A material and manufacturing technique comparison regarding the flooring of a bus

Mechanical Engineering, 15 credits

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A MATERIAL AND MANUFACTURING TECHNIQUE COMPARISON REGARDING THE FLOORING OF A BUS

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1 INTRODUCTION

This Master's thesis is done in the field of vehicle manufacturing. The thesis is conducted for Carrus Delta Oy. Carrus Delta Oy is a bus manufacturer who builds bus bodies on top of Volvo chassis. Their factory is located in Lieto, Finland. Purpose of this Master's thesis is to compare the use of two alternative materials in building of the flooring of a bus. Currently the flooring is built using plywood. Carrus Delta Oy wants to investigate the use of ready-made glass fibre elements instead of plywood elements which are custom cut at their factory. Glass fibre is also presented as potential material of light-weight vehicles by Fenton and Hodkinson (2001).

Carrus Delta is also interested to know, if the carpet that is currently glued on the surface of the plywood could be replaced with a solution that is integrated to the surface of the glass fibre element.

The creation of alternative solutions to the current solution will require engineering work and calculations. It is assumed that the possible new solutions create requirements for the steel supports of the floor structure, that differ from the current situation. This may create an opportunity to simplify the structure and/or reduce the amount of needed floor supports placed under the luggage compartment floor material. This may lead to reduced weight of the vehicle.

1.1 Research Questions

The research questions are:

1. Does the use of glass fibre element reduce the weight of the vehicle?
2. Is the use of glass fibre elements cost-efficient compared to the use of the current plywood solution?

Carrus Delta uses currently plywood in constructing the floors of the bus. They want to collect information and have a comparison, to see that will the use of alternative material, glass fibre, provide benefits compared to the current solution.

3. Does the surface quality of a glass fibre element fulfil customer requirements without additional integrated surface solution?
4. Is it possible to integrate a surface material with similar properties compared to the carpet used nowadays, to the surface of the glass fibre element?
Nowadays Carrus Delta is gluing plastic carpet on top of the plywood floor. They are interested to find out if the carpet could be integrated to the glass fibre panels already when manufacturing process, or would it be possible to create such a surface to the glass fibre elements in their manufacturing process, that the carpet could be left out totally, to achieve cost savings.

5. Is there a difference between fire safety of plywood and glass fibre solutions?
6. Does the use of glass fibre as floor material fulfil ECE-188_02 fire safety requirements?

Carrus Delta wants to make sure that also the alternative glass fibre based solution fulfils the needed fire safety requirements defined in the regulation considering vehicle manufacturing.
2 BASICS OF BUS PRODUCTION – FROM A CHASSIS TO A BUS

A bus is constructed on a chassis. It is common that truck manufacturers manufacture bus chassis and sell the same chassis to several bus manufacturers who use the chassis as a base of constructing a bus. There are also alternative ways of manufacturing a bus, but building on a chassis is the one that Carrus Delta Oy is using. One alternative solution is, that the chassis has been specially designed for the certain body. This is how a recent Finnish start-up Linkker Oy is building their buses. Linkker has designed an aluminium structure combining chassis and body (Linkker, 2018). The use of aluminium as the construction material of the chassis reduces the weight of the vehicle compared the traditional steel chassis. Fenton and Hodkinson (2001) recognize aluminium as a potential construction material for lightweight vehicles.

![Steel chassis of a bus](image)

When manufacturing a bus on a premanufactured steel chassis, the chassis is cut into two pieces in the beginning of the manufacturing process. Additional chassis beams are inserted and welded on their places to achieve the defined length of the vehicle. A bus can have one or two axles on the back end of the vehicle. Two dragging axles create more traction for slippery road conditions than one axle.
2.1 Fulfilment of Fire safety requirements

According to the fire safety standard ECE-118-02 the materials and composite materials installed in a horizontal position in the interior compartment of a vehicle, a fire test shall fulfil the following requirements: “horizontal burning rate is not more than 100mm/minute or if the flame extinguishes before reaching the last measuring point.” (InterRegs Ldt, 2016). Carrus Delta wishes to ensure that the compartment floor elements shall also fulfil the ECE-188_02 standard.
3 THEORETICAL FOUNDATIONS

Designing a vehicle is a complex task because the design has to fulfil a multifaceted criteria. The market of wheeled vehicles splits to three sectors: passenger cars, commercial vehicles, and special vehicles. Commercial vehicles include buses, coaches and trucks including commercial vehicles for a specialized purpose, for example fire trucks and waste management trucks. This thesis concentrates on long-haulage buses, known as coaches.

3.1 Theoretical framework for vehicle design

I hereby present a theoretical framework for vehicle design. Vehicle design is based on market information: information about competitor’s solutions, products and performance; information about customer preferences; information about regulation (for example environmental emission regulation for engines and requirements for passenger safety) and information about (new) manufacturing technologies and (new) materials.
3.2 Aesthetic requirements for vehicle design

The shape of the vehicle and its exterior parts including finishing of interior parts has to be attractive from the viewpoint of the customer. This creates a group of requirements which is in this thesis called as aesthetic requirements for the vehicle design. In the case of buses, the transportation company and their customer, the passenger, can both be seen as the customers of the vehicle manufacturer and the vehicle design process. Many passenger vehicle manufacturers do co-operation in producing their vehicles. They concentrate in differentiating their products on the aesthetic details such as outer shape of the vehicle, some key components such as headlights and backlights, when at the same time sharing some of the key components of the vehicle, such as base plate, engine and transmission of the vehicle (Pöllänen et. al., 2006; Leppänen, 2016). Most passenger vehicles today don’t have an actual chassis, but instead passenger cars have a base plate on which the vehicle (passenger car) is constructed. Many bus body manufacturers build their buses on top of a chassis that is a shared component between several bus manufacturers.

The sharing of some of the technical key components reduce the price of the vehicle due to longer manufacturing series and makes it possible to bring new designs, new models, out to the market in a faster pace, remaining the basis of the design the same. The same phenomenon takes place in the bus market, but in slightly different form. Many companies which manufacture trucks, sell chassis
for independent bodybuilders, who build a bus body on top of it (Virtanen, 2018). A bus chassis is modified from a truck chassis by locating the engine on the back of the chassis whereas in truck the engine is in the front. Carrus Delta Oy is a bodybuilder who builds the buses on top of a Volvo's chassis.

3.3 Technological requirements for vehicle design

Passenger cars and buses have been built for over a hundred years now, and the market expects the produced vehicles to fulfil some basic criteria as a must. Vehicle manufacturers can however differentiate their products with technical characteristics. Many of the technical features by which the vehicle manufacturers differentiate their products nowadays are also linked to the modern consumer electronics such as smartphones.

The technology of the vehicle must be durable and repairable, and spare parts have to be at disposal. It is actually also determined by the international regulation considering vehicle manufacturing, that a vehicle producer must provide spare parts for its vehicles for the time period of 15 years.

When looking at the sector of commercial vehicles the technology of the vehicle has to provide economic benefits to the customer compared to competitors and older vehicles. The fuel economy of a bus is one of the key factors which the bus operators are looking when they select which buses they are going to buy. A bus, or a fleet of buses, is a big investment at the purchasing stage, but actually the operating cost play even bigger role since a bus has a long operation lifetime. It is common to drive over 2 million kilometres with a bus during its lifetime. The mentioned characteristics tell about the product related requirements for the vehicle design which are in this thesis called as technological requirements.

3.3.1 Weight reduction in vehicle design

One of the key alternatives to bring down the operational costs of a commercial vehicle such as a bus, is to reduce its weight. Reducing vehicle's weight leads to smaller fuel consumption. The weight reduction can be implemented for example through changing a material or a design of a part or a component. Weight reduction is especially important in electric vehicles. Reduced weight increases the operating distance of an electric vehicle.
3.4 Production related requirements for vehicle design

Henry Ford invented the basic idea of the modern vehicle manufacturing production, the serial production. Serial production refers to manufacturing of standardized products. In bus market, there exists fully standardized products, but also mass customized products. In bus market the standardized products are based on very long manufacturing series which makes it possible to charge cheaper product prices from the customers. I have worked previously in Scania’s bus manufacturing organization. Scania manufactures both buses for local traffic (buses) and buses for long-haul transportation (coaches). Because of the relatively small scale of production the price tag of a Scania coach rises so high that the only market left for them is actually customizing each bus according the customer’s requirements. Carrus Delta is competing in the same segment with Scania coaches, they also produce coaches with customized solutions.

Optimizing stock value directs to the fact, that one should stock as small number of items as possible and keep that stock on a reasonable level. From the perspective of vehicle manufacturing this means, that there should be as small amount of different parts in a vehicle as possible. This again means, that there should be used as many same parts for different purposes as possible in the design of a vehicle. The tradition of automotive industry using parts from old product generations in the new product generation and the requirement to use as less parts as possible have been inherited from production economics. At Scania these parts that remain the same from the old model to the new model, are called as carry-over parts.

Another requirement from the production economics is to minimize the time used for assembling the parts to achieve the construction, a vehicle. This requirement has created a tradition, that vehicle manufacturers use a lot of subcontracting in their manufacturing operations. Each subcontractor has specialized to some certain components of the vehicle, and deliver the parts to the assembly factory, where internal logistics delivers the parts to right assembly point of the production line. Some of the parts manufactured by subcontractors may also be assemblies, constituting of many smaller parts. It is possible in some areas of the vehicle to make a design where a certain construction replaces several smaller parts. This makes the assembly of the vehicle faster, and it may also be that the price of the part becomes cheaper than manufacturing several smaller parts. This question is in the heart of this thesis. It is investigated that it is more economical to produce the flooring of a bus from glass fibre than from plywood. The material and component cost are one issue, and the labour cost at assembly site is another.
3.5 Optimization in part design

The body of a bus is made of multiple parts and components. Components are parts that have their own functionality within. Vehicle manufacturers usually buy the components from a supplier who has also designed them. But regarding the other parts, vehicle manufacturers design the parts themselves and let the subcontractors manufacture them. Every metal bracket, nut and bolt, piece of plastic etc. is a part. Part design is optimization between several variables, such as technical lifetime of the part or the material of which the part is made of, physical appearance and appeal, price of the material, cost of the assembly and logistics cost of the part.

Everything starts with the purpose of the part and is followed by initial design of the part. The first version of the part must be critically reviewed from several perspectives such as weight, physical attractiveness, price and manufacturability. By doing this analysis the final design will be determined via producing alternative designs. It is crucial to understand that the cost of the solution is determined by a combination of the part price and the working time needed to its assembly. In the following, I will present a model for part design.

1. Purpose of the part

   First design

   Mountability

   Repairability

   Manufacturability

   2. Alternative designs

   Weight

   Price

   Logistics cost

   Attractiveness

   3. Total Cost (part + assembly)

Figure 2. A model for vehicle part design
The current solution used by Carrus Delta is the use of plywood as floor construction material. Also Scania used previously plywood in building the flooring in their coaches. Nowadays Scania uses fibre glass elements. Carrus Delta has a circular saw station where the parts constituting the floor are cut. The parts are then individually fitted to the floor construction. Floor construction using plywood is very time consuming because each plywood part is individually fitted to the floor construction. According to Hämäläinen the construction of the floor of a coach takes 70 to 100 hours of labour (Hämäläinen 2018).

Picture 3. Plywood sawing station
Picture 4. Plywood flooring
Picture 5. Plywood flooring covered with plastic carpet
Picture 6. Plywood side panels

Picture 7. Current heating elements assembled and plywood floor covered with plastic carpet
Picture 8. Current heating elements prior to assembly

In the alternative solution proposed by EC-Engineering, the main construction of the floor is constructed from 5 metres long fibre glass elements. Each bus
floor then needs 2 elements on each side of the aisle, totalling therefore 4 elements to complete a 10 metres long area. According to Ollanketo (2018) the best cost benefit from fibre glass elements is achieved when the implemented area includes a lot of shapes, such as curves. Making curves from straight plywood is time consuming. In picture 8 can be seen the shape of the floor in an example construction of a bus of Carrus Delta. The drawing shows that the width of the floor is 2344mm.

It is also possible to integrate parts or functionalities into glass fibre elements. A plastic carpet can be integrated in the surface of the glass fibre element during its manufacturing process (Ollanketo, 2018) and the mold of the glass fibre element can include shapes that create for example grooves for the installation of rubber hoses.

![Diagram](image_url)

Picture 9. Dimensions of plywood solution
Picture 10. Sketch of the glass fibre solution

4 RESEARCH METHODOLOGY

The research method of this study is based on exploratory search and obtaining of information. The searching and selecting information is followed by critical analysis of information. After analysis, conclusions are made and the critical reflection of the study process is concluded. A method is the process that one uses to get results from the study (Petersson, 2018).
Figure 3. Description of the research method

4.1 Data collection

The data for this research is collected from vehicle manufacturer (Carrus Delta Oy), from a potential supplier of glass fibre elements (EC_Engineering Oy) and from my own work. The material properties including price information re-
garding current solution will be collected from Carrus Delta. The material properties including price information possible new solutions will be collected from EC_Engineering.

The data about used assembly time regarding current solution will be collected from Carrus Delta. The data about assembly time of new potential solutions will be based on estimation made together with Carrus Delta and EC_Engineering. The data regarding customer requirements will be obtained from Carrus Delta.

4.2 Research outputs for Carrus Delta Oy

Carrus Delta Oy will receive a study including cost comparison analysis, weight comparison calculations and information about the potential suppliers, and information about how the glass fibre based solution fulfils the fire safety requirements set by the regulation ECE-188_02.

Carrus Delta Oy wishes to ensure that the glass fibre elements under review shall fulfil the fire safety requirements of the materials use (also) in the interior compartment of the bus.
5 RESULTS

5.1 Techno-economical decision making in vehicle design

Deciding to implement a certain design requires an analysis where technological and economical issues are analysed and weighted on the criteria, which is defined by market need and company strategy. In example in the case of choosing a material, by which the weight reduction is implemented, the cost of the solution plays a crucial role. Carbon fibre is a very light and very durable material, but it is also very expensive to produce constructions from it. In fact, choosing carbon fibre as a floor material on a coach, would probably be “over-engineering” since the material properties would lead to a higher cost-benefit ratio than the manufacturing budget would allow. Glass fibre on the other hand, could offer a possibility to weight reduction and production process simplification with a reasonable cost.

5.2 Techno-economical comparison of alternative solutions

The current solution that Carrus Delta is using is based on cutting and installing plywood panels to construct the vehicle’s floor. The area under comparison is 10 metres long. The total cost of the manufactured solution is formed of material and labour cost. According to Carrus Delta (Hämläinen 2018) the current manufacturing costs of to cover the comparison area is 735 eur including 9,5 hours of labour at cost of 28 eur per hour. In the offer of EC-Engineering the current heating solution of the cabin for this area is renewed. Therefore the costs of the alternative heating solutions must also be taken into account. In current solution the heating is produced with separate heat elements. The total cost for the current heating solution is 579 eur including 8 hours of labour for 10 metres long area. The heating panels are installed on both sides of the cabin, therefore the total length of heating elements is 20 metres. The total cost of the current heating solution is 1644 eur. The installation of carpet to the floor costs 702 eur to the current solution including 12 hours of labour at cost of 35 eur per hour.

The alternative solution consists of 5 metres long glass fibre floor elements which include an integrated heating solution. The heating is produced with hot water flooding in copper pipes that are mounted to the bottom of the floor element. The pipes are covered with aluminium sheet by which the heat will spread to a wider area (Hongisto 2018). The grooves for the heating pipes will increase the stiffness of the composite panel (Hongisto 2018). The direct materi-
al cost coming from the glass fibre panels is 6376 eur for the area in comparison. The estimated cost for the heating system is 628 eur including 1 hour of labour at cost of 28 eur per hour. The glass fibre solution does not need carpet on the vertical surfaces (Hongisto et al. 2018) and therefore it is possible to save 398 eur in carpeting costs. The carpeting of glass fibre solution will cost 304 eur including 6 hours of work at 35 eur per hour. Carpeting the current plywood solution will take 3 times more carpet and twice as much labour. The comparison of the two solutions can be seen below.

<table>
<thead>
<tr>
<th>Current solution</th>
<th>Material</th>
<th>Labour</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor solution</td>
<td>469</td>
<td>266</td>
<td>735</td>
</tr>
<tr>
<td>heating system</td>
<td>1420</td>
<td>224</td>
<td>1644</td>
</tr>
<tr>
<td>carpeting</td>
<td>282</td>
<td>420</td>
<td>702</td>
</tr>
<tr>
<td>total cost</td>
<td>2171</td>
<td>910</td>
<td>3081</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternative solution</th>
<th>Material</th>
<th>Labour</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor solution</td>
<td>6292</td>
<td>84</td>
<td>6376</td>
</tr>
<tr>
<td>heating system</td>
<td>600</td>
<td>28</td>
<td>628</td>
</tr>
<tr>
<td>carpeting</td>
<td>94</td>
<td>210</td>
<td>304</td>
</tr>
<tr>
<td>total cost</td>
<td>6986</td>
<td>322</td>
<td>7308</td>
</tr>
</tbody>
</table>

Table 1. Cost comparison of current and alternative solutions

The total cost of the alternative solution shown in the table 1 above does not include the cost of the moulds needed to produce glass fibre panels. However, since the cost of glass fibre solution is higher than the cost of plywood solution, it is evident that the glass fibre solution will always be more expensive. According to EC-Engineering the cost of a prototype mould that can produce 10pcs of panels costs 1200 eur. The permanent moulds are more expensive but with maintenance they will be able to produce significantly more panels than the simple mould costing 1200 eur. The cost of permanent moulding is about 90.000 eur according Hongisto (2018b) not including the maintenance cost of the moulds. The moulds have to be maintained in good condition so that they can produce high quality parts. The maintenance of moulds again increases the cost of the alternative solution. Because the glass fibre solution is more expensive that the current plywood solution, the investment to moulds would be a waste of money because they would never pay back themselves.

The total weight of current plywood solution is 300kg including the plywood panels and the plastic carpet installed onto surface of plywood. The alternative
glass fibre solution weights 500kg. Therefore, the planned glass fibre solution is heavier than plywood solution and no weight savings can be achieved. According to EC-Engineering the current floor support structures (square steel pipes) can be used with their glass fibre panels. According to EC-Engineering it is possible to integrate plastic carpet to the glass fibre panel in the manufacture process of the panels (Hongisto 2018b). The surface of glass fibre panel as such without additional integrated surface solution does not fulfil the customer requirements and a carpet has therefore to be glued to the surface of glass fibre panel too. Hongisto (2018b) says that this issue can be tackled with further product development in EC-Engineering.

The thickness of the plywood panels used currently are 5 to 12 mm and thickness of the glass fibre panels would be 6 to 10 mm in vertical parts of the panels and 17 to 28 mm in horizontal parts of the panels. EC-Engineering would have charged from doing strength calculations, therefore it was not possible to include the strength calculations into the scope of this thesis. Ec-Engineering however has experience in manufacturing composite panels for similar use. It can be concluded that they know the strength needs for the panels used for this kind of purpose. Thereby, it can be concluded that bus flooring, especially in horizontal parts of the constructions, needs thicker panels when manufactured from glass fibre, compared to plywood as construction material.

From practical experience EC-Engineering knows that adding shapes to the panels, such as grooves for the heating pipes in this case, add the strength of the panel (Hongisto 2018). It can be seen from the picture 9 that EC-Engineering has added grooves to all horizontal levels of the panels. This has been done to achieve higher strength of the panels. According Hongisto (2018) the grooves create a beam effect, that increases the strength of glass fibre panel. The corners of the grooves create hollow beam shapes. Bengtsson (2018) verifies that adding groove shapes to a flat panel increases the strength and torsion resistance of the panel. Bengtsson has worked as quality manager in Thule Ab who manufactures transportation boxes assembled to the roof of passenger cars. Below is a picture of a transportation box manufactured from glass fibre where is strengthening grooves in the glass fibre panel.
The result of the techno-economical comparison is surprising. It was estimated in the beginning that producing buses using glass fibre elements in the flooring would save a lot in labour cost since manufacturing plywood floors is highly labour intensive, and that glass fibre elements could be lighter. According to Carrus Delta the total amount of labour used to produce the flooring of a bus is 70-100 hours depending on the bus model (Hämäläinen 2018). In this comparison, a relatively simple part of the floor was chosen for comparison, since the amount of labour needed to produce 10 metres of flooring is 9,5 hours according to Carrus Delta. Even if the labour needed to install the glass fibre floor panels would be significantly lower (estimated to 3 hours in the comparison above) the glass fibre elements themselves are so much more expensive that the plywood, that the cost of the glass fibre solution becomes very high in comparison to the current plywood solution, and also the glass fibre solution is weighs a lot more that the current solution.

The innovative solution of EC-Engineering has however made possible to remove the current heating elements and rise the comfort level of the bus cabin (more space in the seat by the window and more evenly spread heat). This might make it possible to raise the price of the bus or gain more sales and get new customers. The perspective of this research was however to find cost savings, not increased sales or customer base.

According to Carrus Delta (Hämäläinen 2018b) they expected the glass fibre solution to be more expensive, but they were interested on the possible weight savings of this new alternative solution compared to the existing plywood solution. The result is anyway that the glass fibre elements weigh 66,6 percent more than the current plywood solution. The glass fibre solution is therefore heavier and more expensive.
5.3 Fire-safety properties of the alternative solution

The fire-safety properties of the current solution have been tested by Carrus Delta and the current solution fulfils the current requirements for vehicle structures. The supplier of the alternative glass fibre-based solution is using resin and gel which slow down the progress of the fire. This is the only information EC-Engineering was willing to give for the purpose of this research. They did not want to disclose the information in more detail. It is however known that the supplier EC-Engineering has been producing glass fibre panels for the railroad industry using same resin and gel and they are also producing glass fibre products for automotive industry (Scania buses). According to Hongisto (2018b) the panels produced for railroad industry have passed the fire-safety requirements of standard DIN 5510-2 class 5St2Sr2 which according to DIN (2018) is nowadays expired and replaced with newer standard. But eventually every new panel has to be tested (Hongisto 2018b). The fire safety testing was not possible to conduct in the scope of this thesis. According to Tapanainen and Hongisto (Hongisto et al 2018) the safety requirements for bus manufacturing are going to be tightened in 2019. This increases bus manufacturer’s interested towards glass fibre panels as flooring material since plywood is more flammable than glass fibre (Hongisto et al 2018).

6 CONCLUSIONS

The alternative solution offers possibilities to develop the end-product, the bus, but does not provide cost savings when compared to current solution. I suggest that Carrus Delta remains manufacturing their current bus models with current plywood-based solution and considers the alternative glass fiber-based solution for their new upcoming bus models, since the alternative solution can increase the passenger space and provide more comfort for the passengers due to a different heating solution. This might create an opportunity for Carrus Delta in the future.

The glass fiber solution also makes it possible to speed up the production process, resulting a shorter lead time to produce the buses. This information was given to Carrus Delta, but the actual effect was not calculated in this study. According to Koiranen (Hongisto et al 2018) the use of subcontracting instead of using own production space and personnel also reduces the need for net operating capital, which influences positively on the economy of the production company. The actual effect of this phenomenon was not calculated in this study since there was no such data available from Carrus Delta at hand that would
have made it possible to make the calculation. The researcher received some of
the information in very late stage of the research process, and due to time limit
on the study it was not possible to utilize this late information in the research.

7 CRITICAL REVIEW OF THE STUDY

I decided to do my thesis during summertime because I would have more time
to use for doing it. I needed an input from the supplier candidate, their com-
mercial offer, to proceed with the thesis process. I should have received the ma-
terial before supplier’s summer holiday but eventually I received the material
shortly after summer holiday period. This delay had however not major effects
to my thesis process since the analyzing phase took shorter time that I had
thought it would take. I am very satisfied to the fact that I got an opportunity to
do the Master’s thesis on a subject that interests me a lot. That gave me motiva-
tion to go forward in the thesis making process.

It was a surprise to me that there was so little literature available about the
principles of vehicle design and vehicle part design. This however created me
an opportunity to sum up my personal knowledge about the subject and create
new theory for the field. I believe I have given a significant input for science in
creating my theoretical frameworks regarding vehicle design and manufactur-
ing. As a remark, I can however say that if I would have read earlier the book
Managing for Quality and Performance Excellence by Evans and Lindsay (2008)
which I read after finishing the thesis, I would have found support for the theo-
ry I built in this thesis. It appeared that the principles of vehicle manufacturing,
as they follow the lean philosophy, are supported by this book in the field of
Quality Management as it discusses issues, how to produce quality. Evans and
Lindsay (2008) discuss various perspectives of quality, such as product perspec-
tive, manufacturing perspective, user perspective, customer perspective and
value perspective, which I could have linked to my theory if I would read their
book before.

In engineering some findings can only be proved experimentally. One example
of this is the correction coefficients used in selecting a suitable belt in pulley ex-
ecutions (SKS Mekaniikka, 2018, 8). Specialist manufacturers like EC-
Engineering have a lot of knowledge that has been gained through experi-
mental methods. In area where the technical and production technological find-
ings are trade secrets of private companies, it is more difficult to provide aca-
demic references to a thesis. This phenomenon is present in this thesis.

When conducting the research I summed up my previous knowledge on the
vehicle manufacturing. I find this morally and ethically sustainable even if the
knowledge has been gained in different companies that the customer company
of the research, since it is natural that individuals gain experience on various issues during their professional and private lives.

After the thesis the social relationships with the supplier company remain good, they delivered what they promised. On the other hand, social relationship with the customer company could be better. Carrus Delta did not eventually pay anything for conducting a research to support their R&D. According to them it’s their policy that they only pay a direct scholarship though university and since this was not possible in Halmstad University, they referred to their policy and were not willing to pay anything or compensate any costs of the research project to the researcher. This had negative economic impacts for the researcher. No agreement was written regarding the research project. The project started in good atmosphere of trust and co-operation, and was based on mutual understanding with Jani Tapanainen, R&D Director of Carrus Delta. However, trust to Carrus Delta decreased during the project.

What it comes to environmental issues, it can be said that using plywood is more environmentally friendly than using glass fiber. Plywood is made of wood which can be easily recycled, whereas glass fiber can’t be recycled with ease. Lately glass fiber waste has been started to use in the manufacturing of concrete (Vihanta, 2015). Regarding OSH (occupational health and safety) issues, glass fiber manufacturing is more hazardous than using plywood. This is due to the strong fumes evaporating form the resin used in glass fiber manufacturing. Therefore manufacturing facilities in manufacturing glass fibre have to have a powerful air ventilation and workers have to use respirator mask when working. In the plywood construction the risks lie in using the circular saw at the plywood sawing station.
8 TABLES AND FIGURES

Table 1. Cost comparison of current and alternative solutions

Figure 1. Theoretical framework for vehicle design

Figure 2. A model for vehicle part design

Figure 3. Description of the research method

9 PICTURES

Picture 1. Steel chassis of a bus

Picture 2. A bus with two dragging axles.

Picture 3. Plywood sawing station

Picture 4. Plywood flooring

Picture 5. Plywood flooring covered with plastic carpet

Picture 7. Current heating elements assembled and plywood floor covered with plastic carpet

Picture 8. Current heating elements prior to assembly

Picture 9. Dimensions of plywood solution

Picture 10. Sketch of the glass fibre solution

Picture 11. Transportation box for passenger cars with strengthening grooves in the glass fibre panel

Picture 12. Front part of the floor with more complicated shapes that take more time to make

Picture 13. More complicated shapes of the flooring that take more time to manufacture
10 REFERENCES


InterRegs Ltd. (2016). Status of United Nations Regulation ECE 118-02, Uniform provisions concerning the burning behaviour and/or the capability to repel fuel or lubricant of materials used in the construction of certain categories of motor vehicles.


http://www.linkkerbus.com/technology/


Kimmo Kurppa has working experience in automotive, marine, ICT industries. He holds M.Sc. (econ) and B.Sc degrees.