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Development of Complete Mounting Solutions for the License Plates at Volvo Cars

Master of Science Thesis in the Master Degree Programme, Product Development

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Abstract

This is a master thesis conducted at Volvo Cars for Chalmers University of Technology. The purpose was to investigate and develop new front and rear license plate holders. It goes through all the different phases of the product development process, from background information to virtual prototyping and assessment of the final design. A large part of this thesis also was to conduct a benchmark in order to understand how the competitors solve their mounting and fastening of the license plates.

The current front license plate holders that Volvo Cars uses cannot be kept in the future due to a desire to make the shape of the front more complex. This drives a need to develop a holder that solves this problem without influencing the design in a negative way. The development of the rear license plate holders will focus more on reducing the cost and raising the overall quality of the holder. This is needed in the competitiveness of the automotive industry and it forces the car manufacturers to cut their expenses without compromising the customer needs.

The result of this project is a new front license plate adapter that also acts as the license plate holder. It is form-fitted to the shape of each car model and is to be released in four different variants depending on which market the car is sold. The design is essentially a plastic housing that provides good support to the plate as well as it covers up the area between the plate and the front of the car.

The final design of the rear license plate holder is two different variants of a combined North American, Chinese and Japanese holder. This can be compared to the eight holders that are needed today. The new design also made it possible to reduce the cost of the average license plate holder by approximately 21%.

Preface

This is a master thesis project on the topic “Development of complete mounting solutions for the license plates”. It was conducted in close collaboration between two Chalmers University of Technology students, Andreas Larsson and Anders Olsson. The project was supervised by the associate professor at Chalmers University of Technology, Lars Lindkvist, whom we would like to thank for his continuous support. We also would like to thank everyone at the “Rear opening system” division at Volvo Cars, especially Ulrika Fröström and Jonas Lindström for always listening and giving feedback.

This master thesis has provided us with some insightful information on how it is to work at Volvo Cars and in the automotive industry. The project has included almost everything there is to know about license plates all around the world and their holders. The reader will therefore probably have a broad understanding of the subject after reading this report.

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1 Introduction

This section contains the background, the problem formulation as well as the aim and goal of this development project. Also the scope is defined together with a brief description of the company, Volvo Cars.

1.1 Background

The automotive industry today is subject to increased competition between brands, higher customer requirements and a lowered market demand in this economic climate. Other trends that affect this industry are the increased focus on environmental issues as well as tougher legal restrictions.

These competitive dilemmas have forced the automotive companies to try to cut their expenses. This can be done in several ways. Many brands develop a shared platform throughout their product range which gives a higher economy of scale on the manufactured parts. It has also been more common for brands to merge together into larger company groups. One example of this is the Volkswagen Group which contains 13 brands, where this positive effect can be enhanced even further. One of several downsides of this approach is that the customer will have a problem differentiating the cars from each other.

Volvo Cars as an automotive company is also affected from these trends. As mentioned above they therefore need to investigate their expenses. They are already working with shared platforms within their model range and are looking at other areas that can cut costs without affecting the customer in a negative way. Since Volvo Cars is a premium brand, the quality perceived by the customer is of most importance which is why a cost reduction must not affect the quality of the car.

Today, Volvo Cars has several different license plate holders for different markets and models, but also different rear and front versions. Due to their similarities in size and function it is a potential area to cut costs by developing a common structure for the holder. The current holders have remained the same for a long period of time and no thorough investigations has been made. Volvo Cars has an opportunity to lower the cost as well as raising the perceived overall quality of the holders. Previously there has been a problem where a low quality holder was a subject to vibration and noise. This has partially been solved, but it is something that needs to be further investigated.

The design of the cars has become more complex throughout the years. Today there are almost no flat surfaces left on the car. This creates a problem when mounting the license plate to the front of the car. In order to allow for a complex design, where the designers do not feel limited by the placement of the license plate, an adapter that is placed between the car and the license plate needs to be developed. As a part of this, the fastening methods to both surfaces need to be further investigated. A challenge when designing these fasteners is that the car should look good both with and without a license plate holder in order to fit any situation.

Due to legal restrictions, the rear holder has to be placed on a flat surface which eliminates the need for an adapter. Instead the focus will be on cutting cost as well as raising the customer perceived quality.

The responsibilities of the license plate holder differ on various markets, which is something that needs to be considered and clarified. The reason for this is the many affected participants: Volvo Cars, the manufacturer of the holder, the transport administration, the car dealers, and the customers.

1.2 Purpose

The first objective of this thesis is to develop an adapter (or adapters) for the front license plate that will replace the existing holders. This adapter will be placed between the complexly designed front of the car and the flat license plate. The result of the new concept will be presented visually for a better understanding.

The second objective is to investigate the current holders for the rear license plate, and if necessary develop new and improved version (-s). Depending on the outcome of the investigation, a visual concept or a discussion regarding the future holder will be presented.

As a part of this thesis a complete benchmark is to be made, where several competitors are investigated. Both their front and rear license plate solutions will be examined. The results of this benchmark will be presented with a clear overview where the trends are shown but also more in-depth information will be delivered. The complete results of this thesis will finally also be presented in a technical report.

From the purpose of this thesis some research questions has been extracted to ensure that the objective is fulfilled. The questions correspond to both the front and rear fastening solutions.

- How is the interface between the holder and the car going to be solved?
- How is the interface between the license plate and the holder going to be solved?
- How can the overall quality perceived by the customer be raised?
- How can the overall costs be kept at a minimum?
- How do the competitors solve the stated problems?

1.3 Scope and limitations

The Volvo Cars sales volume divided on the different markets can be seen in Figure 1. USA, China and Europe are the main markets and they sum up to a total of 85% of the sales volume. For these markets either Volvo Cars are providing a suitable license plate holder or a standard license plate holder exist. For legal reasons they also provide license plate holders for the Japanese market which is 3% of the sold cars (Volvo Cars 3, 2013). Apart from this the American holders is used in Canada and Mexico as well. The same trend goes for the European holder which is used in many other countries like South Africa. This makes it possible for Volvo Cars to provide suitable license plate holders for around 97% of their sold cars. The remaining 3% of the sales volume is divided into many smaller markets. They will in the fu-

ture either provide their own license plate holders much like they do today or use one of the developed versions. Therefore the earlier mentioned markets are to be considered as the most important ones during this thesis. The investigated regulations, customer opinions and so forth will mostly be focused on these markets.

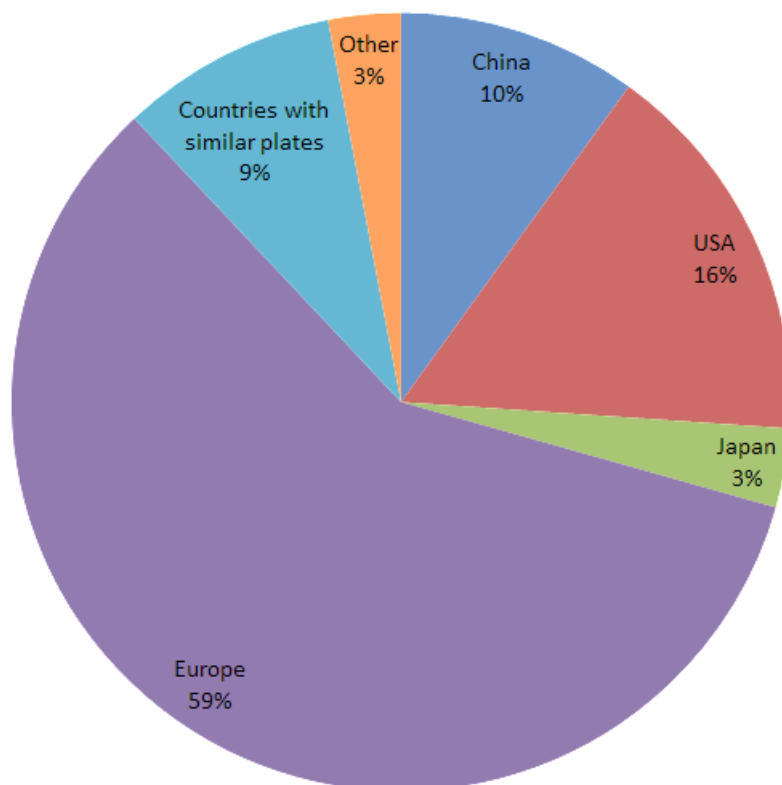


Figure 1 - Sales volume per market (Europe incudes only Russia, Sweden, Norway, Denmark, Finland, Netherlands, Belgium, Luxembourg, France, Spain, Italy, Greece, Portugal, Great Britain, Ireland, Germany, Switzerland, Austria, Poland, Hungary and Czech Republic)

Since this master thesis is conducted in Sweden it is not feasible to investigate license plate holders from other markets to the same extent as the Swedish and European ones. This might lead to a less thorough investigation and presentation of non-European solutions. In addition to this, an overrepresentation of solution and opinions from the English speaking countries is found on the internet. Therefore opinions and solutions written in other languages might not be investigated to the same extent.

The scope of this project is only to deliver conceptual solutions to a front and a rear license plate holder. Therefore exact manufacturing methods will not be chosen and precise manufacturing drawings will not be made.

Estimations on the cost of the new solution will be presented. However, the more precise business case and choice of supplier etc. is not within the scope of this thesis.

1.4 Company presentation

Volvo Cars is a car manufacturer that was founded in Sweden in 1927. It was previously part of Volvo AB, which is mainly a truck manufacturer today. For a time Volvo Cars was owned by Ford Motor Company but it is now owned by Zhejiang Geely Holding Group. The Volvo Cars headquarter and production plant is located in Gothenburg, Sweden. They also have production plants in Belgium and in China. The production in China is also expected to grow in the future due to the fact that China is now their second home market. Volvo Cars corporate strategy is called “Designed around you”, which means that the customer is central in everything. They also have a strong focus on environmental aspects as well as on their trademark, safety. Their vision is: *“To be the world’s most progressive and desired luxury car brand.”*

In 2011 they sold 449 255 cars in more than 100 countries and their long-term sales target is 800 000 cars in 2020. The biggest market is USA followed by Sweden, see Figure 2. In total Volvo Cars sold 12 different car models, where XC60 was the most popular model. (Volvo Cars 1, 2012)

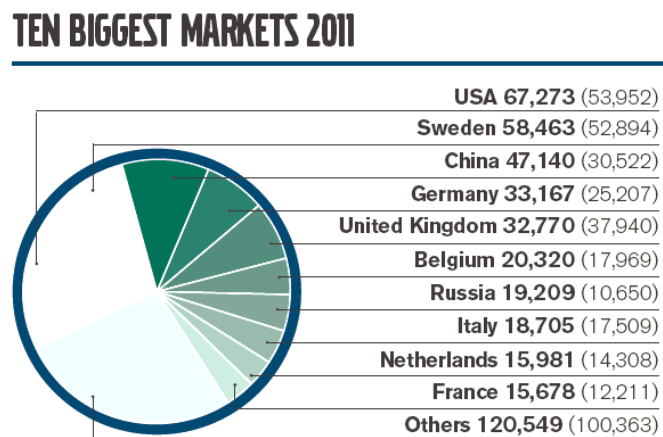


Figure 2 - Ten biggest markets 2011 (Volvo Cars 1, 2012)

In recent years Volvo Cars has become more of a luxury brand than before. This could mean that the future cars will have more of a radical design, with less flat surfaces. Their inspirational vision of the future cars can be seen in their latest concept car called “Concept You” which was released to the public in 2011 (see Figure 3 and Figure 4). The curvature and aesthetics of the front could result in a need to develop new license plate holders that fits a progressive design, which is one of the tasks of this thesis. In the future the aesthetics should not be compromised by limitations of the license plate mountings.



Figure 3 - Concept you side view (Volvo Cars 2, 2011)



Figure 4 - Concept you front view (Volvo Cars 2, 2011)

1.5 Outline

The outline of this report is as follows. It starts with describing the methods that was used during this product development project. It is followed by the pre-development phase where all the background information is identified and presented. It contains for example information about the current license plate holders. Its purpose is to provide the reader with a better understanding of what should be developed. Then follows a comprehensive benchmark that will explain how the competitors and third party manufacturers solve the task, as well as some innovative homemade solutions and patents. Next a customer investigation is made that tries to explain what the customer want to have.

When all this has been presented the actual development phase starts. It is divided into two separate parts, one which explain the development of the front adapter and the other one describes the development of the rear holder. Both of them contain information regarding requirement specification, concept generation and evaluation, as well as the final design that was chosen. The report ends with a discussion regarding the two different solutions, what needs to be done in the future and finally a conclusion.

2 Method

This chapter explains how the project was executed and presents the methods that were used. It has the purpose of strengthening the credibility of the results in this report.

2.1 Pre-study

The thesis started with a theoretical research regarding the background of the subject. Here the laws and restrictions regarding the use of license plates were examined for the different markets and also the corresponding responsibilities. The main sources of this information were legal documents which were translated to English. These documents were found on the Volvo Cars intranet. Moreover theory concerning the license plates, the holders used, as well as the actual fastening of the license plates today was investigated. This information came from product drawings, real life inspections and searches on the internet.

A review of different publications was made to get a clear understanding of what has already been researched by others. However, no previous research could be found that involved the same topic as this thesis. Most publications dealt with software recognition of license plates, either for toll cameras or for building entries etc.

2.2 Benchmark

When the theoretical research was finished a benchmark was made in order to examine the solutions that the competitor uses. It was mainly done by visiting 15 different car dealers that in total covered 28 different car brands. Both notes and pictures were taken during these visits. Apart from this Volvo Cars have access to a competitor analysis database called A2MAC1 (A2MAC1, 2013). This database could be used to investigate high resolution images from all the auto shows as well as comprehensive information and images of how the car looks like when taken apart. This made it possible to see exactly what license plate holder they used and how they fasten it. It also contained detailed information about for example the material that was used, its weight and dimensions. This information was compiled in a spreadsheet, with a total of 34 car brands and numerous of car models from each brand. The different characteristics were then extracted and analyzed in this report, but the extensive spreadsheet is not enclosed. Since this information mostly focused on the Swedish and European market some additional internet searches were made to investigate how the cars look like on the Chinese, Japanese, Italian and North American market.

The products provided by third party manufacturers were also investigated. Their respective web pages provided good information about this. By visiting several different discussion forums that were related to the automotive industry one could collect information on how the customers reason about the license plate holders. The use of third party solutions was confirmed as well as the use of many different homemade solutions.

A thorough patent research was made in the Swedish patent and registration office database called “Espacenet” (Espacenet, 2013) and in Google Patents (Google, 2013), both which present patents from all around the world. Hundreds of relevant patents from the 1930’s up to now were investigated. Three main reasons exist of why one should do a patent investigation.

The first one is to ensure that no existing patent rights are infringed. The second one is that by studying existing patents the development team can get a sense of how probable the outcomes of a patent are. The final reason is that by conducting patent investigations additional background knowledge is received. This knowledge can then be an inspiration in the concept generation. (Ulrich, 2007)

2.3 Development phase

Before the development could start a brief customer survey was made. In total 15 persons was interviewed regarding their opinion on different license plate topics. The questions were formulated with the aspects of the Kano-model in mind. It explains that the customer has three different needs: basic, performance and delighters. Basic needs are the ones that have to be fulfilled if the product shall be acceptable. The performance needs and delighters are the ones which give the product a competitive edge, since not all the competitors are providing these things.

Together with the other background information such as legal requirements and Volvo Cars guidelines a requirement specification for the front and rear holder could be made. The requirement specification was then analyzed to find out the challenges associated with this project.

This information was then used in the development of new concepts for the front and rear license plate holder. The investigated areas were defined as; holder concepts, fastening of the license plate, fastening of the holder, noise and vibration eliminators and different kinds of add-ons. With these categories kept in mind, brainstorming was used as a method to generate a good amount of different concepts. Brainstorming is a method where the development team together draws sketches and talks about different solutions to the stated problem. Several sessions should be made to make sure that the best solutions can be found. During this activity criticism is forbidden to ensure that as many ideas as possible will be generated and that all participants should get their say. (Ulrich, 2007)

During the concept generation the theories of modularization was used as a way to improve the concepts and serve as a background when generating them. Modularization and platform strategies have the purpose to handle the trade-off between product variety and the use of standard components. By having much in common one will have economies of scale due to higher production volumes, but also a reduced set of components which affects the assembly, inventory and so on. (Wickenberg, 2011)

After the concept generation there was a need to reduce the amount of concepts and select a final design. First of all the concepts were evaluated regarding their pros and cons. This method gives a clear overview if the benefits outweigh the downsides (Ulrich, 2007). The first feasibility screening could then be made with an elimination matrix. It has the purpose to eliminate those concepts that are not feasible to develop further. Each concept had to fulfill the main requirements, be realizable in principle and be a suitable solution for Volvo Cars. If one of these criteria were not met it was eliminated. This ensured that the development effort was put into the most promising concepts. (Johannesson, 2004)

The remaining concepts were then inserted into a Pugh-matrix. It has the purpose to narrow down the number of concepts but also improving them while doing so. Each concept is rated as “better than”, “same as” and “worse than” compared to a reference concept. Different criteria are chosen that affects different product parameters such as cost, rigidity and license plate support. The scores can then be summarized and each concept will be ranked. A concept, which has clear drawbacks, can then also be further developed and evaluated once again. (Ulrich, 2007)

Based on the ranking in the Pugh-matrix the most promising concepts were inserted into a Kesselring-matrix. However, in order to do a Kesselring a weight determination matrix first had to be made. Here the different criteria used in the evaluation process are compared to each other to see if the requirements are more important, less important or of the same importance to the customers and the stakeholders. The relative importance of each criterion could then be achieved. Since the criteria are weighted the concepts are more accurately ranked to each other than in a Pugh-matrix. Otherwise the Kesselring has many similarities with a Pugh-matrix. Each concept is compared to an ideal solution and then given a rating on how good the concept is in each criterion. (Johannesson, 2004)

Regarding the front adapter, the outcome of the Kesselring was hard to interpret. Therefore some further evaluations regarding the cost had to be made in order to choose a final concept. To aid in this estimation the cost of current holders as well as the website “Custompartnet” was used. This website helped with the cost estimation of injection molding. The cost was then specified as tooling, material and production costs. (Custompartnet, 2013) The estimations from the mentioned methods was used together with a rational discussion with Volvo Cars and the project group in order to select the most promising concept and continue with its development.

One front and one rear concept were chosen. These concepts were then further developed into their final designs. In this stage “design for assembly” and “design for manufacturing” were used to improve the concepts. These methods aim at reducing the mounting time and manufacturing costs. This can be achieved by making the concepts simpler or adapting them to the assembly and manufacturing methods used. Furthermore, the fastening methods for the license plate and the holder were chosen and described. This was also the case regarding the material, environmental aspects, add-ons etc. The CAD-software Catia V5 was also used to present the new concepts visually for a better understanding. A final discussion regarding the result of this thesis and some recommendations for the future could then be given.

3 Pre-development phase

In this chapter the theoretical background is described to ensure a complete understanding of the results and the development of the holders. Current license plate holders, regulations etc. are things that are described here.

3.1 License plates

License plates for passenger cars have the purpose of helping the local authorities keep track of the vehicles tax and registration status. It originally served the purpose of collecting fees which was used to fund the increased wear of the streets (American number plate, 2013). The very first use of a license plate was seen in Canada in 1884. In this time there were no cars, instead the license plate was made for horse-drawn carriage taxis. Some years later, in 1893, France was the first country to specify national license plates. In the following years, the use of license plates spread quickly all over the world. (Drivesteady, 2011) The size and visual appearance of the plates have varied widely from country to country, see Table 1. To ease the recognition of plates, some efforts to standardize them have been made. In 1957 all the states in USA got the same size. This size has also been spread to Canada, Mexico and some smaller countries like Cuba and Panama. The European Union decided on a common model in 1998, which has been adapted by other non-member countries as well.

Table 1 - Sizes of different license plates

| Market | Width (mm) | Height (mm) |
|---|------------|-------------|
| USA, Canada, Mexico etc. | 305 | 152 |
| European Union and some other countries like Norway, Switzerland, South Africa etc. | 520 | 110 |
| Italy (Front) | 360 | 110 |
| China | 440 | 140 |
| Japan | 330 | 165 |

Even if there is a standard size within the EU, some variations exist. For example it is still legal to have the old size in Belgium and Sweden (without the EU flag). In Monaco, Oman, Switzerland and Liechtenstein you are allowed to have a smaller sized license plate on the front of the car than on the rear. In Sweden it is possible to get a permission to have a “US-sized” license plate if the standard EU size does not fit the bumper. All these variations will however not be any problem when developing a front license plate holder, since the countries are able to use the standard EU size instead of the smaller version. This is however not the case for the Italian front license plate, which means that when developing a front license plate holder this smaller size has to be kept in mind.

The attachment interface of the plates is something that has not been globally standardized. Even if two markets have almost the same size they can have different requirements on how it should be attached to the car, for example two versus four screws. In the European Union the license plate comes without any holes at all, it is up to the car dealer or the owner to drill suitable mounting holes if wanted.

In many countries the license plates are made out of aluminum, for example in Sweden and in India. It has the benefit of being completely recyclable and withstands corrosion well. However, plates made out of other metals such as steel is also common. Historically plates have been made out of porcelain, leather, cardboard, plastic or soybeans with unsustainable result. Self-adhesive license plates in the form of a sticker can sometimes be seen on car shows and meetings, but are not allowed during use (Dekal & Dekor, 2013).

3.2 Investigation of license plate sizes and hole patterns

One can see that the sizes of the different plates differs somewhat. The Japanese and American plates are more squared, while the Chinese, European and Italian versions are wider (see Figure 5).

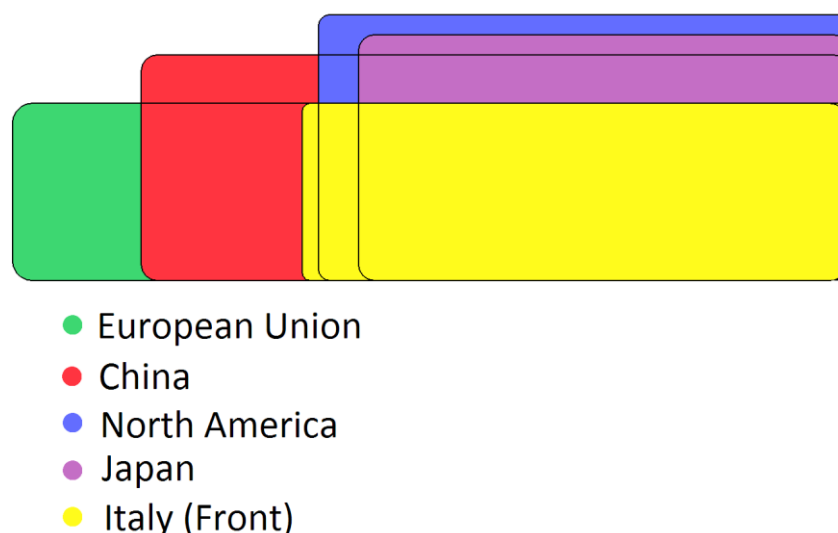


Figure 5 - Comparison of the sizes of license plates

When investigating the three markets that Volvo Cars provide license plate holders for (China, America and Japan), one can see that the mounting holes are closely positioned together (see Figure 6). This background will be necessary to have when the concepts are described later in this report. As seen, the height of the European license plates is too small to actually cover up the mounting holes needed for the other markets. This means that it probably will be hard to merge the other holders with the European versions. One solution to this problem might be to make the holders modularized.



Figure 6 - Comparison of the hole patterns of the plates

3.3 Theft of license plates

License plate thefts are relative common at many locations around the world. These thefts have become more frequent due to an increased usage of automatic readings of license plates. People want to avoid toll roads or for example red light and speeding cameras, which they escape by using someone else's plates. In Sweden you can get up to two years of prison for stealing license plates, but it is more common with fines. However the consequences for the one who steal license plates are often not very severe. In combination with the fact that the license plates often are easy to demount thefts are inevitable. A more serious dilemma is when criminals use someone else's license plates to confuse the witnesses during crimes such as robbery. (Säkerhetsbloggen, 2011)

In some parts of China, for example in Shanghai, the government auction out the license plates in order to reduce the amount of cars that is driven in the city. This means that a pair of license plates can cost up to 100 000 SEK, which is almost the same cost as a new low budget car. In these areas it could be even more important to avoid thefts. (Wantchinatimes, 2013)

When investigating this subject, many solutions on how to minimize the risk of getting the license plates stolen were found. Two examples of such solutions are gluing the plate to the holder or using one-way screws (see Figure 7). There are also markets where there are laws in order to prevent license plate thefts. This is the case in the Japanese market where seals are used on one of the screws that holds the license plate in place. It makes the license plate more difficult to steal and it shows if the seal is broken and if a car drives around without one.



Figure 7 – One-way screw with cover (Minskytt.se, 2012)

In the North American market there is a need for license plates to be easy to demount. This is because in some states the license plate is to be transferred from one car to another at the same time as the car exchange owner. This is also the case when you move to another state. This becomes a conflicting need that has to be dealt with. Today Volvo Cars is providing a holder where the license plate is relatively easy to remove. A more thorough description of the different license plate holders will follow later in sections 3.6 and 3.7.

3.4 Regulations regarding the license plates

In this section relevant regulations regarding the license plates are presented and these are grouped into three areas: general, front and rear. The general regulations concern the overall rules applicable on both front and rear, in contrast to the rules that are specific for either front or rear. Although, it is important to note that these regulations only are from the markets selected in this thesis. The complete list of the investigated regulations can be seen in Appendix 1.

3.4.1 General

Visibility of the license plate is one of the most important areas that have to be secured. Most laws investigated simply stated that the license plate should be visible and in good condition. Other specified that no holder or cover is to be used that can obstruct or impair the recognition of the license plate information.

In order to secure a steady mounting of the license plate, the fastening is often regulated. The level of how specific the laws are does however vary. Some countries only specify that the holders should be securely fastened while for example the Chinese and Japanese laws are much more specific and claims that the license plates have to be fastened with two M6 screws. By 2016 it is also required according to Chinese law to provide a fastening with four M6 screws.

The responsibility of the license plate and its condition lies in the hands of the car owner. However, in for example EU and Japan the license plates are connected to the car in contrast to some American states where the plates belongs to the person. This means that when the car is resold to a new owner the license plates are removed and transferred to the new car.

3.4.2 Front

The visibility of the license plate also has some requirements that are specific for the front attachment. Such regulations seem to be rather common for the Chinese market. The license plate should be vertical or it may be inclined up to a maximum of 15 degrees. The Chinese regulations also specify where on the front the plate is to be located and the USA regulations states the maximum distance the license plate is to be placed relatively to the ground; 1,52 m.

Since the front license plate has an exposed location it can harm others in case of an accident, especially in cases where pedestrians are victims. In Sweden the car can be considered illegal if that is the case. Therefore it is important that the front license plate holder afflicts as little damage as possible.

3.4.3 Rear

The visibility of the rear license plate is essential, thus there are specific requirements regarding both placement and specific angles of the plate. The license plate is supposed to be placed between 0,30 and 1,20 m from the ground, however the USA rules allows the plate to be placed up to 1,52 m from the ground. The inclination of the license plate should preferably be vertical but are allowed to be angled up to 30 degrees. It should also be placed at the center point and perpendicular to the longitudinal plane of the vehicle according to EU regulations.

The fastening of the rear license plate is also something that is highly focused on and specific requirements are stated. For example according to the Japanese rules the license plate holder has to be of sufficient size in order to give good support and prevent the license plate from bending. Moreover the holder should have sufficient rigidity. There are also Japanese regulations regarding how thick the holder should be at the position of the screw in order to allow for at least three threads. In order to prevent illegalities, the Japanese authorities also demands that a seal should be installed on the left side of the license plate. This sealing is to be done by the Minister of Land, Infrastructure, Transport and Tourism or an entrusted seal installer. In the EU the laws does not specify how an eventual holder should look like, but they do say that the attachment surface should be flat with the dimensions of 520*120 or 340*240 mm.

3.5 The use of front license plates in the USA

In the USA today it is not mandatory to have a front license plate in all states, instead it is enough just having a rear license plate. Because of this, many car manufacturers deliver cars that do not have pre-assembled holders or even pre-drilled mounting holes in the front.

The arguments of not having a front license plate come mainly from the car owners. They complain that a license plate on the front ruins the aesthetics of the vehicle. The aerodynamics will be better without a front license plate, since the car sometimes is designed and optimized without one in mind. Also, some drivers claim that the front license plate hinders the airflow, leading to a higher temperature of the car engine. However, many car owners just see it as a way to reduce the likelihood of getting captured by for example a red-light camera. For the involved state it will also be a substantial decrease in cost, which is a strongly contributing factor. Less manufacturing cost as well as a lower environmental impact will be the case since fewer parts have to be produced.

The arguments of having a front license plate is that it is easier to spot cars that are standing still when driving in the dark, since the license plate will reflect some of the light. It also eases the use of for example red-light cameras and speeding cameras, which will increase the driving safety and collect fees for the governments. A front license plate also allows the police and other persons to more easily identify the car, which is something that can be beneficial for example during crimes such as a hit and run.

Currently 29 states in the USA have a regulation that require cars to have a front license plate: Alaska, California, Colorado, Connecticut, Hawaii, Idaho, Illinois, Iowa, Maine, Maryland, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Rhode Island, South Dakota, Utah, Vermont, Virginia, Washington, Wisconsin, and Wyoming. Apart from those states it is also mandatory in the District

of Columbia and in the additional province Puerto Rico. In the other 21 states it is not mandatory to have a front license plate: Alabama, Arizona, Arkansas, Delaware, Florida, Georgia, Indiana, Kansas, Kentucky, Louisiana, Massachusetts, Michigan, Mississippi, New Mexico, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas and West Virginia. (Ehow, 2009; Texas Government, 2013)

However, when looking at different automotive discussion forums it was apparent that even if the drivers are obligated to have a front license plate, some drivers choose to violate this and does not mount a front license plate. These persons think that the benefits of not having a front license plate outweigh the drawbacks. The law enforcement in many of the states does not find it being a serious crime, why these drivers argue that they have been driving for years and years without getting a ticket. If they do get a ticket the fine is often quite small.

3.6 Standard license plate holders

Within the European Union the car dealers has the responsibility to install license plate holders to the front and the rear of the vehicle. Volvo and other car manufacturers do not provide their own holders for this market, but they do have the responsibility to make sure that there is a way to attach the holders to the car. The reason why the car manufacturers do not provide the holders themselves is that it would add an unnecessary cost due to the fact that the cost of the holder today is put on the dealers. Therefore the car dealers are the ones who have to directly contact the manufacturers of these holders. This is also the case for the Italian license plate holder which is somewhat smaller than the license plates in the rest of the European Union.

Due to the fact that there is a standardized size of license plates in the European Union, the holder will look similar regardless of which country in the union it is being used in. Several different manufacturers exist and there are some variation concerning for example material, visual appearance and quality. The holder is also non-brand specific, meaning that the same holder can be used by any brand. This is the reason why there are so many holes on the back of the holder, see Figure 8. These holes correspond to possible brands and car models, which makes it very adaptable.



Figure 8 - Standard European license plate holder (Biltema, 2013)

Car dealers also see the opportunity to provide the license plate holders with the company logo, giving them a very low cost advertising ability. Today this is often used for both front and rear holders by the car dealers, which makes it in their interest to keep the present holder. The possibility to use this kind of advertising is more common for the plastic license plate holder than the more expensive aluminum holder. The plastic version is the most common holder and it is preferred by car dealers since it is cheaper than the more robust versions made out of aluminum or steel. For example a plastic version from “Biltema” (Biltema, 2013) cost 35 SEK and an aluminum version from “Lika” (Lika, 2013) cost 149 SEK.

The license plate is fastened in the holder with a locking strip at the lower edge of the holder. Other solutions seen are plastic clips used to hold it in place. This is not the best option from an anti-theft point of view, but it is a suitable option since the EU-license plate does not have predrilled holes for screws. However, if one wishes to use the EU-license plate without the holder one has the option to drill the holes yourself.

The license plate holder on the rear is typically placed on the tailgate, which leads to another dilemma. When closing the tailgate there has been some problem with noise and vibration due to the low quality of the plastic holder. Despite that the holder is provided by the car dealer, hence not being the car companies’ direct responsibility, this has become a problem for them. Volvo Cars have recently added a stick-on foam pad under the rear license plate holder which reduced the problem substantially.

If Volvo Cars wishes to make a more complex design of the front this license plate holder might not be suitable in the future. It will at least not solve the mounting singlehandedly anymore but could possibly be used in combination with another solution. The cost of the new holder will instead be put in the hands of Volvo Cars. However, the holder can continuously be used for the fastening of the rear license plate due to the demand of a flat mounting surface. If Volvo Cars decides to develop a higher quality holder for the rear license plate, they will also have to take the associated cost. This is a balance that will be dealt with during this thesis.

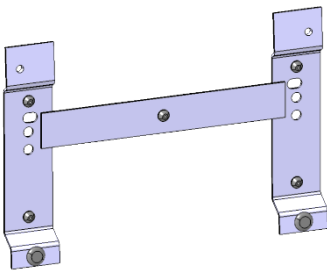
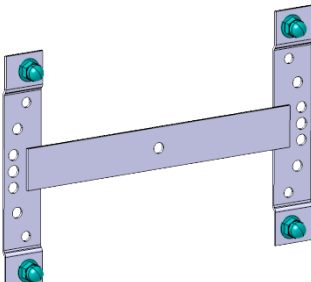

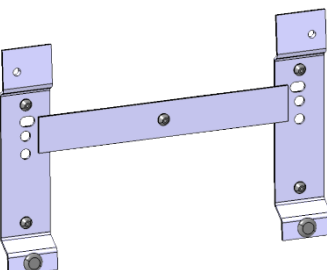
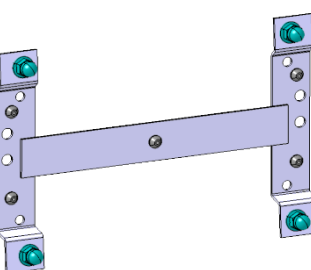

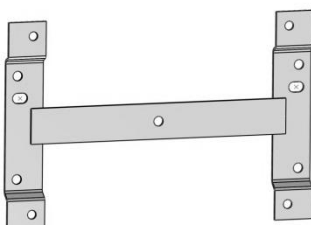
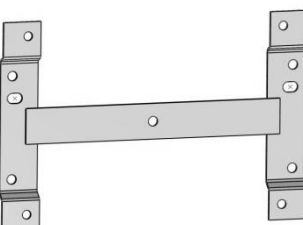

3.7 Volvo license plate holders

The responsibility of who is to provide the license plate holder differs depending on the target market, or country, the car is going to be used in. Therefore Volvo Cars is providing their own license plate holders when the regional laws state it and if there is no standard holder suitable. This also makes it possible to submit a matching high quality holder that coincides with the reputation of the Volvo Cars brand. The downside is that it adds extra cost for the company, compared with using a standard holder provided by the car dealer. The Volvo holders are manufactured by a supplier of Volvo and not the company as such.

Today, Volvo Cars is providing three different types of license plate holders, for North America, China and Japan. In total there are nine different variants of the holder, see Table 2. The Chinese license plate holder needs to be mounted on the car when it crosses the Chinese border, which is why they mount the holders on the car during production. The American and Japanese holders do not need to be mounted on the car during exportation. Therefore they enclose the holders with the cars and let the car dealers mount the license plate holders. This

saves cost for Volvo Cars and it reduces the likelihood that the cars could be damaged during transportation. Also, Volvo Cars does not always know if the buyer of the car wants to use the front license plate holder or not which is the case in some states in the USA.

Table 2 - Current Volvo license plate holders

| Japan | North America | China |
|--|---|--|
| Front  | Front  | Front  |
| Rear  | Rear  | Rear  |
| Rear V40  | Rear V40  | |
| Rear XC90  | | |

3.7.1 Holders for the North American and Japanese markets

The license plate holders for North America and Japan have a very similar design. Three thin metal pieces are spot welded together to form an H-shape, which provide a stable structure for the license plate. These metal pieces are also provided with pre drilled holes that make it possible to fasten the holder to the car. In order to avoid scratches, noise and vibration the holder is also provided with rubber pads facing the car and the plate.

However, due to a varying size of the license plates in the respective countries and different regulations and standards regarding the fastening they are not identical. In USA there is no actual law concerning the fastening of the license plate as long as it is securely attached. However in several states you are required to shift the plate from one car to another when acquiring a new car. Also, some states forces you to replace your license plates every fifth year or so. In total it is not uncommon that the license plates have to be replaced around five times in a cars life span. The license plate holder therefore must allow for some wear. It is also important to have a fastening that is possible to mount and demount, therefore four dome nuts are being used today (see Figure 9). Other solutions seen on the American market are ordinary screws that are easily removed by a flat or Phillips screwdriver, which is the most common method among Volvo Cars competitors. Instead of dome nuts the Japanese license plates are fastened with two M6 Torx screws along the upper edge of the license plate. These are then screwed into threaded holes in the holder itself.



Figure 9 - Dome nuts that are used on the North American holder (RS Delivers, 2013)

The coating is also something that differs between the Japanese and the American holder, see Figure 10. The American version is coated with a layer of galvanic Fe-Zn in order to protect the surface from corrosion. The corrosion resistance capability of this coating is significantly improved if comparing with traditional zinc surfaces (Holzapfel Group, 2013). The Japanese holder is coated with black powder paint that also serves as protection of the metal surface. According to Volvo Cars it provides better corrosion resistance than the American holder, but also comes with a higher cost. This resistance is something that is needed in the much harsher environment in Japan. They have tried to use the same galvanizing method as the American holder, but this method was not good enough according to the quality control division.

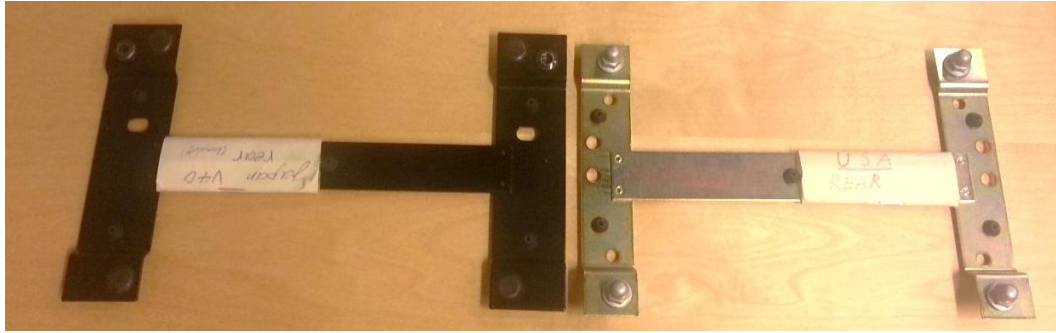


Figure 10 - Comparison of the Japanese holder to the left and the North American holder to the right

Furthermore there are also variants of the license plate holder within one and the same market since the preconditions for different car models differ. The new V40 model for example has specially made holders both for the Japanese market as well as for some places where the model is sold within the North American market. The inclination of the holder is also vertical in contrast to the somewhat angled holders for the other car models. This modification is needed in order to get within the legal requirements and due to the fact that the license plate is placed on the rear bumper and not on the tailgate as it is on the other car models. There is also varying requirements concerning the rear and front license plate holder. For example the rear holders have to be angled in order to meet the legal requirements of having a clearly visible and illuminated license plate by night. The reason why a specific XC90 holder had to be made for the Japanese market is that the plate would not fit with the standard Japanese holder. Therefore new holes were needed and it did not seem to be possible to include them in the hole pattern on the standard Japanese holder.

The American and Japanese holders have been used for several decades which have resulted in adaptations to the holder to suit several different car models and designs. The placement of the attachment holes have been adjusted vertically in order to achieve an optimal position on each car model, which means that several holes have been added to the holder over time (See Figure 11). Due to the fact that the holders have remained essentially the same it can be used as a spare part for older car models, which is a positive aspect. Therefore, it might be an idea to include the same hole pattern on future license plate holders if Volvo Cars wishes to phase out the current ones. This will reduce the need of keeping the “old” holders in the system, which also will save some costs. Although the total saved cost depends on the sales volume of the current holders as spare parts. By adding additional holes the new holder will be more complex and also more expensive.

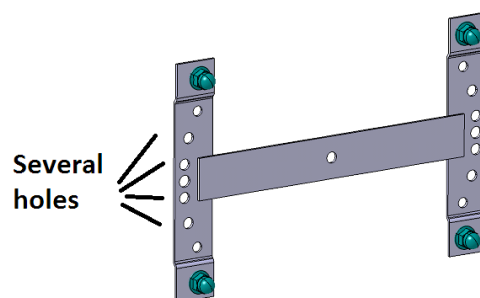


Figure 11 - An American holder with several holes

When investigating the spare part market for the Volvo license plate holder it was also apparent that it is used for fastening of license plates on cars from other car manufacturers as well. This is especially the case when looking at automotive internet discussion forums. The holder is appreciated as it is considered as robust and has four license plate attachment points, which uses all mounting holes on the North American plates. Furthermore, it has dome nuts as well as rubber pads, which contribute to a low vibration. Finally it is also said to be rather inexpensive. (VWvortex, 2011) However there is also a drawback regarding the dome nuts. They are considered to harm other cars (leaving permanent marks) if one accidentally will bump into another car. This is often the case when the driver is parallel parking the car. An American Volvo owner describes it like this; *“What is Volvo thinking??? They are supposed to be all about safety. The license plate nuts stick out too far and caused damage to my other car”* (Volvo Forums, 2011). This is something that the Volvo Cars office in USA is aware of. They describe the situation as *“during parallel parking maneuvers, domed nuts used to hold a front license plate are notorious for dimpling the rear bumper cover of the car ahead. The domed nuts do, however, tend to protect the plate from impact damage”*.

The American holder is often equipped with a license plate frame directly from the dealer. Also different variants that are personalized depending on the car owners' taste are sold as an aftermarket item (See Figure 12). These frames are something that seems to be appreciated by the American users. The frames are mostly sold on the aftermarket; no competitors have been found to use them as a standard part.



Figure 12 - A chrome license plate frame for the US market (Tool King, 2013)

3.7.2 Holder for the Chinese market

The license plate holders for the Chinese market have recently been introduced by Volvo Cars. Earlier the customers used a steel sheet provided by the dealer to mount the license plate to the car. However, this caused a lot of noise and vibration when closing the tailgate. The aim with the new rear holder was to reduce this problem. Due to recent legislation changes regarding the fastening of the license plate a front license plate holder also had to be developed. The front holder also has extra cover on the top of the holder in order to shield off some of the area between the license plate holder and the car.



Figure 13 - The Chinese rear license plate holder

The new regulation stated that the license plate must be mounted with four M6 screws. This means that the license plate cannot be directly mounted on the front bumper, simply because there is not a big enough flat surface for the four screws. The holders are constructed out of black plastic and are almost the full size of the Chinese license plate. Two threaded inserts are used at standardized locations on the car in order to facilitate fastening of the holder. These inserts also match two corresponding holes on the actual holder. Furthermore there are four threaded inserts on the holder that will provide a secure fastening of the license plate. These are combined with the use of screws in order to mount the plate.

3.7.3 Cost of license plate holders

The cost of the holders provided by Volvo Cars differs somewhat. The cheaper license plate holders cost around 10 SEK for Volvo Cars to purchase, while the most expensive holder cost 26 SEK. The main reason for the difference in cost is the higher production volume on some of the holders. This means that the general holders are much cheaper than the model specific holders. Another thing that has an impact on the cost is the design choice and also the number of rubber spots provided to reduce the noise and vibration. The holder made for the Chinese market, which is made out of plastic, is slightly cheaper than the metallic structure chosen for the Japanese and American holder. However, when including the shipping cost of the Chinese holder to Europe the relation is in fact the opposite.

The cost of the different holders shows how much economies of scale do for a simple product such as a license plate holder. Since the automotive industry is a competitive area there is a need to save cost wherever possible. There is therefore a need to reduce the number of variants and by doing so, raising the production volume of the holder.

The Volvo Cars license plate holders are commonly provided as a spare part, both from Volvo Cars themselves as well as from various spare part dealers on the internet. Here the license plate holders cost around 90-140 SEK. The reason why they are more expensive is due to the fact that the sellers have some additional costs such as storage, but they will also need to gain some profit themselves. However, this is still considerably cheaper than many license plate holders sold by third party manufacturers.

3.8 License plate support for the remaining markets

For countries where neither Volvo, nor the car dealer provide a standard license plate holder the customer or the car dealer will have to fasten the plate the best way possible. This is typically done by screwing the license plate directly to the bumper. It is apparent that this is not a very high quality strategy aligned with the reputation of the Volvo brand. However this type of solution is currently only applied on markets where Volvo does not have a big sales volume (3 percent of the sales volume). Since the cars will have a more complex front in the future it might not be possible to mount it directly to the surface. This has to be kept in mind if one wishes to sell cars at the minor markets. However, it might be possible to provide them with one of the license plate holders developed for the chosen market and try to mount the plates the best way possible.

3.9 Fastening of the holders

In this section, fastening system is referring to the actual fastening of the license plate holder to the car itself. Today the rear fastening system contains of two threaded metallic inserts which is placed on the rear bumper or on the trunk lid. The same solution is used for all the different Volvo car models and for all the markets. Previously the same fastening system was used for the front license plate holder. This was then changed to enable a completely flat surface, which instead forces an operation of drilling the screw straight into the bumper. On the new car model “V40” Volvo Cars have yet again placed the metallic inserts to the front of the bumper, and this is considered for the other models as well.

The attachment holes are placed 195 mm apart from each other with M6 threaded inserts in the holes, see Figure 14. The standard license plate holders, as well as the ones provided by Volvo Cars, also have matching holes that corresponds with the pre drilled ones on the car bumper and tailgate. The holders can then be fastened with M6-screws.



Figure 14 - Attachment holes placed on a Volvo front bumper

Since the rear license plate is mandatory on all Volvo Cars markets it is no problem to have predrilled holes for the license plate holder. This is due to the fact that the holes are put close enough together to make sure that the various license plates always will cover the holes. In the front, the problem is that license plates are not always required which is why the car might look less aesthetically attractive if pre drilled attachment holes are made. This problem might also be a fact when the car is in a showroom and Volvo Cars want the car to look at its best,

thus display it without a license plate. This might be one of the reasons why they do not have pre-drilled holes in the front on most models. The V40 on the other hand, which is not sold in the US market, can have pre-drilled holes. If one wishes to cover the holes there is an ability to buy plugs that will fit into the hole, which has the same color as the car (See Figure 15). This is however not a standard spare part from Volvo, but from a third party manufacturer (Bumperplugs, 2013).



Figure 15 - Plugs that cover the holes used by the holder (Bumperplugs, 2013)

In the future, the preconditions will be quite diverse when comparing the mounting of the license plate holder on to the rear or the front of the car. To start with the surface on the rear fastening point has to be flat due to legal requirements. This means that the rear interface can remain the same in the future if wanted. The front however is rarely completely flat and the design is heading in a direction where the flat surfaces are decreasing. This characteristic makes the fastening in the front more challenging and it might not be possible to use the same solution as today.

4 Benchmark

In this section the benchmark will be presented. It contains information about competitors, third party solutions and homemade solutions. Because of the big difference between the front and rear versions, it is divided into two different sections. The gathered information will serve as inspiration when generating new concepts.

4.1 Benchmark of a front license plate adapter

In this part of the benchmark different solutions of front license plate adapter will be described. This section will handle both more conventional solutions solving the fastening in simple cases. However more radical ways to solve the fastening are also investigated. This will give comprehensive information that can serve as inspiration when solving the rather complicated front mount of the license plate.

4.1.1 Competitor analysis

Many car manufacturers have realized the problem with mounting the license plate to a complexly designed front. Many believe that a standard EU holder or a metal H-shaped holder just is not good enough anymore. Instead adapters often are being used to enable a flat surface for the license plate. The way these adapters are designed is very different from one brand to another. Several of these different solutions and possible trends on the market are described below. For a full description of the solutions that each brand uses see Appendix 2.

4.1.1.1 *Nothing at all*

Some car manufacturers have a very flat front bumper where the license plate can be mounted directly without any adapter, see Figure 16. This means that the cars can be delivered worldwide and it will fit every size of license plate. This is the way Volvo Cars currently do on their car models. Some competitors' car models have pre made holes and markings for the license plate while others are completely flat. By using pre made holes there will however be a problem that the holes will be visible if the car is to be used on a market where no license plate is needed in the front.



Figure 16 - A BMW with a flat front

4.1.1.2 Integrated in bumper

Some competitors have an integrated pocket (recessed) on the bumper of the car where the license plate can be mounted (see Figure 17). It does more or less not affect the overall length of the car and may also protect it against collision damage. Another common variant is when the bumper has an extruded flat surface where the license plate is mounted (see Figure 18).



Figure 17 - A Volkswagen with an integrated inlay



Figure 18 - A Hyundai with an extruded surface

4.1.1.3 Integrated in grille

Instead of integrating the license plate holder into the bumper one can integrate it into the grille instead (see Figure 19). This part is often smaller and cheaper than the bumper which means it is more convenient to make different versions for different markets. However the choice to place it in the grille is very much depending on the design of the front and this solution might not always be possible to use.



Figure 19 - A Ford with the holder integrated in the grille

4.1.1.4 Separate adapter

In order to have a free decision of how to design the front of the car, some car manufacturers use a removable separate adapter (see Figure 20). This means that they are able to first design the car and then make a suitable adapter. The adapter can be placed either on the bumper or in the grille or a combination of both. The choice of material is plastic and the most luxurious car models sometimes have the adapter painted in the same color as the car.



Figure 20 - A Porsche with a separate adapter

4.1.1.5 Floating appearance

A few brands had a smaller interface surface between the license plate and the car in order to enable a “floating” visual appearance (see Figure 21). However, full sized support surfaces are the most common choice. A floating appearance gave a cleaner look but some problems with bended license plates could be observed. This problem was more severe when no EU holder was used, as it provides an increased support for the license plate.



Figure 21 - A Porsche with a floating license plate appearance

4.1.1.6 General comments

The complete benchmark was compiled into a competitor matrix (see Figure 22). In this matrix the most important competitors are shown as well as some other interesting brands. The different car models are grouped into different classes depending on their sizes and qualities. For example, A-Class is a very small car and D-Class is more of a medium sized car. The cars grouped in F-class are the more luxurious car models, such as cabriolets and sports cars. Many more brands were investigated and could be inserted into the matrix, but the clear trends were already visible.

Integrated solutions are more common on less expensive cars, while separate adapters are more common for the expensive cars. The estimated threshold is when the car cost around 250 000 SEK. Toyota is a good example of this with their relatively exclusive Prius model compared to the cheaper Yaris. This also means that the integrated solutions is more common for high volume cars and smaller cars, while sports cars and larger SUV's almost always has a separate adapter. This often also comes hand in hand with the much simpler design approach on cheaper car models where it actually is possible to mount the license plate directly to the bumper. However, some brands deviate from this “hidden industry standard”. An example of this is BMW who uses separate adapter on some of their models and mount it directly on to the bumper on others.





| Flat front | | Integrated in bumper | | Integrated in grille | | Separate adapter | | |
|---|-----|---|----------------|--|--------------|---|--------------------------|--------------------|
|  | |  | |  | |  | | |
| Class | A | B | C | D | Small SUV | E | Large SUV | F etc... |
| Volvo | | | C30, V40 | S60, V60 | XC60 | V70, S80 | XC90 | C70 |
| VW | Up | Polo | Golf | Golf Variant | Tiguan | Passat, CC | Touareg | Phaeton |
| Audi | | A1 | A3 | A4, A5 | Q3, Q5 | A6 | Q7 | A8, R8 |
| BMW | | | 1 series | 3 series | X3 | 5 series | X5, X6 | 7 series, Z series |
| Mercedes | | A-Class | B-class | C-class | M-class | E-class | GL-Class | S-class, SLK-class |
| Ford | Ka | Fiesta | Focus | Mondeo | Escape | Taurus | Explorer | Mustang |
| Toyota | iQ | Yaris | Corolla, Auris | Camry, Avensis | RAV4 | Avalon | Land Cruiser, Highlander | GT86 |
| Hyundai | i10 | i20 | i30 | i40 | Tucson, ix35 | | Santa Fe, Veracruz | Equus, Genesis |

Figure 22 - Comparison of the model range of certain competitors (Images from A2MAC1, 2013)

It is also not safe to say that adapters always are the more aesthetically attractive choice even if this could be a hidden standard. An example of this is Chevrolet which had a larger adapter that could be perceived as a clumsy appearance, see Figure 23. The integrated solutions can in some cases seem much more expensive and good looking as well. Did perhaps one premium car manufacturer start to use separate adapters and all the other followed. Since it is highly represented on the more exclusive cars within a brand it could also be a clear way to differentiate a brands own car models more clearly.



Figure 23 - A Chevrolet with a rather deep and large separate adapter

Most brands deliver tailor made solutions for each market, for example the European market gets a wider adapter than the cars for the North American market. This was not always the case for the Italian, Chinese and Japanese market where the adapter often either was too small or too big. One must keep in mind that different markets often have a different selection of car models. Therefore the car manufacturers more easily can make a good looking integrated solution if the car is only to be sold on one specific market, often with an inlay in the bumper.

The reason an integrated solution often is cheaper is that they remove the assembly cost of a separate adapter as well as having reduced material and storage costs. However, if they are to be sold on different markets they will have to manufacture separate bumpers or grilles. This means that one EU version and one US version can exist for the same car model. The economies of scale of these parts will be lowered compared to having one type of bumper and use a separate adapter. Some of the larger manufacturers do however produce the same car model at several locations, only to be close to the actual market. In this case the overall effect of making two different versions is less apparent, since they only have one version for each location.

The use of an integrated solution forces the car manufacturers to use license plates in all of their promotion pictures and videos. This is not the case when you use a separate adapter. Since the cars initially often are designed without a license plate in mind, it often looks better without one.

European manufacturers seem to have a more coherent approach when designing their front license plate holders, compared to the Asian brands. This might however be due to the increased variety of car models and the diversity of the designs that the Asian brands often have. For example, both Volvo Cars and Audi use essentially the same front design for all of their respective car models while Hyundai have a larger variety.

Trends between brands which are part of the same company group were not always found. It might be that they like to differentiate the brands as much as possible. It can also be due to the fact that they often are developed at different places and it lacks collaboration between brands regarding this relatively redundant part. For example, there is no resemblance between Volkswagen and Audi which is part of the same group. However, Citroën and Peugeot are using similar solutions (see Figure 24).



Figure 24 - Comparison between Peugeot to the left and Citroën on the right

Even if many car models already have license plate holders, such as adapters, lots of car dealers did choose to use it together with a standard EU holder. The reasons for this are due to the advertising ability and the easy mounting where no drilling in the plate is needed. The cars that were used without the EU holder had a much cleaner look, but will also be more exposed to impacts which can result in the plate bending.

4.1.2 Third party solutions

Since third party solutions can be a valuable source of information many widely different solutions has been investigated. A special focus has been on solutions that solve the problematic transition from a complex front shape to a suitable fastening area of a license plate, rather than license plate holders used to reduce the likelihood of getting caught by various cameras. Most of the third party solutions offer something more than the original license plate holders. Many of them use “no drill” methods which mean that you do not need to make new holes in the bumper in order to fasten the license plate to the car. This is a much bigger dilemma in USA, where the front license plate is not being used by everyone. The reason is that holes on the bumper can have an impact on the value of the car when it is to be sold to a new owner. These third party holders cost between 50-200 dollars, which is far more than the original holder. But the relatively few buyers who want this solution will have to pay for the smaller production volume and all the development costs.

4.1.2.1 Tow hook fastening

This is a holder that is attached to the tow hook, which is placed to the side of the front bumper, see Figure 25. It is easy to demount from the car and the benefit is that one does not have to make any new holes in the bumper. Several manufacturers of this solution exist, for example “US Mills Works” which provide products for Porsche, BMW, VW and Mini. (US Mill Works 1, 2013)



Figure 25 - Tow hook fastening (US Mill Works 2, 2013)

4.1.2.2 Skene Design bracket

The bracket is mounted underneath the bumper, which reduces the amount of visible holes on the front (see Figure 26). This is good if the car is to be sold to another owner, whom for example lives in an area where you don't require a front license plate. Five different sizes exist to match every car on the market, each in a US or an EU variant. (Skene Design, 2013)



Figure 26 - License plate bracket (Skene Design, 2013)

4.1.2.3 Plateclips

This license plate holder is clamped to the front of the car, preferably the grille (see Figure 27). It requires no drilling and is easy to install and remove by releasing the spring. Several different variants of this holder exist to fit exactly the corresponding car, which are mostly sports cars. (Plateclips, 2013)



Figure 27 - License plate holder (Plateclips, 2013)

4.1.3 Homemade solutions

Homemade solutions can also be an important source of information since needs that have no suitable solution on the market can be discovered. These solutions are often much cheaper than buying a new front license plate holder. This could be the case if the car owner lost the license plate holder or did not get one when buying the car. The homemade solutions also often were used to avoid making permanent holes into the bumper, much like the aftermarket solutions.

Some car owners were found to be using zip ties as a method to fasten the license plate to the front of the car, most commonly in the grille (see Figure 28). The same strategy was used to mount the original license plate holder onto the car, instead of using the screws that came with the holder.



Figure 28 - License plate fastened with zip-ties to the grille (The Car Lounge, 2009)

If the owner instead wants to mount it onto the bumper, Velcro straps could be used to attach the license plate, see Figure 29. This gives a very small gap between the bumper and the license plate, resulting in a sleek look. It also gives the possibility to easily remove it when wanted. Perhaps it is too easy to remove the plate, which means that there is a risk of dropping it while driving. However there are also extra durable versions, for example “3M Dual Lock”, which are able to absorb much more forces (3M, 2013).



Figure 29 - Velcro straps (3M, 2013)

The same visual effect as the Velcro strap version can be found by using double-sided tape to attach the plate directly to the bumper. This can be seen on the Volvo in Figure 30. It requires no drilling but a flat surface are preferable if good bonding is to be achieved. The durability of this solution is questionable and you are not able to remove the plate without using new tape. However, it is not that expensive to apply new tape when you remove the license plate.



Figure 30 - License plate fastened with double-sided tape (Tesla Motors Club, 2012)

Various efforts of attaching the license plate directly to the bumper with the use of strong magnets could be found. Either the solutions mounted the original license plate holder with magnets or the license plate directly. However, if one shall mount the license plate directly it must be made out of a magnetic material which is not always the case for license plates. This solution makes it possible to mount the license plate without drilling in the bumper and it is easy to remove it whenever wanting to. However there could be a risk of losing your license plate while driving or having it stolen. The visual effect will somewhat be the same as the ones described above.

4.2 Benchmark of a rear license plate holder

This section describes different solutions on rear license plate holders. This information concerns both competitor solutions as well as aftermarket holders provided by third party manufacturers. In some cases the rear and front license plate holders look the same. This is often the case on older cars which do not have a flat front and rear and are in no need of any adapter.

4.2.1 Competitor analysis

In order to better understand the market, present competitor solutions are investigated. Mostly North American solutions are looked into in this competitor analysis due to the easy access of information. However, similar solutions as the ones on the North American market are being used on other markets as well. In the European Union the license plate holders are not offered by Volvo Cars since the standard holder provided by the car dealer is used by all car manufacturers. Therefore there is no need to investigate the EU market any further. A more complete mapping of competitor solutions can be seen in Appendix 3.

When comparing the Volvo license plate holders with the competitor license plate holders it was seen that the ones that the competitors are using is often more expensive to purchase for the customer. They were ranging from 100 SEK to 350 SEK compared to the Volvo holder which cost around 100 SEK.

One type of holder investigated, was a holder made by a metal sheet, which was stamped and cut into the final shape. A positive aspect of this design is that there is no need for welding or other ways to assemble the structure. This also makes this type of holder cheap to produce which will save money compared to using a more expensive holder. Depending on the cross section and the material, this thin structure could however make it less rigid. All the holders have pre made holes in order to provide sufficient fastening to both the car as well as the license plate itself. Additionally, some variants have threaded inserts that facilitates a smooth and easy fastening, but this might lead to an increased cost as well. As seen in the legal requirements, it is sometimes necessary to have them in order to be able to sell it on the respective market.

SAAB had a similar holder that was used on some of their older models. What makes it special is however that it is the only holder found that has fastenings for both the North American as well as the Japanese market (see Figure 31). This is made possible by using threaded inserts that matches both markets and since the North American and the Japanese license plate sizes are similar the support is adequate for both markets. By distributing a license plate holder for both markets the volume of the holder increases which in turn gives an economy of scale. For SAAB that had a rather small sales volume it would be of great interest to benefit from the scale effect. In order to achieve the adaptability, two extra threaded inserts are needed for the Japanese market. Thus, it is important that the extra cost associated with this is lower than the actual benefit of the scale effect.



Figure 31 - Saab rear license plate holder (The Saab Site, 2013)

Another common variant is a holder shaped like a square that is being used by BMW and Land Rover (see Figure 32). They are made out of plastic just like the Volvo Cars holder for the Chinese market, and seem to be a bit thicker than the ones made of metal. They have a large pocket in the middle and notches along the edges in order to lower the weight of the structure. Similar to the previous mentioned holders, BMW also uses threaded inserts for both the fastening of the license plate and the mounting on the car. In order to reduce vibrations and the risk of scratching the car both holders are provided with protective pads. Furthermore, BMW has taken advantage of its ownership of MINI by providing this license plate holder for both car brands which increases the volume of the produced holder, thus resulting in an economy of scale.



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Figure 32 - BMW license plate holder (ECS Tuning, 2013)

Another common type of holder is one that is quite similar to the one Volvo Cars is using on the North American and Japanese market. Metal pieces that are a bit thicker than the previous mentioned metal sheets are welded together to form different types of H shapes. This structure is rigid in order to give a good support for the license plate as well as decrease the level of vibration. However, there is a need for welding the pieces together which will add cost to the structure. The rather thick metal pieces do not only make the structure rigid it also makes it possible to produce threaded attachments directly in the holes on the holder. Therefore threaded inserts becomes excessive which in turn, will save money.

The Jaguar license plate holder is made out of a metal sheet that is pressed and cut into its final shape (see Figure 33). It is formed like an “X” with one attachment point in each corner which is where the license plate is to be fastened. The mounting to the car is made possible by three narrowly placed holes in the center surface of the holder, which might make the holder less rigid. The sleek lightweight structure is a big benefit and it is probably cheaper to produce than a welded version. (Carbodyparts, 2013)



Figure 33 - Jaguar license plate holder (Carbodyparts, 2013)

The actual design of the rear bumper/tailgate and the fastening method was something that differed slightly between brands. Some of the brands had a completely flat surface for the rear holder while many others used inserts for the screws used by the holder. Two inserts were the most common strategy, but also versions with four holes existed. The increase of fastening points does increase the stability of the holder, which also reduces the likelihood of noise and vibrations. Additionally, just like Volvo Cars many competitors did provide their cars with rubber or foam pads to reduce vibrations and noise.

Some brands have different versions of the rear bumper or trunk lid depending on where the car is sold. This was the case for SAAB who had two versions; one for EU and one for North America (see Figure 34). This reduces the amounts of different variants needed for the holder, since they are able to make the adaptation to the car instead.



Figure 34 - Rear view of SAAB 9-5 that has an adapted tailgate for two different markets (Saabsunited, 2013)

Another type of design that could be seen when visiting the car dealers were trunk lids with air pockets or bumps in them, see Figure 35. The actual use of these one can only speculate about. Perhaps it is to reduce the overall weight of the trunk lid or it is used to get a closer placement of the license plate to the surface of the car. Some brands also placed the foam pads in these bumps.



Figure 35 - Rear view of a Honda with opening in the tailgate

4.2.2 Third party solutions

On the market there are also third party holders that in most cases are applicable for several different models across multiple brands. This often makes them innovative when it comes to adaptation and diversity, which is an interesting aspect to investigate. Although, one must keep in mind that these third party solutions often does not provide any additional functions or features compared to the original license plate holders that comes with the car. Instead they serve as replacement if the original holder gets damaged or if one simply does not have any holder. These license plate holders cost between 40-100 SEK which is cheaper than the OEM holders.

4.2.2.1 Letai Auto Parts Co., Ltd - America Style License Plate Frame

This is a plastic solution for the North American market that is rather similar to the structure of the standard holder provided to customers within the European Union (see Figure 36). It has slots at multiple places on the back of the surface in order to allow easy and adaptable fastening to the actual car. There is also no need to fasten the license plate with bolts or screws since there is a frame with snap fasteners surrounding the edges, which makes the license plate easy to demount. However it is important to note that the North American license plates already have pre made holes for fastening. (Gasgoo, 2013)



Figure 36 - License plate holder (Gasgoo, 2013)

4.2.2.2 Dorman OE Replacement License Plate Bracket

This holder is similar to the one described above but differs mostly when it comes to the material the structure is made of. In this case it is constructed of a thin metal sheet that is pressed and bent into its shape (see Figure 37). The license plate holder has several specific attachment holes of different shapes and places in order to construct a holder that is adaptable to many models and car brands. (Stylintrucks, 2013)



Figure 37 - License plate holder (Stylintrucks, 2013)

4.2.2.3 Custom Accessories - License Plate Mounting Bracket

This is a design supplied by a large automotive aftermarket manufacturer and it has several weight and material saving pockets and notches, which make it a sleek lightweight design (see Figure 38). However, there is a risk that it is less rigid than a more homogeneous design depending on the material, the profile and the thickness of the structure. It has four pre made holes for mounting the actual license plate which is placed at standardized positions for the North American market. In addition to that there are several slots at many places in order to mitigate flexible fastening for various types of models and brands. (O'Reilly Auto Parts, 2013)



Figure 38 - License plate holder (O'Reilly Auto Parts, 2013)

4.3 Competitor fastening methods

The various ways of attaching the license plate holders to the car was also an interesting aspect to investigate among the Volvo Cars competitors. There were several different methods used that solved this problem. The challenge was also addressed in different ways depending if it concerned the rear or the front mount, so the subject has been divided into two related sections.

4.3.1 Front mounting

The mounting of the front license plate adapter was an interesting aspect that needed a great deal of attention since the preconditions for this mounting can be rather different from the fastening today. For example the car attachment surface might be complex and the new holder will most probably differ significantly from the solution used by Volvo Cars today. In addition to the different fastening methods, indexations were commonly used on the adapters. This was done to make sure that the adapter was mounted in the correct position and not for example upside down. This was achieved by making indexations that fitted to specific places on the car and guided the adapter into place. It is also evident that many of the following methods were used in combination. The competitor database called “A2Mac1” was used in order to investigate possible fastening methods used by competitors.

4.3.1.1 Snap fasteners

Many front adapters did use snap fasteners for an easy and fast mounting procedure during assembly. It is also a very convenient method since it in many cases can be incorporated into the design as a part of the solid structure. This is often done in combination with plastic materials such as Polypropylene. However, snap fasteners might not provide enough robustness, which is why it often was used together with screws from the adapter into the bumper. There is also good examples where snap fasteners are successfully used to fasten a front license plate adapter to the grille.

4.3.1.2 Screws

Screws are both the most classic and commonly used fastening method when mounting an adapter to the bumper. The benefit is that it is a traditional fastening method with known capability. The fastening itself is also sufficient regarding rigidity and reliability. Although, there are drawbacks concerning the assembly of the holder since it can become rather complex. There are two main ways of mounting the adapter with screws; either you are using self-tapping screws directly into the bumper or you are using metric screws that are inserted into threaded holes. The metric screws have the benefit of providing a stable mounting and the adapter is always at the correct location due to the fixed mounting holes. It can also be used to mount and demount an adapter several times without the risk of ruining the holes. Drawbacks are that it is more expensive than the alternative and the threaded hole is not always easy to provide, especially on a complex surface. The self-tapping screws also need a sufficient support from the mounting material in the surface since it often is used directly into the surface. By using indented spots at least the location of the mounting can be secured, but it can still be a risk of a less rigid fastening, and it could be problematic to reuse the same holes over again. The benefit of using self-tapping screws is that you will not have any predrilled holes on the bumper.

4.3.1.3 Flange nuts with separate metric screws

In this case the metric screws with a large square head are snapped into position on the adapter and are then prevented from rotating. The screws are then inserted through a hole in the bumper and on the other side a flange nut is used to fasten the adapter to the bumper (see Figure 39). It could however be challenging to place, tighten and loosen this nut since the only possible access is from within the engine compartment or possibly from under the car. The positive aspect is that the mount is very strong and there is no need of inserts or such in the adapter which makes it cheaper to produce. But fastenings with inserts could still be needed for some markets in order to fasten the license plate itself.

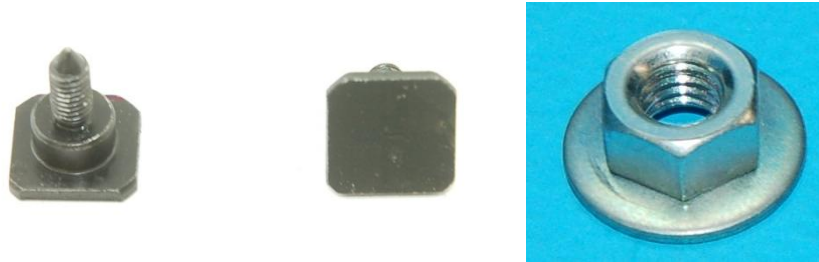


Figure 39 - Flange nut and screw used by Honda (A2MAC1, 2013)

4.3.1.4 Rivet joints

This solution has been used by some of the competitors to fixate an adapter to the bumper of a car. An example of this is BMW who uses five rivet joints that are inserted into five pre drilled holes on specified places (see Figure 40). Rivet joints are rather strong, robust and it makes the adapter tightly fixed to the car. There are also limited requirements of the surface and its material. It has to be sufficiently strong so that the rivet joints do not work loose from the mounting material. A drawback is however that the rivets has to be fastened with the help of special equipment and if it is to be mounted by the dealer that could be a problem. If this instead is done in the factory it could be a rather convenient solution. Once the rivets are mounted to the adapter there would be a problem to demount the adapter, which luckily is not a common thing to do.



Figure 40 - Rivet joints used by BMW (A2MAC1, 2013)

4.3.1.5 Expanding plug

This fastening method is based on using a plastic plug that is inserted through a hole that goes from the adapter into the bumper. In order to make the plug expand a plastic cylinder is inserted in the center of the plug (see Figure 41). This will make the plug expand which will secure that the adapter and the mounting surface is tightly fixed. The one thing you need is pre drilled mounting holes in the bumper in order to fasten the adapter. And the assembly seems easy enough since it is just one single straight push needed to insert the cylinder into the plug. It is also relatively easy to demount from the car even if people perhaps are not very used to the mounting method. One of the few drawbacks with this solution is the fact that it is not a common mounting method with completely known capabilities.



Figure 41 - Expanding plug used by Honda (A2MAC1, 2013)

4.3.2 Rear mounting

The rear holder was most commonly attached with screws. The benefits and drawbacks of this method is the same as when used for the front mounting. Some of the competitors used inserts for the screws while others only had marks where the screw should be placed. The competitors that used four screws instead of two were able to provide a more robust fastening. This also reduced the noise and vibration problem that can occur while using two screws if the holder is not tightly attached.

4.4 Patent investigation

In order to get a wider perspective of possible solutions that have been investigated over the years a patent search was performed. It was also a way to get inspiration for further development and to find possible customer delights that could be incorporated in the final solution. The actual patent search was done on a global database, however most solutions found came from North America or Asia. Since large parts of these markets use several kinds of license plate holders, unlike for example Europe, this is not surprising. The information found was associated with holders both for rear as well as front application. For a complete list of the investigated relevant patents see Appendix 4.

One of the most apparent things found when exploring the patent data base was the incorporation of sensors for parking, or similar use, in the license plate holder. This did not seem relevant for this project since it is more suitable as an aftermarket item that provides a function a car possibly lacks. However, for Volvo Cars it would not be practical, better looking or more economical to attach the sensors to the holder instead of the bumper like they do today.

A large number of patents involved different license plate frames, which is supposed to make the holder look more aesthetically attractive. These frames are rather personal and made in a lot of different variants. The biggest market for these frames is USA. For Volvo Cars this could enable them to make some extra money while the customers will be satisfied by getting a unique car.

A problem that is highly investigated and solved in numerous different ways is the risk of having your license plates stolen. A common way to solve this, according to the patent database, is to have some kind of lock with either a key or an electronic solution controlled from inside the car. Another rather simple design is to use an anti-theft fastener which is a cover that protects the head of the screw that is used to mount the license plate. This is a cheap solution that most probable would solve the problem. However it would not be easy to demount the plate even by the owner if needed. Since license plate thefts are increasing it is a relevant topic and a problem that could need attention.

In contrast to the solutions that are supposed to hinder easy access of the license plate there were numerous holders that were designed to ease the mount and demount of license plates. Some manufacturers use springy fasteners that locks the license plate in place, but with just one grip the fastening of the plate is released. Another solution seen was a holder that was foldable with the help of hinges and without using any screws and bolts, instead taps are to be inserted in the holes of the license plate. The foldable plate is then to be straightened out and forms a fixed surface, see Figure 42.

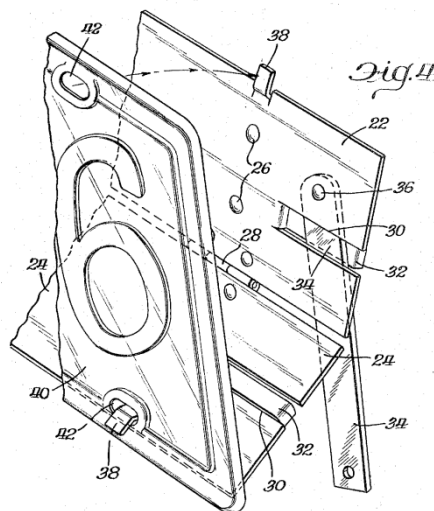


Figure 42 - A patented holder that provides quick fastening (Espacenet, 1967)

A patent regarding safety was also found, which is very interesting since Volvo Cars has such a strong safety focus. The solution was to solve a problem of how to get attention from fellow road users when you are in need of roadside assistance, similar to the warning triangle. In this case the license plate folds down and shows a sign that says “HELP” which is supposed to catch attention. The holder is also backlit and works in both a flashing and fixed mode.

Another solution found in the database could decrease parking damages to the car and the license plate. By using rubber guards on either side of the license plate a protection can be achieved. It could also somewhat protect other cars as well as the owner's car.

Adaptability is also something that is of importance to investigate and there are solutions that concern this challenge. The simpler versions are more or less about providing holes on a fixed surface that can be used for fastening of different kinds of license plates. However there are also more advanced solutions such as one where the mounting holes are placed on moving arms that can be adjusted to fit most license plate sizes (see Figure 43). Although, one drawback of this solution is that it has quite a lot of different parts and there is a risk that it will be rather expensive.

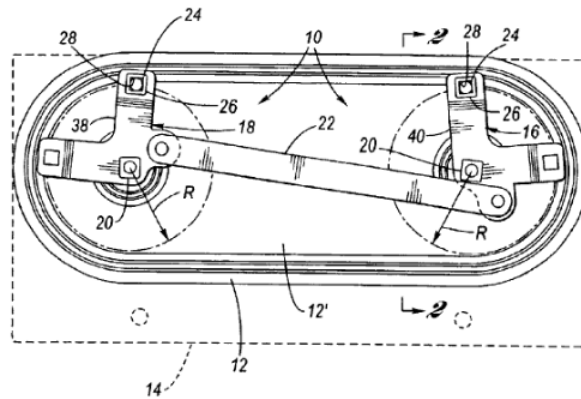


Figure 43 - Patent of an adaptable license plate holder that holds multiple sizes (Google Patents 2, 2013)

Some of the patents reminded of solutions investigated during other phases of the benchmarking. For example adapter solutions used in order to fasten the license plate in the grille on the front of the car. Even fastening systems for adapters patented by Toyota was found in the database.

5 Customer and user investigation

Volvo Cars have several different users of the license plate holder whose demands all need to be considered. The most obvious user is the customer who buys the car. That person also often has family and friends who will act as secondary users. It is these persons who will be affected by the appearance and quality related questions. For example, they probably want a holder that is durable over time so they do not need to replace it after a few years.

Another user is the one who actually mount the license plate holder on the car. It can either be personnel at the Volvo Cars production plant, the car dealers or the customer himself. These persons care that the assembly is easy and take as short time as possible.

Since the car has to be cleaned from time to time it is important that it is easy to clean around and behind the license plate, if there are any visible gaps. This will affect the person who cleans it, whether it is the customer or the personnel at the car wash. The car also needs to be repaired from time to time. This means that the characteristics of the license plate holder also can affect the garage mechanic.

5.1 Survey

In order to fully understand how to develop a license plate holder that the customer wants, a survey was performed. It was also a good way to understand what the customer was prepared to pay extra for and the characteristics that was not so important. The result of this investigation will serve as a guideline when developing the new holders. The respondents of this survey were Swedish citizens with a variety of different parameters such as ages, sex and driving experience. The actual survey can be seen in Appendix 5.

It was easy to see that the customer often did not have that many demands on the license plate holder. Many customers had not reflected upon the license plate holder, since it has such a simple purpose. When looking at the “Kano model” one can describe these as basic needs. From Volvo Cars point of view it is interesting to find the characteristics that would be regarded as performance needs and delighters in order to develop a premium feeling of the whole car. From a customer point of view a good holder is a holder that is securely attached to the car with no risk of losing it either while driving or by a thief. It should be robust so it does not vibrate and generate noise during driving or closing the tailgate. The visual appearance of the license plate holder should affect the design of the car as little as possible.

The first questions in the survey were about the placement of the front license plate. A majority of the interviewed persons want to have the license plate on the lower half of the front, see Figure 44. A reason for this is that “the license plate gets out of the way” and the eye do not draw that much attention to it. This is probably why no one preferred the highest placement of the license plate. The two medium placements are the ones that are most common today among cars. It is therefore likely that the interviewees picked a choice that they recognized. The placement obviously also depends on the size of the grille and other characteristics of the front but also the size and type of car. Almost everyone wanted to place the license plate below the grille instead of in it. This is interesting since there is an increased trend among com-

petitors to place the license plate in the grille. But of course there are other factors that could have influenced the interviewees as well.

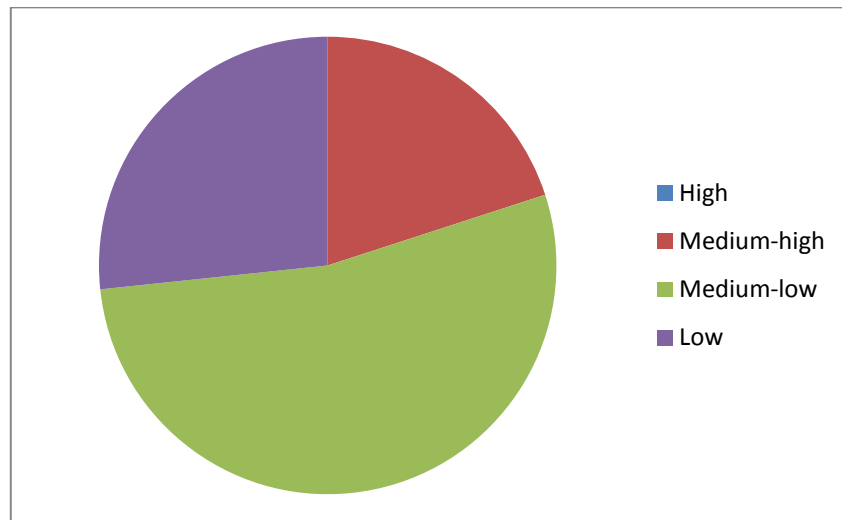


Figure 44 - Preferable position of front license plate

It was not that easy to determine what the best placement of the rear license plate was (see Figure 45). Many of the respondents considered placing it on the trunk equally as good looking as placing it on the lower bumper and had a hard time choosing between them. Overall, slightly more respondents preferred to place it on the bumper. The reasoning was the same as for the front, to get the plate out of sight when looking at the car. This can also be beneficial from Volvo's point of view, since it completely will remove the problem with noise and vibrations when closing the tailgate due to a loose license plate.

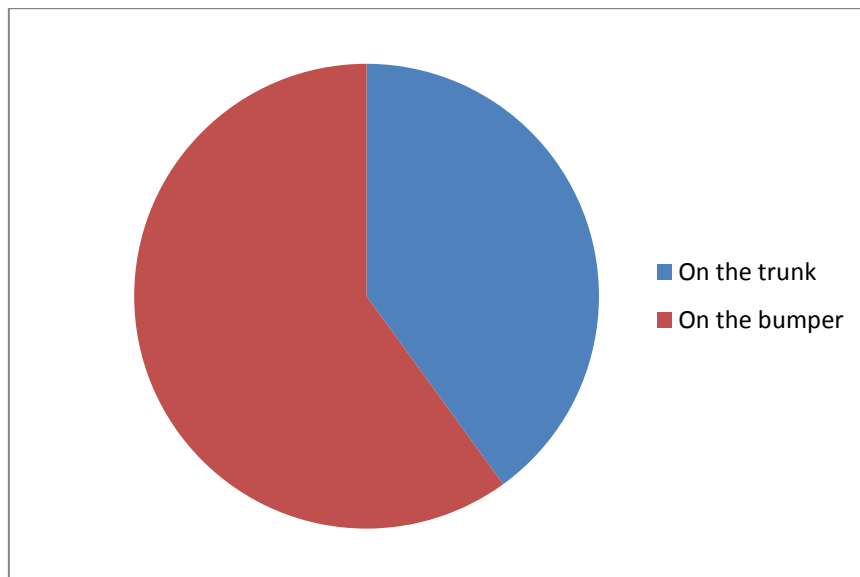


Figure 45 - Preferable position of rear license plate

It was very hard for the respondents to determine what the best option for the front license plate was. Equally as many persons believed that an adapter was best looking as of mounting the plate directly on the bumper. The conclusion can be that from a customer's point of view

the choice does not matter, as long as it is well executed. Some less good looking adapters could be found in the competitor analysis which probably would have been a worse choice than mounting it directly onto the bumper. A way to make the adapter blend in more to the car and create an integrated look is to paint it in the same color as the rest of the car. This look is something that was preferred by most respondents and they also considered paying extra to achieve this look, see Figure 46. The amount was mostly around 0-200 SEK. However, some people considered to pay a lot more while others thought it should come as standard. This look might be more admirable on luxury cars, where the total cost of the car is large compared to the amount of paid extra for the visual add-on. The normal black plastic version was often considered to be more admirable when the car had other contrasting areas, such as a black grille.

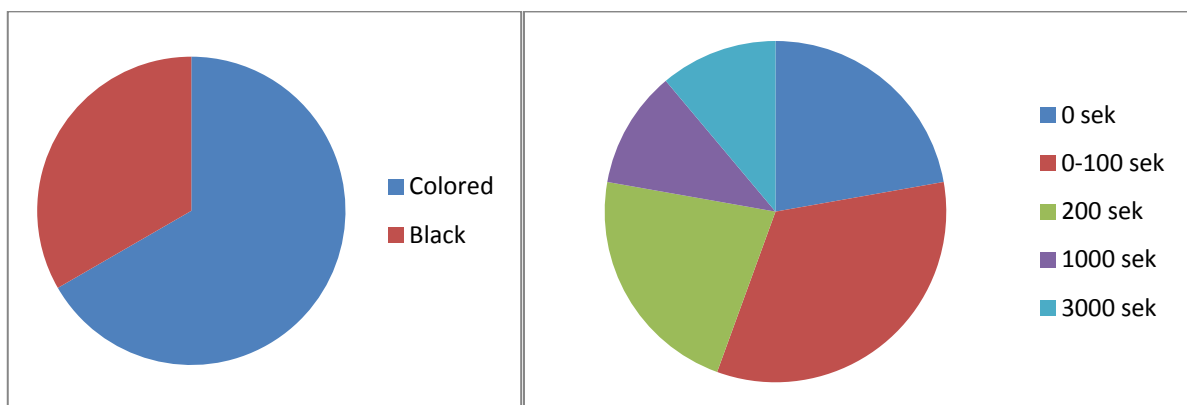


Figure 46 - Preferable look of the adapter and how much to pay for a colored version

Many of the respondents did prefer to have an anti-theft system for the license plates. The ones that did not want to have it did not consider license plate thefts to be a problem, instead they believed that it would make the solution more complicated to use. Of those that wanted to have an anti-theft solution most of them were able to pay extra for it, see Figure 47. The price is probably much lower compared to the amount of problem the customers will have if being a subject to the crime. Therefore it can be seen as an insurance against thefts.

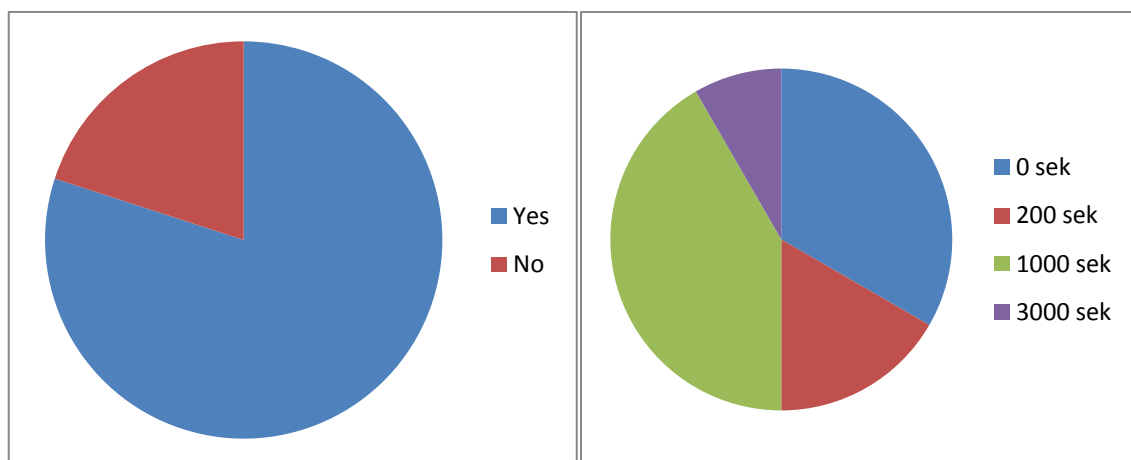


Figure 47 - Desire to have an anti-theft solution and suitable cost of it

When asking questions about the advertisement on the license plate holders most respondents believed that it had a negative impact on the aesthetics of the car, see Figure 48. Some people even expressed that it ruined the whole look of the car just by being there. However, even if they do think it makes the car look less appealing it is not certain that they will solve the problems themselves by replacing the holder. Instead they probably accept the fact that they have a holder that makes the car somewhat less appealing. From a car dealer point of view it is easy to see why they like the advertisement ability since it gives them advertisement at a very low cost.

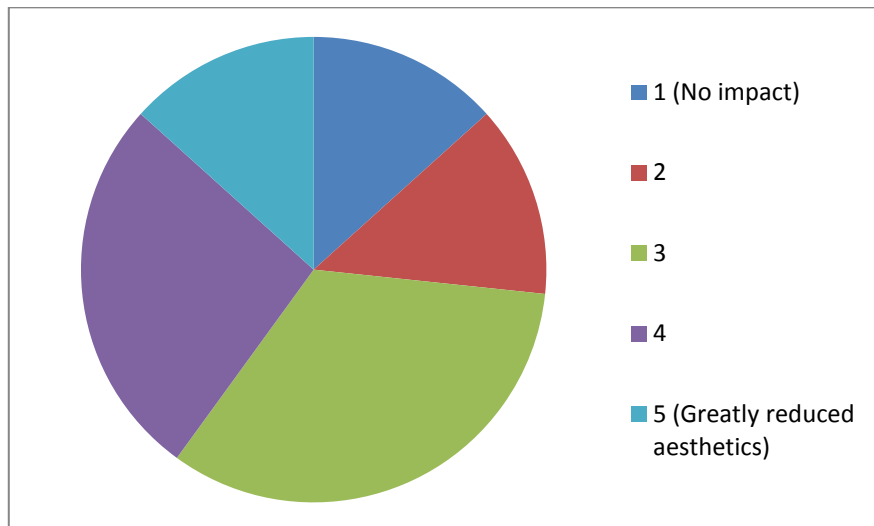


Figure 48 - The impact of advertisement on the license plate holder

6 Development phase

This section includes information about the development of the front as well as the rear license plate holder. The development phase is divided into two sections in order to make it more understandable since the result of the two holders is quite different. They will both start with a presentation of the requirement specification followed by a concept generation and evaluation. After this section the final design will be presented that will match the stated requirements.

6.1 Requirement specification

A requirement specification was made in order to make sure that the end result is satisfactory from all the different stakeholders' point of view. It contains legal demands, Volvo Cars requirements as well as customer desires. In Table 3 the requirements are stated together with a justification and a motivation for each requirement and desire. It is stated if it concerns the rear holder, the front holder or both of them. The desires are those requirements that are wished for in order to create a competitive edge. These are the things that will allow the customer to pay the premium price for the car.

Table 3 - Requirement specification

| Req. / Desire | Front, Rear or Both | Specification | Justification | Motivation |
|-------------------|---------------------------|---|---|--|
| Visibility | | | | |
| R | Both | The license plates must be visible and in good condition. | Swedish, Japanese and American legal documents. | Must be achieved in order to fulfill the function of the license plate. |
| R | Both | A license plate cover or holder must not obstruct or impair the recognition of the license plate information. | American and Chinese legal documents. | Must be achieved in order to fulfill the function of the license plate. |
| R | Front | The front mounting bracket shall be mounted on the front bumper or grille of the vehicle. | Chinese legal document. | Controls the license plate placement in order to make it easy to spot and read. |
| R | Rear | The solution should not impair with the laws for illumination of the rear license plate. | Volvo Cars demand. | It is important that the chosen concept does not make it difficult to illuminate the license plate. |
| R | Front | The license plate on the mounting bracket shall be practically vertical or it may be inclined to the vertical at not more than 15 degrees with the surface bearing the registration number upwards. | Chinese legal document. | Regulation that is ensuring proper visibility of the license plate information. It also controls that the plate is not facing downwards, making it hard to read. |
| R | Rear | Approved vertical inclination of license plate is -5° to 30°. | EU legal document. | Regulation that is ensuring proper visibility of the license plate information. |
| R | Rear | Approved vertical inclination of license plate is 0° to 30°. | Chinese legal document. | Regulation that is ensuring proper visibility of the license plate information. It also controls that the plate is not facing downwards, making it hard to read. |
| R | Front | The license plate shall be placed maximum 1,52m from the ground. | American legal document. | Controls the license plate placement in order to make it easy to spot and read. |

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| R | Rear | The license plate shall be placed between 0,30 and 1,52 m from the ground. | American legal document. | Controls the license plate placement in order to make it easy to spot and read. |
| R | Rear | The license plate shall be placed between 0,30 and 1,20 m from the ground. | EU, Chinese legal documents. | Controls the license plate placement in order to make it easy to spot and read. |
| R | Rear | License plate must be placed at the center point and perpendicular to the longitudinal plane of the vehicle. | EU legal document. | Controls the license plate angles relatively to the longitudinal plane in order to make it easy to spot and read. |
| R | Both | The license plate on the rear mounting plate/bracket shall be perpendicular or practically perpendicular to the longitudinal plane of symmetry of the vehicle. | Chinese legal document. | Controls the license plate angles relatively to the longitudinal plane in order to make it easy to spot and read. |
| R | Both | The license plate mid-point shall not be in the right-hand side of the plane. The license plate and the mounting plate/bracket shall not project beyond the left outer edge of the vehicle's rear end. | Chinese legal document. | Controls the license plate placement in order to make it easy to spot and read. |
| Fastening | | | | |
| R | Both | The license plate must be fastened with four M6 screws in China (by 2016). | Internal mail within Volvo Cars regarding new legal req. in China. | Law stated in order to ensure a secure and standardized fastening of the license plates. |
| R | Both | The license plate must be fastened with M6 screws in Japan. | Japanese legal document. | Law stated in order to ensure a secure and standardized fastening of the license plates. |
| R | Rear | The license plate must be attached to a flat surface (max 5000 mm radius) of following dimensions 520*120 mm or 340*240 mm. | EU legal document. | Stated in order to ensure that the license plate has enough room in order to be securely mounted and visible to others. |
| R | Rear | Installation brackets shall have a sufficient plate thickness at the position of the screw attaching a number plate, etc., so that at least three threads of the screw can be assured. | Japanese legal document. | Regulation that is used to make sure that the license plate always is securely fastened to the license plate holder and furthermore the car itself. |
| R | Both | License plate shall be securely mounted. | Japanese legal document. | Should prevent the plates from swinging and risk of falling of the car. |
| D | Both | The license plate should preferably be difficult to steal. Thus the holder has to be securely fastened as well. | Customer desire. | Many customers want the license plate to be securely attached to the car to reduce the likelihood of plates being stolen. |
| R | Rear | A seal shall be installed at the position for seal on the left side of the motor vehicle registration number plate on the bolt that is used to fasten the plate. | Japanese legal document. | In order to prevent license plates from being stolen the Japanese have stated this law. It will make the license plate more difficult to steal and you will more easily see if the plate has been tampered with. |
| R | Both | It must be ensured that the mounting plates/brackets shall not work loose, deform and not be able to be removed without removing or destroying the license plates during the normal use of the vehicle. | Chinese legal document and customer demand. | Requirement that needs to be assured in order to be sure that the license plate holder is securely fastened to the car. This is a necessity in order to have a good place to fasten the plate. |
| R | Both | The license plate adapter has to have such rigidity and provide sufficient support so that the adapter and license plate can withstand automatic car washes. | Volvo Cars and Customer demand. | This is demanded in order to ensure that the qualities of the car should remain high and that normal use should be possible. |

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| D | Front | The pressure on the bumper distributed from the adapter should be as low as possible in case of parking collision. | Volvo Cars and Customer desire. | If the car is engaged in a parking collision the adapter should have as low negative impact of the damages (on both this car and the other part) as possible. |
| R | Both | The license plate must be possible to demount for the North American market. | Customer demand and internal mail within Volvo Cars regarding legal requirements in the USA. | In some states in the USA the license plates belongs to the person and not to the car. When a car is resold to a new owner the license plates are removed. |
| D | Both | The license plate should be easy to mount and demount from the car. | Customer desire. | In some states in the USA the license plates belongs to the person and not to the car. When a car is resold to a new owner the license plates are removed. |
| D | Front | The license plate and holder should preferably not leave marks when removed. | Customer desire. | Customers in USA and those that show off their cars at gatherings want their car to look nice even without front plates. |
| D | Front | No attachment points should be visible in the front. | Customer desire. | License plates in the front are not used in 21 of 50 states in the USA. Sometimes VCC also uses their cars without license plates, on the front, in commercials and in showrooms. |
| Safety | | | | |
| R | Front | The front of the car cannot have a shape that will be harmful to pedestrians during a collision. | Swedish legal document and Volvo Cars demand. | Volvo is a car brand with strict safety focus and a harmful design could injure pedestrians. |
| R | Both | Not to harm the safety features of the car. | Volvo Cars demands. | Volvo is a car brand with strict safety focus and decreasing the safety capabilities of VCC cars would not be acceptable. Thus it is important to investigate what is behind the mounting surface. |
| R | Both | Not to harm the safety features associated with active safety systems or in any way lower its capability. (Including parking aid etc.) | Volvo Cars demand. | Volvo is a car brand with strict safety focus and decreasing the safety capabilities of VCC cars would not be acceptable. Thus it is important to investigate what is behind the mounting surface. |
| Technical | | | | |
| R | Both | The holder of the license plate should be of sufficient size in order to prevent the license plate from being bent if exposed to external forces. | Japanese legal document and customer demand. | This is a requirement stated in order to prevent the license plates from being bent and becoming in bad condition which will make it less aesthetic and functional. |
| R | Rear | Installation brackets shall have sufficient rigidity. | Japanese legal document. | Sufficient rigidity will be needed in order to give a reliable fastening for the license plate. |
| R | Both | There should be minimum risk of corrosion. | Volvo Cars and customer demand. | By reducing the risk of corrosion both the look and the functionality will be preserved more easily. |
| D | Both | The uses of standard materials are preferable. | Volvo Cars desire. | Standard materials can be used in order to lower cost and have good accessibility to the material on the market. It will also mean that the material has proven its capabilities in previous use. |
| D | Both | The license plate holder should approximately have the same life length as the car it is mounted on. | Volvo Cars and customer desire. | The holder should fulfill its purpose during the time the car is on the market. |

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| R | Both | The license plate and its holder should not cause noise or vibration that will affect the customer perceived experience in a negative way. | Volvo Cars and customer demand. | Vibrations and noise has earlier been a serious problem, especially concerning the rear holder on the tailgate, which has lowered the overall impression of the car. |
| R | Both | The customer perceived quality is to comply with the high quality and luxury level of the rest of the car. | Volvo Cars and customer demand. | In order to comply with the high quality of the rest of the car it is important that the license plate holder is of equally high quality. |
| R | Both | The material use is to be kept at a minimum. | Volvo Cars demand. | In order to use as little resources as possible the use of material should be kept to a minimum. This will save money, decrease weight as well as continue to a sustainable future. |
| Economical | | | | |
| D | Both | The cost of producing the license plate holder should be kept to a minimum. | Volvo Cars and customer desire. | By reducing the cost of the license plate holder the profit of it will increase. |
| R | Front | The holder should not cost more than 30 SEK to produce per car type. | Volvo Cars demands. | A requirement made in order to secure that the cost of the license plate holder does not exceed the budget. |
| R | Front | The tooling costs needed in order to produce the license plate holder should not be more than 1 million SEK per car type. | Volvo Cars demands. | This is a limitation in order to secure that the equipment cost does not become too high. For example new technologies that require brand new production equipment can be a problem. |
| Design | | | | |
| D | Both | The license plate is preferably to be placed fairly close to the body of the car. | Customer desire. | By having the license plate tightly placed it is more likely that the design won't be affected. |
| D | Both | It would be beneficial if the license plate could be kept in a good condition. | Customer and Volvo Cars desire. | A license plate that is in bad condition and covered with dents, cracks and dirt is not good for the overall impression of the car. |
| R | Both | Be applicable for future car models. | Volvo Cars demand. | One of the main goals with this project is to produce a holder that can be used for future car models. |
| D | Both | The solution should be innovative. | Volvo Cars and Customer desire. | An innovative solution is desirable if it offers the customers something extra and the solution becomes more competitive. |
| D | Both | As few versions of license plate holders as possible should be designed (including different markets and car models). | Volvo Cars desire. | In order to keep cost down the number of versions is to be kept to a minimum. This will increase the economy of scale. |
| R | Both | The license plate holder should at least comply with the preconditions for the Chinese, American, Japanese and EU market. | Volvo Cars demand. | The mentioned markets are the ones that are most important or have been found to have strict regulations regarding the license plate and its fastening. |
| D | Both | If the license plate holder is adapted, in a profitable way, to more markets then the ones previously mentioned it is positive. | Volvo Cars desire. | Providing a solution that could solve the fastening of license plates in several smaller markets could be beneficial both regarding cost and the qualities of VCC cars in their markets. |
| D | Both | Affect the overall design approach in a negative way as little as possible. | Volvo Cars and customer desires. | The license plate and the holder are items that often are contributing to the design of the vehicle in a negative way. |

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| R | Both | The material of the license plate holder should not age in a way that significantly will lower the aesthetic or physical capabilities of the holder. | Volvo Cars and customer demands. | By selecting a material that ages in a predictable and favorable way the holder will keep fulfilling its intended function and look as new longer. |
| D | Both | Accessibility of visible surfaces while cleaning should be possible. | Volvo Cars and customer desires. | In order to have a car that is aesthetically attractive it is important that a basic job such as cleaning it is convenient to perform. |
| D | Rear | Making the license plate holder backward compatible. | Volvo Cars desire. | By making the holder backward compatible it is possible to use it as a spare part even for older cars which would be economical. |
| Environmental | | | | |
| R | Both | The license plate holder should be partly recyclable. | European legal document, Volvo Cars and customer demands. | From the year of 2006 the reuse and recovery shall be a minimum of 85 % and the reuse and recycling shall be a minimum of 80 %, by an average weight per vehicle and year. By the year of 2015 the reuse and recovery shall be increased to a minimum of 95 % and the reuse and recycling shall be increased to a minimum of 85 %, by an average weight per vehicle and year. |
| D | Both | The license plate holder should preferably be completely recyclable. | European legal document, Volvo Cars and customer desire. | |
| R | Both | The holder should not include substances that are directly harmful to nature or humans. | Volvo Cars and customer demand. | This is one way to secure that the car is made with sustainable thinking in mind. |
| D | Both | The holder should be as light as possible. | Volvo Cars and customer desire. | If designing a lightweight version the car will use less fuel and hopefully less material. Both aspects will lower the environmental impact. |
| Manufacturing and assembly | | | | |
| D | Both | Make the license plate and its holder easy to assembly. | Volvo Cars, customer and car dealer desire. | It is in everybody's interest that the license plate as well as the holder is easy to mount onto the car. |
| D | Both | The adapter should be constructed so that it is Designed For Manufacturing. | Volvo Cars desire. | By making the adapter easy to manufacture it will be cheaper to produce. |
| D | Both | The assembly time needed to mount the license plate as well as the holder should be as low as possible. | Volvo Cars, customer and car dealer desire. | It is in everybody's interest that the license plate as well as the holder is quick to mount onto the car. |
| D | Both | There should preferably be no need for special tools for the mounting of the license plate holder and the license plate. | Volvo Cars, customer and car dealer desire. | By making it possible to mount without special tools there is less need for new costly equipment. The mounting procedure might also be more familiar. |
| D | Both | The design should be done in a way that makes it clear how to mount the license plate and the holder. | Volvo Cars, customer and car dealer desire. | A design that guides the person that performs the assembly will ease the work and will have many other positive benefits. |
| R | Both | The license plate holder has to be mounted before the car is imported to the Chinese market. | Chinese legal document. | This is a way to secure that there is a way to mount the license plate to the car. |
| D | Both | It would be positive if the license plate holder and its fastening contained as few parts as possible. | Volvo Cars, customer and car dealer desire. | By reducing the number of parts the holder will be easier to mount and there will be fewer parts to store and handle. |

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| D | Both | The degree of commonality should be as large as possible. | Volvo Cars desire. | Having a high degree of commonality will increase the volume of the common parts which will make them cheaper to produce. The assembly will also be easier and storage cheaper etc. |
| D | Both | The number of unique parts should be kept to a minimum. | Volvo Cars desire. | By having as few unique parts as possible the fixed tooling cost will be lower as well as assembly and storage will be more efficient etc. |

6.2 Fastening of the license plates

As seen in the requirement specification there is some countries that have specified the fastening of the license plate through legislation. In China you soon need to fasten it with four M6 screws and in Japan with two. Since these screws have a metric pitch they need corresponding threads in the holder in order to function. This means that other fastening solutions such as self-threading screws cannot be used for these markets.

Volvo's current license plate holder in North America uses dome nuts to fasten the license plates. However, there were no regulations that stated that these had to be used. When investigating the competitors on the American market it could be seen that Volvo was unique with this solution today. All the other car manufacturers use more or less standard screws. The dome nuts are a very expensive solution and do not give that many benefits. Some customers might say that they do look nice, but as mentioned earlier in this report they have a risk of pinching the cars during parking collisions. A better solution would be to replace them with the same kind of screws used for the Chinese and Japanese market.

6.3 Add-ons and delighters

An add-on or delighter could allow the customer pay a higher price for the product by providing them something extra. Most likely it will add an additional cost for Volvo Cars, but it provides a possibility to get an increased profit. It also is highly connected to the "designed around you" principle that Volvo Cars are pursuing, for example by giving the customer a choice to make things more personalized. There is also a driving need in China and some other countries to increase the luxury feeling of the car and to show others that they have style. These concepts provide something extra in addition to the basic qualities of the holders and it could be used together with the main design that will be chosen for the license plate holders.

6.3.1 Specially colored adapter/holder

The adapter/holder can be painted in the same color as the car to make it blend in more (see Figure 49). Another alternative of this add-on is to paint it in a contrasting color to make it stand out even more. This is a premium feature that is used on some competitor luxury car models today. By providing some models with specially colored adapters they would probably be perceived by the customer as a more luxury model and will differentiate the Volvo car model range. It could also be provided as a personal add-on to all the car models if you want to pay extra or be a part of a styling package as one of many additional features. For example it could be included in specific model versions such as the sportier R-design in order to increase its appeal. The only adaptation that has to be made is to color the adapter.



Figure 49 - Adapter that is colored in the same color as the rest of the car

6.3.2 Specially made license plate frames

These frames allow the owner of the car to make it look more personal. The frame can for example be provided with text, sparkling crystals or other embellishments. This could make the holder to be regarded as more premium and therefore attract customers who desire these characteristics. Variants of this are popular in USA today and there is for example Volvo versions of frames provided as well. Similar to the specially colored adapter there is a potential to include this to the model range in some way. These frames would probably also be easily mounted on the holder or adapter, which would make them more or less modular at least within one and the same market.

6.3.3 Advertisement ability

By providing the holder/adapter with advertisement ability the car dealer might be interested to take the cost or part of the cost of the license plate holder. This is currently how it works in EU where the license plate holder is financed entirely by the car dealer which of course is very economically beneficial. However, in this market it is difficult to affect the qualities of the holder itself which in turn might affect the perceived impression of the holder in a negative way. In USA the dealers sometimes adds advertisement on a frame that can be mounted to the holder by using the screws used to fasten the license plate. This makes it possible for them to include advertisement without paying any part of the holder cost. Potential Volvo Cars customers do however get the car dealer information where to buy a new Volvo car.

6.3.4 Help sign

The holder can be provided with an illuminated help sign. This will allow the driver to more easily get attention when in need of help. The hazard warning device used today with flashing lights does warn other road users. However it does not inform when people in a car are in acute need of roadside attention. This would be one way of achieving this with simple means. However, in today's society this solution could be regarded as quite primitive. A more exclusive communication-solution like Volvo's On-Call service might be more appropriate.

6.4 Anti-theft solutions

Since license plate thefts are a big dilemma around the world it was interesting to find out different solutions on how to prevent them from being stolen. These concepts are presented below followed by an analysis of their applicability in this project.

6.4.1 Lock with a key or a code

This solution will use a lock that mechanically will secure the license plate by for example locking a license plate frame in place (see Figure 50). Access can be secured by providing a key or a code that will be used in order to open the protection holding the plate. A drawback with this concept is that the need of accessing the license plate is not frequent so when the actual need of releasing the plate is relevant the code or key is forgotten.

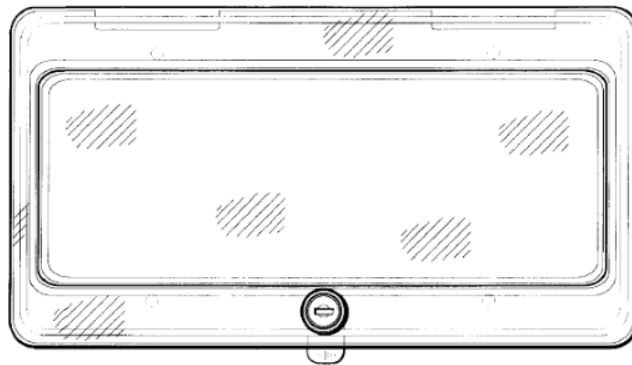


Figure 50 - A patented solution that locks the plate with a key (Google Patents 1, 2013)

6.4.2 Seal/screw cover

Anti-theft fastener is a cover that protects the head of the screw that is used to mount the license plate (see Figure 51). By covering the head it will be much more difficult to demount and steal the plate. However there will also be problematic for the owner to demount the plate as well, which could be a problem on markets where mounting and demounting of the plate is necessary throughout the lifetime of the car. Since these screw covers has an entirely separated function with an interface that matches all possible holders, as long as the plate is fastened with some kind of screws, it can be used as a modular component. The cover can then be added to selective markets where there is a need and a possible profitability in theft protection.



Figure 51 - Screw cover (Rockler, 2013)

6.4.3 One way screws

The license plate could be fixed to the holder by using one-way screws in to the standard mounting holes (see Figure 52). It would however make it difficult for the owner of the car to remove the plate as well. A solution might be to use one way screws on the markets where there is no need to remove the plates and regular screws on the other markets where there is a need to mount and demount the plate. This makes it a somewhat modular concept which could be beneficial since there is no adaptation needed of the holder in order to use this concept.



Figure 52 – One-way screw (Allied Bolt, 2013)

6.4.4 Fastening from the plate to the engine compartment

By having a long screw or something similar that goes through the plate, adapter and the bumper/grille the screw can be securely attached inside the engine compartment with a nut (see Figure 53). The same effect can be made by having a string or a similar fastening. If one wishes to remove the plate you first have to open up the hood which only the owner is able to do. It could however be problematic to reach the fastening inside the engine compartment since it is not much room in there. It would also require a complete design that is adapted to this anti-theft method. It could also be problematic on the markets where there are high demands on accessibility.

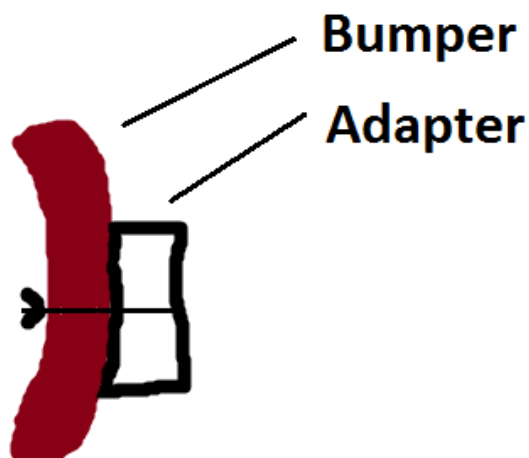


Figure 53 - Screw that goes through the adapter and bumper and locked by a wingnut inside engine compartment

6.4.5 Evaluation of the result

It was found that there often is a trade-off regarding how securely the license plate is fastened and the ability for the owner to remove the plates. Since the Americans need to have a removable fastening solution it will be hard to incorporate an anti-theft solution on this market. The Japanese holders will be provided with a seal from the government which will protect the plates from being stolen. No additional anti-theft solution will be needed for this market. It would be good to provide an anti-theft solution for the European market, but since Volvo are not providing the license plate holders for this market it will be hard to build-in a good solution. This leaves the Chinese market alone as a candidate for an anti-theft solution. Since this is a relative small sales volume it will be too expensive to provide them with an extra anti-theft solution.

It is still not determined if the customers around the world are prepared to pay extra for an anti-theft solution provided by Volvo. In the customer survey many were prepared to pay extra, so there could be a large potential. But on the other hand the study was quite small and only performed on Swedish citizens. Also, several different websites exist that provide these solutions if the customers find out that they do need it. Solutions that fixed this problem can cost as little as 20 SEK which is why it would be hard for Volvo to compete with this offer. Of course there are customers who will not know about this or have the time to fix it themselves that are prepared to pay extra to get the solution directly when buying the car. This is why there could be a market potential after all.

One shall also keep in mind that the customers who get their plates stolen will not blame Volvo as long as the holders have good quality and good fastening to the plate and the car. When looking at the competitors' one can see that no one is providing anti-theft solutions. Therefore the customers at least will not miss this solution or blame Volvo for not providing it.

6.5 Development of the front license plate holder

Here follows the development of the front license plate holder. The main challenges are described in order to better understand what is to be achieved by the holder. Based on this information concepts will be generated and evaluated.

6.5.1 Main challenges

Based on the requirement specification, several different main challenges were discovered. These main challenges served as main focus during the generation of new concepts. Most of these challenges regarded tradeoffs that had to be made in order to fulfill all requirements and create a good quality concept.

When looking at the requirements for the different markets one will see that the sizes of the license plates differs quite a lot. Therefore, there is a need to match these demands by developing several different license plate holders. There is also a desire to have as few variants of the holders as possible which is why a holder that can hold license plates of different sizes could be beneficial. This needs to be combined with the goal that it should look good and function well on all the main markets. At the same time, the cost should be as low as possible, because neither customers, nor Volvo Cars, are willing to pay big money for a license plate holder.

A second challenge is to make a concept that is both rigid, provides good support for the plate, delivers good fastening of the license plate and that is built with high quality. At the same time the holder should be as light as possible in order to minimize the total weight of the car and preferably be environmentally friendly. There is also a customer desire on most markets to make the license plates anti-theft proof which makes it positive to have a license plate that is securely fastened. It is of course also important that the license plate is at its intended position and do not fall off. However, in contrast to the anti-theft desire there is also a need to easily be able to transfer license plates from one car to another in the American market.

The final challenge is regarding the uncertainty on how the cars will look in the future. The only thing that is more or less certain is that the cars is to be designed with a more complex front with less obvious room for a license plate. More practically this will be problematic when the concepts are to be evaluated and one concept is to be chosen. Some concept solutions may for example be more suitable for mounting in the grille while other might instead be more applicable to a more homogeneous front shape.

6.5.2 Different alternatives of the front license plate holder

Several different alternatives regarding the development of the front license plate adapter do exist. Volvo Cars can use the same strategy as today, namely having a flat front together with the current license plate holders. However, since this design was not desired in the future it is no need to develop this any further. The other way of doing it is by having an integrated inlay or an extruded flat surface placed on the bumper or grille. This means that you are able to mount the license plate directly to the surface or use the same holder as today. However, it forces Volvo Cars to deliver several different variants of the bumper for the different markets if the license plates shall match perfectly. This is not efficient from an economical point of view since Volvo Cars have a relative small sales volume. The integrated solution is also mostly used on low-end cars and might not suit the overall appearance of the more premium image that Volvo Cars is looking for.

The most suitable version to solve this problem is by using a separate adapter. This adapter will allow the transition from a complex to a flat surface. Since the adapter is separated from the car it is possible to use the car with or without the adapter. This is for example beneficial when the car shall look at its best during promotion and advertisement without a license plate.

Several different ways of developing separate adapters do exist. Even if some alternatives lead to a reduction of the number of adapters needed, it is the overall cost for Volvo Cars that is out of most importance. The simplest solution is to develop a separate adapter that can be used together with the current front license plate holders. One can also develop an adapter that has integrated fastening mechanisms for the license plate inside the adapter, which will eliminate the need of the holder. Due to the similarity in size between some holders, namely the Japanese and the American one, it might be an alternative to merge them together. This would raise the overall manufacturing volume of the holder. One can also merge all the adapters into one. However, there is a risk that this holder will have lower performance than specialized versions and also be more complex and thus more expensive. The final alternative, and also the most appealing, is to have a holder that is compatible with all the different license plates

in the world. However it is a risk that the holder will be too expensive if one makes it too adaptable. For example if regulations are very specific or strict for one market it could be a wise decision to make a separate solution for that market or one could group markets together that have similar preconditions.

Even if Volvo Cars choose to use a separate adapter for their future cars the placement of it can be uncertain. The most obvious choice is to place the adapter right on the bumper just below the grille, much like they do today (see Figure 54). If they will change the design more radically of the front, it might be a better solution to place the adapter in the grille instead. Today the space in the top grille is occupied by the large logo which will reduce the likelihood of placing it in the top grille, which is why a more suitable position might be in the lower grille. The same goes for the floating or non-floating appearance of the license plate. Whichever choice they will make today is perhaps not the choice they will make in the future. This is why concepts on both appearances have been investigated.



Figure 54 - Volvo V60 Plug-in Hybrid front (Motortrend, 2013)

6.5.3 Concept generation for front adapters

This is a presentation of all of the ideas that came out of the brainstorming sessions. It is important to note that no concept below is complete and most of them only solve part of the problem. The adapter concepts below can more or less successfully be mounted on either the bumper or the grille depending on the future design. Many of the concepts generated deal with the adaptability to several markets. Some of these concepts are designed to be as discreetly as possible in order to minimize the risk of making the car less aesthetic. Some other concepts are designed to make the holder as appealing as possible which can beautify the car.

The estimated number of unique parts is given for each concept below. It will serve as a guideline on how expensive and complex the solution will be. The preconditions stated that the holder should be applicable for the Chinese, Japanese, American and EU market, including Italy. This means that five different markets need to be considered. Since every bumper is unique there is also a need to define the number of car models provided. The estimated number here is 10 different car models.

6.5.3.1 The Full-size

This is an adapter that follow the surface of the car and that cover the whole area of the license plate. This means that many different variants needs to be developed in order to fit the different car models and markets, see Figure 55. This is the solution that is preferred by many competitor car manufacturers, which makes it a safe choice for Volvo Cars. The main benefit is that the holder provides good support for the license plate and integrated mounting attachments. Since the attachment on each adapter is fitted to just one market it will be an easy assembly. On the one hand it is a simple solution which makes it possible to produce it at low cost. On the other hand many different variants are needed since the produced volume will be low which can result in a higher cost.

- + Simple solution, widely used, good support for license plate
- Several variants needed
- o Integrated look, 50 unique parts

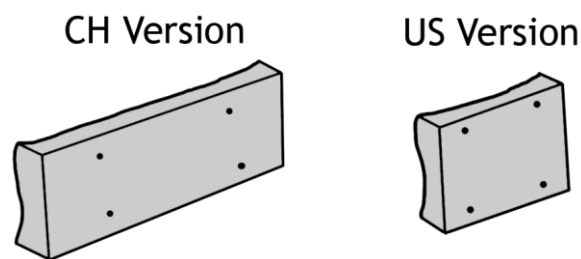


Figure 55 – Two different versions of The Full-size

6.5.3.2 The Big Separate

This is a solution that is based on “The Full-size”. However, instead of integrating the mounting attachment a holder is used together with the adapter in order to separate the mounting function from the adaptability function, see Figure 56. By separating the functions the overall dimensions can be reduced and it will have a better recyclability. There is however a risk that the extra holder will make it more costly than having it integrated. Also, there is a risk that it will be a visible gap between the holder and the adapter which will lower the integrated look intended with this design.

- + Simple adapter without inserts, separated functions
- Both holder and adapter needed, several variants needed, not as integrated as “full size adapter”
- o Integrated look, 51 unique parts

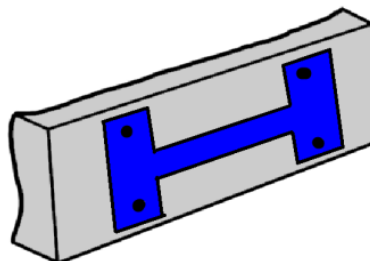


Figure 56 - The Big Separate

6.5.3.3 The Small Separate

This concept uses a small common adapter together with corresponding holders for the different markets, see Figure 57. Since the adapter is so small, a floating visual effect will be achieved. This floating effect leads to a lower plate support compared to many other solutions, which might lead to a deformed license plate. The reason why the holders are needed is due to the lack of space for attachment points on the small surface. It also increases the support and rigidity of the plate. Economically it is beneficial that one and the same adapter can be used on all markets however there is also the extra cost of using separate holders.

- + Common part, simple structure
- Both adapter and holder which adds cost, the plate might be deformed
- o Floating look, 11 unique parts

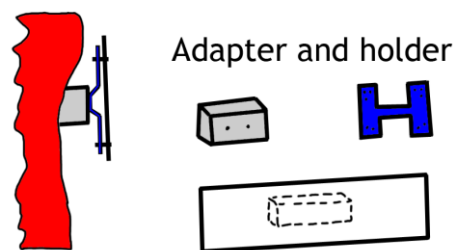


Figure 57 - The Small Separate

6.5.3.4 The Spacer

In this concept a license plate holder is mounted on top of four spacers that are mounted to the car, see Figure 58. This is a concept that is very simple in its design with few parts which means that it probably will be very cheap. The holders can be the same as the ones used today or enhanced versions. Since the standard EU license plate holder is provided for free it will be a very cost efficient solution. This would make the spacers the only thing that is included by Volvo Cars on the European market. The look with this solution will be floating for all markets. However, there is a risk that the holder will be perceived as less rigid and provide less support for the license plate in situations such as taking the car to an automatic car wash with brushes. When performing parallel parking it could also be a risk that the spacers would create high pressure to the bumper, if the car is to collide with another car. The small contact surface might then result in a situation where a hole is being punched through the bumper.

- + Very few unique parts, cheap
- Less rigid, low support of plate, high risk of bumper damage
- o Floating look, 6 unique parts

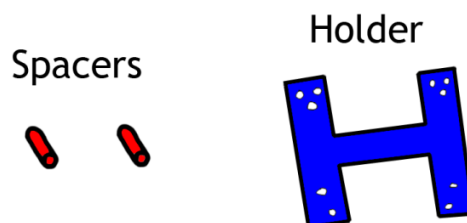


Figure 58 - The Spacer

6.5.3.5 The Cover

This is an extension of the concept “The Spacer”. A full size cover is placed on top of the holder and the spacers in order to provide an integrated look (see Figure 59). By having a separate holder the cover does not need to have any mounting attachments which will reduce the complexity. The cover can also be made very lightweight and simple since it does not need to support anything. However, many different variants of the cover are needed in order to fit all the car models and markets. The volume on the holder and the spacers will be high which might lower the cost. Only spacers and a cover are needed to be provided for the EU market since the holder is provided for free. The assembly time might be extensive due to the separated functions.

- + High volume on some parts, separated functions
- Many parts needed, hard assembly, many unique parts
- o Integrated look, 56 unique parts

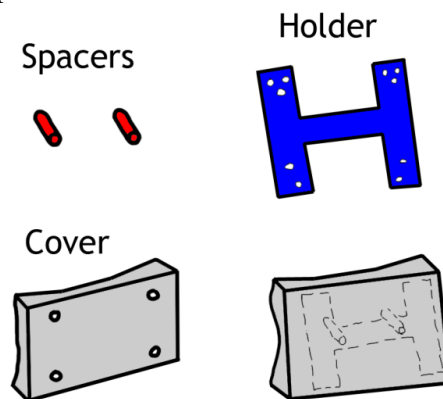


Figure 59 - The Cover

6.5.3.6 The Side Covers

This is an extension of the concept “The Spacer” where a holder is used together with four spacers. In this concept side covers are attached to the holder in order to hide the spacers when looking from the side. This concept is mostly appropriate if the gap between the upper edge of the license plate and the car is rather tight, see Figure 60. This concept will most likely contribute to a floating look for most markets. For the European market where no holder is needed one could mount it on the holder anyway, mount it directly on the spacing's without covers or find a unique side cover solution for the license plate.

- + High volume on some parts, partly integrated look despite little material
- Many parts, low support of plate, hard assembly
- o Mostly floating look, 26 unique parts

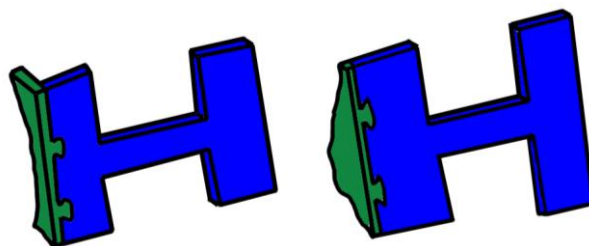


Figure 60 - The Side Cover, with a good design on the right and a not so good on the left

6.5.3.7 The Centerpiece

The adapter has a centerpiece that is common for all markets and license plate sizes. In order to adapt to the different license plate sizes extra parts can be added to the sides. It is these extra parts that have mounting attachments for the plate which means that the centerpiece can be very simple. It will provide an integrated look for all markets which enables very good support of the plate, but many different form fitted pieces is needed to achieve this. For the non-EU markets there will be a hollow area in the lower part of the adapter (see Figure 61). Since lots of parts are needed the assembly will be expensive.

- + High volume on common part, full plate support, few unnecessary attachments
- Many unique parts
- o Integrated look, 101 unique parts

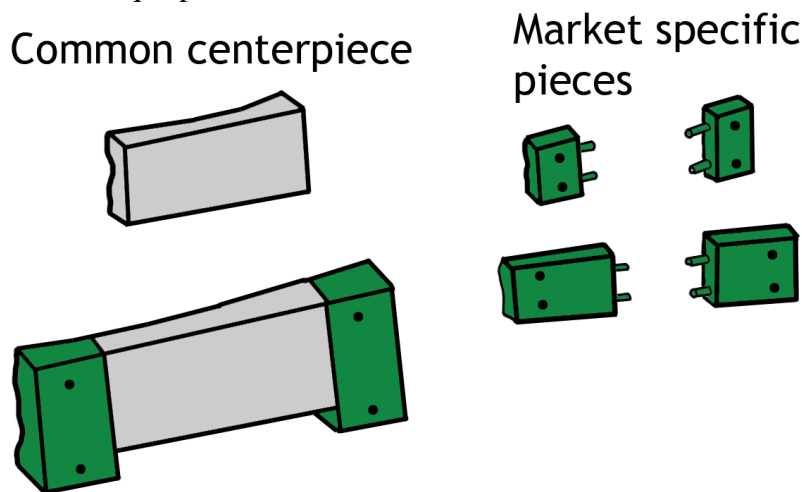


Figure 61 - The Centerpiece

6.5.3.8 The Two-part

This design has a common top part that is used on all the different markets and it is form fitted to the car. Just by using the top adapter you are able to mount the EU plate together with the already provided EU-holder on top of it. By attaching a lower part it will also fit the remaining markets, see Figure 62. The result will be a floating effect for the EU and Chinese markets, and more of an integrated look for the other two markets. It will be high volumes of the common part, but it needs a lot of mounting effort.

- + High volume on the common part, few parts
- Low plate support, different appearance on all markets, high mounting effort
- o Floating as well as integrated look, 11 unique parts

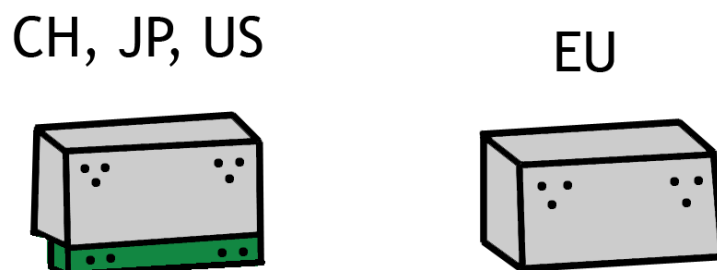


Figure 62 - The Two-part

6.5.3.9 The Wings

A small adapter that is common for all markets is placed on the car that is fitted to follow the shape of the front. On top of this common part another market specific adapter is mounted, which are shaped like wings and will not touch the actual car (see Figure 63). It will create a good support for the license plate and give a somewhat integrated look, but it will never be a fully integrated solution. By using a common adapter for all markets the volume of that part would be high which would lower the cost. On the other hand there will be needed to have individually made wings for all intended target markets. This is unavoidable if the size of the support is to match the license plate.

- + High volume on common part, low number of variants
- Relatively complex design
- o Half integrated look, 15 unique parts

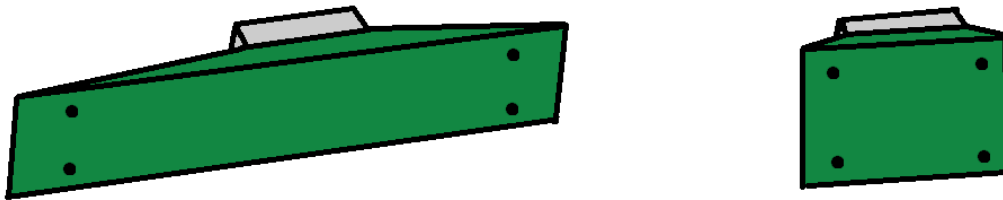


Figure 63 - The Wings

6.5.3.10 The Corner

This concept has four small adapters that is placed at the attachment points appropriate for each license plate, see Figure 64. The most suitable option would be to place these adapters in the grille. Otherwise many different adapters would be needed if they were to be form fitted to the car. A drawback with this approach is that the support behind the license plates is rather poor. It would be a very complex assembly since you have many different parts and they have to be placed at exact locations.

- + Low weight
- Low plate support, high assembly time, many parts
- o Floating look, 200 unique parts

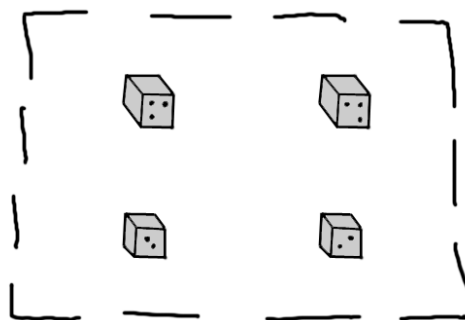


Figure 64 - The Corner

6.5.3.11 The Puzzle

Relatively small building blocks can be assembled together in order to fit all license plate sizes on the market, see Figure 65. This would make it possible to create an adapter that has the same size as the license plate on all markets. It could also be achieved with the same parts which make it very modular and the volume of these parts would be high. Although it might be problematic to organize these pieces in a way that successfully forms all the appropriate sizes. It would also be difficult to make them adapt to the irregular surface of the car and by using this many components it will most probably be time consuming to assemble.

- + High volume on common parts, good license plate support
- Many parts, high assembly time, complex
- o Integrated look, unknown number of unique parts

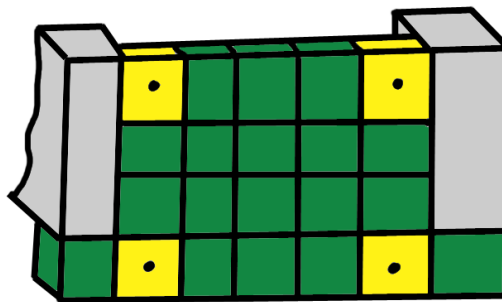


Figure 65 - The Puzzle

6.5.3.12 The Extendable

A form fitted small adapter is mounted to the car. On top of this adapter four extendable arms are mounted, see Figure 66. Since the arms are extendable and rotatable it allows for a mounting of license plates of any size. On each arm an attachment hole could be placed, or a corner piece, that will fix the plate. The volume of the holder will be very high since it can be used on every market. However, the complexity of the part might increase the cost. This solution will also have a very hard assembly of the license plate.

- + High volume of common part, adaptable to any market
- Hard license plate assembly, complex part, low license plate support
- o Floating look, 11 unique parts

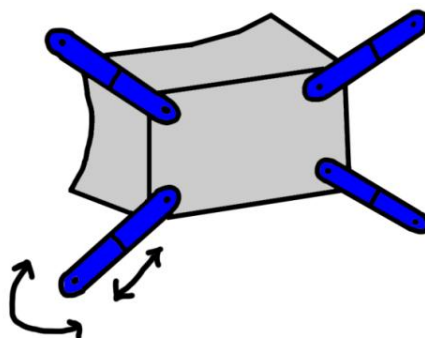


Figure 66 - The Extendable

6.5.3.13 The Rotatable

This concept uses a common centerpiece with fixed mountings at the top and two rotatable arms at the bottom (see Figure 67). Since the arms are rotatable and are provided with a number of holes it can be adaptable to different sizes of license plates and hole patterns. For example; when you mount a plate that is high and narrow the arm would be placed almost vertically. As for a wide plate the arms would be placed horizontally. Unique centerpieces have to be made for all models since they have to follow the shape of the car. By making it fit all markets it will be produced in a large volume which is an economically positive aspect. There will however also be a complex solution with movable parts which could make it more expensive as well. The mounting of the license plate could also be a problem since the rotatable fastenings might be hard to get in the exact position.

- + High volume of common part, adaptable to many markets
- Hard license plate assembly, complex part, low license plate support
- o Floating look, 11 unique parts

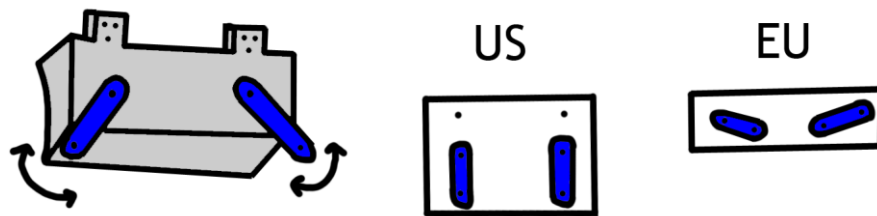


Figure 67 - The Rotatable

6.5.3.14 The Foldable

This solution uses an adapter with fixed mountings at the top together with two small plates with mounts on the bottom of the adapter. The plates can be folded down to extend the surface in which larger plates can be mounted on, typical for the Japanese and American market (see Figure 68). This makes the solution adaptable to a lot of different license plate sizes. For markets with narrower plates the fold down attachment will be in its upper position and the plate could be placed directly on the adapter and the upper mountings. This would create an increased floating appearance for these markets. Since this holder is produced to fit all markets the volume will be high which would affect the price in a positive way. However, the form fitted adapter would increase the number of unique parts somewhat.

- + High volume of common part, adaptable to many markets
- Complex part, low license plate support
- o Floating look, 12 unique parts

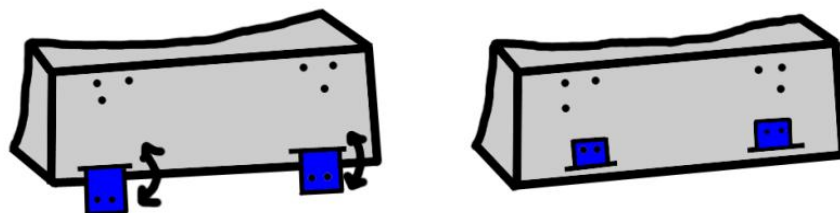


Figure 68 - The Foldable

6.5.3.15 The Springy

This license plate holder is based on one small centerpiece that has fixed mountings at the top and a lower part that are able to move up and down, see Figure 69. The upper part is also equipped with a slot that will function as a counterweight against the force from the springs. The springs are placed below the lower part of the centerpiece and will hold the license plate in place. The springs will make the holder adaptable by providing flexible lower mounts equipped with a slot. By creating a solution that is adaptable to all license plate sizes the volume of the holder will be high which will lower the cost. However there is a high risk that the holder will be expensive since it is a rather complex design.

- + High volume on common part, adaptable to many markets
- Complex, low license plate support
- o Floating look, 13 unique parts

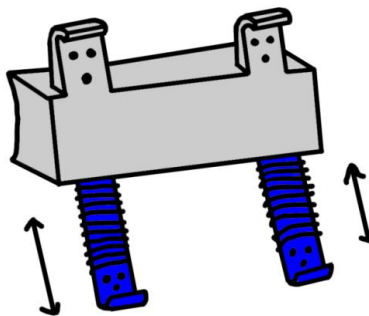


Figure 69 - The Springy

6.5.3.16 The Angle

This is a bracket that holds the license plate and it is mounted to the bumper or grille (see Figure 70). In this example it is an angled bracket but it could be possible to make a holder that is mounted more directly on a flat surface as well. This solution is also cheap since it is a simple design which is easy to manufacture. Depending on the placement of the bracket it can hold various sizes of license plates which make it adaptable. The height could be more challenging to fit for all markets, which probably means that a big and a small version need to be developed. Another problem could be that the holder provides an insufficient support of the license plate surface. It could also be a problem with the mounting of the license plate as well as the placement of the holder to the car, since the distance between the holders is not fixed.

- + High manufacturing volume, simple solution, adaptable to many markets
- Low support for plate, long assembly time
- o Floating look, 4 unique parts

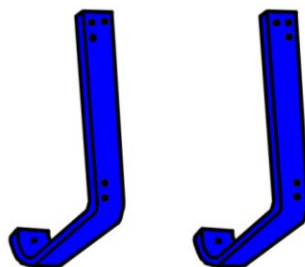


Figure 70 - The Angle

6.5.3.17 The Curtain

In this concept the license plate holders is stored inside the bumper but can be pulled out and placed onto the front depending on which size that is needed. The license plate is then mounted on the dropped down “curtain”, see Figure 71. The parts that are not needed will then be securely placed inside the bumper, which means that unnecessary parts always has to be installed on the car even if they are not to be used. This will contribute to an increased weight and an additional cost. The positive aspect is that the same solution can be used on all markets and the adapter is always there to be used or to be put back.

- + Ability to “hide” the license plate holder, same solution for every market
- Complex solution, takes up space behind the bumper, increased weight
- o Floating look, 5 unique parts

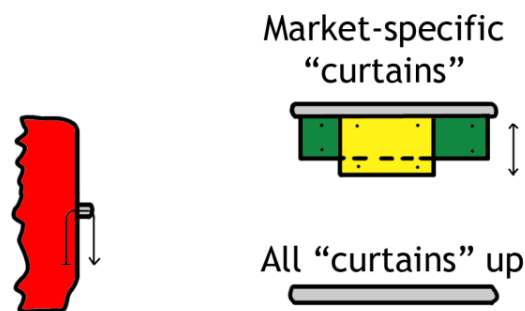


Figure 71 - The Curtain

6.5.3.18 The Pocket

In this concept the license plate can be inserted into a pocket in the grille, see Figure 72. The large pocket also makes it fully adaptable to different license plate sizes. In order to make the license plate fully visible, a hole could be cut out by the dealer that fits the size of the license plate. A small overlap could also be used in order to secure that the plate does not fall out. Another variant of this concept is to have a grille made out of glass with holes all over the surface, and fasten the plate from the outside through these holes with screws. However this would affect the design of the front as well as it would take up room in the grille.

- + Protects the license plate, adaptable to many markets
- Takes place in the front, affects front design
- o Integrated look, 0 unique parts

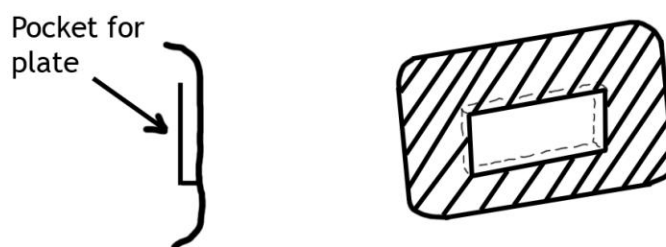


Figure 72 - The Pocket

6.5.3.19 The Screen

A LCD-screen or similar visual equipment can be used as a display of all the different kinds of license plate instead of using the actual license plates (see Figure 73). By doing this an integrated look would be achieved. Using one screen would make it possible to use only one kind of license plate holder for any market which holds the screen in place. Using a screen that is powered by electricity might be problematic regarding reliability. Since the screen is expensive and fragile it might also be a practical problem.

- + Adaptable to many markets, same solution on every car
- Expensive screen, fragile, reliability problem
- o Integrated look, 1 unique part



Figure 73 - The Screen

6.5.3.20 The Mirrors

By using reflecting mirrors the license plate can be mounted somewhere inside the engine compartment and project the visual image of the plate to the front of the car (see Figure 74). The visual effect is as if it was mounted directly to the bumper. It could hold any type of license plate and it would be hard for a thief to steal the plate.

- + License plate is protected from thieves and during light collisions
- Takes up a lot of space, complex
- o Integrated look, unknown number of unique parts

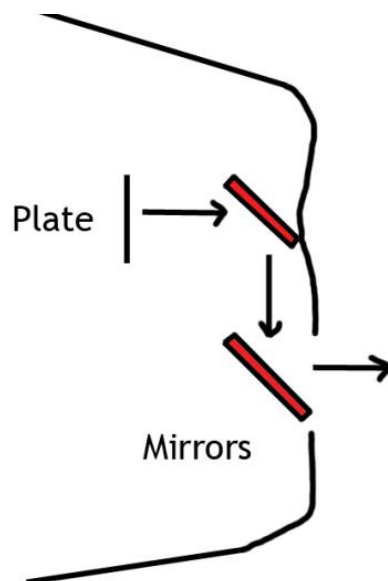


Figure 74 - The Mirrors

6.5.4 Evaluation of separate adapter solutions

To choose between all these concepts some evaluation methods were used. These have the purpose of screening the concepts out until only one final concept remains.

6.5.4.1 Elimination matrix

The purpose of the elimination matrix was to eliminate those concepts that did not fulfill the requirement specification or was not suitable for Volvo Cars (see Figure 75). It resulted in four concepts being eliminated.

| Solutions | Fulfills the demands of the requirements list | Realizational in principle | Suitable for Volvo Cars | Pursue/Eliminate | Comment |
|---------------------------|---|----------------------------|-------------------------|------------------|--------------------|
| Separate adapter concepts | | | | | |
| The Full-size | o | o | o | Pursue | |
| The Big Separate | o | o | o | Pursue | |
| The Small Separate | o | o | o | Pursue | |
| The Spacer | o | o | o | Pursue | |
| The Cover | o | o | o | Pursue | |
| The Side Covers | o | o | o | Pursue | |
| The Centerpiece | o | o | o | Pursue | |
| The Two-part | o | o | o | Pursue | |
| The Wings | o | o | o | Pursue | |
| The Corner | o | o | o | Pursue | |
| The Puzzle | o | o | o | Pursue | |
| The Extendable | o | o | o | Pursue | |
| The Rotatable | o | o | o | Pursue | |
| The Foldable | o | o | o | Pursue | |
| The Springy | o | o | o | Pursue | |
| The Angle | o | o | o | Pursue | |
| The Curtain | o | x | | Eliminate | Too complex |
| The Pocket | o | x | | Eliminate | Affects the design |
| The Screen | x | | | Eliminate | Legally forbidden |
| The Mirrors | x | | | Eliminate | Too complex |

Figure 75 - Elimination matrix of the front adapters

6.5.4.2 Pugh-matrix

The Pugh-matrix was used to eliminate the least promising concepts (see Figure 76). Different criteria were used to help with the evaluation. These criteria had its foundation in the requirement specification. It regarded performance qualities such as rigidity, weight, anti-theft and mounting of plate. Many of the other criteria regarded the cost in many different ways; for example commonality between parts, purchase price and assembly time. The theories of design for manufacturing and design for assembly were used in the evaluation. An example of this is the amount of assembly steps that served as an input on how long the assembly time would be. It resulted in four concepts being eliminated.

| Criteria \ Concept | The Full-size | The Big Separate | The Small Separate | The Spacer | The Cover | The Side Cover | The Center-piece | The Two-part | The Wings | The Corner | The Puzzle | The Extend-able | The Rotat-able | The Foldable | The Springy | The Angle |
|--|---------------|------------------|--------------------|------------|-----------|----------------|------------------|--------------|-----------|------------|------------|-----------------|----------------|--------------|-------------|-----------|
| | | | | | | | | | | | | | | | | |
| Anti-theft | DATUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | - |
| Applicability to new car models | | 0 | 0 | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | + |
| Applicability to remaining markets | | 0 | + | + | 0 | + | + | + | + | + | 0 | + | + | + | + | + |
| Low assembly time/cost | | - | - | 0 | - | - | - | - | - | - | - | - | 0 | 0 | 0 | - |
| Low purchase price | | - | + | + | - | + | - | 0 | - | + | - | 0 | 0 | 0 | - | + |
| Low weight | | - | 0 | + | 0 | + | 0 | + | - | + | 0 | 0 | 0 | + | 0 | + |
| High rigidity | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | + | - | 0 | - | - | - | - | - |
| Parking collision and car wash qualities | | 0 | - | - | 0 | - | 0 | - | - | - | 0 | - | - | - | - | - |
| Innovative solution | | 0 | 0 | 0 | + | + | 0 | 0 | + | + | + | + | + | 0 | + | 0 |
| Easy to mount and demount plate | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 0 | + | 0 |
| Recyclability | | 0 | + | + | + | + | 0 | + | 0 | + | 0 | 0 | + | + | + | + |
| Common parts | | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Number of unique parts | | 0 | + | + | 0 | + | - | + | + | 0 | - | + | + | + | + | + |
| Σ+ | 0 | 1 | 5 | 7 | 3 | 7 | 2 | 5 | 5 | 6 | 2 | 4 | 5 | 5 | 6 | 7 |
| Σ- | 0 | 3 | 2 | 1 | 2 | 2 | 3 | 2 | 4 | 3 | 3 | 5 | 3 | 2 | 3 | 4 |
| Net value | 0 | -2 | 3 | 6 | 1 | 5 | -1 | 3 | 1 | 3 | -1 | -1 | 2 | 3 | 3 | 3 |
| Ranking | 6 | 8 | 3 | 1 | 5 | 2 | 7 | 3 | 5 | 3 | 7 | 7 | 4 | 3 | 3 | 3 |

Figure 76 - Pugh matrix of the front adapter

6.5.4.3 Weight determination matrix

To establish the importance of the various criteria a weight determination matrix was made, see Figure 77. The criteria were compared to each other to see if the requirements were more, less or the same importance. An overall weighting of the criteria could then be established. The most important criterion is the parking collision followed by a low purchase price and a low number of unique parts. These weighing were then to be used in the Kesselring matrix.

| Criteria | A | B | C | D | G | H | J | K | L | Sum | Tot | W(%) |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|------|
| A Anti-theft | | 0 | 0 | 0,5 | 0 | 0 | 0,5 | 0,5 | 0 | 1,5 | 0,042 | 4,2 |
| B Low assembly time/cost | 1 | | 0,5 | 1 | 0,5 | 0 | 1 | 1 | 0,5 | 5,5 | 0,153 | 15,3 |
| C Low purchase price | 1 | 0,5 | | 1 | 0,5 | 0,5 | 1 | 1 | 0,5 | 6 | 0,167 | 16,7 |
| D Low weight | 0,5 | 0 | 0 | | 0 | 0 | 1 | 0 | 0 | 1,5 | 0,042 | 4,2 |
| G High rigidity | 1 | 0,5 | 0,5 | 1 | | 0,5 | 1 | 0,5 | 0,5 | 5,5 | 0,153 | 15,3 |
| H Parking collision and car wash qualities | 1 | 1 | 0,5 | 1 | 0,5 | | 1 | 1 | 0,5 | 6,5 | 0,181 | 18,1 |
| J Easy to mount and demount plate | 0,5 | 0 | 0 | 0 | 0 | 0 | | 0,5 | 0 | 1 | 0,028 | 2,8 |
| K Recyclability | 0,5 | 0 | 0 | 1 | 0,5 | 0 | 0,5 | | 0 | 2,5 | 0,069 | 6,9 |
| L Number of unique parts | 1 | 0,5 | 0,5 | 1 | 0,5 | 0,5 | 1 | 1 | | 6 | 0,167 | 16,7 |
| Tot | | | | | | | | | | 36 | 1,000 | 100 |

Figure 77 - Weight determination matrix of the front adapter

6.5.4.4 Kesselring

The Kesselring was used to eliminate some more concepts (see Figure 78). This time the criteria was weighted, which means that the most important criteria, such as cost, had a much bigger impact on the result. Eight of the twelve remaining concepts were eliminated with the help of this method.

| Concept | | Criteria | | The Foldable | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------|---------------------------------|----------|-------|--------------|------|---------------|------|--------------------|------|------------|------|-----------|------|----------------|------|--------------|------|-----------|------|------------|------|---------------|------|--------------|------|-------------|------|-----------|----|
| | | | | Ideal | | The Full-size | | The Small Separate | | The Spacer | | The Cover | | The Side Cover | | The Two-part | | The Wings | | The Corner | | The Rotatable | | The Foldable | | The Springy | | The Angle | |
| | | w | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t |
| | Anti-theft | 4,2 | 5 21 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | 2 | 8 |
| | Low assembly time/cost | 15,3 | 5 76 | 3 | 46 | 3 | 46 | 4 | 61 | 2 | 31 | 2 | 31 | 2 | 31 | 2 | 31 | 1 | 15 | 4 | 61 | 4 | 61 | 4 | 61 | 4 | 61 | 2 | 31 |
| | Low purchase price | 16,7 | 5 83 | 2 | 33 | 3 | 50 | 4 | 67 | 2 | 33 | 3 | 50 | 3 | 50 | 3 | 50 | 3 | 50 | 3 | 50 | 2 | 33 | 2 | 33 | 1 | 17 | 5 | 83 |
| | Low weight | 4,2 | 5 21 | 3 | 13 | 3 | 13 | 3 | 13 | 4 | 17 | 2 | 8 | 3 | 13 | 4 | 17 | 3 | 13 | 5 | 21 | 3 | 13 | 3 | 13 | 3 | 13 | 5 | 21 |
| | High rigidity | 15,3 | 5 76 | 5 | 76 | 4 | 61 | 3 | 46 | 4 | 61 | 3 | 46 | 3 | 46 | 3 | 46 | 5 | 76 | 3 | 46 | 2 | 31 | 2 | 31 | 2 | 31 | 1 | 15 |
| | Parking collision qualities | 18,1 | 5 90 | 5 | 90 | 3 | 54 | 1 | 18 | 4 | 72 | 2 | 36 | 2 | 36 | 4 | 72 | 2 | 36 | 4 | 72 | 4 | 72 | 4 | 72 | 4 | 72 | 2 | 36 |
| | Easy to mount and demount plate | 2,8 | 5 14 | 5 | 14 | 4 | 11 | 4 | 11 | 4 | 11 | 4 | 11 | 4 | 11 | 5 | 14 | 4 | 11 | 3 | 8 | 4 | 11 | 4 | 11 | 4 | 11 | 4 | 11 |
| | Recyclability | 6,9 | 5 35 | 3 | 21 | 5 | 35 | 5 | 35 | 5 | 35 | 5 | 35 | 5 | 35 | 3 | 21 | 3 | 21 | 3 | 21 | 3 | 21 | 3 | 21 | 3 | 21 | 5 | 35 |
| | Number of unique parts | 16,7 | 5 83 | 2 | 33 | 4 | 67 | 5 | 83 | 2 | 33 | 3 | 50 | 4 | 67 | 3 | 50 | 2 | 33 | 4 | 67 | 4 | 67 | 4 | 67 | 4 | 67 | 5 | 83 |
| | $T = \sum t$ | | ##### | 338,89 | 0,68 | 348,61 | 0,70 | 350,00 | 0,70 | 297,22 | 0,59 | 283,33 | 0,57 | 290,28 | 0,58 | 338,89 | 0,68 | 245,83 | 0,49 | 318,06 | 0,64 | 320,83 | 0,64 | 304,17 | 0,61 | 323,61 | 0,65 | | |
| | T / T_{max} | | 1,00 | 0,68 | 0,70 | 0,70 | 0,70 | 0,70 | 0,59 | 0,59 | 0,57 | 0,57 | 0,58 | 0,58 | 0,68 | 0,68 | 0,49 | 0,49 | 0,64 | 0,64 | 0,64 | 0,64 | 0,61 | 0,61 | 0,65 | | | | |
| | Ranking | | | 2 | 1 | 1 | 1 | 1 | 6 | 8 | 7 | 2 | 9 | 4 | 5 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | | | | |

Figure 78 - Kesselring of the front adapters

6.5.4.5 Concept comparison

Four different promising concepts remained after the Kesselring was made. It was easy to see that it was no solution that was best in every investigated parameter. In order to display this more clearly a concept comparison was made, see Figure 79.

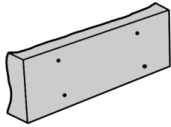
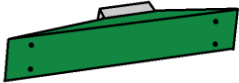
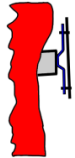
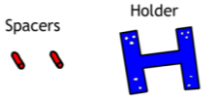
| The Full-size CH Version  | The Wings  | The Small Separate  | The Spacer  |
|--|--|--|---|
| Integrated | ← Visual appearance → | | Floating |
| Convex | ← Suitable shape of bumper → | | Concave |
| Many | ← Number of variants needed → | | Few |
| More | ← Cost to produce → | | Less |
| Expensive | ← Cost to develop new models → | | Cheap |
| More | ← Rigidity → | | Less |
| More | ← Parking collision protection → | | Less |
| Worse | ← Adaptability for remaining markets → | | Good |

Figure 79 - Concept comparison of the remaining front adapters

As seen, the cheapest solution would be to choose the concept “The Spacers”. Since the cost is one of the most important parameters it would be easy to say that it is the winner. However, due to the floating look of this concept there might be some problems with bending of the license plates during car washing and parking collisions. Also the concept is much less rigid than the more integrated solutions. By making it integrated the cost will most likely also be that much higher, so the question is if the floating appearance is good enough and how much difference in cost there actually is between the concepts. A more thorough cost estimation had to be made in order to investigate this.

6.5.4.6 Cost estimation and evaluation

A better cost estimation was made in order to make a decision among the top four concepts, see Appendix 6. The purpose was not to investigate the actual cost of the new holders, but to see how much difference in cost it potentially could be. To help with this cost estimation the Custompartnet website was used (Custompartnet, 2013), together with the already captured knowledge of the current license plate holders production and tooling costs.

The cheapest solution is once again “The Spacers” followed by “The Small Separate” (see Figure 80). The fact that these two concepts are cheaper is due to the fact that they use the free EU standard license plate holder. However, “The Small Separate” is only slightly cheaper than “The Full-size” if one take the tooling cost into consideration. What was interesting was that the concept “The Wings” which initially was considered to be cheaper than “The Full-size” actually turned out to be more expensive. Even though the concept called “The Spacer” is considerably cheaper than most concepts it is not certain that it will provide enough license

plate support and it therefore had to be eliminated. The most promising concept is “The Full-size” since it provides the best license plate support, good rigidity and fast assembly at a decent price. It is also considered to be a safe bet since it is how many competitors are solving it. Even if it is more expensive than some other concepts, it still fulfills the specified requirement of 30 SEK/holder.

| | The Full-size | The Wings | The Small Separate | The Spacer |
|--------------------------------------|---------------|-----------|--------------------|------------|
| Average cost / holder | 13,15 | 12,19 | 7,26 | 1,29 |
| Average cost / holder (inc. tooling) | 18,69 | 25,48 | 15,32 | 6,56 |

Figure 80 - Concept cost estimation

6.5.5 Fastening of the adapter

In order to make the concept complete, there are more things that needs to be included to fulfill the requirement specification and reach the goal of the adapter. The many different ways to fasten the adapter are mentioned in Appendix 7. However it is important to notice that not all fastening methods are possible to combine with the selected concept. This also has to be evaluated and kept in mind when investigating the fastening solutions. Afterwards an elimination matrix is presented together with some words about the chosen concept.

6.5.5.1 Elimination matrix

The fastening concepts are inserted into an elimination matrix in order to remove those that either do not fulfill the requirement specification, are realizable in principle or suits Volvo Cars (see Figure 81).

| Solutions | Fulfills the demands of the requirements list | Realizational in principle | Suitable for Volvo Cars | Pursue/Eliminate | Comment |
|----------------------------|---|----------------------------|-------------------------|------------------|------------------------------|
| Screw with nuts | o | o | o | Pursue | |
| Screw with wingnut | o | o | o | Pursue | |
| Screw with movable nuts | o | o | o | Pursue | |
| Screw with fixed inserts | o | o | o | Pursue | |
| Screw with movable spacers | o | o | o | Pursue | |
| Screw with threaded hole | o | o | o | Pursue | |
| Molly bolts | o | o | o | Pursue | |
| Bolt with molly insert | o | o | o | Pursue | |
| Self-tapping screw | o | o | o | Pursue | |
| Rivet joints | o | o | o | Pursue | |
| Expanding plug | o | o | o | Pursue | |
| Tow hook insert | x | | | Eliminate | Must be placed in the center |
| Tape | x | | | Eliminate | Too easy to remove holder |
| Glue | o | o | o | Pursue | |
| Velcro straps | x | | | Eliminate | Too easy to remove holder |
| Magnets | x | | | Eliminate | Too easy to remove holder |
| Electro magnets | o | x | | Eliminate | Too complex |
| Suction cup | x | | | Eliminate | Too easy to remove holder |
| Snap fasteners | o | o | o | Pursue | |
| String, wire or cable tie | o | o | o | Pursue | |
| Center of gravity | o | o | x | Eliminate | Will add too much weight |
| Clips, clamps and pressure | o | o | o | Pursue | |
| Self-locking geometry | o | o | o | Pursue | |

Figure 81 - Elimination matrix of the fastening methods for the front adapter

6.5.5.2 Chosen fastening solution

Many of the previously mentioned fastening concepts could be used to fasten the adapter in a more or less successful way. However, a choice had to be made and it was self-tapping screws that were considered as the best solution. The other concepts could not match the overall performance of using a simple self-tapping screw. It has the benefit that it requires no changes to the bumper, so it will look good in every state in USA. Also it is very cost efficient and requires no special knowledge or tools to mount it. It is also a solution that will be durable over time.

6.6 Development of the rear license plate holder

The preconditions for mounting the rear license plates has been pretty much the same over the years, which was not the case for the mounting of the front license plate. This makes the challenges quite diverse and the development of the rear license plate holder is more focused on cutting cost rather than delivering a more breakthrough product development. However, there is certainly a need to make the holder work across the Volvo Cars model range and to make it applicable for the target markets.

6.6.1 Main Challenges

Based on the requirement specification, several different main challenges have been discovered that will serve as a future focus when generating new concepts. These are mostly regarding tradeoffs that have to be made in order to fulfill all requirements and create a good quality concept. Since a large part of the challenges are somewhat the same for the front respectively the rear of the car they will be more or less just a summary.

Much like for the front holder, one of the main challenges will be regarding the tradeoff between the need of a lot of variants, in order to adapt to all market needs, and the desire to have as few versions as possible. However, it is not necessary that the solution has to be adapted to the European market which was the case for the front adapter. The EU-holder used today is provided by the car dealer and will add no cost for Volvo Cars. Since it is fulfilling its function in a satisfactory way a new concept would need to be a clear improvement and add significant value for the end customer if it would make sense for Volvo Cars to take the cost. This makes it possible for some concepts to be developed without the eventual need for a European adaptation.

Another challenge that needs addressing is also in common with the front license plate holder. The holder has to be rigid and have a good quality in order to give sufficient support to the license plate. At the same time the cost and weight must be low, as well as it is a desire to use standard materials. Same as for the front there is also a desire to have a securely fastened license plate. At the same time there is a need to transfer the plates from one car to another in some markets which makes it beneficial to have a plate that is easy to remove.

6.6.2 Different alternatives of the rear license plate holder

Several different alternatives on how to proceed with the development of the rear license plate holder existed. Since the current rear license plate holders do work satisfactory the new concepts had to be essentially better in order for it to be wise to replace the old ones. This means

that even if the number of holders could be reduced by some concepts, it is the overall cost for Volvo Cars that was out of most importance.

- Alternative 1: Change nothing. Keep the current holders that have been developed for EU, Japan, USA and China.
- Alternative 2: Enhance the current holders for Japan, USA and China to make them better. Only do small changes, the main concepts should remain the same in order to keep the change cost low. Leave the EU holder as it is.
- Alternative 3: Due to the similarity in size between the holder for Japan and USA it might be an alternative to merge them together. This would raise the overall manufacturing volume of the holder. Leave the China and EU holder as they are.
- Alternative 4: Merge all the current holders into one. However, there is a risk that this holder will have lower performance than specialized versions and also be more complex and thus more expensive.
- Alternative 5: The final alternative, and also the most appealing, is to have a holder that is compatible with all the different license plates in the world. That would make it possible to reach out to new markets to a greater extent than today.

6.6.3 Concept generation for rear holder

Many of the concepts that was generated for the front adapter will somewhat work as a concept for the rear holder as well. However, sometimes additional changes have to be made to the concept in order for it to work perfectly as a rear holder. The concepts will not be described in this chapter once again, instead look in chapter 6.5.3 for a full description. The concepts that are presented here are the ones that only serve the purpose as a rear license plate holder.

6.6.3.1 The Surface

One simple way of dealing with the mounting of license plates could be to directly mount all license plates on the surface of the car (see Figure 82). The mounting of the plate would have to be with screws which mean that several attachment inserts has to be placed on the car. However, several different rear trunks will be needed since the different plates cannot cover up all the mounting holes. This would probably be a rather costly solution. Mounting directly on the surface also increases the likelihood of getting noise and vibration problems.

+ No separate holder is needed

- Different rear trunks is necessary, noise and vibration problems



Figure 82 - A Fiat 500 with mountings for the plate directly on the tailgate

6.6.3.2 The Flat

This concept uses a flat bracket that is fully rectangular and is made in several versions in order to fit all markets, see Figure 83. This concept will be simple and cheap to manufacture. However it will need some kind of fastening for the license plate and car. Since these fastenings will stick out from the holder they can scratch the surface of the car. A spacer could be used to create a distance to the car in order to avoid this. However, the holder would become less rigid by doing so.

- + Simple design
- Scratch risk, less rigid

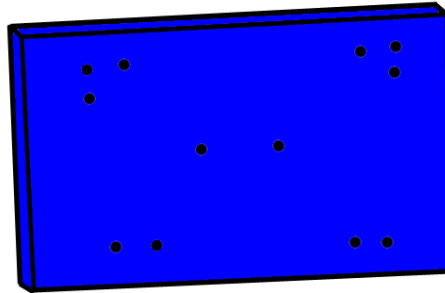


Figure 83 - The Flat

6.6.3.3 The Frame

In this concept a frame forms the outer boundary support for the license plate, see Figure 84. In the center of the holder there will be a hole in order to make the holder lighter. However, it is still important to make it rigid and well designed for fastening. It is also to be bent in a way that distances the fastening from the car which prevents risk of scratches and noise.

- + Low weight
- Lower plate support

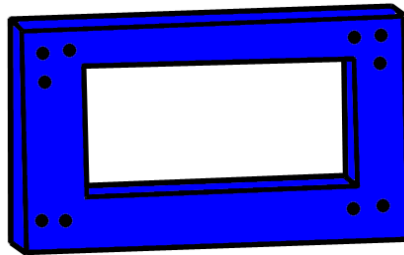


Figure 84 - The Frame

6.6.3.4 The H-bracket

This is a bracket where the holder forms an H-shape in order to provide sufficient support and fastening possibility, see Figure 85. At the same time the slim design makes it possible to make the bracket relatively lightweight. The outer arms of the H-shape are then bent in order to separate the fastening from the car. This is also a design that has been used before and has proven its functionality.

- + Low weight, proven to be well functioning
- Lower plate support

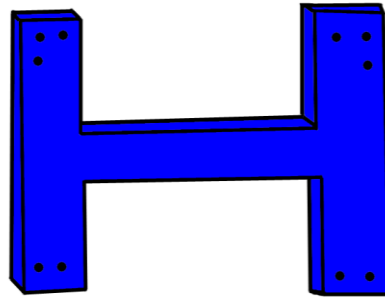


Figure 85 - The H-bracket

6.6.3.5 The Cross

A cross shaped design that will provide a lightweight structure as well as some license plate support, see Figure 86. The center part of the solution is attached to the car and the holder is then bent at the location of the mountings for the plate. Since the fastenings to the car are put closely together, there might be a problem with rigidity.

- + Low weight
- Low rigidity, low plate support

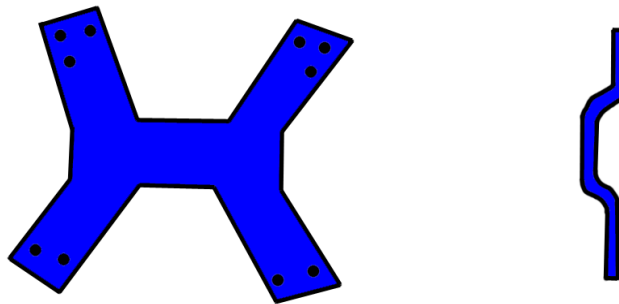


Figure 86 - The Cross

6.6.3.6 The Shape

This holder is made in only one piece and is of the same size as the license plates in order to create good support, see Figure 87. It can also have several weight saving pockets or similar made in order to create a lighter design. However, it will have higher weight and require more material than many other concepts.

- + Good support
- Market specific holders needed, higher weight

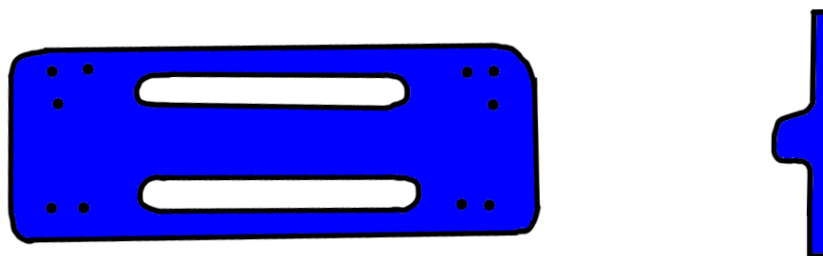


Figure 87 - The Shape

6.6.4 Evaluation of rear holders

To choose between all these concepts some evaluation methods had to be used. These have the purpose of screening the concepts until only one final concept remains.

6.6.4.1 Elimination matrix

The purpose of the elimination matrix was to eliminate those concepts that did not fulfill the requirement specification or was not suitable for Volvo Cars (see Figure 88). It eliminated 14 concepts that were not considered to be a suitable option.

| | Solutions | Fulfills the demands of the requirements list | Realizational in principle | Suitable for Volvo Cars | Pursue/Eliminate | Comment |
|--------------------------------|-----------|---|----------------------------|-------------------------|------------------|---|
| Holder concepts | | | | | | |
| The Full-size | o | o | o | | Pursue | |
| The Big Separate | o | o | o | | Pursue | |
| The Small Separate | o | o | x | | Eliminate | Not needed since EU has separate holder |
| The Spacer | o | o | x | | Eliminate | Not needed since the surface is flat |
| The Cover | o | o | o | | Pursue | |
| The Side Covers | o | o | x | | Eliminate | Not needed since the surface is flat |
| The Centerpiece | o | o | o | | Pursue | (Now only three parts is needed) |
| The Two-part | o | o | x | | Eliminate | Not needed since EU has separate holder |
| The Wings | o | o | x | | Eliminate | Not needed since the surface is flat |
| The Corner | o | o | o | | Pursue | |
| The Puzzle | o | x | | | Eliminate | Not needed since EU has separate holder |
| The Extendable | o | o | o | | Pursue | |
| The Springy | o | o | o | | Pursue | |
| The Rotatable | o | o | x | | Eliminate | Not needed since EU has separate holder |
| The Foldable | o | o | x | | Eliminate | Not needed since EU has separate holder |
| The Angle | o | o | x | | Eliminate | Not needed since the surface is flat |
| The Curtain | o | x | | | Eliminate | Too complex |
| The Pocket | o | x | | | Eliminate | Affects the design |
| The Screen | x | | | | Eliminate | Legally forbidden |
| The Mirrors | o | x | | | Eliminate | No room for mirrors |
| Mount directly on rear surface | o | o | x | | Eliminate | Holes can not be covered by EU holder |
| The Flat | o | o | o | | Pursue | |
| The Frame | o | o | o | | Pursue | |
| The H-bracket | o | o | o | | Pursue | |
| The Cross | o | o | o | | Pursue | |
| The Shape | o | o | o | | Pursue | |

Figure 88 - Elimination matrix of the rear holder

6.6.4.2 Pugh-matrix

The Pugh-matrix was used to eliminate the four least promising concepts (see Figure 89). Different criteria were used to help with the evaluation. Just like in the evaluation of the front adapter, these criteria had its foundation in the requirement specification. However, not all the criteria that was used for the front adapter was relevant for the rear holder.

| Concept | The Flat | The Full-size | The Big Separate | The Cover | The Center-piece | The Corner | The Extend-able | The Springy | The Frame | The H-bracket | The Cross | The Shape |
|---------------------------------|----------|---------------|------------------|-----------|------------------|------------|-----------------|-------------|-----------|---------------|-----------|-----------|
| Criteria | | | | | | | | | | | | |
| Low assembly time/cost | - | - | - | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| Low purchase price | - | - | - | - | - | - | - | - | - | - | - | - |
| Low weight | - | - | - | - | - | + | + | 0 | + | + | + | + |
| High rigidity | + | + | + | + | + | 0 | - | - | 0 | 0 | 0 | 0 |
| Innovative solution | 0 | 0 | 0 | + | + | + | + | + | + | + | + | + |
| Easy to mount and demount plate | 0 | 0 | 0 | - | 0 | 0 | - | + | 0 | 0 | 0 | 0 |
| Recyclability | - | 0 | 0 | 0 | - | - | 0 | 0 | 0 | 0 | 0 | - |
| Common parts | - | - | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Number of unique parts | - | - | - | - | - | - | - | - | 0 | 0 | 0 | 0 |
| Σ+ | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Σ- | 0 | 6 | 5 | 6 | 6 | 4 | 4 | 3 | 1 | 1 | 1 | 2 |
| Net value | 0 | -5 | -4 | -4 | -4 | -2 | -2 | -1 | 1 | 1 | 1 | 0 |
| Ranking | 2 | 6 | 5 | 5 | 5 | 4 | 4 | 3 | 1 | 1 | 1 | 2 |

Figure 89 - Pugh matrix of the rear holder

6.6.4.3 Weight determination matrix

To establish the importance of the various criteria a weight determination matrix was made, see Figure 90. The criteria were compared to each other to see if the requirements were more, less or the same importance. An overall weighting of the criteria could then be established. The most important criteria were low assembly and purchase cost as well as a low number or unique parts.

| Criteria | A | B | C | D | E | F | H | Sum | Tot | W(%) |
|-----------------------------------|-----|-----|---|-----|-----|-----|-----|-----|-------|------|
| A Low assembly time/cost | | 0,5 | 1 | 0,5 | 1 | 1 | 0,5 | 4,5 | 0,214 | 21,4 |
| B Low purchase price | 0,5 | | 1 | 0,5 | 1 | 1 | 0,5 | 4,5 | 0,214 | 21,4 |
| C Low weight | 0 | 0 | | 0 | 1 | 0 | 0 | 1 | 0,048 | 4,8 |
| D High rigidity | 0,5 | 0,5 | 1 | | 1 | 0,5 | 0,5 | 4 | 0,190 | 19,0 |
| E Easy to mount and demount plate | 0 | 0 | 0 | 0 | | 0,5 | 0 | 0,5 | 0,024 | 2,4 |
| F Recyclability | 0 | 0 | 1 | 0,5 | 0,5 | | 0 | 2 | 0,095 | 9,5 |
| H Number of unique parts | 0,5 | 0,5 | 1 | 0,5 | 1 | 1 | | 4,5 | 0,214 | 21,4 |
| Tot | | | | | | | | 21 | 1,000 | 100 |

Figure 90 - A weight determination matrix of the rear holder

6.6.4.4 Kesselring

The Kesselring was used to eliminate some more concepts (see Figure 91). This time the criteria was weighted, which means that the most important criteria, such as cost, had a much bigger impact on the result.

What can be seen in the Kesselring is that there is not that much difference between most concepts. It is therefore quite hard to tell whether or not some concepts are better than the others. Since “The H-bracket” is a concept that has proven to do its job and is very appreciated by the customers it is wise to continue with this design. Some enhancements will also be made in order to increase the perceived quality even more.

| Criteria | Concept | | Ideal | | The Flat | | The Corner | | The Extendable | | The Springy | | The Frame | | The H-bracket | | The Cross | | The Shape | |
|---------------------------------|---------|------|--------|-----|----------|----|------------|----|----------------|-----|-------------|-----|-----------|-----|---------------|-----|-----------|-----|-----------|-----|
| | | w | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t | v | t |
| Low assembly time/cost | | 21,4 | 5 | 107 | 3 | 64 | 2 | 43 | 5 | 107 | 5 | 107 | 5 | 107 | 5 | 107 | 5 | 107 | 5 | 107 |
| Low purchase price | | 21,4 | 5 | 107 | 4 | 86 | 4 | 86 | 2 | 43 | 2 | 43 | 4 | 86 | 5 | 107 | 3 | 64 | 3 | 64 |
| Low weight | | 4,8 | 5 | 24 | 2 | 10 | 5 | 24 | 4 | 19 | 3 | 14 | 3 | 14 | 4 | 19 | 4 | 19 | 4 | 19 |
| High rigidity | | 19,0 | 5 | 95 | 3 | 57 | 4 | 76 | 2 | 38 | 3 | 57 | 5 | 95 | 5 | 95 | 4 | 76 | 5 | 95 |
| Easy to mount and demount plate | | 2,4 | 5 | 12 | 4 | 10 | 4 | 10 | 2 | 5 | 5 | 12 | 4 | 10 | 4 | 10 | 4 | 10 | 4 | 10 |
| Recyclability | | 9,5 | 5 | 48 | 5 | 48 | 3 | 29 | 4 | 38 | 4 | 38 | 5 | 48 | 5 | 48 | 5 | 48 | 3 | 29 |
| Number of unique parts | | 21,4 | 5 | 107 | 3 | 64 | 2 | 43 | 3 | 64 | 2 | 43 | 4 | 86 | 4 | 86 | 4 | 86 | 4 | 86 |
| $T = \sum t$ | | | 500,00 | | 338,10 | | 309,52 | | 314,29 | | 314,29 | | 445,24 | | 471,43 | | 409,52 | | 409,52 | |
| T / T_{max} | | | 1,00 | | 0,68 | | 0,62 | | 0,63 | | 0,63 | | 0,89 | | 0,94 | | 0,82 | | 0,82 | |
| Ranking | | | | | 4 | | 6 | | 5 | | 5 | | 2 | | 1 | | 3 | | 3 | |

Figure 91 - Kesselring of the rear holder

6.6.5 Fastening method of the holder

The many different ways to fasten the holder and the license plate is mostly the same for the front and rear holder with the use of screws, bolts, glue etc.

6.6.5.1 Elimination matrix

The fastening concepts are inserted into an elimination matrix in order to remove those that either do not fulfill the requirement specification, are realizable in principle or suits Volvo Cars (see Figure 92). Seven fastening methods were eliminated this way.

| Solutions | Fulfills the demands of the requirements list | Realizational in principle | Suitable for Volvo Cars | Pursue/Eliminate | Comment |
|-----------------------------------|---|----------------------------|-------------------------|------------------|---------------------------|
| Fastening method of holder | | | | | |
| Screw with nuts | o | o | o | Pursue | |
| Screw with wingnut | o | o | o | Pursue | |
| Screw with movable nuts | o | o | o | Pursue | |
| Screw with fixed inserts | o | o | o | Pursue | |
| Screw with movable spacers | o | o | o | Pursue | |
| Screw with threaded hole | o | o | o | Pursue | |
| Molly bolts | o | o | o | Pursue | |
| Bolt with molly insert | o | o | o | Pursue | |
| Self-tapping screw | o | o | o | Pursue | |
| Rivet joints | o | o | o | Pursue | |
| Expanding plug | o | o | o | Pursue | |
| Tow hook insert | x | | | Eliminate | No tow hook in the rear |
| Tape | x | | | Eliminate | Too easy to remove holder |
| Glue | o | o | o | Pursue | |
| Velcro straps | x | | | Eliminate | Too easy to remove holder |
| Magnets | x | | | Eliminate | Too easy to remove holder |
| Electro magnets | o | x | | Eliminate | Too complex |
| Suction cup | x | | | Eliminate | Too easy to remove holder |
| Snap fasteners | o | o | o | Pursue | |
| String, wire or cable tie | o | o | o | Pursue | |
| Center of gravity | o | o | x | Eliminate | Will add too much weight |
| Clips, clamps and pressure | o | o | o | Pursue | |
| Self-locking geometry | o | o | o | Pursue | |

Figure 92 - Elimination matrix of the fastening methods of the rear holder

6.6.5.2 Chosen solution

The chosen solution is to use screws together with threaded inserts at the location of the car mount. It was the most promising concept and also the one that is used today. It provides good robustness and it makes sure that the holder and the plate is mounted horizontally. The permanent inserts will be no problem since all the markets uses rear license plates.

6.6.6 Reducing the noise, vibration and risk of scratches

Since there have been problems with vibration, noise and risk of scratches this is an area that has to be dealt with. It is important both regarding the contact surface between the license plate and the holder as well as between the holder and the car. However there are multiple ways in order to prevent it.

6.6.6.1 *Integrated rubber surface*

The back of the license plate and/or the holder can be provided with a rubber surface which can dampen the vibrations.

6.6.6.2 *Rubber/foam spots*

Small pads made out of rubber or foam can be placed on strategic locations on the back of the holder and/or the license plate.

6.6.6.3 *Rubber/foam pad*

A large rubber/foam pad can be used to reduce vibrations, much like the pad that Volvo Cars are providing the EU holders with today.

6.6.6.4 *Distance to the car*

By having enough distance between the surfaces the likelihood of the components causing unwanted vibrations will be reduced. However, the plate will be more vulnerable to external forces.

6.6.6.5 *Chosen solution*

The most suitable choice for the H-bracket design is to have small rubber spots, which is the solution used today on the North American and Japanese holders. It provides good noise cancelling abilities and the holder does not vibrate or scratch the surface of the car. However, several holes need to be drilled into the bracket for the placements of the rubber plugs. This might not be the cheapest solution. Another alternative could be to use small sticker foam pads used instead, like Volvo has on the Chinese holder. This investigation will be left as future work.

7 Final design of the front adapter

In this section the final design of the front adapter will be presented. It is based on the concept that solved the core goal the best, in addition with the add-ons that might give something extra to the customer. The entire concept will then have qualities that works well together and that delivers a promising result as a whole. The concept will be described as if it were to be mounted on the front bumper of the car, but in theory this concept would be applicable for mounting in the grille as well. The main difference would then be the mounting fasteners and the increased possibility of using an adapter that fits several different car models, since the grille is more likely to be similar on different models.

7.1 The full-size

This is the concept that had most promising qualities and that fulfilled the requirement specification in a successful way. It is a solution that has been used by other car manufacturers and it is proven to work well. It has also been a clear trend that a full sized adapter has been used more specifically on cars that are in the more expensive price range. It is in this region where the car models of Volvo Cars are situated and will be in the future. This makes it advisable to use a full-size adapter that will show customers that this is a more refined luxury car.

7.1.1 Design

The concept is first of all a support to the license plate and it is shaped to fit all the plates from the addressed markets (see Figure 93). It is more or less leveled behind the license plate in order to create this support. There are some pockets on the support surface that will make the adapter a bit lighter. Along the edges of the license plate a discrete frame is extruded from the adapter which surrounds the license plate. Due to this framing the plate is somewhat protected from damage since it is recessed into the adapter.

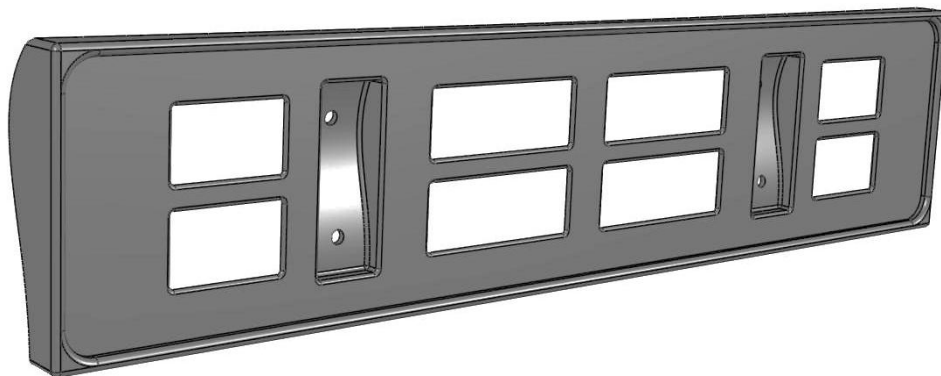


Figure 93 - Front view of the EU-adapter

One other main goal was to compensate for the complex front of the car that might be designed in the future. This is solved by letting the shape of the adapter follow the shape of the car front. This makes it possible to distribute the pressure over a rather large area which is good in case of for example a light parking collision or when the car is being cleaned in an automatic car wash. By having a shape that follows the curvature of the car the adapter will also look integrated to the car and it will not be possible to see any of the less attractive mountings etc. The curvature of the adapter can be seen in Figure 94.

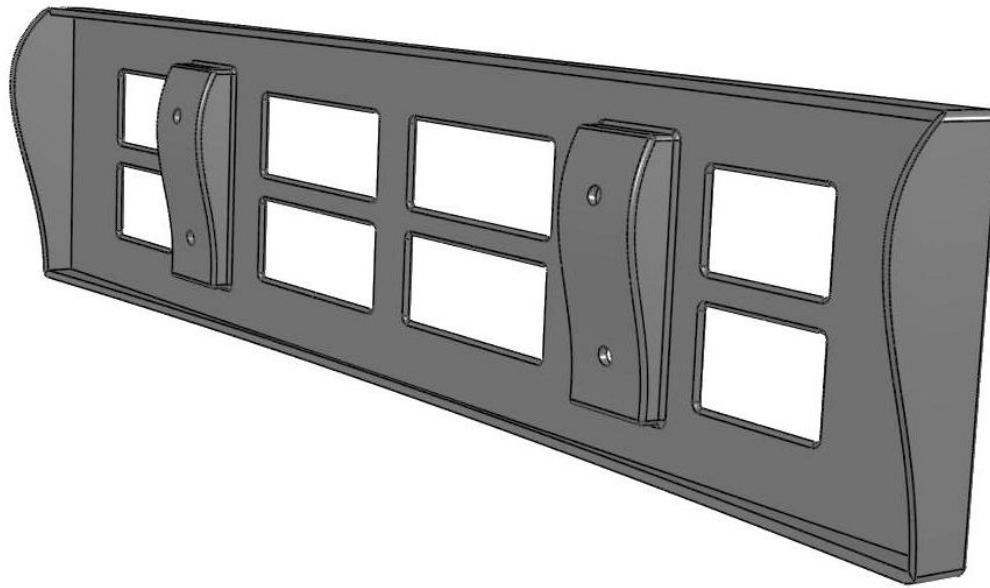


Figure 94 - Rear view of the EU-adaptor that shows the curvature

Design for manufacturing has been a foundation to the selection and final design of the concept. For example in order to provide a cheap and well-functioning process it is important to have a design that is simple and suitable for the intended tool. Since it is always important with safety the adapter also has rounded edges that will prevent people from cutting themselves. However this is not a main focus since there is not much human interaction with the front license plate and the adapter in the first place.

The design of the adapter together with the license plate will be perpendicularly placed on the bumper, relative to the ground. This is the most aesthetically appealing look and no angled versions were needed due to legal requirements. Today the Japanese license plate holder is a combined front/rear version and it is thus angled to fit the rear preconditions. This will not be needed when using a separate front adapter.

7.1.2 Variants

Since this is a concept that is fitted to each individual license plate from the target markets there will be several variants needed. However it is decided to combine two of the markets on one and the same adapter. The North American and the Japanese license plates are quite similar in size thus it is possible to get an adequate result on a common adapter. Since the Japanese market is a market with lower sales numbers it would also become rather expensive to provide specific adapters for this market. The Japanese license plate will exceed the size of the American sized adapter, which will make it look a little less appealing. However, the extruded frame along the adapter edge is lower on this version (US/JP) so there will be no practical problems to do this. Two extra fastenings will also be needed on the adapter to mount the Japanese license plate. In total there will be four different versions of the adapter for the different markets; European Union, Italy, China, Japan/North America. The combined Japanese/North American holder can be seen in Figure 95 and Figure 96.

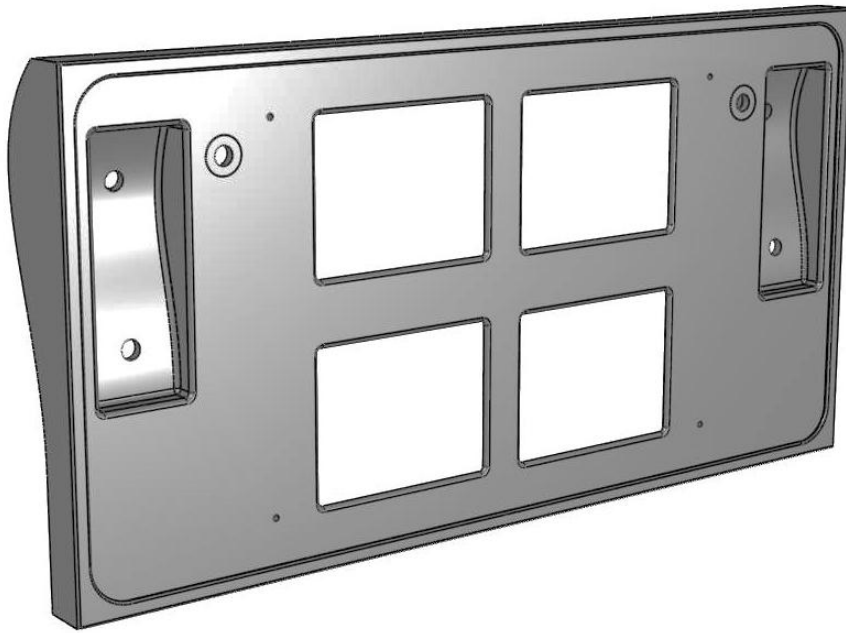


Figure 95 - Front view of the Japanese/North American holder

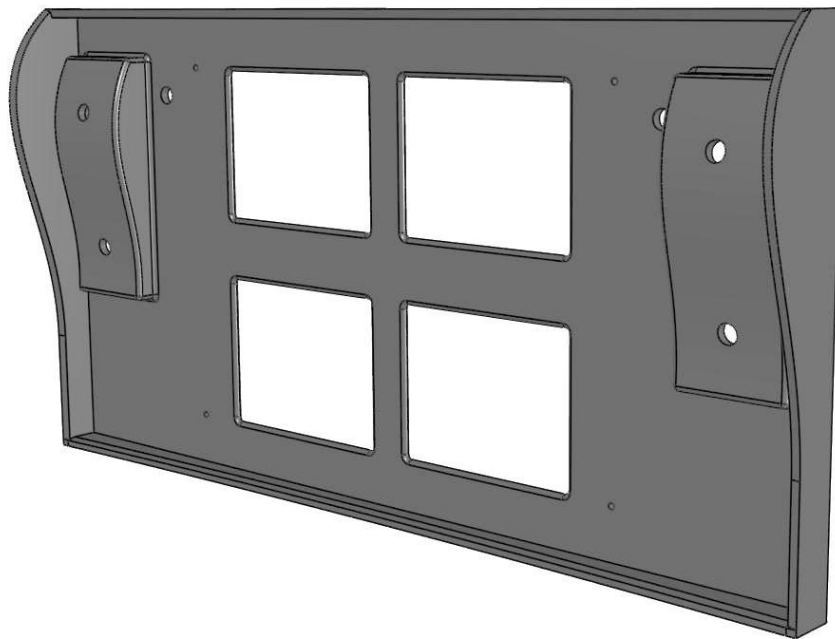


Figure 96 - Rear view of the Japanese/North American holder

It will also be required to make the adapters fit the different car models. This is due to the fact that the curvature on the car models will be different depending on the size and design of the car. Even different versions of the same model, such as Volvo Cars R-design, might have a different curvature of the front. If one suppose that Volvo Cars will have 10 different car models this will result in 40 different kinds of adapters. This is due to the fact that the solution proposes four different market specific adapters.

7.1.3 Fastening of the adapter

The adapter also needs a fastening to the car that is reliable, cheap and easy to mount, just to mention some of the many qualities needed. In order to secure this the mounting is made by using self-tapping screws (see Figure 97). Volvo Cars has discovered that the current EU-holder can be torn off when using two screws, especially after frequent use of automatic car washes. It is therefore recommended to use four screws to fasten the front adapter in order to provide a secure mounting. Since these screws are self-tapping there will be no need to make premade holes in the bumper. This will make the front of the car look more aesthetically attractive on the markets where license plates in the front are not needed.



Figure 97 - Different versions of self-tapping screws (Topnetting, 2013)

When developing the fastening of this adapter there has been a focus on Design for Assembly as well as some ergonomic aspects. For example in order to secure that the fastening is done at the right location dimples is used where the screw is to be placed on the bumper (see Figure 98). One can also provide contrasting stickers at the location of the dimples to make it even easier during assembly to find the right location. If one is not using a front license plate one is able to see the dimples when looking closely. When watched from a few meters away they will however become almost invisible.



Figure 98 - Two dimples placed on the front bumper to aid the mounting of the adapter

Indexations are also a method that can be used to guide the adapter into place. However this is strictly dependent of the preconditions such as the curvature of the future car front. In the proposed solution the adapter will be locked in all the necessary degrees of freedom so there will be no need for additional indexations (see Figure 99 and Figure 100). If the design of the car only makes it possible to lock it in some of the degrees of freedom one could add additional indexations, such as snap fasteners or blocking geometry. Finding the right mounting location should however not be a problem if the adapter is assembled in an automated process at the assembly line.



Figure 99 - Side view of the front adapter



Figure 100 - Upper view of the front adapter

The adapter itself also has to be designed so that it will provide a tight mount to the car. The surface behind the license plate will be suppressed at the locations where the screws are to be located. These areas will then be parallel to the surface of the car at the mounting location (see Figure 101). This makes it possible to place the screw perpendicular through the premade holes of the adapter into the dimples in the bumper. These mounting holes should also be easily accessible in order to make them more suitable for assembly.

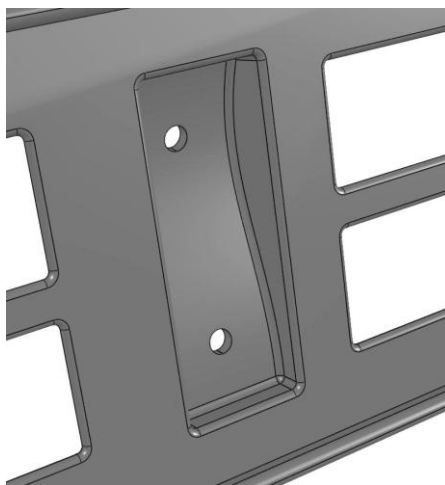


Figure 101 - Mounting holes for the adapter

7.1.4 Fastening of license plate

In China as well as in Japan there is a legal requirement that M6 screws have to be used to fasten the license plates. Using threaded inserts in the surface of the adapter solves this. For the remaining markets the license plate will be mounted with self-tapping screws since this is the cheapest solution. This was made possible due to the fact that there is no legal reason to use either M6 or the American dome nuts for these markets. However, for the American market it is important that the license plate is easy to mount and demount. Using self-tapping screws seems to be good enough in this aspect and it is also a solution that is used by the majority of the competitors. This shows that it is best practice to do it this way. The fastening on the combined Japanese/North American holder can be seen in Figure 102.

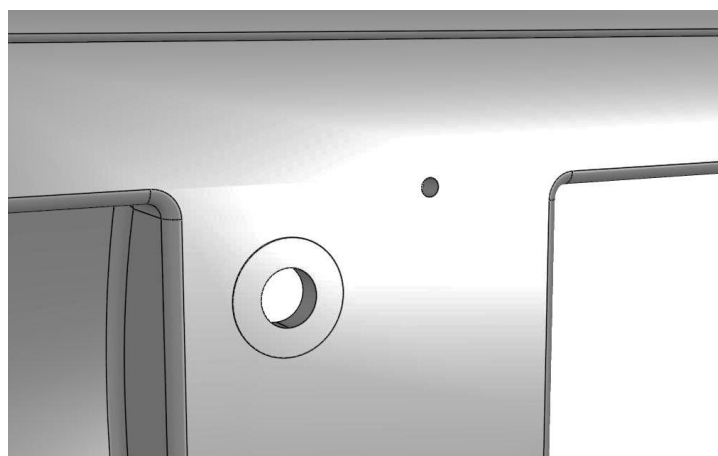


Figure 102 – On the left there is a threaded insert for the Japanese market and to the right there is a small hole for the North American market

The European Union and the Italian license plates do not have pre specified mounting holes. One solution used by some competitors is to drill holes in the license plate and then mount the plate with self-tapping screws and color matched screw head covers. In this case self-tapping screws is best practice and has sufficient qualities in this aspect. Mounting the plate directly on the adapter gives a sleek appealing look that is preferable, see Figure 103. Although there is a risk that some customers also might dislike the fact that screw head covers sticks out from the flat surface making it look less appealing.

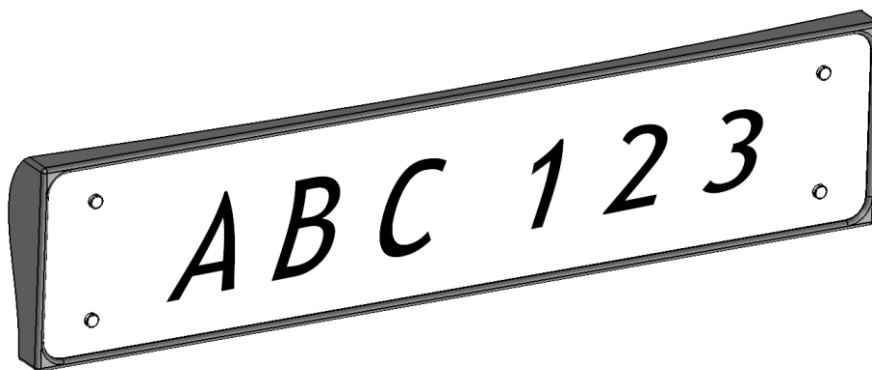


Figure 103 - An EU-plate placed in the EU-adapter without the standard holder

When not using the standard EU-holder the car dealer will have a slightly more complex assembly and there will be no possibility for dealer advertisement. Therefore it can be a problem to implement this if Volvo Cars cannot force them not to use the standard holder. This means that it is probable that at least some dealers will continue using the standard license plate holder. By using the standard holder on top of the adapter the result will be a bulky appearance, see Figure 104. However, a benefit for the dealer when not using the standard EU holder would be that they do not need to pay for the holder and the car will look even better which makes it easier to sell.



Figure 104 - A Volkswagen with both adapter and standard holder

7.1.5 Reducing the noise, vibration and risk of scratches

This issue has not been a big problem when mounting the holder on the front of the car. It is also most probable that it even in the future will work well without any large actions taken to prevent these problems. By having a large support area the chances of large vibrating motions will be even lower.

7.1.6 Material selection and environmental aspects

A material has been selected that is easy to use in the manufacturing process at the same time as it withstands external impacts and provides sufficient mounting capabilities for the self-tapping screws. In order to fulfill these requirements a plastic material was decided to be used. The material that is used by virtually all competitors is PP+EPDM, which also is the material used in Volvo Cars Chinese license plate holder today. It is a polypropylene polymer mixture with “ethylene propylene diene monomer rubber” which makes the material less brittle and more rubber like. (Rutland Plastics limited, 2013) The homopolymer PP has low toughness and can crack very easily if used in temperatures lower than 0°C. If instead PP is mixed with for example 10% EPDM the material will get good toughness even at temperatures down to -40°C. (Edshammar, 2007) This property is significantly important when the material is used on a car in all different climates and temperatures. A material with more rubbery qualities like

this will also be better in contact with the car from a noise and vibrations perspective. This material is also frequently used, will be rather cheap to produce and its qualities are proven to be good.

Using PP+EPDM also makes it possible to recycle the adapter in a good way and the polymer mixture can be used once again. For example PP+EPDM bumpers has been recycled commercially in Europe since the early 1990's. (Utracki, 2002) PP is a non-toxic plastic and it is used for example for food storage. Pure EPDM is for instance used as rubber seals within the automotive industry. It can be somewhat harmful to humans and the environment but all ingredients are tightly bound to each other in a polymeric matrix so there is a low risk of inhalation or ingestion of the ingredients. An exposure of the constituents is unlikely during normal processing conditions and use. In this design with approximately only 10% EPDM the environmental effects and the impact on humans is neglectable during normal use. If it is burned EPDM substances could possibly be evaporated, but since PP+EPDM is recyclable this can be avoided. (Federal Mogul, 2006) As mentioned before this is also a polymer mixture that is used for several different components within the automotive industry already, both among Volvo Cars and its competitors.

The environmental aspect also is a large part when talking about the actual design of the adapter. However, a thorough Life Cycle Analysis has not been made since a more complete design and weight information etc. would have been needed. If one ought to mention some environmental aspects the inserts for example is made of metal in contrast to the rest of the adapter which could make the recycling a bit challenging. The inserts are fitted tightly in the plastic which probably makes it necessary to break the adapter in order to get the inserts out. When the materials are separated it is perfectly possible to recycle the whole adapter.

7.2 Add-ons

In combination with this concept add-ons could be used in order to improve the customer perceived impression. A good idea would be to provide an adapter that is coated in the same or a contrasting color as the car (see Figure 105 and Figure 106). This could especially be a strategy for the more expensive models or as an extra that the customer pays more money for. In similar way a frame could be used that is personalized to fit each customer's taste (see Figure 107). This would serve as a possible extra income for Volvo Cars.

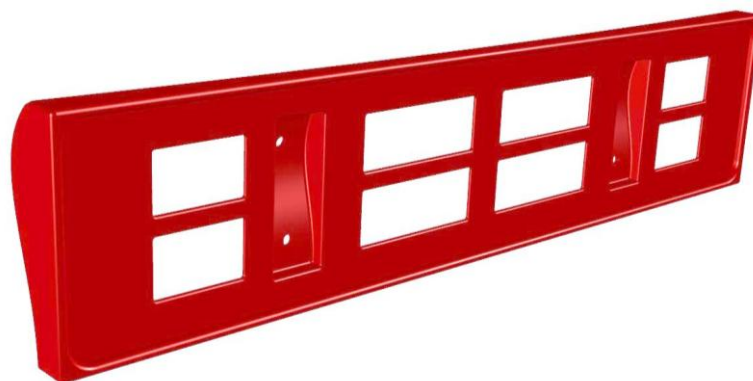


Figure 105 - A colored EU-adapter without the EU-plate



Figure 106 - A colored EU-adapter with the EU-plate



Figure 107 - Diamond covered license plate frame (Devasbling, 2013)

7.3 Cost estimation and business case

Today Volvo Cars is only providing front license plate holders for the Japanese, North American and Chinese market. The large volume of the sold cars is in Europe where they do get the license plate holder for free, namely the car dealer is the one who purchase them. This means that the average cost of the front license plate holders for the total market, including Europe, today is 3,59 SEK. By implementing front adapters on all the car models the average cost per holder will be raised to 16,68 SEK. If one includes the additional tooling costs that is associated with the needed variants the average cost per holder will raise to 21,10 SEK (by dividing the tooling costs over five years). So even if the adapter fulfills the requirement of a cost below 30 SEK, it will still raise the average cost of each sold car by 17,51 SEK. However, since the current holders cannot be used in the future, in combination with the complex front design, Volvo Cars does not have that many options. They will have to take the additional cost or continue using the flat front design as they have today.

The whole cost estimation can be seen in Appendix 8. The estimated costs come from comparison with the current holders, for example the front Chinese holder which is similar looking as the front adapter. This is although something that needs to be verified by the supplier before implementing the new holders.

8 Final design of the rear license plate holder

In this section the final design the rear license plate holder will be presented. It will contain a more thorough description of the design, number of variants, fastening methods, material selection etc. Also a business case regarding the new versus the old holders will be presented.

8.1 The H-bracket

The chosen concept is “The H-bracket” whose design is very similar to the current Japanese and American holders. This design will be adapted to the Chinese holder as well, in an effort to merge these holders together. The standard European Union and Italian license plate holders will remain the same, since the quality of those holders are good enough. It would not be wise to add the cost of providing an own Volvo Cars license plate holder for these markets.

Much good feedback has been received regarding the design, robustness and price of the North American and Japanese holders. This is why the essential design, structure and manufacturing methods will be kept the same. There is no need to fix what is not broken.

Volvo Cars have 9 different license plate holders today for three different markets. Five of these holders have a flat design while the other four are angled upwards. Despite that all three markets has various different license plate sizes the mounting holes for the license plates are placed closely together. Since there were no risk of these holes clashing with each other it is possible to combine the holders. Furthermore an effort was made to merge these holders into two different variants by investigating the hole patterns regarding the mounting to the car, see Figure 108.

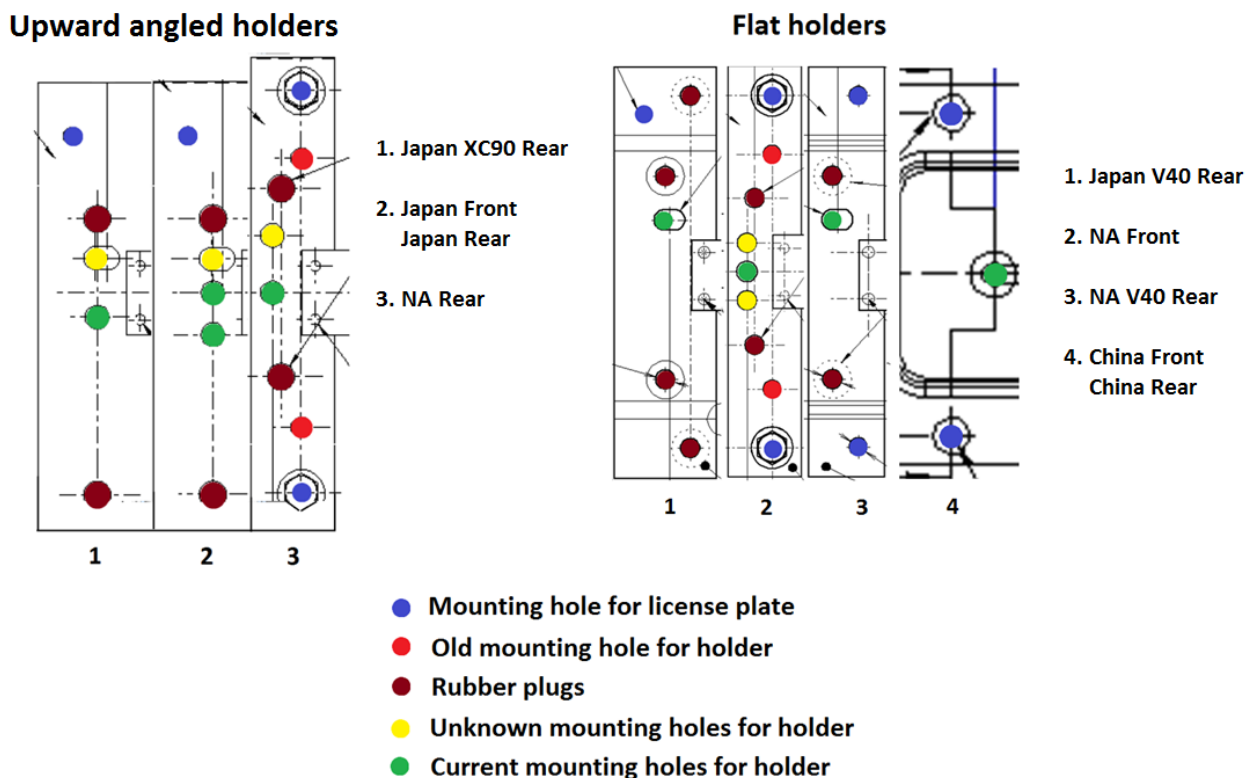


Figure 108 - A comparison of the hole pattern between the current license plate holders

All the different variants of the flat holders are able to be merged together since the hole patterns do not collide anywhere. As for the upward angled holder there is a collision between the hole pattern of the Japanese XC90 holder and the regular Japanese one. However, it is no problem to merge the other angled holders and let Japan XC90 remain the same. This is not a big issue since the XC90 car model will be replaced shortly anyway.

When investigating what holes that actually are needed, it was found that the holes marked in red in the figures above could be eliminated since they date way back and are not being used anymore for the current car models. Also, the car manufacturers do not have to provide spare parts for car models that have not been sold for the last ten years. It would most probably be possible to use any of the other mounting holes on those older car models as well. The holes marked as brown only indicates where the rubber spots are being placed. The exact location of these can change in the future and it is not essential for the overall function of the holder where they are located.

The green marked mounting holes are the ones that were specified to be in use on the current car models. There were also some unknown holes marked in yellow that were not specified which car they were meant for. It could be older car models or current car models that not have been specified in the drawing. Since the hole pattern of the unknown and current mounting holes did not collide it was decided to keep all of these holes. This will ensure that the holder will be backward compatible. Since the actual hole pattern has not been changed the position of the license plates will remain the same, as once specified by the designer at Volvo.

8.1.1 Design

This holder is made out of three pieces which is placed in the shape of an “H”. The holder is bent at the upper and lower part of the holder to provide room for the screws that holds the plate so that they do not scratch the car (See Figure 109). The guidelines of “Design for manufacturing” were used to make the holder as simple as possible which for example will ease the production process. This resulted in a holder that can be stamped into shape, including all the holes. The holder will also have milled holes provided with threads for the screws that hold the license plate in place. It is a suitable choice for the chosen manufacturing method and it is possible to make threads directly into the material.

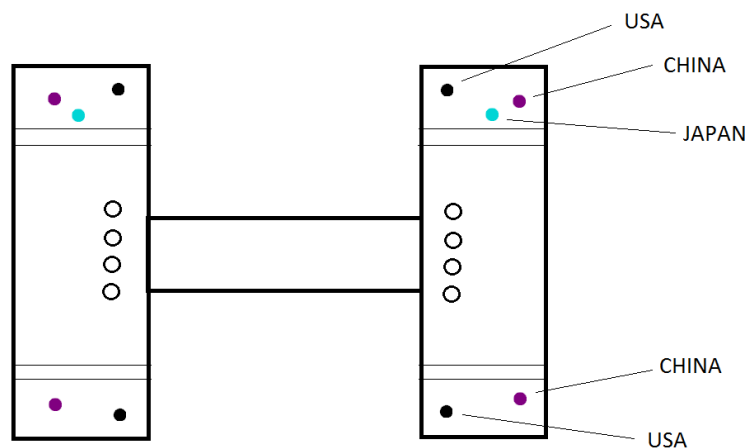


Figure 109 - Sketch of the new license plate holder

The sizes of the North American, Japanese and Chinese license plate differs slightly. This will not be a problem since the license plate holder is smaller than the plates (see Figure 110). It will still cover a large area in order to provide sufficient plate support and rigidity. Since the license plate is securely placed in the recessed area of the tailgate it will not be a subject to impacts, whereas the need of license plate support is not as severe as it is for the front adapter.

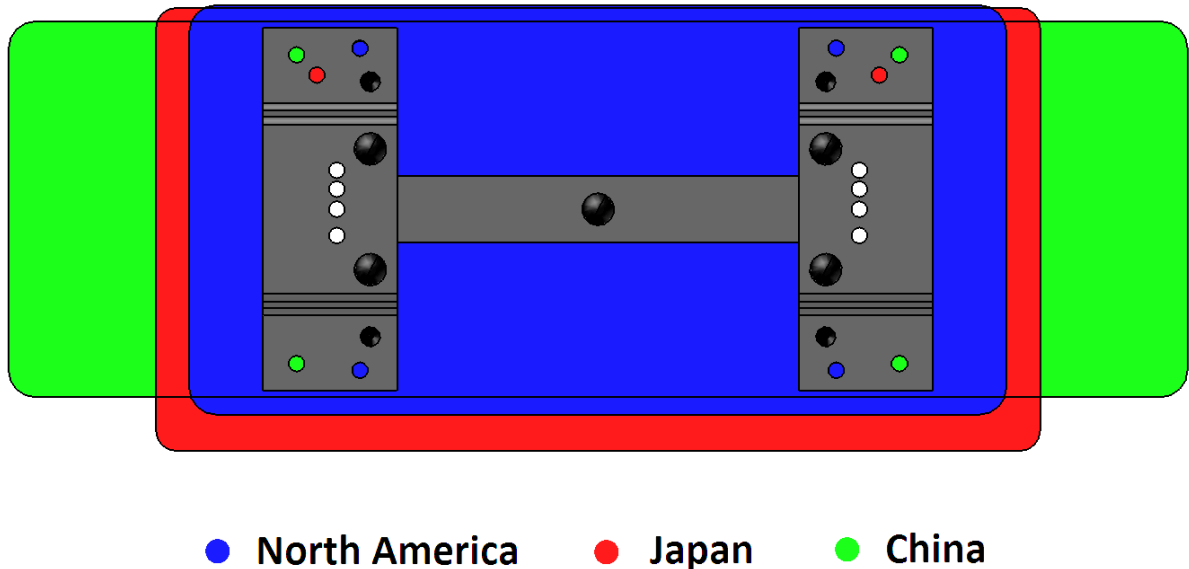


Figure 110 - The new flat holder with three different plates

However, as one can see the Chinese license plate will not have as large support area as the other license plates. The plate is rather securely placed at the rear mount and the holder will not stand out too much. But even if the license plate most probably never will bend due to external forces, it can be a problem with noise and vibration. Since the plate is very close to the surface of the car the plate might vibrate when driving or when someone closes the tailgate. By including a foam pad on both sides of the holder, behind the plate, the problem will be eliminated. It will be an effective and cheap solution and it will be possible to mount the foam pads at the assembly line. One will also have to investigate how it will look and function as a front license plate holder and spare part for the current car models. It might be a problem that the lack of plate support will cause the license plate to bend during parking collisions and during a car wash.

8.1.2 Variants

Two different variants of this design are needed depending on the car type and legislation on different markets. The flat holder will replace five holders previously used on the Chinese, Japanese and North American market (see Figure 111). The other holder is a slightly upward angled which was needed due to legislation. It will replace three holders that were used on the Japanese and North American market (See Figure 112). Since the angled holder only will be used on two different markets it will have fewer mounting holes for the license plate compared to the flat version. A comparison of the two different holders can be seen in Figure 113.

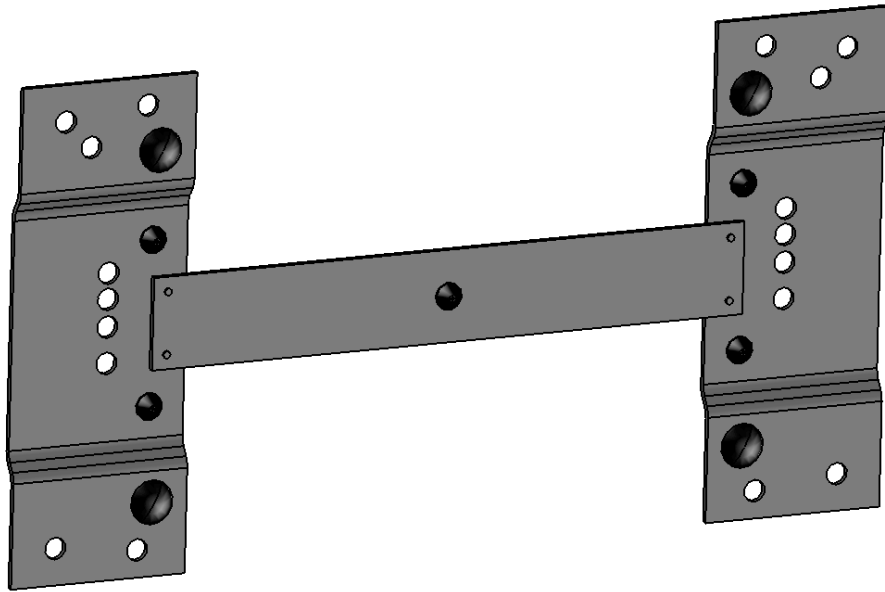


Figure 111 - CAD image of the new flat holder

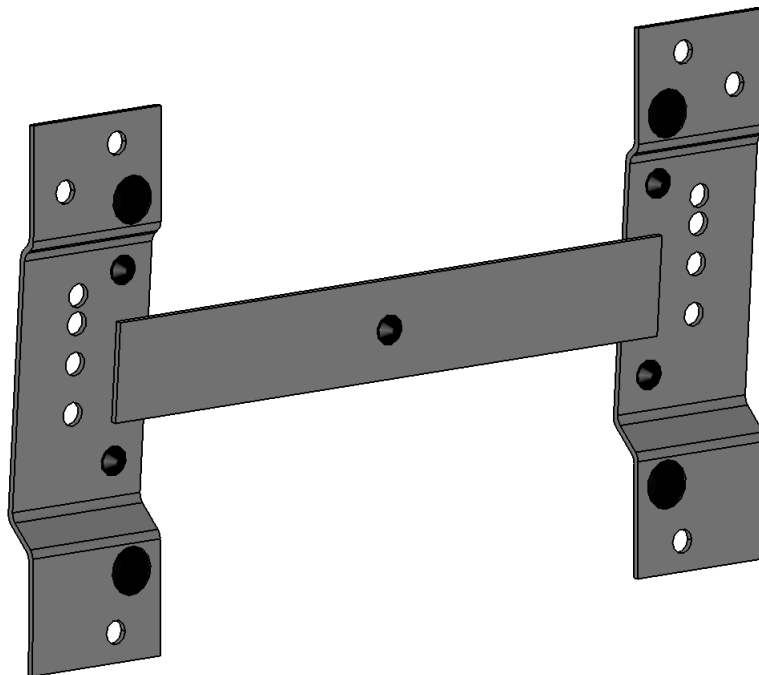


Figure 112 - CAD image of the new angled holder

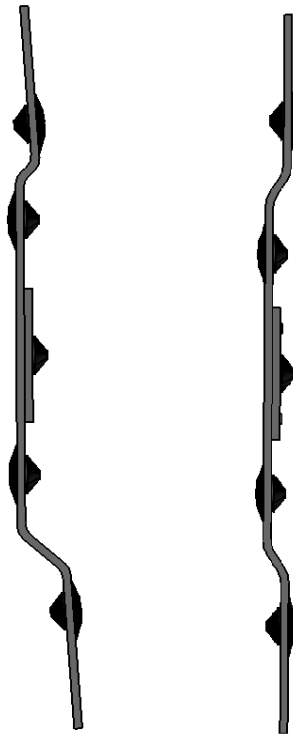


Figure 113 - Comparison of the slightly angled holder to the left and the flat holder to the right

8.1.3 Fastening of the holder

The actual fastening of the holder will be done with standard M6 screws. The mounting surface at the rear of the car will have threaded inserts, which allows a secure fastening of the holder. This is the solution which is already used today and it is proven to work very well.

The hole pattern on the angled holder were able to be transformed into the new design without any collisions. This was made possible by moving all the Japanese holes 1 mm upwards relative to the North American holder. It will not result in any differences when the holder and the plate are in use. The design intentions of Volvo will therefore remain the same. As for the flat holder there was a collision between a hole that is currently used by a car model and an unknown hole. This collision was solved by moving the unknown hole 2,3 mm downwards. This will probably not affect the current car model, since there was no documentation on it being in use. However, the front license plate on the North American market will be moved 2,3 mm upwards if this hole were to be in use. The aesthetical impact and consequences of this design change will have to be investigated in the future. One should also bear in mind that the only impact is when the license plate holder is being used as a front holder. This will not be for a long time if Volvo Cars decides to replace the front holders with adapters instead.

The holders will have four different holes to allow for different placement of the holder relative to the car (see Figure 114). This is needed since the same mounting holes cannot be used for all car models and markets, due to different sizes of the license plates. However this makes the assembly somewhat more difficult since you will have several holes to choose from when mounting it by hand. In an interview with a car dealer in the USA it was apparent that even if the person who mounts the plate have several different holes to choose from, one simply will take the hole that looks the best on the car model. This might result in a case

where everyone uses different holes even on the same car model, depending on what one thinks look the best. A solution to this would be to enclose a simple mounting instruction with each car that is car model and market specific. If Volvo mounts them to the car themselves at the assembly line, like they have to do for the Chinese market, it will at least be less of a problem. It is also the possibility that the mounting will be done by an automatic assembly process in this case.

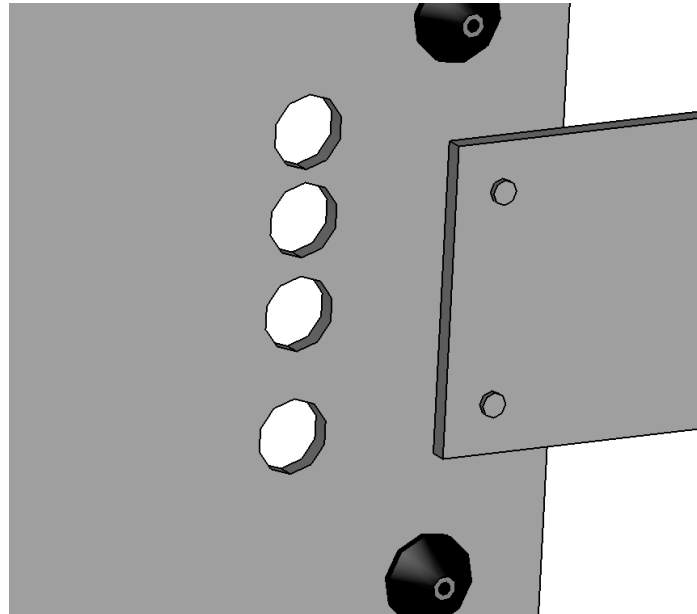


Figure 114 - Holes used for mounting of the holder to the car

8.1.4 Fastening of the license plate

The plate will be fastened with standard M6 screws for both the Japanese, North American and Chinese market. Their relative position can be seen in Figure 115. As previously mentioned the dome nuts on the North American market could be eliminated which makes it possible to use the same kind of screw for all the markets.

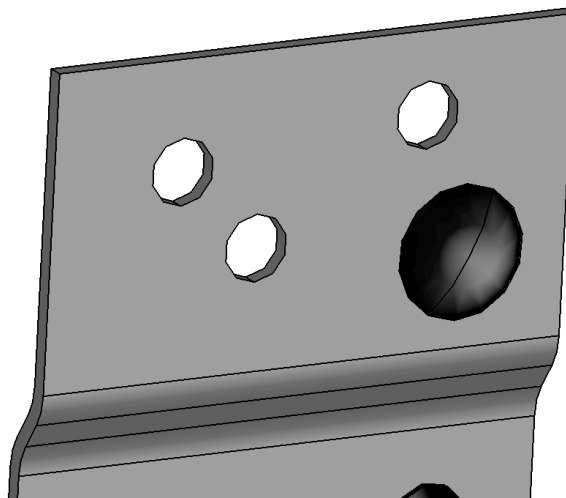


Figure 115 - Holes used for mounting of the plate to the holder

8.1.5 Reducing the noise, vibration and risk of scratches

Five rubber plugs will be placed on the holder to face the surface of the car, one in each corner and the one in the middle. One of these rubber plugs can be seen in Figure 116. The front of the holder will have rubber plugs in each corner to reduce the vibrations from the license plates. It is a cost efficient solution to reduce the risk of noise and proven to work well with the current Japanese and North American holders. As mentioned before, foam pads can be used for the Chinese market to reduce the problem since the plate is slightly larger than the holder.



Figure 116 - Rubber plug that will reduce noise and vibration

8.1.6 Material selection and environmental aspects

The holder will be made out of cold rolled low carbon steel, “DC01 EN 10130” which is the same steel as in the Volvo metal holders today (Steelnumber 2013). It is a cheap solution that fits the chosen manufacturing method. Since it is a small part which already is lightweight there is no large benefit to make it in another material, like the much more expensive aluminum. The holders will be coated with a powder paint to ensure that the holders will not corrode and inflict the premium feeling of the car. It is a more expensive solution compared to coating it with Fe-Zn, which is what they do on the current North American holders. However, it is necessary to use the powder paint to provide enough corrosion resistance on all markets. The powder paint is used on the Japanese market today with a satisfying result. Using black powder paint also makes the holder look better. This can be important since the customer sometimes will see the holder, for example when changing the license plates in the USA.

The holder is very environmentally friendly since it only is made out of one material. The steel is a material that requires relatively low energy to produce and it is a material that there are plenty of. The noise reducing plugs will be made out of rubber and can easily be removed during disassembly. This means that it is fully recyclable and it is an aspect that Volvo Cars take pride in. The powder painting is also a method that is more environmentally friendly than other coating methods. There is a low waste of paint during coating which makes it very efficient. It is also more friendly for the operators to handle. (AkzoNobel, 2013)

8.2 Add-ons

A possible add-on for the rear license plate holder is to provide the customers who pay extra a license plate frame. This can be the same one as the ones provided for the front plate. Apart from a personalized and exclusive look the frame also improves the support and rigidity of the plate. This is something that could be beneficial for the Chinese market since their plate is larger than the holder itself.

8.3 Cost estimation and business case

The average cost of today's license plate holders is 14,18 SEK. The tooling costs of introducing the two new variants proposed in this section will be around 500 000 SEK. The estimated average cost of these two holders will be 11,17 SEK. This results in a net save of 3,01 SEK per holder. The new tooling costs will therefore have a payback time of just above 8 months. After this time Volvo Cars will start to save money.

The reason why the average cost will be lower is due to the higher manufacturing volume, the elimination of the expensive dome nuts and the expensive shipping costs from China. They also do not need to have that many different variants in stock. This last mentioned factor has not been taken into account while doing the cost estimation, since it was hard to get an accurate result. This means that the overall effect will be even better, thus even more money saved. However, the production volume will decrease in the future if the front license plate holders will be replaced by separate adapters instead. This will raise the average cost slightly.

The complete background of the cost estimation can be seen in Appendix 9. Most of the data are from internal sources. The cost of the new holders was estimated and compared with a similar holder that is used today. This is although something that needs to be verified by the supplier before implementing the new holders.

9 Discussion

This chapter will contain a discussion that serves as a wrap-up of the whole project. Both the front and the rear license plate holder will be discussed regarding the outcome of the result. The overall goals that were initially stated will be examined to see if the project fulfilled its purpose. Finally the recommendations and the things that are left for future work are presented.

9.1 Front license plate holder

The front license plate holder is very much dependent on the future design plan since the preconditions will vary heavily depending on the front curvature. Will the front get more complex or stay similar to the one that is being used today. Some luxury competitors such as BMW are using a flat mounting surface without an adapter just like Volvo Cars does. If it fits the design it is no doubt the cheapest and most practical alternative to use no adapter. According to the customer study it was even preferred by many to mount the license plate directly on the bumper. However even BMW has differentiated their car models and some of them has an adapter despite that the front is equal to the others. It has become a hidden standard for the luxury car manufacturers to use license plate adapters, especially for their most expensive cars. It might be a risk that Volvo Cars will not be perceived as part of this segment if they are missing many of the important attributes, where the adapter seems to be one of them.

The adapter solution developed for Volvo Cars would provide positive qualities that they lack today. It would for example create a greater possibility to differentiate their car models. But as said above it will come with a price that Volvo has to pay if this is to be a reality. The proposed solution is not extremely expensive and it is within the budget set internally at Volvo Cars. One must also keep in mind that it will result in a large number of different variants of the adapter. However the total number of car models is unknown for the future, as well as the number of models with complex front in need of adapters. This makes it extremely difficult to make a fully reliable business case.

One way to strengthen the business case could be to supply something extra to the customer that Volvo can charge more money for. This could increase the economical profit margin at the same time as the car models might be perceived as something extraordinary. This would also increase the possibility to personalize your car, which is a strategy much aligned with the leading principle “Designed around you”. One way to get closer to this goal is to deliver a license plate adapter in any desired color, possibly the same color as the car or a nice contrasting color that will accentuate the front. Another similar way can be to provide personalized frames, around the license plate edges, or possibly an anti-theft protection that will make the driver feel safer.

There are also more uncertainties regarding the main design of the future cars, since trends change continuously. Today it is getting more common with large grilles at the front of the car and it is seen that many of the car models are designed with the license plate on the grille. The adapter solution that is developed in this case could possibly be used even on the grille if the fastenings were to be changed into something more like snap fasteners. Other car manufactur-

ers such as Audi use several different adapters and fastening solutions for their car models which actually could be avoided if the grille has similar shape on all car models. That strategy would lower the number of variants as well as decreasing the cost. If one ought to design a front with a large grille one has to make sure that the overall airflow through the grille is sufficient when the license plate is mounted. This will make it difficult to choose a design where the license plate is fastened in a small grille.

9.2 Rear license plate holder

The importance of the front and the rear holder is quite different. While the front adapter often is more in focus, the car manufacturers chose to hide the rear holder as much as possible. This is why there have not been that many innovations in this area. The car manufacturers simply do not think that putting development resources onto this part is out of most importance. It is easy to understand why since the customer does not come in contact with it, it just has to fulfill its function.

What is beneficial for the car manufacturers that sell cars in Europe is that the car dealers take the cost of the standard license plate holder. This has led to a silent agreement between all the car manufacturers that this solution is good enough. No one has chosen to develop their own European license plate holders. Therefore there is no need for Volvo to do it either since it only would add unnecessary costs.

For the other markets; North America, China and Japan the case is somewhat different. Many of the competitors investigated have very simple designs of their holders. Just like Volvo, the fastest solution when developing a new car might be to develop a new license plate holder as well, rather than investigating if one can use one of the existing holders. This results in a lot of different variants and adaptations of the holders which reduces the produced volume of each individual holder. This might not be that devastating for larger car manufacturers who have a large sales volume of their cars, but it is not the best idea for Volvo. With the final design they are able to reduce the number of variants from eight to two variants. This will raise the produced volume per part and lower the overall cost of the car. It is small things like this where Volvo have to be innovative in order to compete in the automotive industry.

As previously mentioned, Volvo has many different holes for mounting of the holder to the car in order to achieve a “perfect” placement of all the different license plates. A strive for perfection makes the design and mounting more complex which adds some costs. For example, would it be necessary to develop a new license plate holder if the plate were to be misaligned by a few millimeters? It might be enough to focus on these details on the main markets only, and not on the minor markets like Japan. The same reasoning goes for the backward compatibility that Volvo is achieving by having additional holes. At one point enough is enough, it will probably not be wise to keep 30 year old holes just to be able to sell a few holders as spare parts annually.

The need of adaptation also comes hand in hand with how much the design of the different car models differs. Most of Volvo Cars license plates are placed on the tailgate, but on some models they did chose to place it on the rear bumper instead. By choosing a common design for all the car models the design of the license plate holder would become much simpler and

the number of variants needed would decrease even more. This reasoning is only realistic to some extent, Volvo cannot afford to increase the similarities too much and loose differentiation. It is also not wise to change the whole design of the rear just to reduce the variants of license plate holders.

9.3 Fulfillment of the project goal

The first objective of this thesis was to develop an adapter for the front license plate that would replace the existing holders. The main purpose of the adapter was to solve the problem of having a complex front and a flat license plate. This was achieved by constructing four plastic adapters that is designed to follow the shape of the car at the same time as it is adopted to the license plate sizes. By doing this, the main focus markets will have sufficient license plate fastening which in turn will cover approximately 97 percent of the market.

The second objective was to investigate the current holders for the rear license plate, and if necessary develop new and improved version (-s). It was soon discovered that there were a lot of different variants used that had been developed one after another and many of them were several decades old. These holders were then possible to merge into two different variants that served the same function as eight other holders. Depending on the mounting preconditions on different car models one has to be angled and one has to be straight, at least if adapting to the current models.

Benchmarks were decided to be an important part of this thesis, thus several kinds of competitors were investigated both regarding the front and the rear holder. When it comes to the front attachments of license plates there were mainly four different variants used by competitors. These were, direct mounting on a flat bumper, having an inlay or an extrusion in the bumper, having an adapter integrated in the grille and finally having a separate adapter mounted on the bumper. In this case there were a clear trend that separate adapters were used on exclusive cars which is the segment that Volvo Cars wants to be part of.

The benchmark of the rear holder showed different kinds of separate holder designs, many similar as the design Volvo uses today. There were for example also different types of holders which had been combined to fit different markets. In this case the Volvo Cars steel holders are seen as a well-functioning alternative to the competitor solutions.

In order to fulfill the goal of this thesis the research questions and requirement specification were in focus. One of the main demands was that the license plate holder is to be securely and steadily mounted to the car. The front adapter is fastened with self-tapping screws and the rear holder is fastened with M6 screws in order to achieve this. It will make it possible to have a car front that looks nice without license plate as well, which is a desire in order to make it more aesthetic in for example some parts of American.

The fastening of license plates is something that is heavily regulated with legal demands. Thus the license plates will be fastened with M6 screws in China and Japan. On the front holder it is not legally controlled how the license plate is to be fastened in Europe or the USA but it is best practice to use screws. Since it is cheaper to avoid threaded inserts on the front adapter self-tapping screw is used. This will secure that the demand of a secure mount is ful-

filled at the same time as the desire of having the possibility to mount and demount the plate is met. However there is a tradeoff between the cost and how efficient this mount is. On the rear holder it is convenient to use M6 and threaded holes on all markets since the rest of the fastenings are done with screws and there is no possibility to use self-tapping screws into the steel holder.

One of the most important goals to handle was to keep the cost down and it has been a strong focus throughout the project. In different ways this is executed on both the front and the rear holder by giving attention to making a simple design, with cheap materials and focus on both Design for Manufacturing and Design for Assembly. Keeping the number of variants as low as possible has also been given a lot of attention. This is achieved practically by having the Japanese and the North American license plate on the same adapter in the front. For the rear the number of holders has been reduced from eight to two which significantly will raise the production volume and lower the cost.

The final research question that was stated in order to ensure that the objective is to be fulfilled was regarding the customer perceived quality. The front adapter was made to solve a front complexity problem but it is also a way to raise the luxury feeling complying with the main competitors. The adapter will also make the license plate look more integrated and there will be a possibility to personalize it by adding extras such as license plate frames or coloring the adapter according to taste. Concerning the rear holder, the task was not as centered on improving the customer perceived quality since it was sufficient before as well. However some things were possible to change in favor of the quality impression, such as all markets now has a powder coating that gives better corrosion resistance and look. The North American dome nuts were not very appreciated and are costly to include, hence they were excluded in the new design. The new holder is also larger than some of the old holders which will increase the support on some markets. The drawback is that the support actually will get a bit lowered for the Chinese market but the significance of this is not determined. All in all the cost was lowered while the quality remained the same or increased slightly.

9.4 Future work and recommendation

This thesis delivers two concept solutions, one for the front license plate and one that is more suitable as a rear holder. However these concepts will not be complete in all aspects so in this section some future work and recommendations are presented that has to be investigated before a possible launch of the new designs are to be considered realistic.

9.4.1 Front

In order to succeed with implementing the front license plate adapters a strategy is necessary. First of all, should Volvo proceed with this concept? The mounting used today, which is directly on the bumper is by far the cheapest option but on car models that uses a complex design the new solution is needed. It is however not sure that all car models need the complexly designed front. Instead it can be used to differentiate the more exclusive model range. When needed the adapter is the most promising alternative and it gives a high quality look in a relatively cheap way.

When this concept is to be implemented depends on the strategic design criteria for future cars. Thus complete drawings and specific information will have to wait until more detailed strategy information is stated. The same goes for the economical part of the project. Possibly a more thorough business case could be made with more reliable cost estimations. It should also be combined with estimates based on supplier information in order to get fully trustworthy information.

When the frontal design is specified and the technical work will be more involved an increased focus should be on the placement of the license plate and fastening in relation to residual technique. For example important safety equipment and sensors have to be located in the bumper. It is also important that the holders meet all the legal requirements set. Even if there has been a large focus on them there are things that have to be validated before launch.

Another strategic decision is where the license plate adapter is to be launched. Today five different markets are seen as the main target. They are; North America, Europe, Italy, China and Japan. All these markets have different license plate sizes, but by supplying adapters to them 97% of the market will be supplied. How this is to be done is by producing preferably four different versions for these markets where North America and Japan shares the same adapter since they have similar license plate sizes. However the economic benefit of this has to be further evaluated. Another aspect that needs to look into is how the residual 3% is to solve the fastening of their license plates and which adapters that they are going to use. Whichever chosen it will not match the license plate and it might look unaesthetic. However it is important to note that the sales volume is low on these markets, but of course, if there is no focus on them it is a risk that it will continue that way. The current mounting which is directly on the bumper is not associated with this problem to the same extent.

There are also add-ons evaluated in this thesis that could be used to raise the customer impression and provide personalization of the car. It needs to be evaluated if there is possible to include these extras in package deals such as R-design or similar. Providing extras as a separate option could also be a possibility and it should be thoroughly investigated how much customers would pay for it. However the customer investigation shows that there are customers willing to pay more money for a similar feature.

9.4.2 Rear

The rear license plate holder needs an implementation plan similar to the one for the front adapter. Thus a decision has to be made whether or not the new holders should be used in the future or not. According to the findings in this report there is no need to wait since the implementation will save money for the company. However it has to be investigated if the new concept will work in practice and the exact functionality and quality has to be proven. The same thing goes for the economic plan which has to be further investigated, preferably in collaboration with suppliers to give a more exact estimate.

Before fully implementing this concept there will also be a need to check so that all laws regarding the use of the new license plate holders is met and so it can be certified for usage on the car models today. If this is to be more expensive than expected one has to think about if the new holders should be implemented first in the next series of car models. Finally there is a need to make drawings that are complete and detailed in order to be able to manufacture the part.

The new holders are made for three countries which are China, USA and Japan. All these markets can use the same new holder which will raise the volume of the holder. An angled as well as a straight version is needed depending on where the license plate is to be placed. There is also one version that was not possible to include in the two new holders, it is the holder for the Japanese XC90. However this is a car model that soon will be renewed and today's XC90 holder will only be sold as a spare part. Regarding the European market it is decided that the standard license plate holders for both Europe in general and Italy will have to do, since they have sufficient functionality and are free of charge for Volvo Cars.

The new holders that are developed will be backward compatible and are a combination of the front and rear holders in order to make them usable as spare parts as well as usable for future rear applications. The full extent of this concept also depends on how and when the front adapter is to be implemented. If the adapter is not to be used in the front, the holder could be used on future cars for mounting of the front license plate as well. However this has to be investigated further to secure full functionality. One issue could be the support for the Chinese license plate on the rear holder. Since the Chinese license plate is larger than the other plates some kind of foam pads could be used so that the plate does not make any noise when in contact with the car. This increased support could also be needed if the plate is to be used in the front, but conditions for this have to be evaluated.

Since the current eight holders are merged into two holders there are a lot of different holes to choose from when the holder is to be mounted. These holes are necessary in order to make it fully backward compatible, but exactly on which cars these holes are used could be investigated and documented in a hands on manner at each market. Other ways could be to check in CAD or send for license plates to test them here. There is a large possibility that several holes are associated with car models dated several decades ago. By starting from scratch some of these holes would be able to be deleted. However, since most mounting is to be done in factory or by a car dealer a mounting instruction could be sufficient. Economically the benefit is also a clear fact so it should be implemented according to these results.

10 Conclusion

This thesis project is mainly conducted in two separate parts, the front and the rear holder. Both areas were successfully investigated and all requirements were fulfilled. The end result of the two final concepts together with this report well achieved the aim and goal with this project.

Initially in this project there were a large focus on finding an innovative solution of the adaptability problem that would make the front holder work for all markets and car models. However it was discovered that it was no use in denying the fact that such a solution, if it exists, would be extremely expensive compared to alternatives in this case. When examining the more innovative concepts they had to be eliminated, one at the time. It was difficult to justify their existence when the hard facts about the superior concept were presented. A simple design with high quality and look was selected instead. This solution was more expensive than some but seemed to be within reasonable cost. The conclusion from this is that the old saying *“the simplest idea is often the best one”* really is true in this case.

The second part were associated with the rear holders and at first it was seen by the project team, and the manager at Volvo Cars, as a good extra project that needed to be investigated. This area did however become increasingly intriguing as the project went by. This meant that the outcome from this part gave great results as well. The chosen simple design where eight holders were merged into two will result in less variants, lower cost and higher quality.

The project group hopes that this master thesis will serve as a good foundation in to the final development and implementation within this area. It would also be interesting to see if the proposed add-ons were examined more thoroughly as well as investigating the possibility to include them as a separate extra or as part in a package design deal.

To wrap up this report it has to be stated that it was an enjoyable and educational project that has given many important lessons. The project team of two people worked closely together at Volvo Cars for approximately five month. It really gave a positive experience of the company as a working environment as well as it turned out to be a pleasant place to be. These precondition laid the foundation to a great result.

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Appendices

Appendix 1: Regulations regarding license plates

Appendix 2: Competitor analysis front adapters/holders

Appendix 3: Competitor analysis rear holders

Appendix 4: Patent investigation of different kind of license plate holders

Appendix 5: Customer survey

Appendix 6: Initial cost estimation – front adapter concepts

Appendix 7: Fastening methods of the plate and the adapter

Appendix 8: Cost estimation front adapter

Appendix 9: Cost estimation rear holder

Appendix 1: Regulations regarding license plates

The laws that are described here mainly focuses on the chosen markets; European Union, Sweden, USA, China and Japan. However, information about other countries was found as well. These laws are however only presented here and are not taken into consideration throughout the rest of the report. It is also important to note that this list is not complete since the information to investigate is extensive.

General

Visibility

- The license plates must be visible and in good condition (Sweden 1)
- The license plates must be visible and in good condition (USA 1)
- A license plate cover or holder must not obstruct or impair the recognition of the license plate information (USA 1 and China 1)
- “Those who purposely try to cover, soil or damage the vehicle license plates or who don’t install/place them in the proper location can be penalized...”(China 3)
- Number plate shall be mounted in a conspicuous place at both the front and rear ends of the vehicle so that the motor vehicle number plate is clearly visible while the vehicle is in operation. (Japan 1)
- Vehicles shall have on the front and rear an appropriate area on which to fix owner identification (registration) plates with minimum dimensions as follows: Width - 400 mm, Height - 130 mm. (Argentina 1)
- The license plate on the front mounting plate/bracket shall be perpendicular or practically perpendicular to the longitudinal plane of symmetry of the vehicle. (China 1)

Fastening

- The license plate must be fastened with two M6 screws by 2013 and four M6 screws by 2016. (China 2)
- The hole diameter shall be 6 mm. As regards the shape, tapping shall be performed by a metric screw (pitch = 1.0 mm). (Japan 2)
- Number plate shall be securely mounted at both the front and rear ends of the vehicle (Japan 1)
- “It must be ensured that the mounting plates/brackets shall not work loose, deform and not be able to be removed without removing or destroying the license plates during the normal use of the vehicle.” (China 1)
- License plates shall be securely fastened to the vehicle to prevent the plates from swinging (USA 1)

Environmental

- From the year of 2006 the reuse and recovery shall be a minimum of 85 % and the reuse and recycling shall be a minimum of 80 %, by an average weight per vehicle and year. By the year of 2015 the reuse and recovery shall be increased to a minimum of 95 % and the reuse and recycling shall be increased to a minimum of 85 %, by an average weight per vehicle and year. (EU 2)

Front

Visibility

- “The license plate on the mounting bracket shall be practically vertical or it may be inclined to the vertical at not more than 15 degrees with the surface bearing the registration number upwards.” (China 1)
- The license plate shall be placed maximum 1,52m from the ground. (USA, legal documents)
- The front mounting bracket shall be mounted on the front bumper or grille of the vehicle. (China 1)
- The license plate mid-point shall not be in the left-hand side of the plane. The left-hand edge of the license plate and the mounting plate/bracket shall not project beyond the right outer edge of the vehicle's front end. (China 1)

Other

- The front of the car cannot have a shape that will be harmful to pedestrians during a collision. (Sweden 2)

Rear

Visibility

- License plate must be placed at the center point and perpendicular to the longitudinal plane of the vehicle. (EU 1)
- Approved vertical inclination of license plate is -5° to 30° (EU 1, Vietnam 1)
- “The license plate on the rear mounting bracket shall be practically vertical...it may be inclined to the vertical at not more than 30 degrees with the surface bearing the registration number upwards.” (China 1)
- The license plate shall be placed between 0,30 and 1,20 m from the ground. (EU 1, China 1, Vietnam 1)
- The license plate shall be placed between 0,30 and 1,52m from the ground. (USA 1)
- The license plate mid-point shall not be in the right-hand side of the plane. The license plate and the mounting plate/bracket shall not project beyond the left outer edge of the vehicle's rear end. (China 1)

Fastening

- The license plate must be attached to a flat surface (max 5000 mm radius) of following dimensions 520*120 or 340*240. (EU 1)
- Installation brackets shall have a sufficient plate thickness at the position of the screw attaching a number plate, etc., so that at least three threads of the screw can be assured (Japan 2)
- The holder of the license plate should be of sufficient size in order to prevent the license plate from being bent if exposed to external forces. (Japan 2)
- “The plate shall be fastened with non-removable/non-reusable snap lock fitting system on rear of the vehicle at the premises of the registering authority” (India 1)
- A seal shall be installed at the position for seal on the left side of the motor vehicle registration number plate mounted to the rear end of the vehicle. This sealing is to be done by the Minister of Land, Infrastructure, Transport and Tourism or an entrusted seal installer. (Japan 1)

Other

- “Installation brackets shall have sufficient rigidity” (Japan 2)

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EU

(1) European Union (2010) *COMMISSION REGULATION (No 1003/2010)* <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:291:0022:0030:EN:PDF> (2013-03-21)

(2) European Union (2000) *Directive on end-of life vehicles - Commission Statements (Article 7 No 2 a-b)* <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0053:EN:NOT> (2013-04-30)

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(2) Volvo Cars Internal Mail Conversation (2013)

(3) Volvo Cars Intranet (2013) *The People's Republic of China Road Traffic Safety Laws*

Japan

(1) Volvo Cars Intranet (1951) *ROAD VEHICLES ACT*

(2) Volvo Cars Intranet (2008) *INSTALLATION BRACKET AND INSTALLATION METHOD FOR MOTOR VEHICLE REGISTRATION NUMBER PLATES AND VEHICLE NUMBER PLATES*

USA

(1) California Department of Motor Vehicles (2013) *V C Section 5201 Positioning of Plates* <http://www.dmv.ca.gov/pubs/vctop/d03/vc5201.htm> (2013-03-19)

(2) California Department of Motor Vehicles (2005) *V C Section 11713.17 Front License Plate Bracket* http://www.dmv.ca.gov/pubs/vctop/d05/vc11713_17.htm (2013-03-15)

Argentina

(1) Volvo Cars Intranet (2013) *Resolution_88_94_License_Plate*

Vietnam

(1) Volvo Cars Intranet (2013) *ROAD MOTOR VEHICLES TECHNICAL REQUIREMENTS WITH REGARD TO THE SPACE FOR MOUNTING REAR REGISTRATION PLATES OF AUTOMOBILES, TRAILERS AND SEMITRAILERS (Vietnam)*

India

(1) Volvo Cars Intranet (2013) *Central motor vehicles rules of 1989*

Appendix 2: Competitor analysis front adapters/holders

Acura: Acura is the premium brand of Honda for the North American market. In 2012 they sold 156 216 cars. They are not sold on the European market, which is why they could not be investigated at the car dealers in Sweden. Acura uses a separate adapter for the license plate. It is mounted on the bumper. Previously they mounted them directly on the front.



Figure 117: Acura TL (Wikipedia 1, 2009)



Figure 118: Acura RDX (Wikipedia 2, 2012)

Alfa Romeo: Alfa Romeo is part of the Fiat Group. In 2011 they sold 130 000 units. They place their license plate to the side of the bumper. The adapter is extruded from the bumper and the size of the extrusion is somewhat smaller than EU size. Therefore it does not fit a standard EU size, nor does an American sized plate fit very well. The dealers mounted the license plate without any EU holder in the front.



Figure 119 - Alfa Romeo Giulietta front and bumper (A2MAC1, 2013)



Figure 120 - Alfa Romeo with small sized license plate

Audi: Audi is part of the Volkswagen Group. In 2012 they sold 1,455,100 cars. In most of the Audi car models the license plate holder is integrated in the grille. It has an inlay that matches the size of the EU license plate. They also have external adapters for their most premium cars A7, A8 and R8. However, they are still somewhat integrated into the grill to achieve the same design as if they would have been fully integrated. The car dealers always used an EU holder. They deliver special solutions for the US market.



Figure 121 - Audi A3 front and grille (A2MAC1, 2013)



Figure 122 - Audi A7 front and separate license plate adapter (A2MAC1, 2013)

BMW: In 2012, BMW sold 1,540,085 cars. BMW mount their license plate either on an external adapter or directly on the bumper (the ratio is around 50/50). If the front has a deep curvature the likelihood of using an adapter is bigger than if the front is more flat. It had no relation to how expensive the car was, i.e. 1 and 5 series had no adapter while 3 series had one. The dealers used no EU holders.



Figure 123 - BMW 118i (A2MAC1, 2013)



Figure 124 - BMW 320d front and separate adapter (A2MAC1, 2013)

Chevrolet: Chevrolet is part of General Motors. In 2011, Chevrolet sold 4,760,000 cars worldwide. Chevrolet only uses external adapters for their license plates. Two different versions exist, a framed version and a smaller version which gives a floating effect. They have less wide versions of their adapters for the North American market. Many of their adapters have a very big depth which gives a bulky look.



Figure 125 - Adapter with less height gives a floating effect



Figure 126 - Framed version

Chrysler / Lancia: The brand Chrysler is a part of Chrysler Group which is a part of Fiat Group. The Chrysler cars are sold on the European market under the name Lancia. 135,000 cars were sold under the name Lancia and 221,000 under the name Chrysler. Lancia mount the license plate directly to the bumper which had marking for where to place the screws. They also have versions where an adapter is integrated in the bumper. The sizes of their adapters is somewhat between US and EU size and serve as a compromise for the two markets. The car dealers used it together with EU holders. Lancia Thema has the plate directly to the bumper, while the US Version (Chrysler 300) has an external adapter.



Figure 127 - Lancia bumper without adapter



Figure 128 - Lancia Ypsilon front and bumper (A2MAC1, 2013)

Citroën: Citroën is part of the PSA Peugeot Citroën group. Citroën sold 1,435,688 cars in 2011. They do not officially sell vehicles in USA, which is why they don't need a separate license plate holder for that market. Citroën mostly uses an adapter for the license plate which is integrated in the grille. They also have some versions where it is placed in the bumper with an inlay. The dealer used no EU holder.



Figure 129 - Citroën C4 front and bumper (A2MAC1, 2013)



Figure 130 - Adapter integrated in the grille

Dacia: Dacia is a brand owned by Renault, which has a strategic alliance with Nissan. In 2012, Dacia sold 359,631 cars. Dacia mostly places their license plate directly to the bumper together with an EU holder. They also have a version where they have made an inlay in the bumper for the license plate.



Figure 131 - Dacia Duster front and bumper (A2MAC1, 2013)



Figure 132 – License plate placed directly to the bumper

Dodge: Dodge is a brand of Chrysler Group, which is part of Fiat. They no longer sell cars in Europe officially; instead they focus on the American market. In 2011, Dodge sold 451,040 cars. They mostly have bigger cars with a flat front. Therefore they don't have any problems just mounting the license plate directly to the bumper. Some of their car models partly have an inlay to make it even easier.



Figure 133 - Dodge Caliper (A2MAC1, 2013)



Figure 134 - Dodge front (Dodge, 2013)

Fiat: Fiat had 2011 a sales volume of 2,032,900 cars. They do not have any external adapters. Instead they are integrated into the bumper, either with an inlay or an extrusion. They don't officially have American versions; they use the same bumper as EU.



Figure 135 - Fiat 500, adapter extruded from bumper



Figure 136 - Fiat 500L, adapter with inlay in bumper

Ford: In 2008 Ford had a sales volume of 5,532,000 cars. In most of Ford's cars the adapter for the license plate is integrated in the grille. The actual design of the grille differs slightly between models. They also have the smaller Fiesta model where the license plate is placed on the bumper which has an inlay. The car dealers always used an EU holder. They have separate grilles for the European and American markets. Their larger SUV models that are made for the American market have external adapters. Ford has a very sleek and integrated design, especially the chrome grille versions.



Figure 137 - Ford Focus front and grille (A2MAC1, 2013)



Figure 138 - Ford Fiesta

Honda: In 2008 Honda sold 3,783,000 cars. Honda mostly uses an external adapter for their car models. However, their cheaper cars have the adapter integrated in the bumper with an inlay. They have separate versions of their adapters for EU and North America.



Figure 139 - Honda Civic with external adapter



Figure 140 - Honda Jazz with inlay in bumper

Hyundai: Hyundai sold 4,051,905 cars in 2011. They have several different versions of their license plate holders. Their cheaper and smaller cars have an integrated solution in the bumper, either with an inlay or an extrusion. Their SUV's and more expensive cars have external adapters, both a floating version and a full EU size version. Some models also have the license plate mounted directly to the bumper. The car dealer mostly used both the adapter and the EU holder.



Figure 141 - Hyundai Santa Fe floating license plate



Figure 142 - Hyundai with extruded bumper

Jaguar: Jaguar is owned by Tata Motors. In 2012 Jaguar sold 54,226 cars. They mostly have different versions of external adapters for their models. However, on one car model the license plate was mounted directly to the bumper. They have separate versions for the US market.



Figure 143 - Jaguar with external adapter

Jeep: Jeep is part of Chrysler group, which is part of Fiat. In 2012 they sold 701,626 cars. They always mount the license plate directly to the flat bumper. The Grand Cherokee version has made a small inlay to flatten it out and ease the mounting. The dealer mounted it with an EU holder.



Figure 144 - Jeep with license plate mounted on bumper

Kia: Kia is partly owned by Hyundai. They sold 2,478,959 cars in 2011. They have many different variants of their license plate adapters. On some models they are integrated in the bumpers, either with inlay or extruded. On their smaller cars the holder is integrated in the grille. Some other models have the license plate directly mounted on the flat bumper. Their larger SUV's have external adapters.



Figure 145 - Kia model where it is integrated in bumper



Figure 146 - Kia Picanto front and grille (A2MAC1, 2013)

Land Rover: Land Rover is owned by Tata Motors. In 2012 they sold 251,632 cars. They have two versions, either they use an external adapter or they place it directly to the bumper. It is used together with an EU holder.



Figure 147 - Land Rover with an external adapter



Figure 148 - Range Rover Evoque with a flat bumper

Lexus: Lexus is the luxury brand of Toyota. They sold 364,630 cars in 2011. Lexus only uses external adapters for their cars. Two versions of the adapter did exist, one which covered the whole license plate and one which only covered half of its height. At the car dealers they were used together with an EU holder. They deliver special versions of their adapters for the American market.



Figure 149 - Lexus with half height adapter



Figure 150 - Lexus with full height adapter

Lotus: Lotus is owned by Malaysian company Proton. They sold 2,675 cars in 2011. They have curved external adapters with low height, which give a visual effect of the license plate being floating. It is used together with an EU holder.



Figure 151 - Lotus Elise without license plate



Figure 152 - Lotus with floating license plate

Mazda: Mazda sold 1,285,815 cars in 2010. Mazda mostly uses external adapters for their car models, they exist in both EU and US versions. They also have a cheaper car model where it is integrated in the bumper.



Figure 153 - Mazda CX-5 front and adapter (A2MAC1, 2013)



Figure 154 - Mazda 2 with integrated adapter

Mercedes: In 2012, Mercedes sold 1,320,097 cars. Mercedes had adapters that were integrated in the bumper for their cheaper cars (A and B-class) and external adapters for their more expensive ones (E-class, sports cars, SUV's etc.). The adapters had an angle to blend in with the front of the car. This means that also the license plate holder had to be bent. They did not have any colored adapters, which probably mean that they think a contrasting black color is more suitable. They have special versions for the American market.



Figure 155 - Mercedes with external adapter



Figure 156 - Mercedes with an integrated adapter

Mini: The Mini brand is a part of the BMW group. In 2012 they sold around 300,000 units. Mini does not use any adapters. They mount the license plate directly to the flat bumper without an EU holder. Previously they used external adapters, but they have been excluded in current versions even if the exterior has remained almost the same.



Figure 157 - Mini Cooper without any adapter

Mitsubishi: Mitsubishi sold 1,105,000 cars in 2010. Mitsubishi does have a flat surface in the bumper/grille area where the license plate can be fastened without any adapter. For their newest version they have moved to integrate the adapter into the bumper with an EU sized inlay. They do not have special versions for North America.



Figure 158 - Mitsubishi with room for the plate in the flat bumper/grille

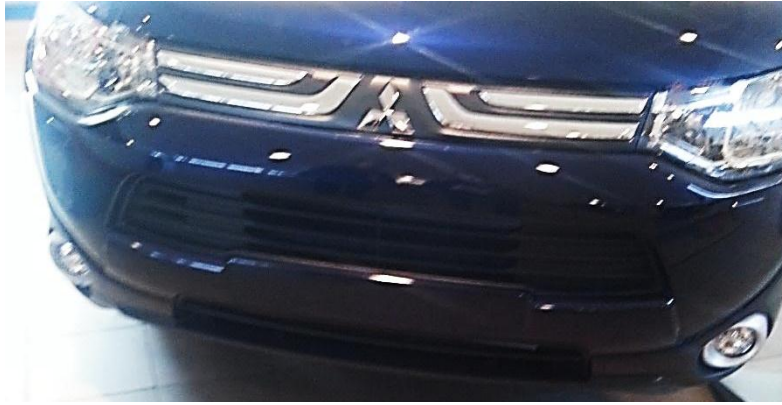


Figure 159 - Mitsubishi with an inlay in the bumper

Nissan: Nissan is in collaboration with Renault. They sold 3,515,000 units in 2010. Nissan has many different solutions on how to fasten the license plate. Their European SUV Qashqai has an inlay integrated in the bumper, while other models have an extrusion from the bumper. They also have external adapters and adapters which are integrated in the grille. On their sports car GR-R it is mounted with Velcro stripes. They have many other car models for the US market.



Figure 160 - Nissan with extruded adapter



Figure 161 - Nissan Juke with external adapter



Figure 162 - Nissan Qashqai with an inlay"

Opel: Opel is owned by General Motors. In 2009 they sold 1,209,121 units. Opel mostly use adapters which are integrated in the bumper with an inlay. They are made to fit the European market and they do not seem to make alterations to the US market. They also have an SUV which has an external adapter.



Figure 163 - Opel with an inlay in the bumper



Figure 164 - Opel Mokka with external adapter

Peugeot: Peugeot is part of PSA Peugeot Citroën. They Sold 2,142,000 units in 2010. They do not officially sell cars in North America. Peugeot basically has two different variants, but varying designs of each variant. Either they have an adapter integrated in the grille or it is integrated into the bumper. On their newest models they move more towards having it in the grille. The dealer did not use any EU holders.



Figure 165 - Adapter integrated as part of the grille



Figure 166 - Adapter integrated in the bumper

Porsche: Porsche is part of the Volkswagen group. They sold 81,850 units in 2010. Porsche only uses external adapter, however different variants exist. For their sportier cars (911 and Boxster) they have smaller curved adapters with a “floating” design. However, this is something that differs depending on where the car is sold. In some countries it is sold together with a full sized external adapter which is colored to blend in with the vehicle. This is also the adapter that is most common for the Porsche Cayenne, which is their SUV. Some of the adapters had an EU holder, while others did not. Special adapters for the US market exist.



Figure 167 - Porsche 911 with floating appearance



Figure 168 - Larger external adapter for Porsche Cayenne

Renault: Renault sold 1,861,389 cars in 2009. They no longer sell cars in USA. Renault only has adapters which are integrated in the bumper, either with an extrusion or an inlay. It is used together with an EU holder.



Figure 169 - Renault Fluence with adapter integrated in bumper (A2MAC1, 2013)



Figure 170 - Renault Clio adapter integrated in grille/bumper

Saab: Saab was previously part of General Motors. They sold around 130,000 cars each year. Saab had both external adapters and ones that were integrated in the bumper with an inlay, both depending on model and year. They also mounted it directly to the bumper.



Figure 171 - Saab 9-5 with external adapter (Saabcentral, 2013)

Seat: Seat is a part of the Volkswagen group. They sold 339,501 cars in 2010. Seat does not sell cars in USA. Seat has their adapters integrated in the bumper with an inlay. They are made to fit an EU sized license plate.



Figure 172 - Seat bumper with an inlay

Skoda: Skoda is a part of the Volkswagen group. They sold 875,000 cars in 2011. They do not sell cars in the USA. Most of Skoda's car models do not have any adapter; instead they are mounted directly on the flat bumper. The Skoda Octavia however, has an inlay integrated in the bumper. The dealer always used it together with an EU holder.



Figure 173 - Skoda with a flat bumper



Figure 174 - Skoda with an inlay in the bumper

Subaru: Subaru is partly owned by Toyota. They sold 656,964 units in 2011. Subaru uses either external adapter or a small integrated adapter. Two different versions of their external adapters exist, one full height version and one half height version. The integrated adapter is very slight, which means that it gives the appearance of being mounted directly to the bumper. The car dealer used it together with the EU holder.



Figure 175 - Subaru with external adapter



Figure 176 - Subaru with extruded bumper

Suzuki: Suzuki is partly owned by Volkswagen group. They produced 2,545,000 units in 2010. Suzuki no longer sells cars in the North America. On most of their cars they have an extruded adapter which is integrated in bumper. Two different versions exist, a short and a long version. They were used together with an EU holder. Their more expensive car “Suzuki Kizashi” has an external adapter.



Figure 177 - Suzuki Swift front and bumper (A2MAC1, 2013)



Figure 178 - Suzuki Kizashi with external adapter (Carlist, 2013)

Toyota: Toyota sold 7,278,659 cars in 2010. Toyota mostly got integrated adapters in their bumper, some with inlay and some with an extrusion. Their more expensive cars (SUV's, Prius and GT86) have external adapters, either full height or half height. The car dealer did use them together with an EU holder.



Figure 179 - Toyota Yaris with an inlay in the bumper



Figure 180 - Toyota Prius with external adapter

Volkswagen: Volkswagen sold 4,502,827 cars in 2010. VW has two different models of license plate holders; integrated adapters with inlay in the bumper and external adapters. Inlay seems to be more common on cheaper models like “Golf” and “Polo”. Their premium car “CC” had a colored external adapter to blend in more with the front. Some of the cars had both an adapter and an EU holder, while others had only adapter. In North America the Golf model is sold with a clean bumper and an external adapter instead of an inlay.



Figure 181 - VW Beetle with an external adapter



Figure 182 - VW Polo with an inlay in the bumper

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Appendix 3: Competitor analysis rear holders

BMW: An American sized rear license plate bracket for BMW/MINI. It fits almost all BMW models and cost 17,95\$. It uses threaded inserts and foam pads on the back of the holder. They also have some other similar versions of this bracket that cost around 26\$.



Figure 183 - BMW Bracket (ECSTuning 1, 2013)



Figure 184 - Another BMW bracket (ECSTuning 2, 2013)

SAAB: A rear license plate holder for SAAB 9-3 that fits both the American and Japanese license plates. It is made out of metallic and has threaded inserts for the holes. It cost 39,77\$.



Figure 185 - Saab rear license plate holder (Thesaabsite, 2013)

Porsche: A rear license plate holder that is appropriate for models from 1974 to 2005. It costs 34,25\$. The holder also requires 4 expanding nuts to function correctly. They also use a similar looking license plate holder for some other car models which cost 28\$.

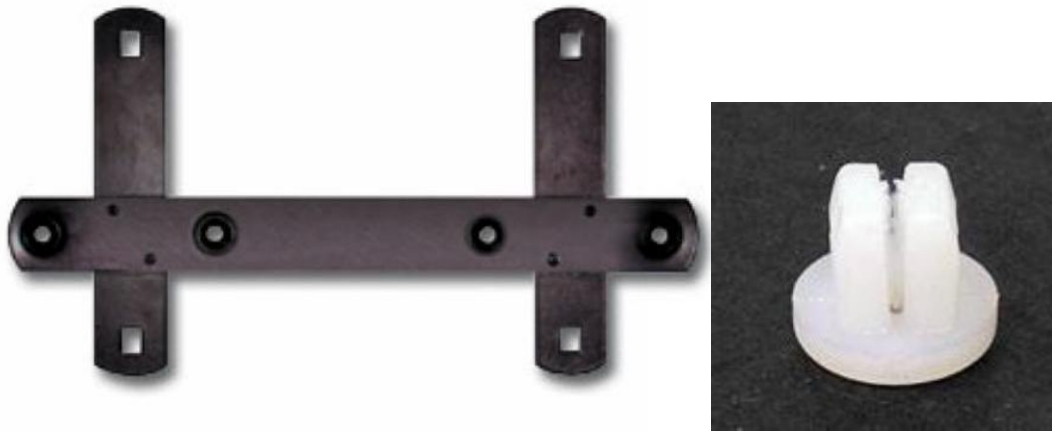


Figure 186 - License plate bracket and expanding nut (Vertexauto, 2013)



Figure 187 - Porsche 911 license plate bracket (Ebay, 2013)

Lotus: Uses an H-shaped bracket with some other loose parts. It is made out of thin metal and cost 52,77\$.



Figure 188 - Rear license plate bracket for Lotus (Lotustalk, 2013)

Fiat and Alfa Romeo: Uses a simple H-bracket style as rear license plate holder. It fits many different car models of various years.



Figure 189 - Rear license plate bracket (International-auto, 2013)

Chevrolet: Two different versions were found; a flat version with four holes and a smaller version which only fasten the plate in the top two holes. Both were made for the US license plate and cost around 30\$.



Figure 190 - A license plate holder for the 1995-1998 Chevrolet Cavalier



Figure 191 - Older license plate bracket (Classicchevy, 2013)

Jaguar: Uses an X-shaped bracket. It claims that no drilling is required and that it has good quality and an easy installation. It fits any Jaguar model and cost 44,07\$.



Figure 192 - Jaguar license plate holder (Carbodyparts, 2013)

Jeep: This is a relocation bracket for The Jeep JK Wrangler if one has equipped the vehicle with rear quarter armor and needs to mount the plate on the tailgate instead.



Figure 193 - Jeep license plate holder

Land Rover: Two different plastic license plate holders were found. They are made for the American market. It has features such as weight saving pockets and noise reduction foam pads. The cost was 36,95\$ for the slightly older holder and 14,95\$ for the current rear holder.



Figure 194 - License plate holder used for Freelander 02-05 and Discovery 99-04 (Roverparts, 2013)



Figure 195 - Current license plate holder for Land Rover and Range Rover models (Atlantic British, 2013)

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<http://www.vertexauto.com/ShowItem/2361%20Porsche%20License%20Plate%20Bracket%20-%20Rear.aspx> (2013-03-23)

Appendix 4: Patent investigation of different kind of license plate holders

This is a list of the most interesting patents which were investigated in this thesis. A brief explanation of the patents is given together with an internet address which leads to more thorough information about the corresponding patents.

License plate holders that can hold multiple sizes (Universal)

- **A General Motors universal license plate holder that can hold many different sized of license plates.**
<http://www.google.com/patents?id=kGMQAAAAEBAJ&printsec=abstract&zoom=4&hl=sv#v=onepage&q&f=false>
- **A universal license plate holder for All-Terrain-Vehicles that can hold plates of different sizes.**
http://worldwide.espacenet.com/publicationDetails/biblio?CC=CA&NR=2471980A1&KC=A1&FT=D&ND=3&date=20041230&DB=worldwide.espacenet.com&locale=se_SE
- **Adjustable license plate holder which involves a rotating screw.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=213&ND=3&adjacent=true&locale=se_SE&FT=D&date=19411216&CC=US&NR=2266715A&KC=A
- **Different adjustable license plate holder, which contains a frame.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=217&ND=3&adjacent=true&locale=se_SE&FT=D&date=19400102&CC=US&NR=2185787A&KC=A
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=218&ND=3&adjacent=true&locale=se_SE&FT=D&date=19391226&CC=US&NR=2185085A&KC=A
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=219&ND=3&adjacent=true&locale=se_SE&FT=D&date=19391226&CC=US&NR=2185084A&KC=A
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=221&ND=3&adjacent=true&locale=se_SE&FT=D&date=19390613&CC=US&NR=2162634A&KC=A

Easy to remove the license plate

- **A license plate holder where it is easy to remove the license plate. It is also a cheap version using straps/wires.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=63&ND=3&adjacent=true&locale=se_SE&FT=D&date=20071220&CC=US&NR=2007289176A1&KC=A1

- **A license plate holder where it is easy to remove the license plate by releasing a spring.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=124&ND=3&adjacent=true&locale=se_SE&FT=D&date=19681224&CC=US&NR=3417957A&KC=A
- **A fastening which allows for a fast removal of the license plate.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=131&ND=3&adjacent=true&locale=se_SE&FT=D&date=19670404&CC=US&NR=3312010A&KC=A
- **Another license plate holder which allows for a fast removal of the license plate.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=139&ND=3&adjacent=true&locale=se_SE&FT=D&date=19600503&CC=US&NR=2935281A&KC=A
- **A two piece license plate holder that allows the owner to fast change the license plate from one car to the other.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?CC=DE&NR=102011101754A1&KC=A1&FT=D&ND=3&date=20120315&DB=worldwide.espacenet.com&locale=se_SE
- **A temporary license plate holder that sticks to the rear windshield.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?CC=US&NR=5141191A&KC=A&FT=D&ND=3&date=19920825&DB=worldwide.espacenet.com&locale=se_SE
- **A license plate holder that is stuck to the vehicle by magnetic strips.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=194&ND=3&adjacent=true&locale=se_SE&FT=D&date=19720815&CC=US&NR=3683529A&KC=A
- **Another easy to remove the license plate, without any tools.**
http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=206&ND=3&adjacent=true&locale=se_SE&FT=D&date=19510605&CC=US&NR=2555706A&KC=A

Hard to remove the license plate (Anti-theft)

- **Three different versions of Anti-theft license plate holder which require a key to remove the license plate.**
<http://www.google.com/patents?id=gTKBAAAEB&printsec=abstract&zoom=4&hl=sv#v=onepage&q&f=false>
<http://www.google.com/patents?id=jS4gAAAEB&printsec=abstract&zoom=4&hl=sv#v=onepage&q&f=false>
<http://www.google.com/patents?id=5UcYAAAEB&printsec=abstract&zoom=4&hl=sv#v=onepage&q&f=false>

- **Two versions of anti-theft fastener for license plates.**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=53&ND=3&adjacent=true&locale=se_SE&FT=D&date=20080206&CC=CN&NR=201015985Y&KC=Y

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=240&ND=3&adjacent=true&locale=se_SE&FT=D&date=19361124&CC=US&NR=2062057A&KC=A

- **Anti-theft versions which involve a string attached to the trunk.**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=186&ND=3&adjacent=true&locale=se_SE&FT=D&date=19750415&CC=US&NR=3877264A&KC=A

Other

- **Porsche fastening method of an external adapter in the grille (Rotate adapter to lock it in place).**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=61&ND=3&adjacent=true&locale=se_SE&FT=D&date=20070208&CC=US&NR=2007028490A1&KC=A1

- **A way of reducing the clearance on Toyota external adapter.**

http://worldwide.espacenet.com/publicationDetails/biblio?CC=JP&NR=2007038700A&KC=A&FT=D&ND=3&date=20070215&DB=EPODOC&locale=se_EP

- **License plate holder with bumper guards to protect during impact.**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=78&ND=3&adjacent=true&locale=se_SE&FT=D&date=20060720&CC=US&NR=2006156595A1&KC=A1

- **Nissan rear license plate holder/adapter with integrated illumination lights.**

<http://www.google.com/patents/US4406490?dq=license+plate+holder&hl=sv&sa=X&ei=QKM9Ua-iDoWA4gSh7YHQCw&ved=0CEkQ6AEwBzgU>

- **A license plate holder that has an integrated “Help” sign**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=90&ND=3&adjacent=true&locale=se_SE&FT=D&date=20040928&CC=US&NR=6796060B1&KC=B1

- **A design protection of a license plate holder. It contains weight-saving pockets and grooves that allow the fastening on many different cars.**

<http://www.google.com/patents?id=JoA9AAAAEBAJ&printsec=abstract&zoom=4&hl=sv#v=onepage&q&f=false>

- **A license plate holder that folds over the license plate. It also allows for advertisement.**

<http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide>

.espacenet.com&II=31&ND=3&adjacent=true&locale=se_SE&FT=D&date=20090827&CC=US&NR=2009211127A1&KC=A1

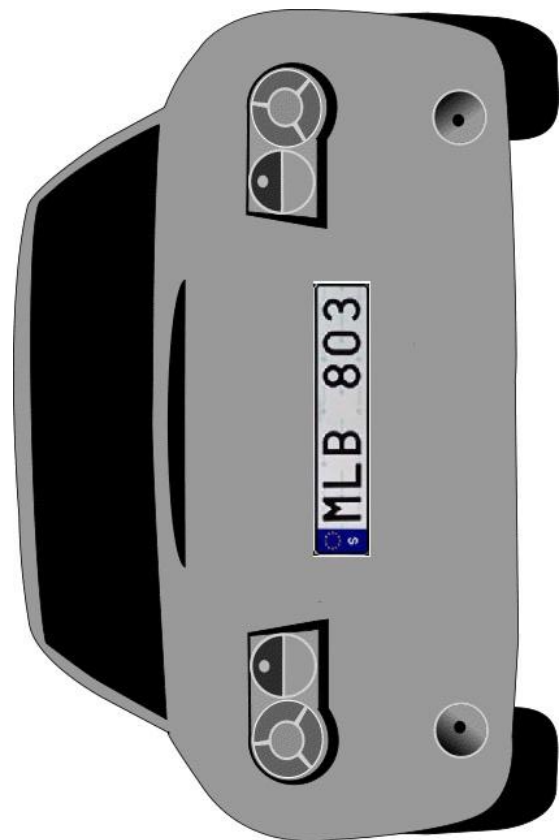
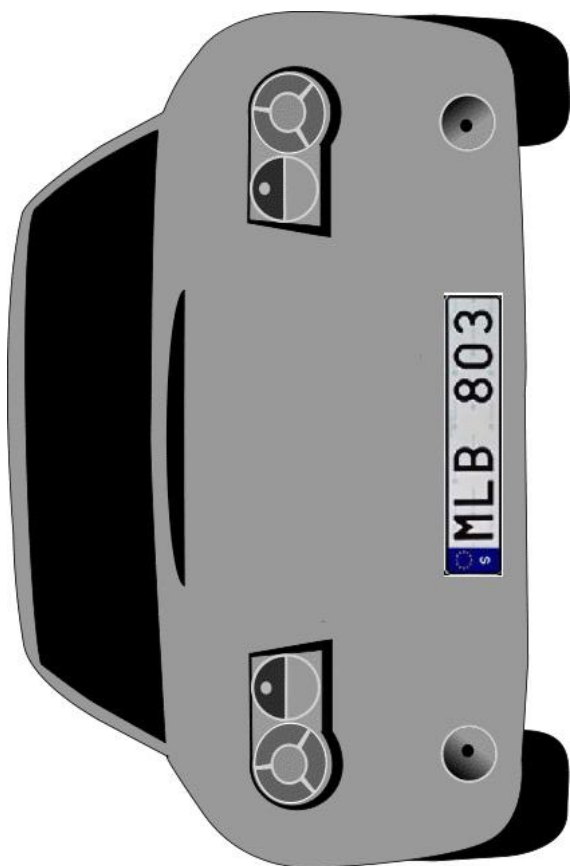
- **License plate bracket for a complex front.**

http://worldwide.espacenet.com/publicationDetails/originalDocument?DB=worldwide.espacenet.com&II=205&ND=3&adjacent=true&locale=se_SE&FT=D&date=19490906&CC=US&NR=2481437A&KC=A

Appendix 5: Customer survey

1. Where do you want to place the front license plate with regard to the appearance?
Choose between cars 1-4.
2. Which placement of the front license plate do you prefer? The left one which has it in the grille or the right one who has it below the grille?
3. Do you believe that the advertisement on the license plate holder reduces the overall aesthetic appeal of the car? If yes, how much? (Scale 1-5, where 1 = not at all and 5 = to great extent)
4. What look do you prefer; to place the front license plate directly on the car or use an adapter?
5. What look do you prefer; to place the rear license plate higher up on the tailgate or lower down on the rear bumper?
6. What is most appealing, an adapter colored in the same color as the car or a contrasting black color? Would you consider paying extra for a colored version? If so, how much?
7. Do you appreciate an anti-theft solution which locks the license plate in place? Would you consider paying extra for it? If so, how much?

1.



2.



3.



4.

With adapter:



Without adapter:



5.



6.



Appendix 6: Initial cost estimation – front adapter concepts

| The Full-size | | | | | | The Full-size (USA and Japan needs extra inserts) | | | | | | The Wings | | | | | | The Small Separate | | | | | | The Spacer | | | | | |
|---------------|----------|---------|---------|---------|--|---|------------|---------|---------|--|-----------|-----------|---------|--------|---------|------------|---------|--------------------|------------|----------|-------------------|----------|------------|------------|-------------------|----------|---------|----------|--|
| EU | USA | China | Japan | Italy | | EU | USA, Japan | China | Italy | | EU | USA | China | Japan | Italy | INNER PART | EU | USA, China, Japan | INNER PART | EU | USA, China, Japan | Italy | INNER PART | EU | USA, China, Japan | Italy | Spacers | | |
| 31000 | 7000 | 5000 | 200 | 2000 | | 31000 | 7200 | 5000 | 2000 | | 310000 | 70000 | 50000 | 2000 | 20000 | 45200 | 310000 | 122000 | 20000 | 45200 | 310000 | 122000 | 20000 | 45200 | 310000 | 122000 | 20000 | 452000 | |
| 310000 | 70000 | 50000 | 2000 | 20000 | | 310000 | 72000 | 50000 | 20000 | | 310000 | 70000 | 50000 | 2000 | 20000 | 452000 | 310000 | 122000 | 20000 | 452000 | 310000 | 122000 | 20000 | 452000 | 310000 | 122000 | 20000 | 1808000 | |
| 1550000 | 350000 | 250000 | 10000 | 100000 | | 1550000 | 360000 | 250000 | 100000 | | 1550000 | 350000 | 250000 | 10000 | 100000 | 2260000 | 1550000 | 610000 | 100000 | 2260000 | 1550000 | 610000 | 100000 | 2260000 | 1550000 | 610000 | 100000 | 9040000 | |
| 3100000 | 700000 | 500000 | 20000 | 200000 | | 3100000 | 720000 | 500000 | 200000 | | 3100000 | 700000 | 500000 | 20000 | 200000 | 4520000 | 3100000 | 1220000 | 200000 | 4520000 | 3100000 | 1220000 | 200000 | 4520000 | 3100000 | 1220000 | 200000 | 18080000 | |
| 13,00 | 13,22 | 13,33 | 22,76 | 13,92 | | 13,00 | 13,22 | 13,33 | 13,92 | | 10,93 | 15,19 | 15,21 | 16,83 | 15,31 | 12,09 | 0,00 | 9,00 | 0,00 | 12,09 | 0,00 | 9,00 | 0,00 | 12,09 | 0,00 | 9,00 | 0,00 | 1,00 | |
| 20150000 | 4627000 | 3332500 | 227600 | 1392000 | | 20150000 | 4759200 | 3332500 | 1392000 | | 16941500 | 5316500 | 3802500 | 168300 | 1531000 | 27323400 | 0 | 5490000 | 0 | 27323400 | 0 | 5490000 | 0 | 27323400 | 0 | 5490000 | 0 | 9040000 | |
| 40300000 | 9254000 | 6665000 | 455200 | 2784000 | | 40300000 | 9518400 | 6665000 | 2784000 | | 33883000 | 10633000 | 7605000 | 336600 | 3062000 | 54646800 | 0 | 10980000 | 0 | 54646800 | 0 | 10980000 | 0 | 54646800 | 0 | 10980000 | 0 | 18080000 | |
| 2500000 | 2500000 | 2500000 | 2500000 | 2500000 | | 2500000 | 2500000 | 2500000 | 2500000 | | 200000 | 200000 | 200000 | 200000 | 200000 | 1500000 | 0 | 300000 | 0 | 1500000 | 0 | 300000 | 0 | 1500000 | 0 | 300000 | 0 | 0 | |
| 1,61 | 7,14 | 10,00 | 250,00 | 25,00 | | 1,61 | 6,94 | 10,00 | 25,00 | | 0,13 | 0,57 | 0,80 | 20,00 | 2,00 | 0,66 | 0,00 | 0,49 | 0,00 | 0,66 | 0,00 | 0,49 | 0,00 | 0,66 | 0,00 | 0,49 | 0,00 | 0,00 | |
| 0,81 | 3,57 | 5,00 | 125,00 | 12,50 | | 0,81 | 3,47 | 5,00 | 12,50 | | 0,06 | 0,29 | 0,40 | 10,00 | 1,00 | 0,33 | 0,00 | 0,25 | 0,00 | 0,33 | 0,00 | 0,25 | 0,00 | 0,33 | 0,00 | 0,25 | 0,00 | 0,00 | |
| 22650000 | 7127000 | 5832500 | 2727600 | 3892000 | | 22650000 | 7259200 | 5832500 | 3892000 | | 17141500 | 5516500 | 4002500 | 368300 | 1731000 | 28823400 | 0 | 5790000 | 0 | 28823400 | 0 | 5790000 | 0 | 28823400 | 0 | 5790000 | 0 | 9040000 | |
| 14,61 | 20,36 | 23,33 | 272,76 | 38,92 | | 14,61 | 20,16 | 23,33 | 38,92 | | 11,06 | 15,76 | 16,01 | 36,83 | 17,31 | 12,75 | 0,00 | 9,49 | 0,00 | 12,75 | 0,00 | 9,49 | 0,00 | 12,75 | 0,00 | 9,49 | 0,00 | 1,00 | |
| 42800000 | 11754000 | 9165000 | 2955200 | 5284000 | | 42800000 | 12018400 | 9165000 | 5284000 | | 34083000 | 10833000 | 7805000 | 536600 | 3262000 | 56146800 | 0 | 11280000 | 0 | 56146800 | 0 | 11280000 | 0 | 56146800 | 0 | 11280000 | 0 | 18080000 | |
| 13,81 | 16,79 | 18,33 | 147,76 | 26,42 | | 13,81 | 16,69 | 18,33 | 26,42 | | 10,99 | 15,48 | 15,61 | 26,83 | 16,31 | 12,42 | 0,00 | 9,25 | 0,00 | 12,42 | 0,00 | 9,25 | 0,00 | 12,42 | 0,00 | 9,25 | 0,00 | 1,00 | |
| 42229100 | | | | | | 39633700 | | | | | 57583200 | | | | | 34613400 | | | | | | | | | 14830000 | | | | |
| 8445820 | | | | | | 7926740 | | | | | 11516640 | | | | | 6922680 | | | | | | | | | 2966000 | | | | |
| 13,15 | | | | | | 13,11 | | | | | 12,19 | | | | | 7,26 | | | | | | | | | 1,29 | | | | |
| 18,69 | | | | | | 17,54 | | | | | 25,48 | | | | | 15,32 | | | | | | | | | 6,56 | | | | |
| 71958200 | | | | | | 69267400 | | | | | 112666400 | | | | | 67426800 | | | | | | | | | 29360000 | | | | |
| 7195820 | | | | | | 6926740 | | | | | 11266640 | | | | | 6742680 | | | | | | | | | 2936000 | | | | |
| 13,15 | | | | | | 13,11 | | | | | 12,19 | | | | | 7,26 | | | | | | | | | 1,29 | | | | |
| 15,92 | | | | | | 15,32 | | | | | 24,93 | | | | | 14,92 | | | | | | | | | 6,50 | | | | |

Appendix 7: Fastening methods of the plate and the holder

- **Screw with nuts**
Some kind of nuts is used together with screws in order to attach the holder.
- **Screw with wingnut**
Screws are used in combination with wingnuts.
- **Screw with movable nuts**
The nuts are inserted into holes in the bumper and used together with screws. The placement of the nuts can be at different locations depending on the size of the license plate.
- **Screw with fixed inserts**
Inserts that provides a threaded attachment is used in combination with screws.
- **Screw with movable spacers**
Self-tapping spacers can be placed anywhere on the bumper by the installer, and can be used in combination with screws. The spacers provide threads for the screw.
- **Screw with threaded hole**
The bumper has threaded holes and could be used together with screws.
- **Bolt with molly insert**
Threaded molly inserts is used that expands on the other side of a thin material which gives a fixed mounting. The insert should also be threaded in order to make it possible to use metric screws in combination with the molly insert.
- **Molly bolts**
Similar to the concept above but the bolt and the foldable part is connected here. Threaded molly bolts are used in order to provide an attachment on a thin material. The molly bolts has expandable wings that will be folded out when the bolt is tightened. The wings will then squeeze on the other side of the surface and the bolt will securely fix it on the outer side.
- **Self-tapping screw**
Screws that are self-tapping is used to secure the adapter. Some reinforcements on the bumper might be needed.
- **Rivet joints**
Rivets used by inserting them into pre drilled holes through both the holder and for example the bumper. Rivet joints are rather strong, robust and it makes the adapter tightly fixed to the car.
- **Expanding plug**
This fastening method is based on using a plastic plug that is inserted through a hole in the adapter as well as a hole in the bumper. In order to make the plug expand a plastic cylinder is inserted in the center of the plug. This will make it expand which will secure that the adapter and the mounting surface is tightly fixed.
- **Tow hook insert**
This concept allows a mounting of a license plate holder to the tow hook insert in the front of the car.

- **Tape**
The adapter can be fastened with double sided tape.
- **Glue**
The adapter can be fastened with glue. It is often permanent.
- **Velcro straps**
The adapter can be fastened with Velcro straps which does allow for a removal.
- **Magnets**
The adapter can be fastened with magnets. Depending on how strong they are the adapter can be easy or hard to remove.
- **Electro magnets**
The holder can be fastened with electro magnets. It is anti-theft proof since the driver will be the only one who can turn them on and off.
- **Suction cup**
One or several suction cups can be used as a fastening method.
- **Snap fasteners**
Snap fasteners can be used to hold the holder in place.
- **String, wire or cable tie**
The holder can be fastened with strings, wires or cable ties. They are somewhat easy to cut in half which is why they are not that good from an anti-theft point of view.
- **Center of gravity**
By using a counter weight attached to the adapter it can be fastened inside the bumper or grille, by theories of center of gravity.
- **Clips, clamps and pressure**
The holder can be mounted to the bumper or grille by using clamps which creates a pressure to keep it in place.
- **Self-locking geometry**
The holder can be fastened by using a self-locking geometry, for example an anchor which can be twisted into a hole in the grille or bumper and be locked behind it.

Appendix 8: Cost estimation front adapter

| | TODAY | | | | | FUTURE | | | | |
|------------------------------------|---------------|---------|-----------|---------|-----------|----------------|-----------|------------|------------|--|
| | Holders front | | | | | Adapters front | | | | |
| | EU | Italy | USA | Japan | China | EU | Italy | USA, Japan | China | |
| Vol/variant | 308 000 | 20 000 | 70 000 | 2 000 | 50 000 | 31 000 | 2 000 | 7 200 | 5 000 | |
| Vol. | 308 000 | 20 000 | 70 000 | 2 000 | 50 000 | 310 000 | 20 000 | 72 000 | 50 000 | |
| Vol. 5 years | 1 540 000 | 100 000 | 350 000 | 10 000 | 250 000 | 1 550 000 | 100 000 | 360 000 | 250 000 | |
| Vol. 10 years | 3 080 000 | 200 000 | 700 000 | 20 000 | 500 000 | 3 100 000 | 200 000 | 720 000 | 500 000 | |
| Cost / part | 0,00 | 0,00 | 11,83 | 12,66 | 15,25 | 16,50 | 17,50 | 17,00 | 17,00 | |
| Manufacturing cost (5 years) | 0 | 0 | 4 140 500 | 126 600 | 3 812 500 | 25 575 000 | 1 750 000 | 6 120 000 | 4 250 000 | |
| Manufacturing cost (10 years) | 0 | 0 | 8 281 000 | 253 200 | 7 625 000 | 51 150 000 | 3 500 000 | 12 240 000 | 8 500 000 | |
| Tooling | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 2 500 000 | 2 500 000 | 2 500 000 | 2 500 000 | |
| Tooling / part (5 years) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,61 | 25,00 | 6,94 | 10,00 | |
| Tooling / part (10 years) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,81 | 12,50 | 3,47 | 5,00 | |
| Total cost (5 years) | 0 | 0 | 4 140 500 | 126 600 | 3 812 500 | 28 075 000 | 4 250 000 | 8 620 000 | 6 750 000 | |
| Total cost / part (5 years) | 0,00 | 0,00 | 11,83 | 12,66 | 15,25 | 18,11 | 42,50 | 23,94 | 27,00 | |
| Total cost (10 years) | 0 | 0 | 8 281 000 | 253 200 | 7 625 000 | 53 650 000 | 6 000 000 | 14 740 000 | 11 000 000 | |
| Total cost / part (10 years) | 0,00 | 0,00 | 11,83 | 12,66 | 15,25 | 17,31 | 30,00 | 20,47 | 22,00 | |
| Total cost during 5 years | 8 079 600 | | | | | 47 695 000 | | | | |
| Total cost during 5 years / year | 1 615 920 | | | | | 9 539 000 | | | | |
| Average cost / holder | 3,59 | | | | | 16,68 | | | | |
| Average cost / holder inc. Tooling | 3,59 | | | | | 21,10 | | | | |
| Total cost during 10 years | 16 159 200 | | | | | 85 390 000 | | | | |
| Total cost during 10 years / year | 1 615 920 | | | | | 8 539 000 | | | | |
| Average cost / holder | 3,59 | | | | | 13,11 | | | | |
| Average cost / holder inc. Tooling | 3,59 | | | | | 18,89 | | | | |

Appendix 9: Cost estimation rear holder

| | TODAY | | | | | | | | TOMORROW | | | FUTURE | | | |
|-----------------------------------|----------------------------|------------|--------------|---------------|-------------|------------|-------------|--------------|-----------------------|---------------|--------------|----------------------------|---------------|--------------|--------------|
| | Holder both rear and front | | | | | | | | Holder rear and front | | | Holder rear, adapter front | | | |
| | US Front | JP Front | CH Front | US Rear | US V40 Rear | JP Rear | JP V40 Rear | JP XC90 Rear | CH Rear | Straight | Angled | JP XC90 Rear | Straight | Angled | JP XC90 Rear |
| Spare part volume/year | 100,00 | 5,00 | 75,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 2,00 | 0,00 | | | 53 375,00 | 71 405,00 | 400,00 |
| Vol. | 70 000,00 | 2 000,00 | 50 000,00 | 70 000,00 | 3 000,00 | 1 400,00 | 200,00 | 400,00 | 50 000,00 | 173 200,00 | 73 400,00 | 400,00 | 266 875,00 | 357 025,00 | 2 000,00 |
| Vol. 5 years | 350 000,00 | 10 000,00 | 250 000,00 | 350 000,00 | 15 000,00 | 7 000,00 | 1 000,00 | 2 000,00 | 250 000,00 | 866 000,00 | 367 000,00 | 2 000,00 | 533 750,00 | 714 050,00 | 4 000,00 |
| Vol. 10 years | 700 000,00 | 20 000,00 | 500 000,00 | 700 000,00 | 30 000,00 | 14 000,00 | 2 000,00 | 4 000,00 | 500 000,00 | 1 732 000,00 | 734 000,00 | 4 000,00 | | | |
| Cost / part | 11,83 | 12,66 | 15,25 | 15,09 | 22,79 | 17,45 | 25,93 | 22,00 | 14,49 | 11,00 | 11,50 | 22,00 | 11,00 | 11,50 | 22,00 |
| Manufacturing cost (5 years) | 4 140 500,00 | 126 600,00 | 3 812 500,00 | 5 281 500,00 | 341 850,00 | 122 150,00 | 25 930,00 | 44 000,00 | 3 622 500,00 | 9 526 000,00 | 4 220 500,00 | 44 000,00 | 2 935 625,00 | 4 105 787,50 | 44 000,00 |
| Manufacturing cost (10 years) | 8 281 000,00 | 253 200,00 | 7 625 000,00 | 10 563 000,00 | 683 700,00 | 244 300,00 | 51 860,00 | 88 000,00 | 7 245 000,00 | 19 052 000,00 | 8 441 000,00 | 88 000,00 | 5 871 250,00 | 8 211 575,00 | 88 000,00 |
| Tooling | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 250 000,00 | 250 000,00 | 0,00 | 250 000,00 | 250 000,00 | 0,00 |
| Tooling / part (5 years) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,29 | 0,68 | 0,00 | 0,94 | 0,70 | 0,00 |
| Tooling / part (10 years) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,14 | 0,34 | 0,00 | 0,47 | 0,35 | 0,00 |
| Total cost (5 years) | 4 140 500,00 | 126 600,00 | 3 812 500,00 | 5 281 500,00 | 341 850,00 | 122 150,00 | 25 930,00 | 44 000,00 | 3 622 500,00 | 9 776 000,00 | 4 470 500,00 | 44 000,00 | 3 185 625,00 | 4 355 787,50 | 44 000,00 |
| Total cost / part (5 years) | 11,83 | 12,66 | 15,25 | 15,09 | 22,79 | 17,45 | 25,93 | 22,00 | 14,49 | 11,29 | 12,18 | 22,00 | 11,94 | 12,20 | 22,00 |
| Total cost (10 years) | 8 281 000,00 | 253 200,00 | 7 625 000,00 | 10 563 000,00 | 683 700,00 | 244 300,00 | 51 860,00 | 88 000,00 | 7 245 000,00 | 19 302 000,00 | 8 691 000,00 | 88 000,00 | 6 121 250,00 | 8 461 575,00 | 88 000,00 |
| Total cost / part (10 years) | 11,83 | 12,66 | 15,25 | 15,09 | 22,79 | 17,45 | 25,93 | 22,00 | 14,49 | 11,14 | 11,84 | 22,00 | 11,47 | 11,85 | 22,00 |
| Total cost during 5 years | 17 517 530,00 | | | | | | | | | 14 290 500,00 | | | 7 585 412,50 | | |
| Total cost during 5 years / year | 3 503 506,00 | | | | | | | | | 2 858 100,00 | | | 1 517 082,50 | | |
| Average cost / holder | 14,18 | | | | | | | | | 11,57 | 11,17 | | 12,12 | 11,32 | |
| Total cost during 10 years | 35 035 060,00 | | | | | | | | | 28 081 000,00 | | | 14 670 825,00 | | |
| Total cost during 10 years / year | 3 503 506,00 | | | | | | | | | 2 808 100,00 | | | 1 467 082,50 | | |
| Average cost / holder | 14,18 | | | | | | | | | 11,37 | | | 11,72 | | |

