD model of the final concept showing the hood as closed (left) and in service position (right).

[1] Black boxes censored by Volvo Cars Corporation

The new hood, fender and side of the car were imported into Showcase, a 3D presentation software by Autodesk, in order the further illustrate the new concept and how it can appear on an actual car. Figure 39 and Figure 40 show the model from showcase illustrating the re-drawn split-lines.

Figure 39: Visualization of the final concept

Figure 40: Visualization of the new split-line

The final result of the concept has four hinges total. Two on each side in the back where the regular hinges are today, and two in the front, see Figure 41 and Figure 42. These hinges are only to illustrate an example of the principle behind the hinges needed for this concept and are not set as a final design. The hinges lift the hood and push it forward, enabling the service position. The hinges are placed at a position that was found fitting in the already existing model, and is not to be regarded as an exact position. The back hinges are placed on the side beam on the same place as the regular hinges are placed on the V40. The hinges connect to the nearest position on the hood. As mentioned, the model drawn in CATIA V5 is mainly to illustrate the concept and the main principles with it. The back hinges are activated by a button or lever on the inside of the car. When in closed position, the back hinges are locked in place, once the hood is to move to service position the hinges rotate forward and lock in service position.

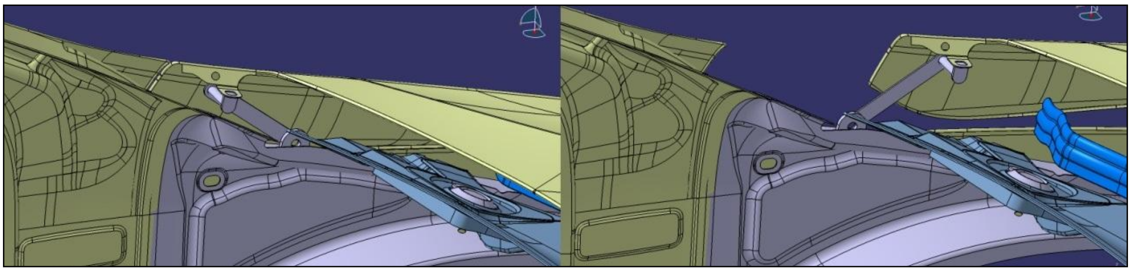


Figure 41: CAD model, back hinge

The front hinges are in the model placed on the pin bracket in the front of the car. This is due to that the existing model is not adapted for this solution and there was no space in the front of the car to place the front hinges and maintain their functionality. Due to the fact that the hood only is a surface and the hinges are placed very low they needed to be longer in the model than they would in a final design. The front hinges are locked in place when in closed position and then released when the hood is to move into service position.

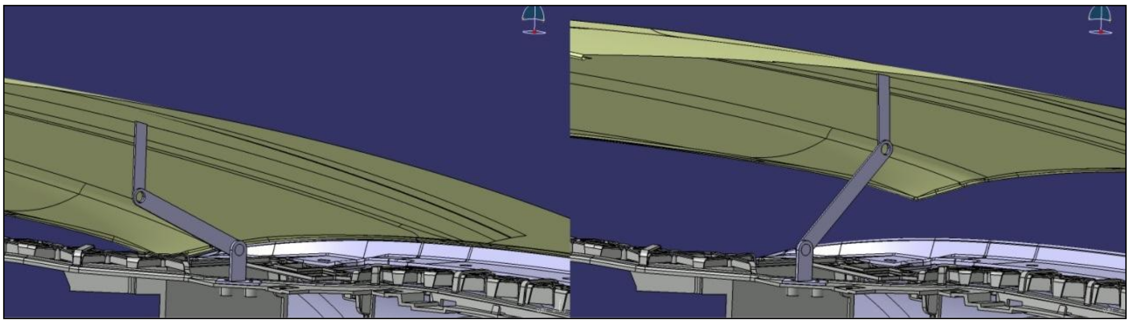


Figure 42: CAD model, front hinge

The hood is moved from closed position into service position, see Figure 43, by either pressing a button or pulling a lever from the inside of the car. Therefore no physical contact is necessary with the hood when moving it to service position. The movement is to be carried out electronically or mechanically, which is excluded in this thesis work.

Figure 43: Visualization of the opening system

From the service position the hood can be either be opened conventionally or lifted off completely, see Figure 44. Both options will demand softer handling of the hood when closing or putting the removed hood in place. Opening the hood will not be necessary for the driver of the car as oil and washer fluid will be reachable from the service position. The hood is mainly to be completely opened in the car workshop. More careful handling and the fact that neither of these options allows the hood to be slammed down to completely closed, reduces the need for a gap allowing over-slam.

Figure 44: Two alternatives to access the engine

In service position, see Figure 45, oil and washer fluid can be refilled at the plenum area. The washer fluid is placed at left side of the car. Filling washer fluid is the most common maintenance that needs to be performed with the car, having it as the same side as the driver is regarded the most logical place to locate it, see Figure 46.

Figure 45: New solution in service position

Figure 46: Washer fluid filling cap

The oil is filled, see Figure 47, just like the washer fluid, in the plenum area, however on the right side of the car. The cap for the oil and washer fluid is to be flipped up allowing easy opening of the filling caps.

Figure 47: Engine oil filling cap

4.4.1. Possibility of new split lines

One of the most important problems to solve during the thesis is the s-curve and the geometrical difficulties it causes. By developing a concept, independent of how the split-line is placed, the design department is given a larger freedom. The current split line runs through a surface with two curvatures, see Figure 48.

Figure 48: Old current split-line

The Slider concept, see Figure 49, allows the split-line to be placed in a way, more independent of the opening mechanism. The final concept has a new split-line placed closer to the front door. The V40 has a detail in the front of the side view mirror called a "cheater panel". The new split-line runs back along the front fender to veer up aligned with the cheater panel.

Figure 49: New split-line

The cheater panel is not a common feature in other Volvos and is not determined if it will be reoccurring in future models. A proposal based on the Volvo S60 shows the possibilities if the cheater panel is removed to get a clean look where the split line appears as a prolonged edge from the door, see Figure 50.

Figure 50: Possible split-line on a S60

4.5. Sustainable development

Having a hood that enables easier maintenance of the car will contribute in extending the life-span of the car as easier filling of engine oil could lead to a more frequent filling. This would mean longer durability for the engine due to better lubrication. By this less parts or the car would be necessary to replace, and the cars life-span would increase. Furthermore, not having a hood that is intended to be opened and closed as frequent as today's solution. The hinges for the new hood solution could be less robust. Also the hood could be designed as less robust. This would lead to potential for weight and cost reduction, as the hood and hinges could be dimensioned for less wear. Even small weight reductions contribute to reduced fuel consumption for the car, this would lead to lower emission. The weight reduction can also enable possibilities to move from combustion engines to electrical engines as the lower weight reduces the power needed from the engine.

5. Discussion

The idea of using a hood that does not need to be opened for customer maintenance has been investigated on several occasions. It has however never been fully investigated how the customer would perceive this type of solution. Recently this concept has been brought up again as it is regarded that the benefits motivate a deeper investigation of the concept, as today's products have several opportunities for improvement connected to the hood. These span from geometry, pedestrian safety, engine compartment and exterior (hood hinges). The biggest profits for the attribute of Perceived Quality are reduction of gap and flush and better looking split-lines.

The GANTT chart, established in the beginning of the project, together with the product development methods chosen has worked out well. The specific planning of methods and deadlines facilitated the overall work. If the project would be performed one more time, the only changes would be around the decision making. If the decision making procedure would have been more effective, more time could have been spent on the final concept development.

5.1. Discussion market research

Performing a SWOT and PEST analysis in the project start contributed in obtaining knowledge of the market situation. This gave a good overview regarding the market situation for the new concept and also a sense of direction early in the project.

The first exploratory interviews provided useful information how to formulate the confirmatory internet survey. It was proven efficient to conduct the interviews before sending out the internet survey. The survey generated more answers than expected and is considered a successful way to gather a large amount of answers in confirmatory purpose. The amount of answers that were obtained was considered to be of statistical value and conclusions were possible to be drawn from the results. However 620 of the respondents were from automotive forums, these were regarded to be more conservative regarding today's hood solution due to their large interest for the car and its components. Therefore several of the answers from the motor forums might not come from the typical customer that will buy a brand new Volvo. This could be a reason for less positive attitude toward a new hood solution. When sorting out the motor forum answers, a clear differentiation was discovered.

A respondent base with a more even gender distribution might have given a different result. Most respondents were from Sweden. Unfortunately, USA and Germany's respondent rate was too small to be considered as a completely reliable information base. The difference in answers from the different countries were analyzed and discussed, but no major differences were discovered. The survey was evaluated in a comprehensive view and all decisions were made based on all the results. The age group 18-29 was the most representative with 67.4% of the total amount of the respondents. It is considered that there might be a possibility that a different respondent age would give a different result for the survey.

The three most common reasons to open the hood according to the survey were refilling of washer fluid, checking oil and refilling oil in the order they are mentioned. This correlated to the initial assumptions that oil and washer fluid would need to be possible to refill in order to satisfy the customers and the cars need for regular maintenance. As new cars have the oil level displayed inside the car, there is no reason to be able to check the oil by accessing the engine room.

Accessing the battery pole was not a major reason to access the engine room, however it is regarded important to have as a possibility to access the battery pole in case a jumpstart is necessary to perform. The decision of putting the battery pole in the truck gives the customer this possibility without the need of opening the hood. It was also clear that most people open the hood of their car once a month or once a week. It is regarded that if refilling washer fluid and oil and checking oil can be solved without opening the engine hood, it would not be necessary to open it as frequently, perhaps not at all. Worth mentioning is also that with the motor forum answers not included, the opening frequency is still once a month but points at once half a year.

5.2. Concept generation and elimination

During the concept generation, a lot of different steps were taken in order to assure a successful final result. In the initial steps of creating the black box and function tree, difficulties occurred to formulate one transforming function for the black box due to the size of the project. It was considered that a complete black box is not necessary to establish a function tree. The work carried out with discussing the black box was sufficient as a basis for the function tree. Also the function tree was proven to be difficult, this due to that each function hade several sub function. In order to be able to meet the goals and find an overall solution for the new hood, it was decided the function tree would not be divided into further smaller steps than what is presented in the results. The function tree did not include means as it was considered there was risk for unnecessary constraints early in the product development process. Although some modification needed to this process, it is considered that establishing a function tree made a good foundation, helping to solve problems independent of each other.

When combining the concepts for the solutions of the sub functions, the morphological matrix was used. This step is regarded fairly uncertain. A systematical way to combine sub solutions was difficult to find due to a large number of combinations. This step has a tendency to be time consuming to process. In order to use the morphological matrix systematically, a concept weighting method was used. Even though this was somewhat systematical, it is still dependent on the people combining the different solutions and the results can vary depending on the users. There is not time to evaluate all combinations which leads to risks of missing out on good concepts.

Following the concept generation was the concept elimination. This step contained several tools in order to assure a successful final concept. The tools used during this step are straight forward, and with support of the requirement specification, a simple way to compare the different concepts and decide the final concept. When deciding the criterions for the tools used during the elimination matrix, it is a good idea to include representatives from all areas included in the concept. During this project the main input during this step was from the attribute perceived quality. Some of the different areas are fairly uncertain to rate and need wide knowledge to be able to rate properly.

5.3. Final design

The final design solves the sub problems that needed to be solved during the thesis project. All final concepts managed to solve the sub problems but with perceived quality as job requestor and high weighing criteria, independence of split lines and s-curve elimination was the crucial factor when choosing Slider as the final concept. It has potential for two ways of accessing the engine room. As shown earlier the hood can be lifted off completely when the hood is in service position or it can be opened similar to the conventional solution from the service position. The decision of having a hood that enables a traditional hood movement additional to the movement to the service position is to have an option that can be implemented earlier without having to do major changes to the manufacturing processes and getting the customers used to the hoods service position. In the future, it is recommended that the hood should be lifted off from the service position in order to allow access to the engine room. Removing the hood from service position will not require the additional hinge for the traditional opening and would result in more weight and cost reduction, as well as more control over the gap and flush between the hood and fender.

An important step in further developing the concept Slider was to decide which path to go regarding the opening system to move to hood into service position. The main idea to let the hood slide forward into this position was based on using some sort of sliding function. However this was early regarded a bad idea due to risk for the hood colliding with the soft nose when moving into service position. If the future cars are able to be produced with a semi soft nose, the sliding mechanism may function. Dirt in the sliding mechanism reducing its functionality was also an issue that would need solving. It was decided that choosing a hinge mechanism, lifting and moving the hood forward, would be the simplest and cheapest alternative to implement.

The movement of the hood was tested in CATIA V5 in order to assure that there was no clash between the hood and fender or doors when moving the hood to service position and opening the hood. The limiting parts, most critical to clash, is the a-pillar in the car body side and the soft nose bumper. The movement needs to be in an angle upwards and in the cars moving direction.

It is considered that the hood should move to service position by pressing a button or pulling a lever on the inside of the car, from the driver seat. This would give a more premium impression of the solutions. Having the movement automatically would also enable easier filling of washer fluid and engine oil, as this could be performed from the service position without handling the hood. This would mean that the customer will not risk getting dirt on their hands or clothes by having to open the hood. Another issue that was expressed in the answers from the internet survey was the problem of finding the locking mechanism for the hood when wanting to open it. For moving the hood to service position, this will not be an issue if having the hood automatically moving into this position.

Having the hood move automatically would however add to both weight and cost as using an electrical motor or mechanical solution would demand added components. As this thesis has focused on generating a concept these aspects have not been taken into further consideration. However, it is fully possible to move the hood into service position by hand. This would require a locking of the hood in place in a similar way as it is today. A lever on the inside of the car would unlock the hood allowing the customer to move the hood into service position by hand.

When wanting to refill engine oil or washer fluid it is regarded easier only having two refilling caps. This means that the customer does not need to find the oil and washer fluid refilling caps by searching the whole engine room. Instead they only have the two most common refilling caps to take into consideration. This solution makes the fill of oil and washer fluid easier and more logical. Having the two refilling places on each side, a long way from each other, further reduces the risk of making a mistake. The plenum area is large enough to have more fluid refilling options. Doing this puts high demands in differentiating the different caps and putting them far enough from each other in order to remove the risk of the customers putting in the wrong fluids in the wrong place.

5.3.1. Economic and weight benefits

As shown in the results, there are several opportunities of economic benefits as well as weight reduction possibilities with having a closed hood. These results show what the weight and cost reduction would be when having a complete closed hood. However, not all these components can be completely removed. The old hinges and locking devices are to be replaced by the new hinges. In this case it is hard to predict what the cost and weight would be of the new hinges. This is due to the fact that the hinges are not fully design to a certain car model, hence there is no way of fully specifying the design for the hinges. The same goes for the new design for filling of washer fluid and engine oil in the plenum area. As the final results of this thesis were to develop a concept, no specific component has been fully developed to the degree were exact weight and price reduction information can be obtained for the final concept.

It is however regarded that the new hood design has potential for both price and weight reduction. For example, the engine hood on the V40 weights 10.8 kg. If the hood is not opened in the same frequency, then there is no need for the same thickness of the sheet as well as the same robustness of the hinges. This would allow large weight reduction possibility as the hood is able to be manufactured in a lower thickness. Another potential for economic benefits is the engine cover. As mentioned this is needed for noise and vibration dampening. In the same time this cover needs to have a certain degree of styling as it is an area that the customer will be able to se. Having a hood that is not intended to be opened by the customer the engine cover styling could be reduced and by that giving a higher degree of freedom in designing the cover for better noise and vibration dampening. Also time and resources would be saved not having to put work effort on the styling of the engine cover. The final area of benefits is the wiring in the engine room. Today this is done with so the customer will not be able to see the wiring. If having a hood that the customer will not need to open, this could be done in a more optimized way.

5.4. Recommendations for further work

This solution allows a higher degree of freedom when drawing the split-lines between the hood and fender. In order to get the most of this solution it is necessary to take into account how the split-lines for this solution are to be drawn. During this thesis work changes were made on an already existing design. This gave restrictions on how the split-lines could be drawn, however the layout of the split-lines is to show an alternative to the already set design and illustrate how the new solution gives more design freedom. The concept generated during this project only has simple hinges due to the thesis aiming to developing a concept. The hinges are needed to be worked on further in order to find the best design solution for them.

For filling of engine oil and washer fluid, a design solution was suggested in order to show how this can be solved. However this needs further development. Engine oil was found to be especially hard to find different solutions for. Further work in this area could prove useful in order to find even better solutions for this.

If having a hood that moves to a service position and then is to be lifted off, styling can be reduced in the engine room. More effort can be put into making a more functional design in the engine room. During this project it was found that a majority of people that answered the internet survey had a negative opinion for a hood that would be necessary to lift of. However it was shown that if this is pulled off in a way that adds value for the customer, there is potential for success for this project.

VCC has to take a decision if wanting to work with this, and implement it in a future car project from the beginning in order to get the most out of this concept.

In order to get information on how frequently Volvo drivers open their hood, the VIDA service system can be used with the help of sensors to collect information whenever the hood is opened. This can be used for both statistical reasons and for workshop service reasons. Implementing this in the future car models might give a good indicator whether VCC can take the step to close the hood or not.

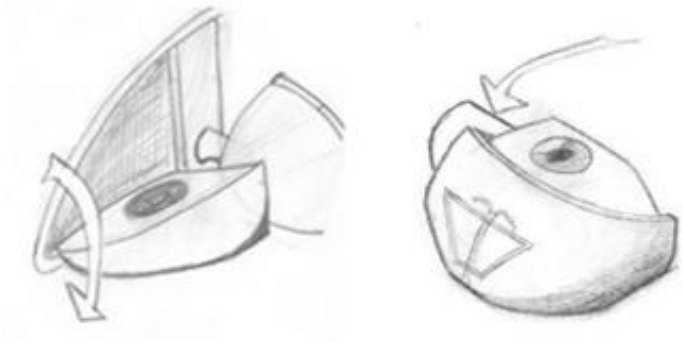


Figure 51: Concept for filling in side rear mirror

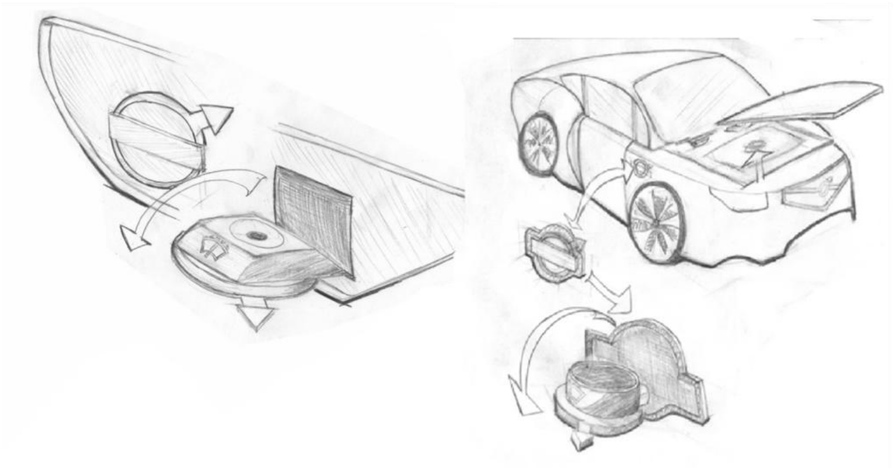


Figure 52: Concept for filling behing a Volvo logo

During this master thesis a lot of different concepts were generated for filling of washer fluid and engine oil. Two ideas for washer fluid that are considered to be of value for further consideration are presented in figure 44 and 45. In figure 44 the washer fluid is to be filled in the area of the side rear mirror. This concept has is considered to have a good placement for the filling position of washer fluid, as the height and position of the side rear mirrors could enable easy refilling for the customer. The other idea for refilling washer fluid is placing the filling area behind either the front logo or a potential side logo. Both these ideas would cover the filling areas completely and not require the customer to handle the hood in order to refill washer fluid.

6. Conclusions

The market research show signs of a conservative market where customers want to have the control of their own car. If the project can be carried out to retain the benefits with the current hood and in the same time create a service solution that eliminate the most common reasons for hood opening, many of the conservatives might be persuaded.

The final concept will be able to eliminate the need for over-slam since the opening and closing to the engine room now is performed whilst in service position, positioned a few cm over the fully closed position. Since the hood is opened up and forward, the possibility to discard split-lines through the s-curve is high. The split-line is now possible to be drawn all the way back to the door. The independency for split-lines is one of the reasons why the Slider concept was chosen as the final concept.

By using a hood with a thinner sheet thickness combined with the new hinges, both cost and weight reductions are possible. If the hood is able to be lifted off, the hinges can be made easy and light.

The new service position enables easier filling of washer fluid and engine oil. There are possibilities to place even more fluid fillings here to eliminate more reasons to open the hood. The battery pole placement turned out easier to solve than the fluid fillings. It can be placed either in plenum, accessible from the service position or placed in the trunk.

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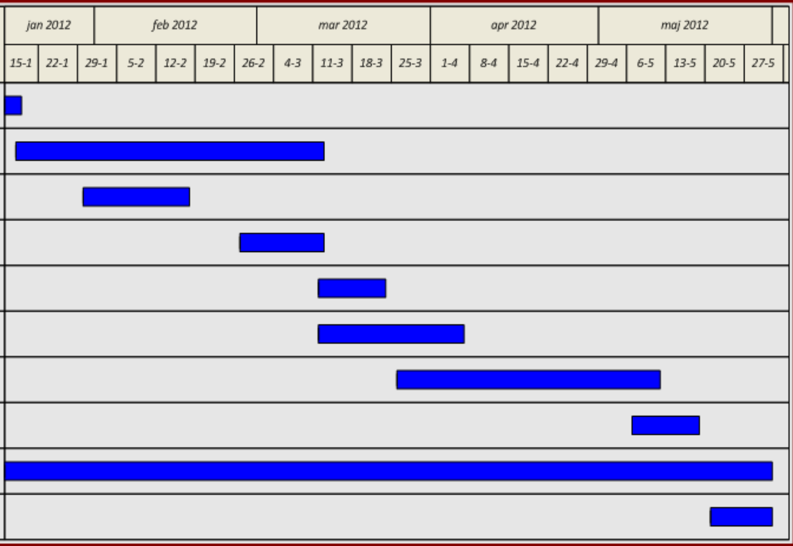
8. Appendices

Appendix A GANTT Chart

ID	Task Name	Start	Finish	Duration
1	Project Plan	2012-01-16	2012-01-18	3d
2	Market research	2012-01-18	2012-03-12	39d
3	Requirement specification	2012-01-30	2012-02-17	15d
4	Concept generation	2012-02-27	2012-03-12	11d
5	Concept selection	2012-03-12	2012-03-23	10d
6	Concept evalutation	2012-03-12	2012-04-06	20d
7	Final design	2012-03-26	2012-05-11	35d
8	Prototype	2012-05-07	2012-05-18	10d
9	Report	2012-01-16	2012-05-31	99d
10	Presentation	2012-05-21	2012-05-31	9d



Appendix B KJ Method

Appendix C Requirement Specification

Abbreviation	Explanation
D/W	Demand/Wish
Y/N	Yes/No
Ev.	Evaluation by the group
N/A	Not available
Calc.	Calculation

Requirement specification for Closed hood			Date: 2012-06-04	Version: 04		
Req. no	**Requirement**	**D/W**	**Value**	**Unit**	**Verification method**	**Stakeholder**
	Design					
1	Easily implented in future car projects	D	Y/N	-	N/A	VCC
2	Few parts	W	Y/N	-	Ev.	VCC
3	Small gap and flush	D	Y/N	-	Ev.	VCC, End user
4	Oil symbol coded with ISO symbol	D	ISO 2575: F04	-	Ev.	VCC, End user
5	Diam. size of Oil container filler hole	D	>45	mm	Test.	Service/End user
6	Diam. size of Washer container filler hole	D	>45	mm	Ev.	VCC, End user
7	Distance from the exterior point of front bumper or front fender to center point of fillment	D	<350	mm	Ev.	VCC, End user
8	Washer fluid symbol coded with ISO symbol	D	ISO 2575: C05	-	Ev.	VCC, End user
9	Space needed to be able to fill washer fluid from a 5 l can.	D	Y/N	-	Ev.	VCC, End user
10	Space needed for starter cable connection clamp	D	>25	mm	Ev.	VCC, End user
11	Space needed around the connection clamp for the hand when connecting starter cable connection clamp	D	>25	mm	Ev.	VCC, End user
12	The connecting points shall be coded with ISO-symbols/text: Symbol no 0679	D	ISO 5006 ISO 6405	-	Ev.	VCC, End user
13	No s-curve	D	Y/N	-	Ev.	VCC
	Service					
14	Persons required in order to access the engine room	W	1	person	Test	Service, End user
15	Not require special tools to access the engine room	D	Y/N	-	Ev.	Service, End user
16	DRO Freeze frame VIDA	W	Y/N	-	N/A	
17	Time to access engine room	D	<30	s	Calc.	Service
18	Time to close engine room	D	<30	s	Calc.	Service
19	Not require to lift off the hood to access to engine room	W	Y/N	-	Test	Service/End user
	Safety					
20	Pedestrian safety requirements are not to be compromized	D	Y/N	-	N/A	VCC, End user
21	Collision safety requirements are not to be compromized	D	Y/N	-	N/A	VCC, End user
22	Aviod injuries when accessing the engine room	D	Y/N	-	N/A	Service, End user

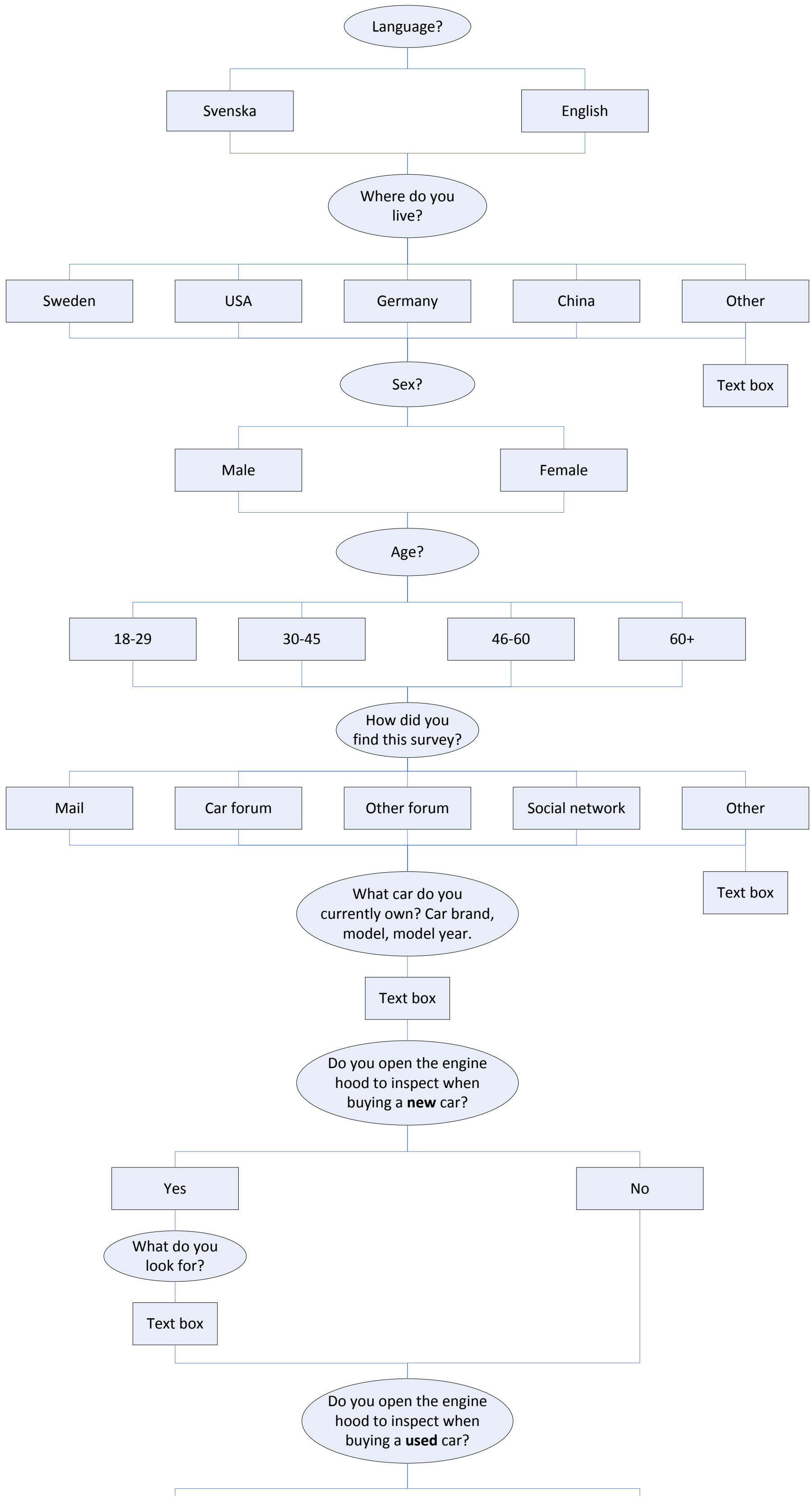
23	Avoid risk for electric shock	D	Y/N	-	N/A	End user, Service
	Manufacturing					
24	Manufacturing price as todays hood solution or less	D	Y/N	-	Ev.	VCC
25	Paint the hood mounted on the car	W	Y/N	-	Ev.	VCC
26	Manufacturing process similar to todays process	W	Y/N	-	Ev.	VCC
	Usability					
27	Steps needed to access battery poles	D	3	steps	Test	End user
28	Time to access battery poles	D	2	min	Test	End user
29	Allow access to battery poles without opening the hood	W	Y/N	-	Ev.	End user
30	Steps needed to access refilling of washer fluid	D	2	steps	Test	End user
31	Time to access refilling of washer fluid	D	20	s	Test	End user
32	Allow refilling of washer fluid without opening the hood	D	Y/N	-	Ev.	End user
33	Steps needed to access refilling engine oil	D	2	steps	Test	End user
34	Time to access refilling of engine oil	D	20	s	Test	End user
35	Allow refilling of engine oil without opening the hood	D	Y/N	-	Ev.	End user
36	Refill height from full oil refill bottle	D	<5	cm	Test	End user
37	Refill height from full washer fluid bottle	D	<5	cm	Test	End user
38	Easy to locate	D	Y/N	-	Ev.	End user
39	Allow changing of light bulbs	W	Y/N	-	Ev.	End user/Service
40	Oil and washer fluid refills should be reachable from the front area of the car	D	Y/N	-	Ev.	End user/Service

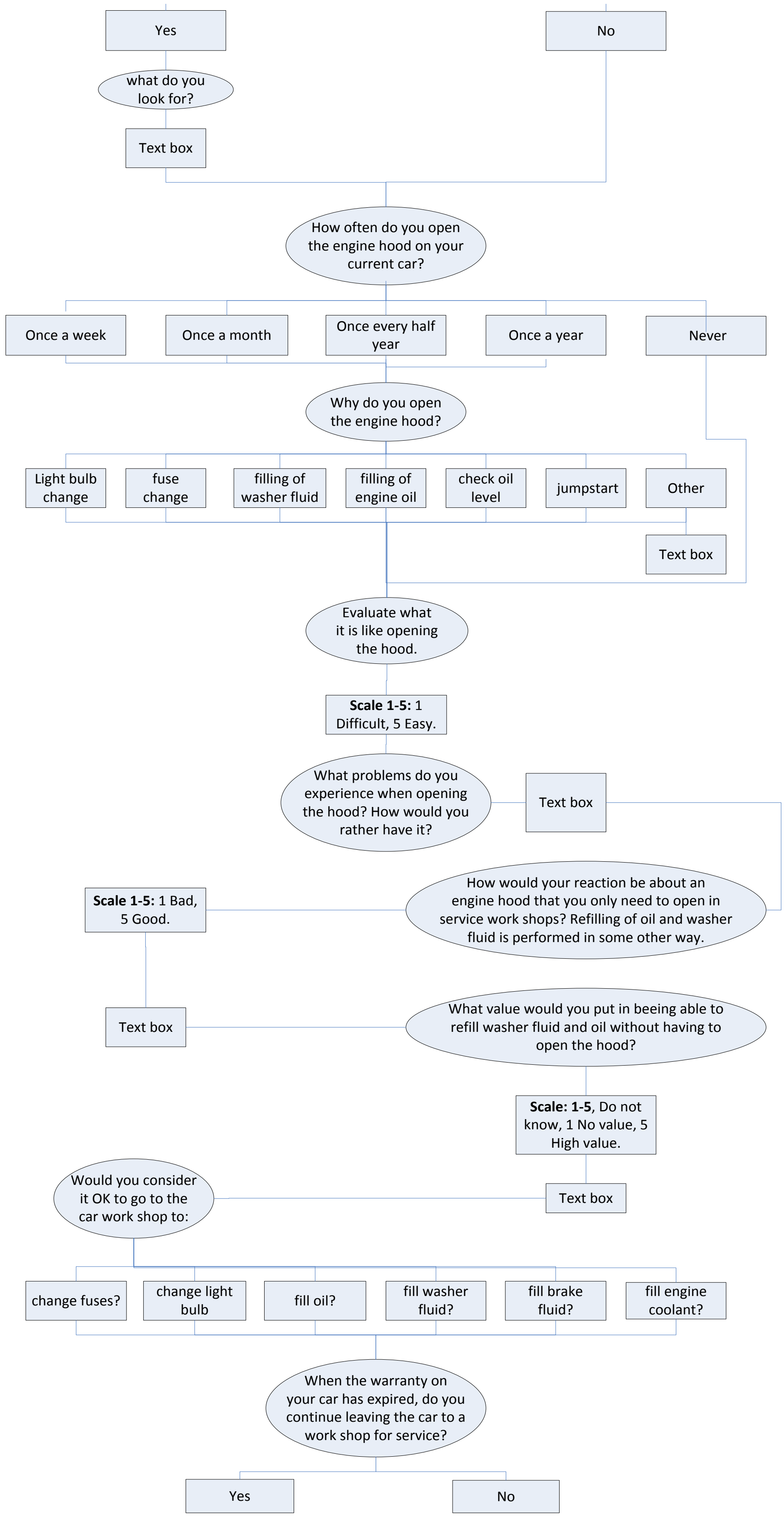
Appendix D Hood Master thesis survey

Hood Master thesis survey

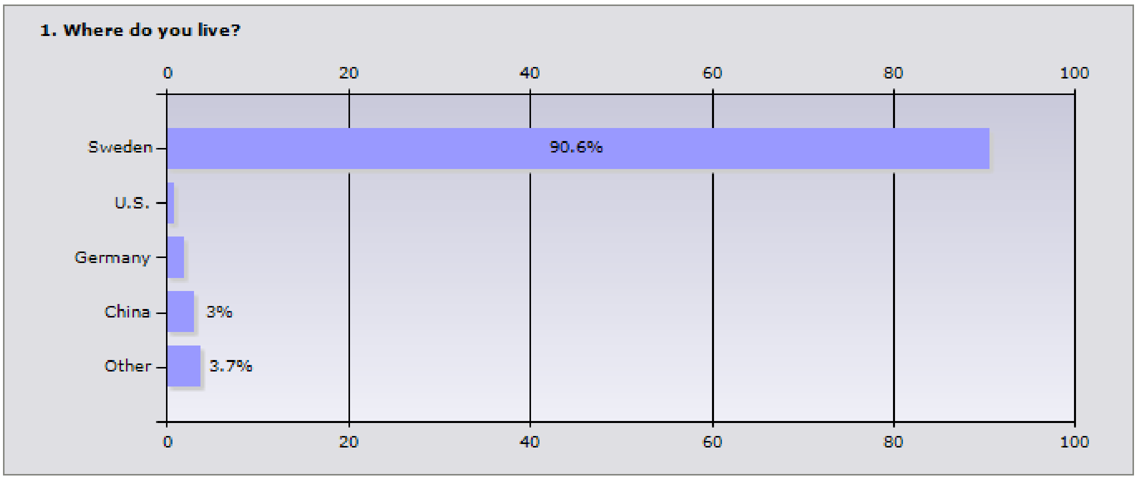
Compilation of statistics from internet survey

Question workflow in the internet survey

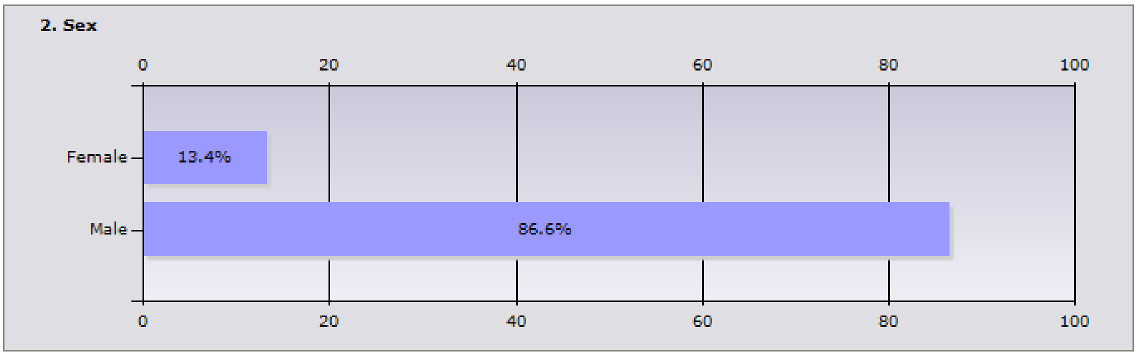




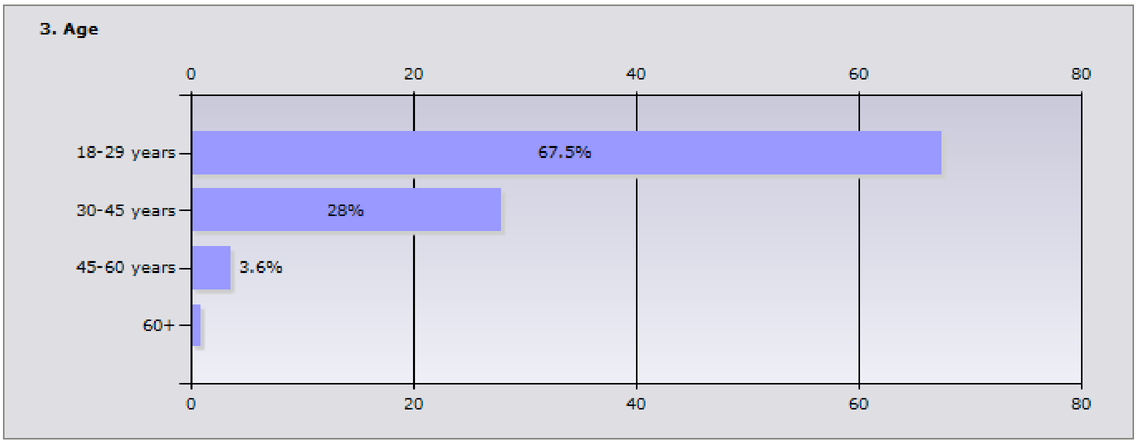
Yes
No
what do you look for?
Text box
How often do you open the engine hood on your current car?
Once a week
Once a month
Once every half year
Once a year
Never
Why do you open the engine hood?
Light bulb change
fuse change
filling of washer fluid
filling of engine oil
check oil level
jumpstart
Other
Text box
Evaluate what it is like opening the hood.
Scale 1-5: 1 Difficult, 5 Easy.
What problems do you experience when opening the hood? How would you rather have it?
Text box
How would your reaction be about an engine hood that you only need to open in service work shops? Refilling of oil and washer fluid is performed in some other way.
Scale 1-5: 1 Bad, 5 Good.
Text box
What value would you put in beeing able to refill washer fluid and oil without having to open the hood?
Scale: 1-5, Do not know, 1 No value, 5 High value.
Text box
Would you consider it OK to go to the car work shop to:
change fuses?
change light bulb
fill oil?
fill washer fluid?
fill brake fluid?
fill engine coolant?
When the warranty on your car has expired, do you continue leaving the car to a work shop for service?
Yes
No



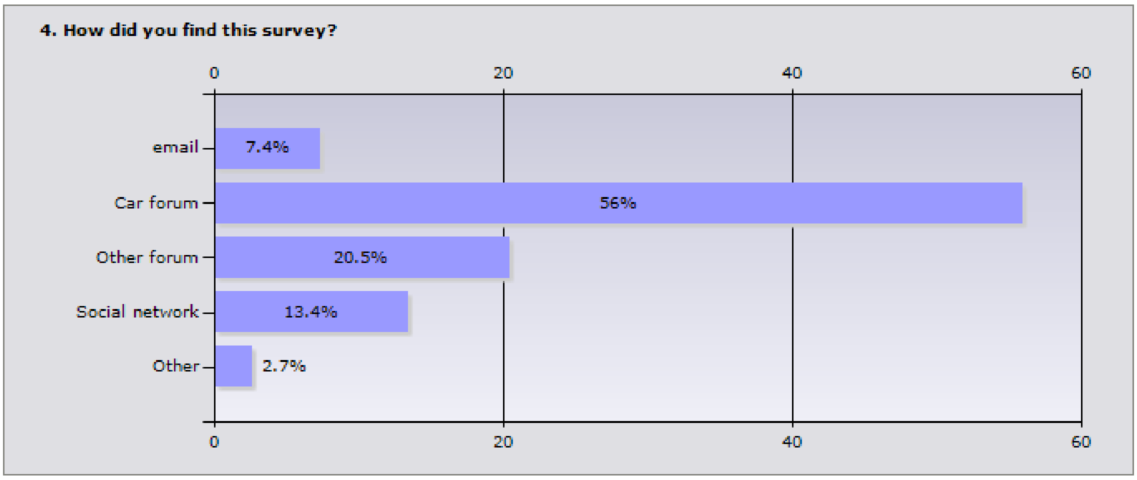
	Percentage	Count
Sweden	90.6%	942
U.S.	0.8%	8
Germany	2%	21
China	3%	31
Other	3.7%	38
	Respondents	1040
	No response	1



	Percentage	Count
Female	13.4%	139
Male	86.6%	896
	Respondents	1035
	No response	6

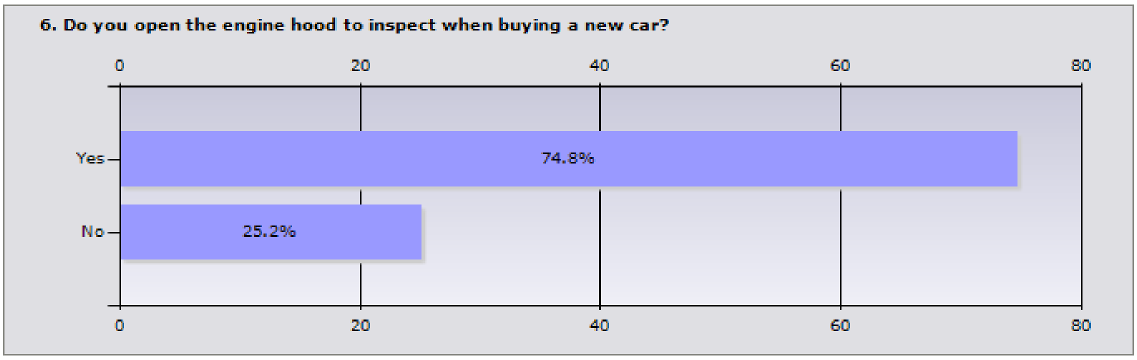


	Percentage	Count
18-29 years	67.5%	695
30-45 years	28%	288
45-60 years	3.6%	37
60+	1%	10
	Respondents	1030
	No response	11



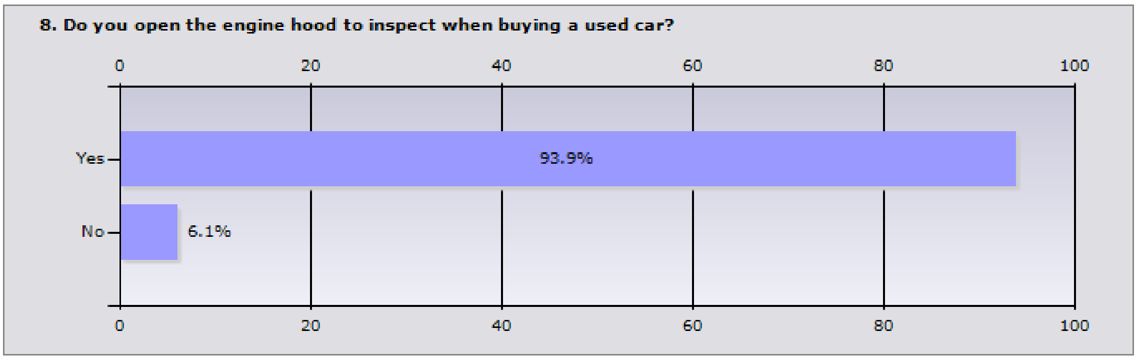
	Percentage	Count
email	7.4%	76
Car forum	56%	574
Other forum	20.5%	210
Social network	13.4%	137
Other	2.7%	28
	Respondents	1025
	No response	16

5. Comments



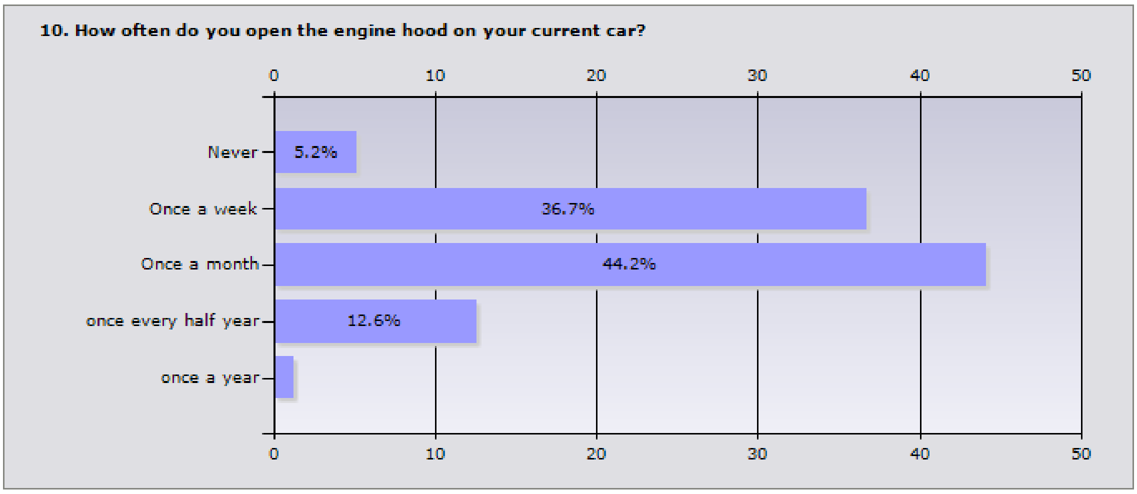
	Percentage	Count
Yes	74.8%	698
No	25.2%	235
	Respondents	933
	No response	108

7. Comments

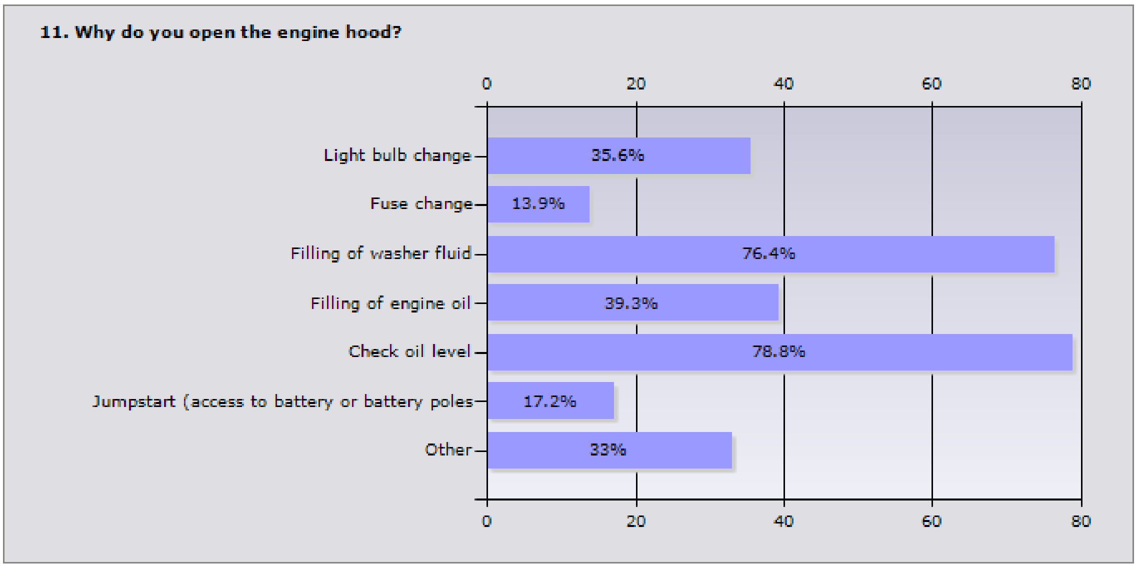


	Percentage	Count
Yes	93.9%	802
No	6.1%	52
	Respondents	854
	No response	187

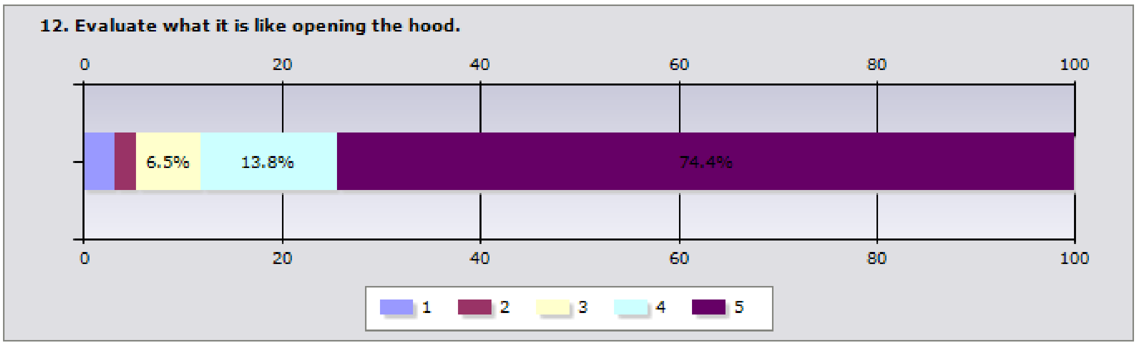
9. Comments



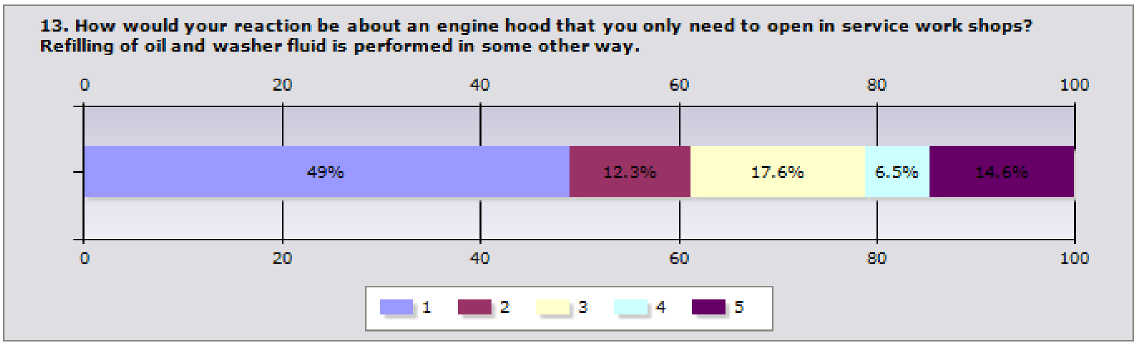
	Percentage	Count
Never	5.2%	43
Once a week	36.7%	306
Once a month	44.2%	368
once every half year	12.6%	105
once a year	1.3%	11
	Respondents	833
	No response	208



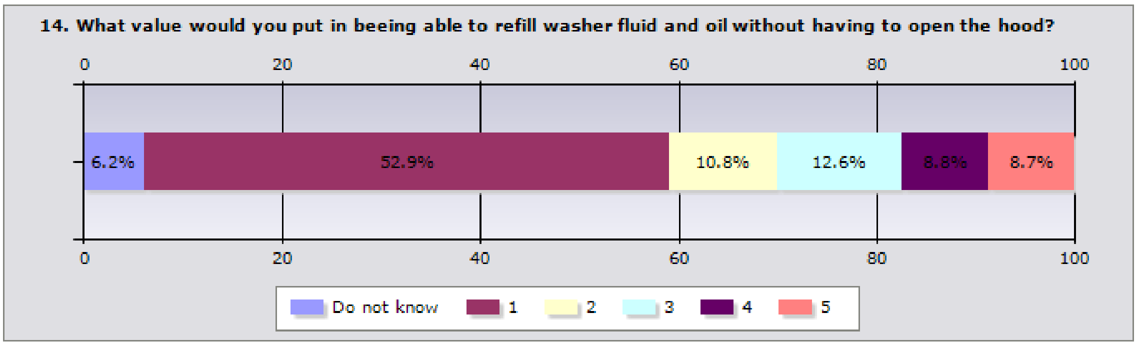
	Percentage	Count
Light bulb change	35.6%	279
Fuse change	13.9%	109
Filling of washer fluid	76.4%	598
Filling of engine oil	39.3%	308
Check oil level	78.8%	617
Jumpstart (access to battery or battery poles	17.2%	135
Other	33%	258
	Respondents	783
	No response	7



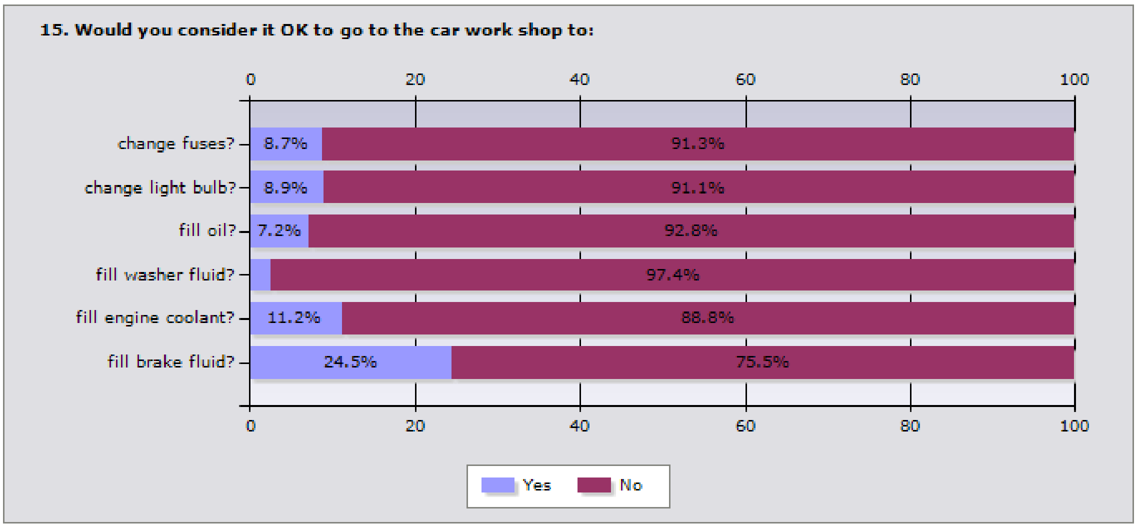
	Difficult				Easy			
	1	2	3	4	5	Average	Respondents	No response
	3.1%	2.2%	6.5%	13.8%	74.4%	4.54	827	214
					Total	4.54	827	214



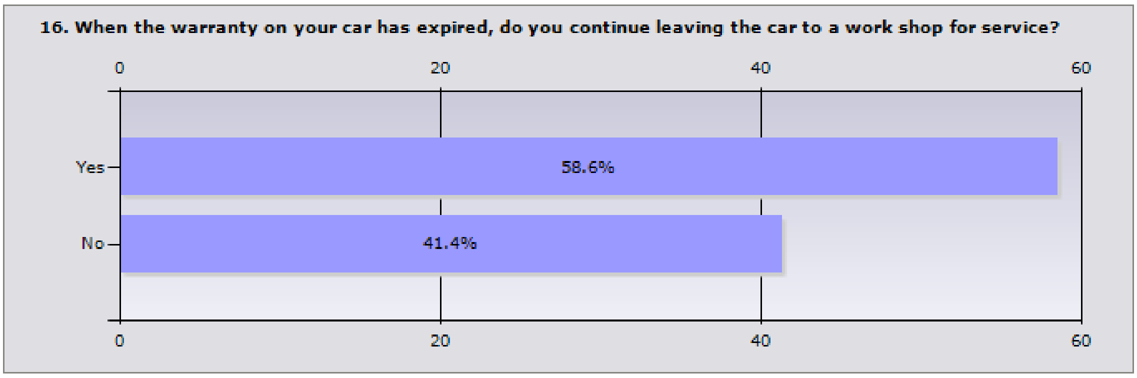
	Bad			Good				
	1	2	3	4	5	Average	Respondents	No response
	49 %	12.3%	17.6%	6.5%	14.6%	2.25	816	225
					Total	2.25	816	225



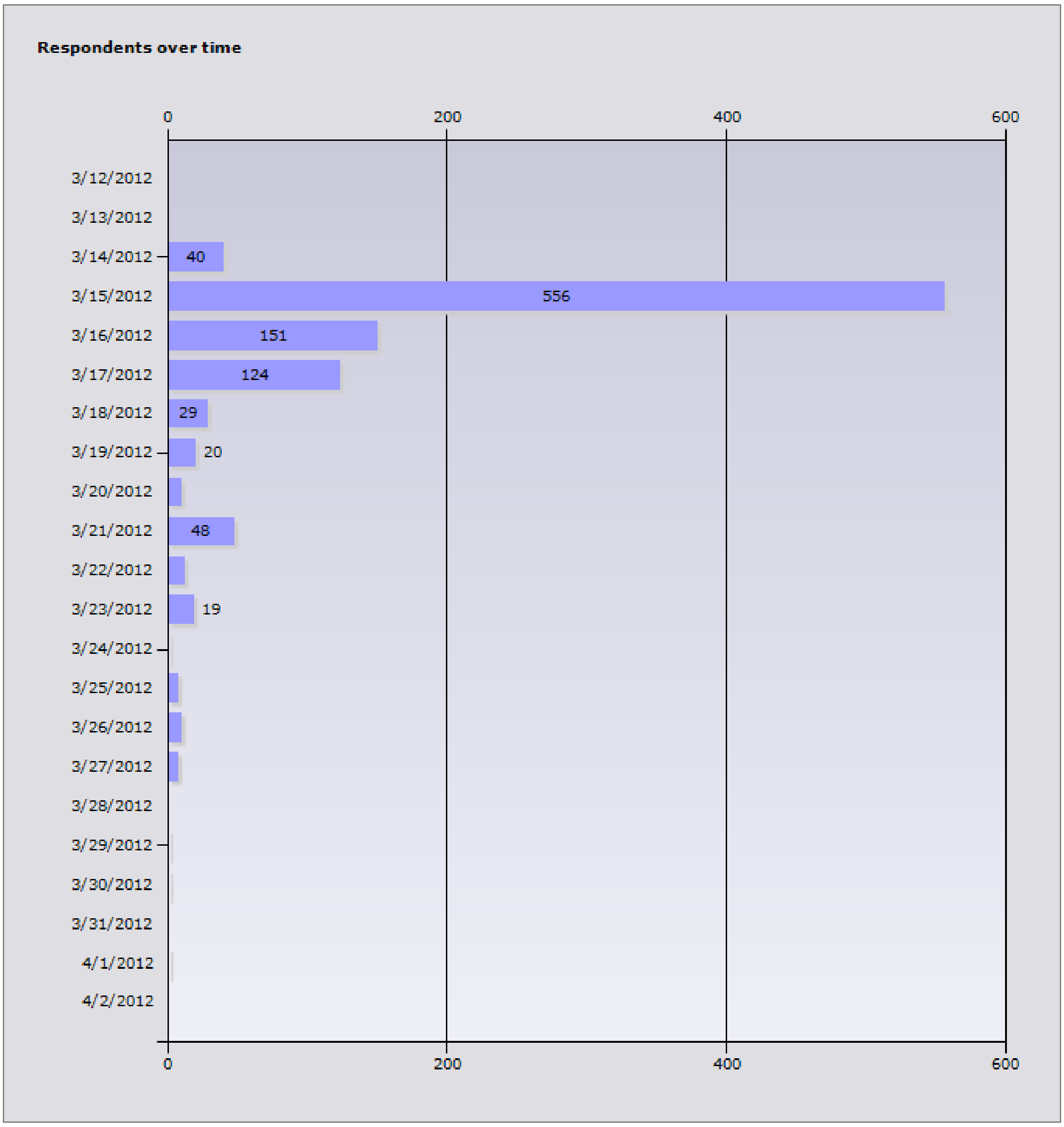
	Do not know	1 (No value)	2	3	4	5 (High value)	Average	Respondents	No response
	6.2%	52.9%	10.8%	12.6%	8.8%	8.7%	2.04	818	223
						Total	2.04	818	223



	Yes	No	Respondents	No response
change fuses?	8.7%	91.3%	812	229
change light bulb?	8.9%	91.1%	810	231
fill oil?	7.2%	92.8%	811	230
fill washer fluid?	2.6%	97.4%	810	231
fill engine coolant?	11.2%	88.8%	815	226
fill brake fluid?	24.5%	75.5%	812	229
		Total	816	225



	Percentage	Count
Yes	58.6%	465
No	41.4%	328
	Respondents	793
	No response	248


Respondents over time
0
200
400
600
3/12/2012
3/13/2012
3/14/2012
40
3/15/2012
556
3/16/2012
151
3/17/2012
124
3/18/2012
29
3/19/2012
20
3/20/2012
3/21/2012
48
3/22/2012
3/23/2012
19
3/24/2012
3/25/2012
3/26/2012
3/27/2012
3/28/2012
3/29/2012
3/30/2012
3/31/2012
4/1/2012
4/2/2012

Group	Recipients	Not reachable	Respondents	Response frequency
Facebook	522	0	118	22.6%
Familjeliv	63	0	58	92.1%
Garaget	261	0	253	96.9%
Motortalk Tyskland	29	0	19	65.5%
Mottgare Sverige	102	7	63	66.3%
Sweclockers	208	0	181	87%
Vet ej vad	8	0	0	0%
Xcar (Kina)	34	0	30	88.2%
Ytterligare en	2	0	0	0%
zatzy	343	0	319	93%
Total	1572	7	1041	66.5%

Appendix E Morphological matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Allow access to engine room	P-hinge	Flip front	Slide off	Railway	Slip and slide	Pop snap	Forward hood	Crutch	Slide and lock	Door lock	Conventional	
2. Allow oil filment	P-hinge	Fender flip	Slide off	Sidekick	Oil flip	Barbeque	Pull out	Eye-ball	Logo flip	Conventional		
3. Allow washer fluid filment	P-hinge	Fender flip	Slide off	Sidekick	Oil flip	Barbeque	Pull out	Eye-ball	Mirror fill	Funnel	Logo flip	Conventional
4. Allow access to battery poles	P-hinge	Fender flip	Slide off	Sidekick	Trunk slide	Grill pole	Screwpull	Energy flip	Conventional			

Appendix F Example of concept weighting for a successful combination and a unsuccessful combination from the morphological matrix

Concept 3				
Function	Solution	Criteria	Synergy	Description of interaction
	1.8 Crutch			
Allow access to				
engine bay		A		Discreet design, risk for large gap
		B		Easy service
		C		Easy to find and use
	2.5 Oil flip	D		Risk for reduced pedestrian safety
		E		Hard to fix
Allow oil filment		F		Hard to separate
		A		Visible but subtle
		B		Easy to seperate
		C		Easy to use, hard to find
	3.10 Funnel	D		Risk for reduced pedestrian safety
		E		Seperated manufacturing
Allow washer fluid		F		No effect
filment		A		Seperated from eachother
		B		Easy service
		C		Easy to use, hard to locate
	4.5 Trunk slide	D		Seperated from other service
		E		Seperated
Allow access to		F		No risk for electric shock
battery poles				

Concept 2				
Function	Solution	Criteria	Synergy	Description of interaction
	1.1 P-hinge			
Allow access to				
engine bay		A		Discreet design
		B		Easy to access service
		C		Simple principle with easy access
	2.1 P-hinge	D		Safety principle as today
		E		Few components
Allow oil filment		F		No extra value for workshop
		A		All service hiden in the same place
		B		Everything in one place
		C		Risk for mix of oil and washer fluid
	3.1 P-hinge	D		Does not effect safety
		E		Everything in on place
Allow washer fluid		F		Everything in one place
filment		A		Two moving parts on eachother
		B		
		C		
	4.4 Sidekick	D		
		E		
Allow access to		F		
battery poles				