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可靠度與壽命分析-美國與歐洲重型卡車製造商與顧客

Reliability and Durability of Heavy-Duty Trucks
- Implications for American and
Western European Manufacturers and Customers

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ABSTRACT

This Master's Thesis focuses on the reliability of Heavy-Duty Trucks and how this affects satisfaction and brand image among customers. A considerable share of the thesis is concerned with quantitative analyses, founded on regression analysis, with the objective of measuring how strong the reactions of customers in Western Europe and the US are to changes in reliability. The thesis provides measures of how well changes in customer satisfaction with reliability and reliability image can be predicted by changes in reliability performance.

Seven face-to-face interviews were also carried out with managers of Swedish truck fleets in order to understand better how customers acquire, utilise and diffuse information about reliability and durability.

Finally, the thesis deals with economical aspects of durability, which initially was supposed to be the focus of this thesis and which is also closely connected to reliability. A model is created to describe my understanding on the issue and the constituents of the model are discussed.

The report is made together with the *Institute of Management of Technology* at National Chiao Tung University, Taiwan, and the *Department of Technology Management and Economics* at Chalmers University of Technology, Sweden.

Keywords: reliability, durability, heavy-duty trucks, customer satisfaction, image.

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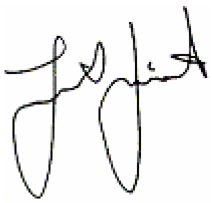
Gothenburg, Sweden, January 9th 2008.



Jacob Lindmark

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1 Introduction

1.1 Background

I will start this report by introducing the reader to how this topic "Reliability and Durability of Heavy-Duty Trucks – Implications for American and Western European Manufacturers" was chosen. It puts the contents of the thesis into context and also raises some ideas on future research which will be elaborated in the discussion section.

The idea for this thesis originates from a concern at Volvo Powertrain Corporation in Gothenburg, Sweden. There was a need for further knowledge in the area of product durability. More specifically, the company wanted to know more about how product durability affects the business economically, through aspects such as customer satisfaction, company image and the aftermarket business. The actual impact of changes in product durability on the aftermarket is not clear and needs to be analysed and further explored. On one hand, one can argue that with more durable trucks there is more time to sell spare parts and provide repair services. On the other hand it might be so that more durable trucks are generally more reliable and there would thus be fewer repairs needed.

There are many characteristics of the truck industry that make this kind of studies complex. For instance, in some markets the sales of original spare parts end long before the trucks stop being useful, due to the presence of unauthorized workshop services and non-original parts that are competitive in price. Furthermore, a large share of the trucks are sold to large fleets and they tend to keep trucks only for a few years, while the reliability is very high, causing them not to notice an improved durability. It soon becomes clear that these issues are very hard to penetrate. Although the great complexity of this area, my supervisors and I decided that I should proceed with the task, although not attempting to provide a complete picture. A brief overview of the subject with some new understanding would provide great value for the organization, while the current knowledge is very limited.

However, it became clear after a while, that many of the analyses were impossible to carry out. Not because the knowledge and data was not located at one single place, but rather because it did not exist anywhere in the corporation. Therefore the focus on durability moved to reliability, an area in which the data is much more accessible. My focus on the driveline also had to broaden so that I whenever necessary look at the complete vehicle instead of only the driveline.

The next step was to make a brief pre-study on customer satisfaction and reliability and the connection between them. It soon became evident that the commercial customer surveys that are purchased by the organisation are a great resource and provide studies on many relevant factors with relatively large samples. Therefore, there is a relatively large focus on these studies and the new conclusions that they can facilitate. In order to gain some more qualitative and rich knowledge through this thesis, I have also performed a set of interviews with fleet managers with the objective of getting input about how customers might reason about reliability and durability and how knowledge and impressions on the topic are utilised and diffused within the industry

1.2 Objectives

We know that the quality dimension reliability is important for the overall satisfaction of customers and for their loyalty to brands. However, there is much yet to find out about how customers reason and how strong their reactions might be to changes in reliability. The objective of this thesis is to create some quantitative base for the sensitivity of customers to changes in reliability and what factors we should look at when we try to measure it through surveys. Besides this, we will try to get a more nuanced picture of how customers reason regarding the reliability and durability of trucks. The thesis will analyse some features of reliability and more closely look at how changes in reliability might affect customer satisfaction and image. The research can be described more concretely by the following research questions:

Research question 1

What market research measures of reliability available to the Volvo Group have the largest explanatory power for the customer satisfaction with reliability?

Research question 2

How clearly are changes in product reliability on US and Western European markets reflected in customer satisfaction with reliability? Is there a difference between improved and worsened reliability?

Research question 3

Different customers have different images of the ability of truck manufacturers to provide reliable trucks. How are these images affected by changes in truck reliability?
Is there a difference between reliability improvements and reliability deteriorations concerning the size of the effects that they have on image?

Research question 4

Can good[1] service compensate for poor reliability?

[1] With good service, we mean service that makes customers satisfied. The service satisfaction is in this thesis measured through a sum of several service ratings. This is further explained in section 3.1.4.

Research question 5

How is knowledge about the reliability and durability of truck models generated and diffused among truck customers? What importance does it have when making decisions about replacements of trucks?

Research question 6

What are possible economical effects for Volvo of a changed durability of driveline components?

1.3 Motivation

Reliability is a quality dimension that has large importance in most industries. The heavy-duty truck industry is one where its importance almost can not be overestimated. Reliability is in a major European customer satisfaction survey listed as the most important factor for customer retention, both as stated by customers and as a result of correlation studies between customer repurchase intentions and satisfaction with different factors[2]. Furthermore poor reliability is often mentioned as the main reason not to repurchase a truck of the same brand. Also in studies of the US market, the importance of reliability is emphasized. For instance, reliability has a large share of the customer satisfaction index constructed by JD Power and Associates, which is based on customer statements. According to Brian Etchells, senior research manager in the commercial vehicle group at J.D. Power and Associates[3] "Performance and quality account for 65 percent of total product satisfaction, so it's easy to see how problems quickly erode owner satisfaction". He elaborates "Time is money in the trucking business, and when a truck is in for service, it impacts the fleet's bottom line,"

In line with the great importance of reliability for a truck manufacturer, there are a lot of efforts in Volvo as well as its competitors to keep a good reliability that will make the customers satisfied and make them loyal to their brands. However, there are many and large areas in which the knowledge can be further extended.

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[2] Correlation between factors does not imply a cause-and-effect relationship, but it can support such hypotheses based on other arguments such as, in this case, statements by customers. A discussion about the use of correlation studies to show importance can be found in Section 5.1.

[3] *Press Release: Class 8 Truck Quality Declines Due to More Problems with Low-Emission Engines* (16 August 2006). Available: <http://www.jdpower.com/press-releases/pressrelease.aspx?id=2006136> (2007-08-17)

Reliability and even more so durability are areas that need to be evaluated during a relatively long period of time and therefore they are not as well analysed as are features that can be evaluated more or less instantly, such as aesthetics or user-friendliness. Any added knowledge in these areas is therefore valuable, even if it might be on a seemingly basic level. During the warranty period, the monitoring of reliability is usually good, however, after this period the knowledge is limited. Also, there are still opportunities for improvements when it comes to connecting the reliability to the reactions of the customers. This thesis can provide benefits to Volvo, in terms of some added understanding of how customers respond to product reliability.

Being more specific, I will explain why I believe that the listed research questions are interesting. We know that reliability is a very important feature for trucks customers. The reliability of trucks has, when looking a few decades back improved tremendously. It is clear that technical progress can improve reliability in the long run. However, in the short run, it is commonly so that technical innovations can lead to deteriorated reliability due to new concepts and components being introduced. New technology causes uncertainties in both the development and in the production. When the root causes of the problems have been found, they can generally be solved and after a while the production becomes more stable, yielding more reliable products.

So we have a situation where technical development is generally positive for the reliability in the long run but often negative in the short run. Some innovations and improvements are necessary in order to be competitive at all, some might be necessary only if one wants to provide state-of-the-art technology. How innovative one chooses to be has an impact on reliability in both the short and the long run, and it would be interesting to know the impact better. One important aspect is whether the deteriorated reliability early after a new technology introduction can be compensated for with improved reliability later. The more specific question that we ask is if there is a difference in the size of the reactions in customer satisfaction from reliability changes between deteriorations and improvements (Research question 2). If there is no such difference, we can reason that even though our technological advances might have a negative effect on reliability in the short run, the satisfaction will recover when the better reliability as a result of the innovation is seen. If the reliability deteriorations have a much bigger effect on the satisfaction than the improvements do, then we might need to be careful with having a reliability that jumps up and down.

It is also interesting to look at the same question for the image, which is done through research question 3. Do deteriorations and improvements have the same power in affecting image? One major difference between image and customer satisfaction is that only those who own a truck of a certain brand can be satisfied or dissatisfied with it, but everyone who has heard of a make can have their own image of it. Therefore, while looking also at image, it would be relevant to know how customers acquire information about other trucks than their own and how they discuss the reliability of trucks with others (Research question 5).

The first research question is necessary to facilitate research questions 2 and 3, where we need to have the best measure of reliability for which we study the effects in satisfaction. RQ1 also has relevance in itself. The commercial surveys that many manufacturers buy provide several measures of the product reliability. In many cases there is a relatively large correlation between these measures, but sometimes they give completely different pictures. It is then valuable to know which of these measures that generally best describe reliability in the sense that it has a high correlation with the satisfaction with reliability stated by the customers. Research question 4 came up as something we wanted to test after hearing from one customer after another in our interviews that problems happen to everyone, the important thing is how they are solved. We interpreted this as if they were saying that quite a few problems can be acceptable as well as they are solved well and fast. It would be very interesting to test this hypothesis on a large sample.

1.4 Delimitations

Due to methodological reasons we make several delimitations concerning geographical coverage. Research questions 1-4 are all concerned with quantitative analysis of secondary data from commercial customer satisfaction surveys. Such studies available to the Volvo Group provide a good picture of the Western European and US markets, which together comprise about 70% of the sales of Volvo Trucks. In other markets, the sales are substantially lower and the coverage of detailed customer satisfaction surveys is limited. Therefore, we limit ourselves to the US and Western Europe. For research questions 3 and 4 we have furthermore excluded the US market, leaving only Western Europe. For RQ3, the reason is that there are no questions about image in the survey of the US market that could access and in the case of RQ4, there was a need to access the responses on an individual level rather than at a brand or model level as was the case for the data available to me for the US market. The time periods on which quantitative analyses have been made are 2000-2007 for Western Europe and 2002-2006 for the US. Research question 5 has been investigated through face-to-face interviews. Therefore we chose to limit ourselves to the Swedish market to satisfy the time constraint present.

The countries that in this thesis represent what we refer to as Western Europe are Germany, the United Kingdom, the Netherlands, Belgium, France, Spain and Italy. This list of countries is based on the scope of the customer survey that we have used for secondary data analysis and we have not had any possibility to affect it, except for the option to exclude countries. We believe that these countries give a fair representation of Western Europe.

The trucks that the secondary data, and thereby also my analysis is confined to is, for the US, Heavy Duty Trucks, more specifically Class 8 vehicles, i.e. less than five-axle tractor[4]/single trailer for medium-haul delivery[5] The vehicle are of model year two years prior to the year that the survey is carried out. For Western Europe, the trucks are Heavy Duty Trucks with a

[4] See *Appendix 1: Abbreviations and Key* for a verbal description of a tractor truck and *Appendix 3: Basic types of trucks and trailers* for a picture.

[5] US Department of Transportation. *FHWA Vehicle Classes* (Electronic). Available: <http://tmip.fhwa.dot.gov/clearinghouse/docs/accounting/appendix_e.stm> (2007-11-18)

Gross Vehicle Weight[6] of 16 tons or more that have been delivered during the last 6 - 24 months when survey is carried out.

1.5 Organisational presentation

"The Volvo Group is one of the world's leading manufacturers of trucks, buses and construction equipment, drive systems for marine and industrial applications, aerospace components and services"[7].

The group has approximately 82,000 employees and its net sales in 2005 amounted to 23 billion Euro[8]. Volvo Powertrain is a business unit in the Volvo Group and has about 8000 employees. They provide integrated powertrain systems comprising diesel engines, transmissions and drive shafts for the end products of the Volvo Group. In the 9–18 liter classes, Volvo Powertrain is the world's largest producer of heavy diesel engines[9].

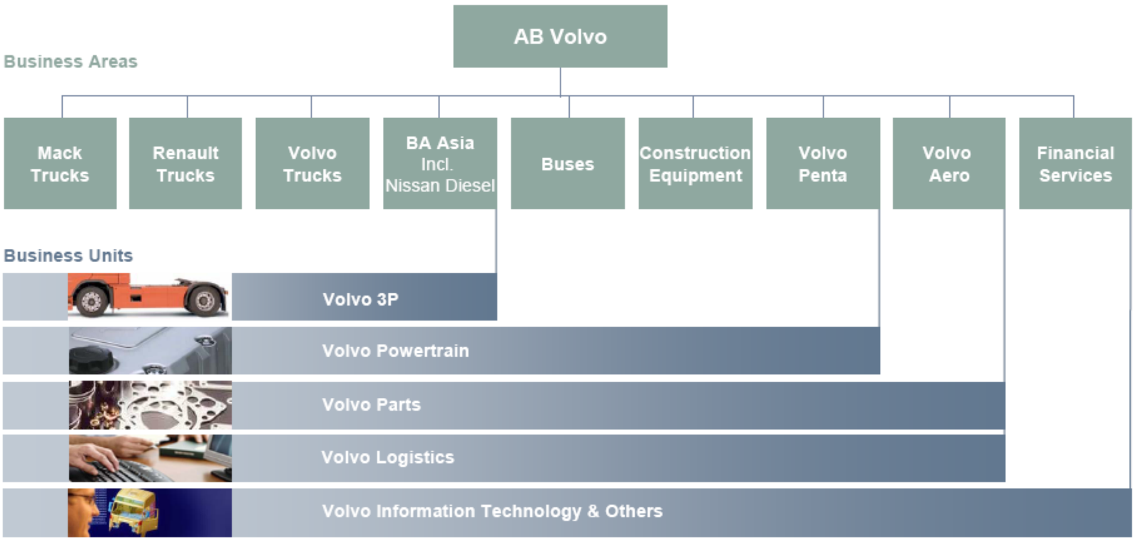

Figure 1: The business areas and business units of the Volvo Group[10]

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[6] "*The maximum loaded weight (including the vehicle itself, passengers, and cargo) for which a vehicle is designed, as specified by the manufacturer. Often used as a criterion of vehicle size for the purpose of legislation; the exact definition may vary depending on the jurisdiction*".
DieselNet, *Glossary* (Electronic). Available: <http://www.dieselnet.com/gl-e.html> (2007-11-18)
[7] Volvo Homepage (2007)
[8] Ibid.
[9] *Uniform Power* (2006). Information leaflet. Available: <http://www3.volvo.com/investors/finrep/ar06/eng/volvopowertrain/pops/printable/16_volvo_powertrain.pdf> (2007-07-03)
[10] Volvo Group (2006)

The business areas are the divisions that provide products and services to external customers. Volvo Powertrain, as indicated in Figure , providing driveline components for the four truck brands: Mack Trucks, Renault Trucks, Volvo Trucks and Nissan Diesel. It further delivers components to buses, construction equipment and marine applications through Volvo Penta.

2 Theoretical Framework

2.1 Quality

Most companies of today recognise the importance of quality, whether they are providing products, services or both. However, what quality actually means is in many cases a matter of interpretation biased by the objectives of the observer. For instance, a common situation according to Garvin (1984) is that marketing departments focus on quality to satisfy customers and thereby increase sales. Manufacturing departments on the other hand, see the main benefits of quality as lowering costs of scrap and rework. We need to be aware that there are different views and that this affects our business. Garvin (1984) has identified five main approaches to quality, some with their own objectives.

The transcendent approach

Quality is ”innate excellence”. This view implies that there is no precise definition and Garvin draws parallels between the transcendent approach to quality and Plato’s discussion of beauty, where Plato says that one can understand beauty only by being exposed to a series of objects that have the characteristic.

The product-based approach

In this view quality reflects the quantity of some desirable ingredient. This view could for instance imply that a digital camera with many pixels is of higher quality than one with fewer pixels.

A problem with the product based approach is that one must know the desired ingredients that in many cases can differ greatly between different users. It is also common that an increased quantity of an ingredient can have a positive effect on the performance of a product only within some interval, and that it outside the interval have no effect at all or even a negative effect. A consequence of the product based approach is that increasing the quantity of some desirable ingredient is often costly and it therefore implies that quality improvements need to be costly.

The user-based approach

There are many definitions of quality that fall into this category. One of them is that of Bergman & Klefsjö (2003). “The quality of a product is its ability to satisfy, or preferably exceed, the needs and expectations of the customers”. In this view quality is subjective. An important feature of this view is that quality can be improved by better understanding the needs and wants of the customers and it therefore does not necessarily have to be costly. If considering the potential for increased sales that a better understanding of the customers will yield, there is of course no cost at all; rather, quality improvements are sources of increased profitability.

The manufacturing-based approach

With this approach, the measure of quality is conformance to specifications. High quality products are those that are produced as specified and for which the variation between individual units are low. This view takes the customer into account to some extent, while it is assumed that products outside specifications generally perform less good than those within and that variation in itself can have a negative effect on customer satisfaction. The main focus, however is reducing costs of scrap and rework by doing things right the first time.

The value-based approach

The unique characteristic of this approach is that it takes price into account. A high quality product is one that performs well at an acceptable price. A problem with this view is that we equate quality with the extent to which it is worth its price. It makes practical considerations regarding quality improvements hard and it becomes hard to judge the difference in quality between two products. In some cases a small quality increase is irrelevant, but in some cases it is very important and worth paying extra for.

There appears not to be one definition that suits all products and conditions. Rather we should have different foci, depending on our current objective. The overall main concern for a corporation however, must however always be to satisfy their customers. In general, one can see a trend that companies are moving more and more towards customer focus. The marketing guru Philip Kotler (2003), puts the need of increased customer focus into words by saying that

> “If your people are not thinking customer, they are not thinking. If they are not directly serving the customer, they'd better serve someone who is. If they don't take care of your customers, someone else will.”

Or as someone at Ford supposedly once said (Kotler, 2003):

“If we're not customer driven, our cars won't be either”

Garvin (1984) furthermore names eight dimensions of quality. They are

- Performance,
- Features,
- Reliability,
- Conformance,
- Durability,
- Serviceability,
- Aesthetics,
- Perceived quality,

Whether this is an exhaustive group or not and whether these are more important dimensions than others can be discussed, but the list helps us to think about what aspects there can be of quality. Furthermore, this set of dimensions has been accepted by many and is generally considered a “seminal work in the area of strategic quality management” (Curkovic, 1999).

2.2 Reliability

It is important that we have a clear picture of what we mean by reliability. Most definitions are essentially in line with that of O'Connor (2001), stating that reliability is

"...the ability of an item or of items to keep operating, or to be available for operation, over a period of time without failing".

The most common measures of reliability are mean time between failures, mean time to first failure and failure rate per unit time(Garvin, 1984), the latter which is a probability distribution rather than a deterministic number.

That reliability is important is commonly accepted and this usually holds also for people who are not actively working to promote prioritising of quality efforts on the manufacturer side. As consumers, we constantly experience the drawbacks of poor reliability. We expect our consumer electronics, our transportation, and our kitchen appliances etc. to work and when they do not, they often create large distractions and dissatisfaction. One side of it is that we often are burden with a cost when for instance our car breaks down. Another side is that we loose our trust in our products. When using them, we need to feel certain that they can provide us with the services that they are supposed to. Poor reliability can on top of cost also create risks to our safety, as in the case of car brakes loosing its function or the material defects making buildings or bridges collapse. For the manufacturer, poor reliability causes costs of scrap and rework in production, warranty costs and bad reputation among other things.

A concept with close ties to reliability is that of *dependability*. The factors that comprise dependability are (Bergman & Klefsjö, 2003): reliability, maintainability and maintenance support. Reliability is as defined above, the ability of a unit to keep operating without failing. The maintainability describes how easy the problems in the unit can be found and fixed. Finally, the maintenance support refers to the availability of a service organisation. Obviously, the worse the reliability is the greater is the need for the other two factors to be satisfactory. For many customers in the truck industry, it is the time that the truck is not available for service that is the greatest problem, rather than the cost of the repairs themselves. Therefore, the concept of dependability is highly relevant for the studied topic.

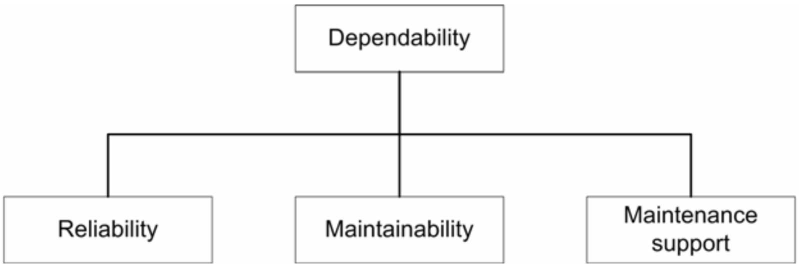

Figure 2: The concepts that constitute dependability. Adapted from Bergman and Klefsjö (2003)

2.3 The customer concept

In the case of the heavy-duty truck industry, the customer concept is multifaceted. There are people who pay for the trucks and there are people who use them; sometimes they are the same, sometimes not. Those who own and drive their own vehicles are commonly referred to as *owner/operators*, whereas trucks who are owned and driven by different people, in most cases belong to so called *fleets*. The lion's share of all trucks are owned by fleets[11]. For the owner/operators businesses it is easy to know who to ask about satisfaction. In the case of fleets on the other hand, it is hard. Large fleets usually have a high number of drivers, a president of the business, one or several owners of the business, a manager of maintenance etc. In the customer satisfaction studies made for Volvo on the US market, they ask what they call the principle maintainer. What they mean is the person that knows the most about the maintenance of the truck. In the case of fleets, it is usually the Manager of Maintenance or similar. An interesting aspect of this is that it means that in many cases, the one who is asked about his satisfaction with driving experience, repurchase intention etc. is neither the user, nor the owner of the truck. Studies like the ones analysed in this thesis are far reaching and treats multiple areas, such as the sales experience, the truck itself and the workshop experience. Thus, one would like to ask questions to several different people to get the full picture. However, this is probably not possible, due to cost and time of both the survey company and the participating company. It is hard to avoid this problem, but it is something that we must be aware of. If the respondents were chosen among drivers, the driving comfort might be rated as more important than when asking the principle maintainer and if asking the one who purchases trucks, the stated importance of the behaviour of sales staff would probably be increased.

[11] According to JD Power and Associates, the fleets accounted for 97% of the market in 2006.

The most important person for the manufacturer of trucks is probably the one who makes the purchasing decision. As long as they continue to buy trucks, the manufacturing firm will prosper. Obviously there will be some communication between the one with the purchasing responsibility, the one with the maintenance responsibility, the drivers etc. and therefore we have to assume that the answers from one of them is a relatively good approximation for how the manufacturers products and services are perceived at the customer business. When referring to customers in a general sense in this thesis we most often mean the ones making the purchasing decisions. When referring to surveys, however, we mean the respondents of the survey, assuming that they can give a relatively good view also of the experiences and feelings of the purchasers and drivers.

2.4 Customer satisfaction and loyalty

Juran and Godfrey (1999) defines customer satisfaction as "A state of affairs in which customers feel that their expectations have been met by the product features."

In the view of Szwarc (2005),

> "customer satisfaction is how customers view an organization's products or services in light of their experiences with that organization (or product), as well as by comparison with what they have heard or seen about other companies or organizations."

Szwarc (2005) means that while the customer satisfaction is based partly on what they have heard or seen of other companies and products, these impressions of others should be included in customer satisfaction research, something that is very commonly overlooked.

The attention to customer satisfaction grew slowly during the 1960's and 70's before accelerating in the 80's and taking off in the 90's. Before the 80's, there was little focus on customer service and customer satisfaction and the discussion was rather about whether customers bought products or if the products were sold to them (Szwarc, 2005). In the 1980's, people like William E Rothschild of the US General Electric Corporation realised that customer service could not only be a support for business, it could be a strategic advantage. Market research methods started to emerge, increasing the focus on customer satisfaction. (Szwarc, 2005). At the same time, the Japanese got recognition for their efforts towards increased customer satisfaction and lowered costs through keeping defects at a minimum. The efforts of the Japanese had begun already in the 50's however, inspired by Joseph M. Juran and others (Kondo & Kano, 1998). The awareness of the importance of customer satisfaction was spreading at several fronts, although the driving forces were different in nature in different places. In the 90's there was a further push forward through the concepts of balanced scorecards and customer relationship management (CRM) (Szwarc, 2005). The balanced scorecards allow managers to take customer satisfaction into consideration as a key indicator of business performance, instead of as traditionally just monitoring financial measurements. CRM made it possible to, through improvements in IT technology, keep records of customer behaviour and thereby customize offers and communication. Today, many corporations have realised the importance of the customers and become customer-centric. When working with improving the satisfaction of our customers, one challenge is how to evaluate it. What methods should be used and what are the important measures.

Bäckman and Olin (1995) state that one should not stay with evaluating customer satisfaction. They mean that a satisfied customer is one whose expectations are met. If the expectations are low, it will not be enough to meet the customer's expectations. Instead, one needs to incorporate loyalty into the analysis.

When talking about repurchase intentions of customers, there are two terms that commonly appear: *loyalty* and *retention*.

> "Loyalty is about a customer's intention or predisposition to buy, but retention is the actual act of buying again. Retention is a stronger measure than loyalty. It can also be measured using internal company data, while loyalty usually has to be measured through market research surveys."
>
> Johnson and Gustafsson (2000)

An interesting feature about customer satisfaction and loyalty was found by Xerox corporation who, by analysing customer surveys including over 500 000 responses, found that loyalty rates were six times higher for customers who were completely satisfied (5 on a scale from 1 to 5) than for those who were only satisfied (4 on a scale from 1 to 5) (McCarthy 1997, see Szwarc 2005). Szwarc (2005) further elaborates on the results from McCarthy (1997) that satisfaction does not necessarily mean that customers are loyal and will stay with the company. It simply means that they do not have any negative feelings about the company providing the product and they do not have any special reason to leave them.

A significant contribution to the research on customer satisfaction was made by Noriaki Kano, who proposed a way of categorising different types of quality attributes. It was introduced in Kano et al (1984) and has since been discussed by many (see for instance Bergman and Klefsjö, 2003). Following Bergman and Klefsjö, the Kano model is based on three main categories of quality attributes: *attractive quality*, *expected quality* and *must-be quality*. The must-be attributes are things that the customer takes for granted and therefore will not ask for. In the case of a new car today, an air condition system is must-be quality. If the must-be attributes are not there, the customer probably would be very dissatisfied, but if they are, they would not create very high satisfaction.

The second category contains the expected quality attributes. These are things that one knows can differ between products and that one is likely to ask for. If they are there and good, they can create high satisfaction and if they are not there, they will create dissatisfaction. The fuel consumption of a truck could be an example of expected quality. The better it is, the more satisfied you get.

Finally, attractive quality attributes are things that are positive, but that we would not have thought about and therefore not asked for. These attributes are often new technologies or new applications, but they could also be simple product or services. Attractive quality on a modern car could be for instance a USB memory in the key or some new type of compartment, but it could also be a free car cleaning kit or pre-programmed radio stations. The absence of this kind of factors will generally not create dissatisfaction, but having them can create very high satisfaction and they have a great potential of being mentioned to acquaintances of the customer.

The different categories are visualised in Figure, where one can see how the satisfaction depends on the degree of fulfilment for the different categories.

Figure 3: The Kano model. Adapted from Bergman and Klefsjö (2003). Ideas originally proposed by Kano (1984)

2.5 Brand image

First of all, what is a brand? The concept is not very easily defined and most efforts to define it end up with some list of key elements or some general sentence that still does not say very much. I believe that Niall Fitzgerald, chairman of Unilever hit the spot when she said that a brand is "a storehouse of trust" (Kotler, 2003). I find it particularly accurate for the truck industry, where productivity is of very high priority and it is important to be able to trust that the truck will provide you with service as intended and not brake down. By staying with a brand that has proved itself before, the owners can minimise the risk of unexpected problems.

The concept of image can be seen in several ways and there are many concepts that fall close to it in our reference frame (such as reputation and impression). Marconi (2001) means that reputation and image are two different things. Image, he explains is a perception of a company or a product that a customer can acquire quite fast. Through heavy advertising, a highly promoted event, or a primetime appearance, one can deliver a message that creates an image among customers. A reputation, on the other hand, Marconi claims, can not be achieved solely through advertising and it takes a long time to foster. When it comes to destroying a reputation, however, the situation is different. Even a reputation that has been built up through a century of persistent efforts and good performance, can be reduced to nothing instantly (Marconi, 2001). There seems to be no general agreement with Marconi's differentiation between image and reputation; rather, image is commonly used to describe what Marconi defines as reputation. In this thesis, we choose not to separate the two, but let us remember the point that a brand image (reputation) can be destroyed instantly, a point that is well publicly accepted.

There seems to be a trend towards trying to appeal the hearts of the customers instead of their heads (see for instance Kotler, 2003 and Gobe, 2001). Kotler (2003) means that the traditional benefit marketing, such as saying that "Volvo is the safest car" have played out their role. He means that the competition has more or less caught up with the brands that used to be much better than others in some aspect. The new thing is to create feelings about a brand and sell it as a feeling or a lifestyle rather than just a product. We believe that this observation is correct when it comes to Business-to-consumer (B2C) marketing, but maybe not for Business-to-business (B2B) marketing. For the large truck fleets the purchases of new trucks are made by purchasing professionals and it seems likely that they are still appealed by promises about benefits, such as good reliability, low fuel consumption etc. However, for the owner/operators, especially in the cases where the owner of the truck sleeps regularly in the truck and spends most of his/her time on the roads, the truck manufacturer might be better of marketing the truck more through feelings and the lifestyle the brand can be associated with. We will get some input on this issue through the interviews carried out with fleet managers.

2.6 Priorities of truck customers

In an analysis made in a Master´s Thesis at Scania Trucks (Ivarsson & Johansson, 1996), one can see how Scania customers in Sweden rate different factors associated with problems and their resolution. The questions were asked through a questionnaire that was sent to 200 customers in 1995. As a part of the questionnaire, the customers were asked to rate six factors where a 1 is appointed to the most important factor and a 6 to the least important factor. 90 customers responded to that specific question. The mean ratings and the 95% confidence intervals for these factors are presented in Table. The presented means are estimations of the mean of the entire population for which the sample is expected to be representative, i.e.

Swedish owners of Scania trucks of type R143 and with axle configuration 6x2, running in long haul traffic. The confidence interval describes the interval in which we can expect the true mean of the population to lie if the customers in the sample are randomly picked from the population we want to analyse.

Table 1: The priorities of Scania R143 customers (Ivarsson & Johansson, 1996). The factors are translated from Swedish. For the factors in Swedish, please refer to Appendix 7

Factor	Mean	95% confidence interval of mean
Few breakdowns	1.99	1.73-2.24
Few repairs	2.61	2.40-2.83
Durable components	2.92	2.62-3.23
Low repair costs	3.32	3.00-3.64
Easy to repair	4.77	4.57-4.96
Easy to locate problems	5.39	5.16-5.61

2.7 The impact of quality on business importance

Several previous studies are concerned with the relation between quality and business performance. Curkovic (2000), provides an empirical study of suppliers to the three large American car manufacturers: GM, Ford and Chrysler. Through principal components factor analysis he first groups quality attributes into core factors. Founded on his empirical results as well as previous research he presents two core factors: product quality and service quality. Product quality incorporates four sub-factors, namely design quality, conformance to specifications, product reliability and product durability. Among these factors, product reliability and product durability are found to be the main contributors to the impact of the core factor product quality on business performance. Service quality consists of pre-sale customer service, post-sale customer support and responsiveness to customers. Both product quality and service quality are found to be positive contributors to business performance. This is shown for asset based (Return on assets pre- and post-tax) and investment based measures (Return on Investments pre- and post-tax) as well as market share based measures. Whereas the significant relations with market share measures seem to suggest that quality generally increases market share, the investment and asset based measures furthermore suggest that there are not costs incurred by quality efforts that substantially offset the gains produced by quality. These empirical results support the classic quality ideas that quality does not have a net cost, but rather improve financial performance.

In a study of many different industries, Buzzell and Wiersema (1981) looks at the association between change in market share and different potential causes. Results include, for industrial products, a correlation of 0.2 between change in quality and change in market share. Under the hypothesis that the true value of the correlation coefficient is zero, the probability of yielding this sample estimate of the correlation coefficient is calculated to be 1% suggesting that the association between market share change and quality change is significant.

I want to raise a warning flag though for being to confident that these results actually do anything more than suggest the mentioned implications. That there is a strong relation between quality and business performance does not prove that it is quality that is the cause and business performance that is the effect. There might be, to varying extents in different cases, an effect that firms that perform well have enough resources to produce high quality items. This reasoning does not mean that I do not believe that quality has a net cost, but building up competence, using better components, developing better processes etc. might require an investment. I believe that the results of these studies are indicative and to a high extent representative although the methodologies used limit the reliability of the results.

2.8 Optimal reliability

Improving reliability generally improves customer satisfaction, but whether efforts to improve reliability will improve the profitability of a manufacturer or service provider depends on the relation between costs of the efforts and the financial benefits of them. This relation is discussed by Chowdhury et al (2004), who build their reasoning on a graph, Figure 42, showing costs for the manufacturer or service provider and the customers respectively.

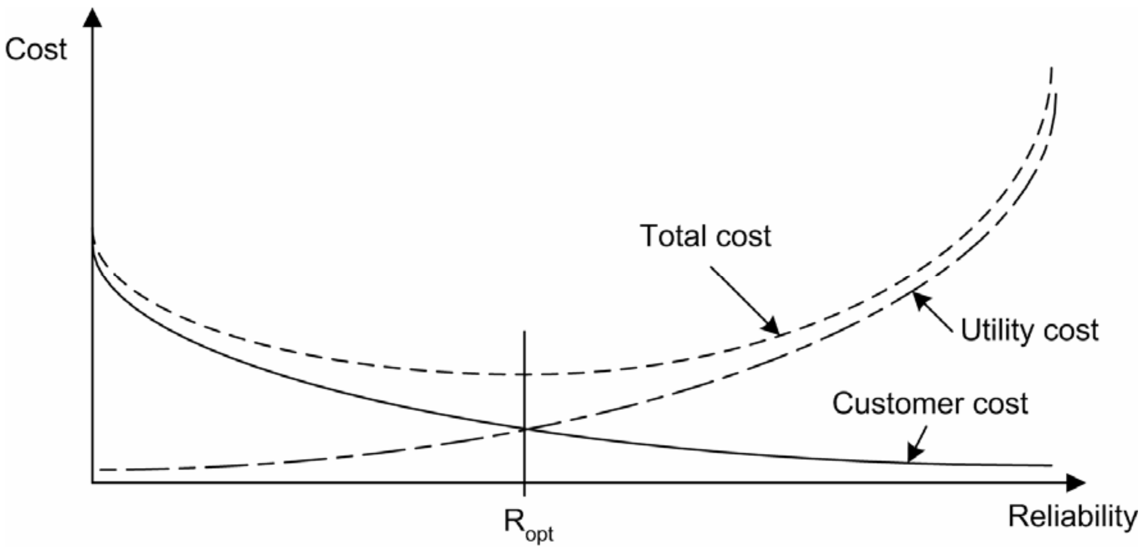

Figure 42: Reliability cost/reliability worth concept. Adopted from Chowdhury et al (2004)

The line referred to as customer cost shows how the cost for the customer that is incurred by failures depends on the reliability. The utility cost represents costs that are assumed to be necessary in order to achieve different reliability levels. The total cost is the sum of the two costs and according to Chowdhury et al (2004), this sum is what we need to minimize. The reliability corresponding to the minimum of the total cost is considered to be optimal reliability, marked in the figure as R_{opt}. The utility costs of different efforts are relatively easy to calculate. It is harder to know in advance how much they will improve reliability. Therefore, the relation between utility cost and reliability is anything but easy to estimate before the efforts are done and one can study the effects. While the model is concerned with how to find optimal reliability, one needs to estimate these connections before taking the decision whether to implement an effort. In order to estimate the customer costs we need to survey the customers and ask them to estimate their costs due to failures in product or service (Chowdhury et al, 2004 and Sullivan et al, 1996)).

This approach can be a good starting point when discussing optimal reliability. In order to fully understand what reliability that would be optimal for a specific product however, there are many factors that need to be investigated. This will only briefly be discussed in the general discussion section of the final report.

2.9 Durability and economic life

Durability is a quality dimension which I believe most people have a similar view of, but which is hard to formally define and therefore can be defined in many different ways. O'Connor (2001) defines durability as an item's ability to "withstand wear out mechanisms, such as fatigue, wear, etc". For non-repairable products this view gives a simple and convenient approach.

When looking at repairable products, the situation becomes more complex. Garvin (1984), defines durability for repairable products as "…the amount of use one gets from a product before it breaks down and replacement is regarded as preferable to continued repair." This view implies that the durability is to some extent based on decisions made by the user. The decision whether to repair a product or to buy a new one would, Garvin elaborates, be based on such factors as repair costs, personal valuations of time and inconvenience, downtime losses and relative prices. Taking the decisions made by the user into consideration, as Garvin does, is in my opinion very relevant. We must be aware that the period during which a product will be used is limited not only by technical aspects.

I find it necessary to use two different properties, one which I refer to as *durability* and one which I call *economic life*. I define economic life to facilitate my analysis of external factors that affect the choice regarding when to replace trucks. For practical reasons, I use the Volvo definition of durability, a definition from 2004 that has been agreed upon by Volvo 3P, Volvo Powertrain, Volvo Truck Corporation and Renault Trucks. This definition is specific for trucks and would need to be adjusted to be applicable also for other products.

Durability is the products ability to perform its required function under stated conditions of use, and under stated conditions of maintenance, until the failure of a component, which has a significant cost compared to the expected residual truck value, and which needs to be overhauled[12] *or replaced.*

Economic life is the period during which it is considered attractive, according to the owner's business conditions, to have the product in use.

The customer I refer to is the one who pays for the usage of the truck, whether it is a purchase or a lease. For a private customer the attractiveness can be decided by such factors as comfort, fuel consumption, if the customer feels proud of the truck etc. For commercial customers however, who comprise the lion's share of the truck market, the truck is a tool used for providing services that generate revenue. For them the economic life will be decided largely by the ability of the product to provide service at a profitability level that is competitive with the main alternative which is buying a newer truck. When it is considered smarter to replace it, the product most often still has a value, at least a selvage value, but the economic life is considered to be over.

The difference between the durability and economic life, in my view, is that durability defines how much use one can get until the cost of getting the truck running is substantial compared to the residual value, while economic life is how much use the an owner gets before he considers it to be better to replace it. Taking the decision to replace it does not necessarily require that it needs to be repaired. For instance, if a product becomes technologically obsolete, because there is a rapid technological development of new products, the product does not become less durable but its economic life might be shortened. Likewise, if you need to pay some fee to use an old product (for instant road tolls), that product does not become less durable, but its economic life is reduced. This view of these attributes implies that durability is largely technical. Economic life on the other hand is unique for each market, segment etc, while they all have different conditions. A product like a truck usually have

[12] Here "overhaul" refers to a major repair.

several users and owners and both needs and wants of the owners and users might vary greatly between different countries, conditions of use etc. When one user decides that it is not profitable to keep using the truck, there is often another user with other needs or a different business model that is willing to buy the truck. I therefore choose to view economic life as a property based on the circumstances each customer act within. Many potential limitations of economic life such as regulatory environment and needs of reliability are different between markets and segments, but often relatively homogenous within them. Thus, when the economic life is over in one market or segment, it may continue in another.

For a product like a truck, built up by a large number of components, it is a matter of interpretation what makes the truck to be “worn out”. If some small and cheap components fail, they can probably be replaced and the truck must not necessarily be taken out of use. If we only need to make small repairs to keep the truck in service for a long time, the truck can be considered as quite durable. However, if we make big repairs, we need to start thinking about whether it really is the same truck as before. If we always change the components that break without any limitations, the truck will of course always be able to provide service.

In order to measure durability of trucks we usually measure something like the “technical life” of the truck. We define some unit that we measure it in, for trucks the number of kilometres travelled seems most appropriate. We also need to define clearly what repairs we allow before we consider the “technical life” to be over.

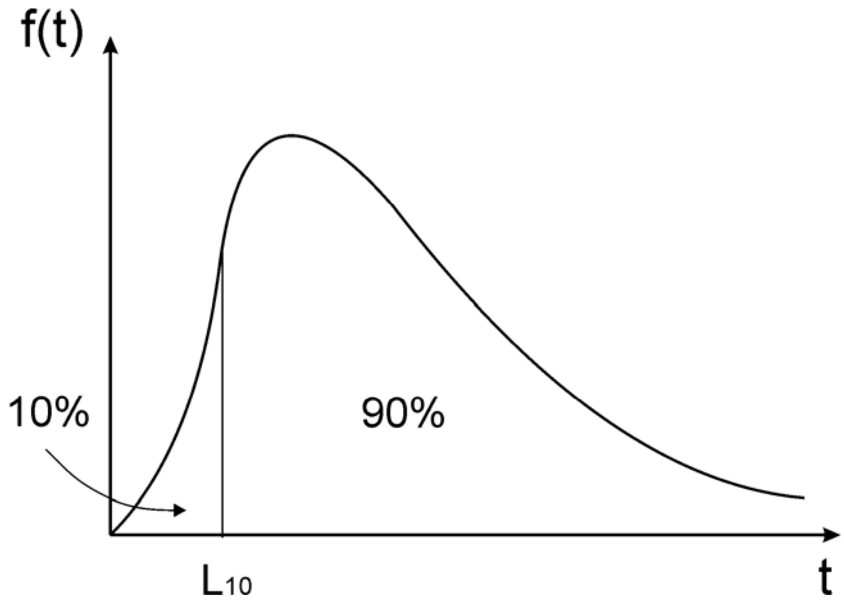

Figure 5: An example of a lifetime percentile curve

At Volvo Powertrain the durability of for instance an engine type is generally measured as a mileage at which a certain percentage of the engines in some population have failed. The measure can be applied also on a component level and it is stated as for instance L_{10} = 800 000 km, meaning that 10% of the units will fail before 800 000 km. Currently there are 12 components for the engine that are defined as "durability components". The components are based on the criteria that they should either demand a so called major overhaul or have a repair cost exceeding a certain amount. When at least one of these components fails, there is a durability failure and the current mileage is our durability measurement. While also a large number of small failures together can create high total repair costs for the customer and thereby cause the customer to sell the truck earlier than planned, there is currently a discussion in the company about having a durability definition that takes total repair cost into consideration.

2.9.1 Classic durability economics theory

Much of the early research that was done on economical aspects of quality was concerned with product durability and its impact on the profitability of manufacturing companies. However, most of it focused on the question of what durability a manufacturer should have in order to maximise profits in a monopolists market (see for instance Kleinman and Ophir, 1966, Swan, 1970).

Some models have also been made to explore optimal durability in a perfect market. Kleinman and Ophir (1966) conclude that an increased interest rate will decrease optimal durability but that the demand of service from the products has no effect on it. These results are though somewhat shadowed by the fact that Swan (1970) proved some assumptions and thereby conclusions in the article to be wrong.

A general feature of the research on durable goods theory is that it so far consists of numerous models, whose assumptions are often arguable and which limit the validity and applicability of the conclusions severely. One of these assumptions (employed in Swan, 1970 and Sieper and Swan, 1973 and criticised by Avinger, 1981 and Waldman, 2003) is that units of service are perfect substitutes in consumption irrespective of the age or durability of the product supplying the services. One can easily see how there could be a difference between the service supplied by a brand new truck and that of an old one. Driving comfort, safety, reliability and fuel consumption are only a few important aspects that could be age-dependent.

Planned obsolescence

One way to create planned obsolescence is to frequently introduce changes in style that increases the difference between new and used trucks (Waldman, 2003). With a bigger difference it is easier to increase the price of new units without having the old ones as competition that is limiting the price.

Adverse selection

The concept of adverse selection applied on the automobile second hand market was described in Akerlof (1970). It is founded on the assumption that there will always be an asymmetry in information when a used product is sold, meaning that the seller has more knowledge about the quality of the individual car than the buyer does. If we assume that the buyer only knows something about the group of cars defined by model, production year etc, this is what will define the price. The consequence is that the sellers that own cars with lower quality than the group average will have the most benefit from selling. The owners of cars with over average quality on the other hand have little incentive to sell while they probably will not be able to get a price reflecting the high quality. The essence of this market mechanism is thus that the majority of the second hand market turnover will consist of cars of relatively low quality and the asymmetric information will overall reduce the activity of the second hand market. The adverse selection, it should be noted, is not as applicable when there are warranties defining a minimum quality level. After the warranty period however, the mechanism is applicable as long as the buyer can not have as much knowledge as the seller about the individual item for sale.

If adverse selection is highly present, then the second hand market will be constrained, leading to a lower pricing of used cars (Hendel and Lizzeri, 1999). A lower second hand price and lower second hand market turnover will naturally effect sales of new goods, but the effect on the new car price from adverse selection is not absolutely clear. The lowered second hand price affects the new good price negatively, while it increases the cost of ownership for the buyer of the new car. On the other hand, a lower quality of the second hand market makes the used cars less substitutable for new ones which allows for higher pricing of new cars (Hendel and Lizzeri, 1999).

2.9.2 Potential implications of durability on business

The most relevant previous work that I have found on this topic is an article by Saleh et al (2006). In his article, Saleh discusses the issue of optimal durability from three different perspectives: the customer, the manufacturer and the society at large. For each interest party he lists a number of things that might be affected by the durability of a system and whether he considers it to be mainly positive or negative for that party. Saleh uses the case of a spacecraft as an example but the ideas are meant to be applicable in a more general sense. I have studied each of the proposed potential consequences of a change of durability and judged whether it may be relevant also for the case of heavy-duty trucks. While most of the consequences of extending the lifetime are reverse when shortening it, I am assigning consequences only to extending the design lifetime. In my view, these potential consequences depend on the actual durability rather than the design lifetime, but the expected value of the durability is the same as the design lifetime.

Potential implications to an extended design lifetime proposed by Saleh that I judge as relevant for trucks can be found in Table.

Table 2: Potential consequences of an extended design lifetime (A=Advantage, D=Disadvantage)

Customer's perspective	Manufacturer's perspective
A: Smaller volume of purchasing	D: Lower sales volumes
D: Increased risk of technological or commercial obsoleteness	A: Lower demand for the company to be technically up-to-date and attentive to the voice of the customer
D: Longer technology generations, slowing down improvements of technology based on feedback from customers[13]	D: Longer technology generations, slowing down improvements of technology based on feedback from customers[14]
A: Potentially smaller cost per operational day.	A: More opportunities for revenues from services.
	D: Extended warranty needed
	A: High durability magnifies reliability as a competitive advantages

I believe that most of these ideas are correct in a general sense. When applied to trucks though, it becomes a little more complex and requires further discussion and unfortunately a lot of information is needed to allow us to judge whether the above stated implications and other potential implications that I will present really apply. A simplified model of how I have come to view the issue of driveline durability is shown in the results section, while it is essentially conclusions based on internal interviews and general industry knowledge, although the ideas of Saleh (2006) are an integral part of the foundation.

[13] Saleh mentions as an advantageous effect of shortening the design lifetime that there are more frequent iterations of getting products to the market, getting feedback from customers and solving issues before an improved product is put to the market. It seems reasonable to assume that this would translate to the opposite if the design lifetime is extended.

[14] Same as above.

3 Methodology

3.1 Methodological considerations

The methods that are used for answering each research question are presented below.

3.1.1 Research question 1 (RQ1)

What market research measures of reliability available to the Volvo Group have the largest explanatory power for the customer satisfaction with reliability?

Secondary data from customer surveys is analysed comparing different brands as well as different years. Regression analysis is employed.

The surveys are purchased by Volvo from external suppliers and the data is considered to be internal information. Volvo has committed not to use the results for external communication. For this reason, no brand names are disclosed in connection to results from these surveys. Neither are the suppliers mentioned by name.

For the US market we have used data from a survey that covers eight brands in annual studies during the years 2002-2006.
The survey of the Western European[15] markets covers seven brands in annual studies carried out during the years 2000-2007.

The trucks that the data is confined to is, for the US, Heavy Duty Trucks, more specifically Class 8 vehicles, i.e. less than five-axle tractor[16]/single trailer for medium-haul delivery[17]. The vehicles are of model year two years prior to the year that the survey is carried out. For

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[15] For some years, the European study covers also some countries in Eastern Europe. To be able to track markets over time, we have only included countries that are covered all years. Thereby, the results we have used are only valid for Western Europe.
[16] See *Appendix 1: Abbreviations and Key* for a verbal description of a tractor truck and *Appendix 3: Basic types of trucks and trailers* for a picture.
[17] US Department of Transportation. *FHWA Vehicle Classes* (Electronic).
Available: <http://tmip.fhwa.dot.gov/clearinghouse/docs/accounting/appendix_e.stm> (2007-11-18)

Western Europe, the trucks are Heavy Duty Trucks with a Gross Vehicle Weight[18] of 16 tons or more that have been delivered during the last 6 - 24 months when survey is carried out.

The measures that we have looked at are presented in Table.

Table 3: Reliability measures

US	Western Europe
Problems per 100 vehicles	Share of trucks with problem(s)
Problems per 10.000 miles	Number of problems among trucks with problems
Times with downtime	Number of problems among all trucks
Total days with downtime	

An important thing to note is that all measures of problems are only approximations of the number of problems. What the measure of number of problems on the European markets really measure is the number of parts of the truck (transmission, cab etc.) that has had any problem. This probably describes the number of problems relatively well in most cases, but naturally fails to do so in cases where there are many problems in the same part in of a truck. The measures of the number of problems for the US market are more accurate, while parts of the truck are broken down to a very detailed level. However, not even these measures can take into account several failures of the exact same component. For simplicity reasons we will still refer to the measures as above.

For the US market, the measures are taken straight from the data provider, whereas for the Western European market we have created two new measures based on the available data. There are not a large number of questions in the European study that are related to reliability. However, in one question the interviewees are asked if they have had any problem with their truck the last 12 months. For those respondents that state that they have had some dysfunctional part, there is a list of parts of the truck for which the respondents answers if there has been any problem (parts such as engine, transmission, cab etc.). This question can not account for multiple problems in one part, but it is reasonable to assume that the number

18 “*The maximum loaded weight (including the vehicle itself, passengers, and cargo) for which a vehicle is designed, as specified by the manufacturer. Often used as a criterion of vehicle size for the purpose of legislation; the exact definition may vary depending on the jurisdiction*”.
DieselNet, *Glossary* (Electronic). Available: <http://www.dieselnet.com/gl-e.html> (2007-11-18)

of parts with problems can give a hint about the total number of problems. During the years, there have been some minor changes in the parts that are mentioned. The parts might be better described as categories of components and for some years the transmission category has been split up into several to facilitate more detailed analysis. To be able to use data from multiple years, we have used the lowest number of categories available any year and adjusted the data from other years to make it consistent. We thereby end up with nine categories, which thus is the maximum number of problem categories that any customer can have. First of all, we have summarized per respondent the number of categories for which that respondent has had any problem. If we then multiply the average number of problem categories for customers that have had some problem with the share of all customers that have had any problem we will get the average number of problem areas for any customer. This is done for the means per brand and year. The data is from studies carried out 2000-2007. We end up with the following measures.

X_1: The share of trucks with some dysfunctional part,

X_2: The average number of dysfunctional parts on those trucks that had some problem.

These two measures cover the reliability aspect in different ways and individually, both of them leave out a lot of information. We have therefore chosen to create the predictor

X_3: The average number of dysfunctional parts among all trucks,

where $X_3 = X_1 X_2$

Our response to study is

Y: Customer satisfaction with reliability

As mentioned above, multiplying X_1 and X_2 together gives us the average number of problem parts among all trucks in the sample. This factor is a much more rational measure of failure frequency than the two variables that comprise it. We have chosen to look at all three variables and see how their amounts of correlation to Y differ from each other.

The measures of satisfaction that we have looked at are customer satisfaction with reliability for the European market and customer satisfaction with reliability and dependability for the US market. While there seems to be no explanation to the respondents what dependability is, we assume that the answer very similar to how they would answer if the factor was just called reliability. The reason why we have chosen to look at customer satisfaction with reliability rather than overall customer satisfaction is that we are using regression analysis to evaluate how strong the connection is between reliability and satisfaction. We can always look at correlation, but in order to draw any conclusions about the relationship between factors, we need to have other things that we base our hypotheses on. Reliability and the customer satisfaction with reliability should rationally be closely connected and therefore we dare look at correlation and draw some cautious conclusions. If we would look at the correlation between reliability and the overall customer satisfaction, the relation would be expected to be weaker and the impact of other factors would be hard to single out. The same reasoning applies in the section where we have looked at the effects of changes in reliability on reliability image. A discussion regarding correlation and using it to rate the importance of different factors can be found in section 5.1.

While we have chosen to look longitudinally at several brands on the US and Western European markets respectively, there are two general things that we expect to see. They are, in to the terminology of Frees (2004):

- *Cross-sectional relation*
  When comparing brands, those that have more problems are expected to have a lower customer satisfaction with reliability.

- *Dynamic relation*
  When comparing means for several years for one individual brand, those years with more problems generally show a lower customer satisfaction with reliability than years with fewer problems.

We will map the cross-sectional relation between satisfaction with reliability and different reliability measures by presenting scatter plots, where we easily can compare different brand means with each other. The dynamic relation between satisfaction with reliability and different reliability measures is even more interesting, mainly because it gives us a hint about what measures that might best explain a change in satisfaction among customers. The dynamic relation is also necessary for providing us with input about which measures to look at in research question 2, where we only look at the measures that best "predict" the satisfaction with reliability.

For the analysis of RQ1, we use regression analysis and focus on correlation. I will present the univariate correlation coefficients (Pearson r) as well as multivariate partial correlation coefficients and semi-partial correlation coefficients for all brands collectively. The small number of data points makes it risky to look at each brand independently. If we would do so, we would have only one data point per year, yielding 5 data points for each brand on the US market and eight points per brand on the Western European market. On the US market we will look at four different measures of reliability (X's) and on the Western European market the corresponding number is three. Looking at brands separately could yield strong correlations between satisfaction and different measures of reliability that might not be important, simply because the number of correlation calculations is so high. My choice to look at all brands collectively is supported by Frees (2004), who states:

> "Intuitively, if there is a dynamic pattern that is common among subjects, then by observing this pattern over many subjects, we hope to estimate the pattern with fewer time-series observations than required of conventional time-series methods"

3.1.2 Research question 2 (RQ2)

How clearly are changes in product reliability on the US and Western European markets reflected in customer satisfaction with reliability? Is there a difference between improved reliability and worsened reliability?

The secondary data that we analyse is the same as for RQ1 in terms of brands, countries, years and vehicle types.

We treat changes in reliability as predictors and changes in satisfaction with reliability as responses and try to find out how the responses depend on the predictors.

This method is useful only under the assumption that reliability is a major cause of satisfaction with reliability. We find this assumption fair, even though we know that there are also other factors that affect the satisfaction with reliability, such as expectations, the ability of the service organisation to solve problems that occur etc. As usual with causality, we must be observant of the amount of explanatory power of the regression model and be careful with our conclusions. One question that we need to ask ourselves before proceeding is whether we should look at the absolute changes $x_2 - x_1$ and $y_2 - y_1$ or the percentage changes $\frac{x_2 - x_1}{x_1}$ and $\frac{y_2 - y_1}{y_1}$.

While we have no clear picture of which one to prefer, we proceed by studying both .

This analysis largely resembles the dynamic relation studied in RQ1. The main objective with this analysis, that distinguishes it from RQ1, is to see if we can show a difference between the strength of reactions to worsened reliability and to improved reliability. To compare the reactions, we plot all annual averages of reliability and satisfaction with reliability. We also perform a regression analysis, in which we separate all points that represent reliability improvements from those that represent reliability deteriorations. This yields two regression lines, whose slopes represent how strong reactions are considering the change in reliability. The two lines can be compared to see how reliability deterioration differ from reliability improvements and how well the lines are fitted to the data points decide how predictable the reactions are (assuming a linear model is appropriate)[19] and thereby how much we can say about them.

[19] One could argue that according to the Kano model, satisfaction would not depend linearly on reliability while it in most cases is a kind of must-be quality. However, with a limited satisfaction rating scale, as is the case in the source of my secondary data, I believe that the effect that those who experience very poor reliability are extremely dissatisfied is not seen and I believe that a linear model is the best approach.

3.1.3 Research question 3 (RQ3)

Different customers have different images of the ability of truck manufacturers to provide reliable trucks. How are these images affected by changes in truck reliability?
Is there a difference between reliability improvements and reliability deteriorations concerning the size of the effects that they have on image?

Secondary data from customer surveys is analysed longitudinally. Regression analysis is employed. The methodology is essentially the same as in RQ2. The only difference is that this analysis is concerned with image instead of satisfaction and for this reason the US market is not included in the analysis, while there is no such data included in the survey that we have acquired secondary data from.

3.1.4 Research question 4 (RQ4)

Can good service compensate for poor reliability?

Customer satisfaction surveys have been studied to see how the answers regarding authorised workshops and their performance are connected to answers regarding reliability and repurchase intention. Satisfaction with the workshop service is measured through the average of several service ratings. They are:

- Quality of service/repairs
- Availability of the workshop service when needed
- Solving the problem at the first time
- Total amount of time needed to bring you back to business
- Emergency breakdown services

The ratings are assigned equal weights.

Based on input from Swedish fleet managers, we have the hypothesis that it can be acceptable with quite a few problems as long as the service provided is good so that there are no major obstructions to business. This is tested quantitatively by comparing two groups in a large sample of truck owners. The members of one group are satisfied with reliability but dissatisfied with the workshop service. The other group is dissatisfied with reliability but satisfied with the service provided with the workshop.

3.1.5 Research question 5 (RQ5)

How is knowledge about the reliability and durability of truck models generated and diffused among truck customers? What importance does it have when making decisions about replacements of trucks?

Face-to-face interviews with seven Swedish customers have been carried out in order to get an input about how customers may act. The interview guide is presented in *Appendix 5: Interview guide (English)*.

The interviews were carried out during August and September 2007 with people who are managers and/or owners of truck fleets in Sweden. In each interview we have been 2-3 interviewers. Notes have been taken by hand and then compiled before we tried to find pattern in the responses and find ways of describing the views of the group or of subgroups when appropriate. Each interview lasted for 1.5-3 hours. We have carried out the interviews together with Stig Källberg and Per M Johansson of Volvo Powertrain.

The fleets were chosen on the basis that they all have had some previous contact with Volvo, for instance having test vehicles in their fleet. By choosing these customers, we probably got a sample that was more positive to Volvo than the entire population of Swedish fleets. It is unclear however how large that effect is and what implications it has on the results. Our sample exclusively contains fleets that consist almost completely of trucks from Volvo and Scania. This feature is however represented by quite a large share of the Swedish fleets. In 2004, 91.5 % of the Swedish market consisted of Scania's and Volvo's. Scania had a 45.2% market share and Volvo 46.3% (Andersson, 2005). We do therefore believe that the sample is an acceptable representation of Swedish fleets when talking about how people acquire knowledge and reason about reliability and durability. We can not, however, generalize conclusions from this sample and claim that they are valid also for fleets with very different representations of truck brands. Especially for questions regarding preferences, the sample will clearly be biased towards Volvo compared to the entire population of Swedish fleets and even more so when comparing to fleets in other countries. With such a small sample, we can say that this study gives a hint about how fleets with mainly Scania's and Volvo's might reason. A fact that makes this study relevant is that the questions that we were really interested in were about how the firms acquired knowledge about reliability and durability and about communication in the business in general, rather than which truck they preferred, so the representation of brands in the fleets is not necessarily a very important property. It was considered important to sit down and talk face-to-face with the respondents in order to get rich qualitative answers. Due to time constraints, this lead to a strict limitation of the sample size, but this issue had to be accepted. It was considered better to get rich information from a few respondents that could serve as input to future research rather than having less detailed information for a larger sample size.

3.1.6 Research question 6 (RQ6)

What are possible economical effects for Volvo of a changed durability of driveline components?

Based on the ideas from Saleh (2006), different potential implications of an improved truck durability are investigated through qualitative interviews within the organisation. Furthermore, the interviews provide input on how the market might respond to durability changes and what is needed for changes to be shown. Quite extensive studies of the regulatory environment and technological advances in the truck industry is needed to understand the conditions of businesses, so such an investigation is also carried out.

3.2 Secondary data analysis

Secondary data analysis deals with data that have been collected for some other purpose than the current research. In most cases the secondary data analysis is made by other persons than those who collected the data and made the primary analysis. Malhotra and Birks (2000) point out that secondary data can be an economical and quick source of background information and that primary data should not be collected until the available secondary data has been analysed. In Bryman (2004), some important benefits and limitations of secondary data are presented. The most obvious benefits are that analysing data that has already been collected instead of collecting it yourself saves time and money. If we look at the benefit from the viewpoint of this thesis, available secondary data will most likely also have a considerably larger sample and geographical coverage than would be possible in primary data generation. It might allow for longitudinal analysis, in cases where data has been collected in the same manner over a period of time and in some cases it allows for subgroup analysis and crosscultural analysis. Such dimensions are rarely possible through primary data in the framework of a Master's Thesis. In many areas there are secondary data of high quality but a main limitation is that the knowledge about the quality is often limited and there is no control of it. Other limitations are that the analyst lacks a familiarity with the data that one gets automatically when generating it. When large data sets are used, the complexity and extent might be overwhelming and in most cases there are some factors that one wishes to analyse that are not covered by the data (Bryman, 2004).

3.3 Causality analysis.

The nature of the research questions provide us with the task of judging the relevance of potential causes of satisfaction or dissatisfaction. One way to study causes and effects is to do causality analysis. However, this type of analysis can be misleading when performed wrongly and it should be kept in mind that it is very hard to get results that are very reliable. Before suggesting that there is a causal relationship between two variables we should test it with three criteria (Malhotra and Birks, 2000), that is: concomitant variation, time order of occurrence and elimination of other possible causal factors. These criteria are necessary but not sufficient to prove causality. They can however, together with a good understanding of the system under study, provide a basis for suggesting that a certain causal relationship seems likely to be correct. To describe the three criteria we will exemplify with the hypothesis that the reliability of trucks is influencing customer retention rate positively.

Concomitant variation means that the variables vary together in the way that the hypothesis suggests. In our example it would mean that brands or models with a high reliability would have higher customer retention than those with low reliability. To base causality merely on association is unacceptable and warnings about this are found in most textbooks on the subject.

Regarding the time order of occurrence, we can say that per definition, a cause must happen before or simultaneously as its effects. If, in our example, the customers' retention rate seems to change first, where after the reliability changes in the same direction, we should be very suspicious about regarding reliability as the cause. Instead it is likely that there is something else causing the changes in reliability. Here the third criterion comes into the picture. It is not enough that brands with higher reliability also have higher retention rates and that the changes in the two variables occur simultaneously. We must also rule out that there are other variables that might be causing the behaviour of the hypothesised effect. Perhaps it is so that all service technicians have regular training and that their service towards both trucks and customers is better just after the training, leading both to higher reliability of the trucks and higher customer retention. This last criterion is often the hardest one to fulfil, while most variables are affected to some extent by a large number of other variables. In an experiment, one can have control of what is thought to be the most relevant variables and thereby see the effect of the studied one separately. There is always a risk though that one misses important variables and this makes causality impossible to prove. In the case that one can not make experiments, but instead is analysing secondary data, the last criterion poses a great obstacle. It is very hard to know what variable that might have changed during the course of the data sampling. If doing a longitudinal study, unknown changes might occur over time and if comparing different groups of people, there might be other things that the people within the groups have in common than the dimension that is studied and when one does not have all the details of the sample, it is impossible to detect them. The conclusion we can draw about analyzing causality is that we can never fully fulfil the conditions and therefore we can never strongly support a hypothesis only by correlations, much less could we ever prove it. As a source of support of a logical reasoning or a hypothesis supported also by other means it could have a value though.

3.4 Regression analysis

The most commonly used regression model is probably the linear least-squares regression. It is based on the following theoretical description (Anscombe, 1973).

The given number pairs (x_i, y_i) are related through the expression

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \qquad (i = 1, 2, \ldots, n)$$

Where β_0 and β_1 are constants and the errors ε_i are independently drawn from a "normal"(Gauss-Laplace) probability distribution with mean zero and constant variance.

For β_0 and β_1, we calculate the estimates b_0 and b_1 and get the regression equation (Anscombe, 1973)

$$\hat{y}_i = b_0 + b_1 x_i$$

and the residuals

$$e_i = y_i - \hat{y}_i .$$

Minimising the sum of squares of the residuals is guiding the calculations of the estimated constants.

3.4.1 Multivariate regression analysis

There are several ways of describing the contribution of each independent variable in multivariate regression analysis. The first thing one might do is to start with simple univariate analysis and look at the Pearson product moment correlation coefficient, sometimes referred to simply as the *Pearson r* which describes the degree to which two variables vary linearly together. If we look at two variables X and Y, the Pearson r is defined as (Chatterjee, Hadi and Price, 2000, p.24):

$$r_{XY} = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{y_i - \bar{y}}{s_y} \right) \left(\frac{x_i - \bar{x}}{s_x} \right)$$

The Pearson r describes how variation in one of the variables is related to variation in the other. The values range from -1 to 1, where both -1 and 1 indicates perfect correlation. If the coefficient is negative, it means that an increase in X will happen simultaneously as a decrease in Y and vice versa. If the correlation is zero, the two variables have no common variation at all.

When looking at relations between more than two variables, the Pearson r is not sufficient. We must expand our set of tools to incorporate partial and perhaps also semi-partial correlation coefficients. The meaning of these coefficients can be visualised with the ballantine of two independent variables X_1 and X_2 and one dependent variable Y, as seen in Figure (Cohen et al, 2003). The circles represent the variation in the variables. The areas that are covered by more than one circle represent variation that is common between those variables. For instance, b represents the common variation of Y and X_2 and c represents the common variation of all three variables.

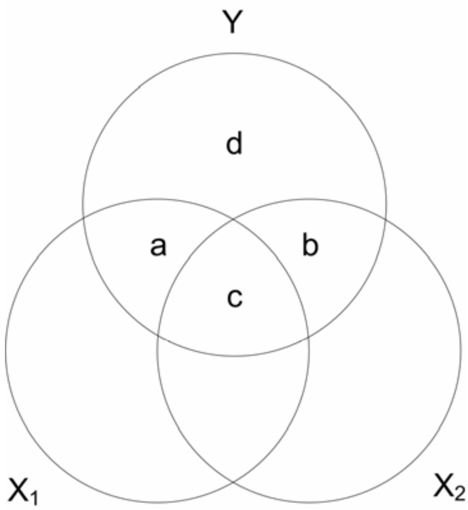

Figure 6: Ballantine for X_1 and X_2 with Y.
Adapted from Cohen et al (2003, p. 72)

The square of the Pearson correlation coefficient, r^2, is the proportion of its variation that a variable shares with another variable. For X_1 and Y this would be the area

$$\frac{a+c}{a+b+c+d}.$$

The squared partial correlation coefficient of X_i, pr_i^2 is the proportion of Y's variation that is not accounted for by other independent variables but accounted for by X_i. Thus

$$pr_1^2 = \frac{a}{a+d}$$

We can obtain a general expression for the partial correlation coefficient of X_i by starting from the ballantine. Our area $a+d$ is actually the residuals obtained when regressing Y on all X's except X_i. Similarly, the variation in X_i that is not shared with any of the other X's equals the residuals obtained when regressing X_i on all X's except X_i itself. The partial correlation coefficient can then be calculated by taking the correlation between the two sets of residuals.

By taking the residuals from the regressions we have excluded all the variation that is covered by other X's and by the last correlation calculation we will find how much of the variation in Y that is not explained by other X's that can be explained by X_i. Thus (Cohen et al, 2003, p. 85):

$$pr_i = Cor\left(Y - \hat{Y}_{12..(i)..k}, X - \hat{X}_{i.12..(i)..k}\right),$$

where $\hat{Y}_{12..(i)..k}$ is Y regressed on all X's except X_i and where $\hat{X}_{i.12..(i)..k}$ is X_i regressed on all X's except itself.

The semi-partial correlation coefficient sr_1 of X_1 describes the proportion of all variation in Y that is accounted for uniquely by X_1.

$$sr_1^2 = \frac{a}{a+b+c+d}$$

The semi-partial correlation coefficients can be obtained through

$$pr_i = Cor\left(Y, X - \hat{X}_{i.12..(i)..k}\right),$$

where $\hat{X}_{i.12..(i)..k}$ is X_i regressed on all X's except itself.

If not interested in the sign of the semi-partial correlation coefficients, they can also be calculated from the multiple correlation coefficient R^2 that describes how much of the variation in Y that a group of X's can account for together. The squared semi-partial correlation coefficient sr_1^2 equals the increment in the multiple correlation coefficient that is obtained when adding X_i to the regression model (Cohen et al, 2003, p. 84).

$$sr_i^2 = R^2_{Y.12...i...k} - R^2_{Y.12...(i)...k}$$

Having a large number of predictors generally make the regression model seem more powerful. The reason for this is that any predictor would have some correlation with the response, even if there might be no connection between the variables. This correlation would then come from random variation and can be adjusted for. There is also a risk that two variables seem to have a strong connection, but where there correlation exists because both variables vary similarly with a third variable. A common case is that two variables vary similarly with time and when they are plotted against each other it appears as if they had some connection. Such risks can only be avoided by always looking for rational explanations to covariation.

We will use the following adjustment formula to take the number of predictors into account (Cohen et al, 2003, p. 84):

$$\tilde{R}_Y^2 = 1 - (1 - R_Y^2)\frac{n-1}{n-k-1},$$

where n is the number of data points and k is the number of predictors in the model.

3.5 Longitudinal data

A basic feature of longitudinal data is that it is data of something that is studied over time. What makes it different from the commonly employed time series data is that it involves a number of subjects rather than just one. This allows us to study both dynamic aspects, i.e. the development over time and cross-sectional aspects, i.e. differences between subjects (Frees, 2004).

3.6 Interviews

3.6.1 Structured interviews

The main point of a structured interview is that the interviewer should follow a predestined schedule (Bryman, 2001). All respondents are supposed to get the same questions and to get the questions in the same way.

3.6.2 Unstructured interviews

An unstructured interview is as the name suggests not as strict as a structured one. Here there is no exact schedule for asking questions. Instead the interviewer has a rough list of topics or at least an idea of the topics that he/she wants to discuss. The interview is made up of open and broad questions and follow-up questions on the responses. The benefit compared to a structured interview is that the interviewee gets more space to reveal his/her opinion and the data will be richer. (Bryman, 2001)

3.6.3 Semi-structured interviews

When conducting a semi-structured interview, the researcher has a list of questions that will be used. The order of them is not definite, but all of the questions will be asked to all the respondents. The questions are generally open and there is some flexibility for the interviewer to add follow-up questions that are connected to topics discussed in other questions (Bryman, 2001). The interviewer may assist the respondent in understanding the questions and may order the questions as is considered suitable. The benefits of semi-structured interviews are that one can get rich answers, while the respondents are given open questions, but at the same time, the answers are largely comparable between respondents, while the same questions are asked and in similar ways.

We have chosen to carry out the interviews in a semi-structured manner. We want to have some questions that are answered by all respondents to allow for comparisons. At the same time, We wish to let the respondents speak freely, which a relatively unstructured approach can facilitate and we want to be able to ask follow up questions whenever the respondents give very interesting answers that we wish to have elaborated.

4 Results

4.1 Measures of failure frequency and unscheduled downtime (RQ1)

Which measures of problem frequency and unscheduled downtime that are found in customer surveys have the highest ability to predict the variation in satisfaction with reliability of the complete vehicle?

Section summary

US

When looking at stated reliability and corresponding ratings of satisfaction it seems that the number of times that the truck experiences downtime is a more relevant measure than measuring the number of problems per time or distance or the total amount of downtime in days. Our secondary data analysis gives these results for trucks that are up to 2 years old, but research at Scania suggests that the conclusion that the amount of downtime is more important than the number of problems is valid also when the trucks are about 6 years old. The Scania study looks at Swedish customers, but we see no reason why these results could not hold for most markets.

The connection between reliability measures and the customer satisfaction with reliability seems to be relatively strong for all measures except the number of problems per 10.000 miles. Furthermore the customers of some brands are more easily satisfied than those of other brands. The study also measures the expectations of customers relative to other brands on the market. This reveals that customers that expect more of their brand also seem to be more satisfied with reliability than customers who expect less for comparable reliability levels.

Western Europe

The measures of reliability seem to have a quite poor ability to predict satisfaction with reliability. The average number of problems among all trucks, a measure we have created from the measures in the original survey is the measure that seems to have the strongest explanatory power for reliability satisfaction. Among the other two measures, the share of trucks with problems has a stronger correlation with reliability satisfaction than the average number of problems among trucks with problems.

With a few exceptions, brands with a good reliability image generally get higher satisfaction ratings for reliability than others, even when having the sane reliability levels.

4.1.1 US market

The study of the US market that I have chosen to analyse presents two measures of failure frequency for the complete truck: Problems per 100 vehicles during the last 12 months (in this report referred to as “Problems per hundred vehicles”) and Problems per 100 vehicles per 10.000 miles (in this report referred to as “Problems per 10.000 miles”). When comparing between brands, none of these measures makes all brands justice. Trucks that travel long distances generally do so on relatively good roads and therefore they get a low failure frequency per distance unit. Vehicles that travel shorter distances often do so on less good roads and in tough conditions meaning that the failure frequency per distance is higher. When looking at problems per vehicle during a specific time period, trucks that have travelled long distances during that period tend to have had more failures than trucks travelling shorter distances. Two other relevant measures included in this study are concerned with the amount of downtime experienced due to defects. One factor measures the number of times of unscheduled downtime that the respondent has had during the last 12 months. The other measures the total number of days of downtime during the same period.

The data, which consists of annual averages for the years 2002-2006 for eight different brands gives us 40 data points to base our calculations on.

The P-values describe the probability that the number we have calculated have arisen only from random variation.

In a regression model, the response is the variable that one is trying to express as a function of other variables. Variables that are intended to explain the variation in the response are called predictors. An important point here is that we use this kind of modelling in order to see how useful the measures of reliability are. If we do not have perfect correlation between the customer satisfaction with reliability and the measures of reliability, we need to be aware of that the gap is not only explained by the inability of the failure frequency measures to represent the real failure frequencies; it is likely that the actual failure frequency is not enough to explain customer satisfaction with reliability. Things as expectations and earlier experiences might also affect the satisfaction.

The predictors are denoted as follows:

X_1 = Problems per 100 vehicles

X_2 = Problems per 10.000 miles

X_3 = Times with unscheduled downtime

X_4 = Days of total unscheduled downtime

Cross-sectional relation

The following scatter plots of the cross-sectional relations between satisfaction with reliability and the studied reliability measures provides interesting input regarding differences in expectations of customers and how well different brand have deserved their satisfied or unsatisfied customers. The data points refer to brand means for the period 2002-2006. Due to secrecy reasons, the brand names can not be disclosed. Just by looking at the scatter plots (Figure-Figure), we can see that the measures "Problems per hundred vehicles", "Times of unscheduled downtime" and "Days of downtime" have relatively strong cross-sectional relationships with satisfaction with reliability. A brand with few problems and little downtime generally has more satisfied customers. The measure "Problems per 10 000 miles" on the other hand shows a more random pattern where there is little connection between the number of problems that a truck of a certain brand has per distance and the satisfaction level of its customers. For instance, brand US6, with twice as many problems per distance as Freightliner has a significantly higher customer satisfaction with reliability than the latter. That the picture is quite different when looking at problems per distance or per time unit tells us that there is a large variation between the brands in annual distance travelled. This can also be confirmed through descriptions of the samples, provided by the supplier of the data. It seems that, when comparing brands, the number of problems per time is more relevant than the number of problems per distance, which might imply that customers travelling longer distances do not accept a higher number of problems in a certain time period than customers travelling a shorter distance. For the measures that are defined by a time period, i.e. all except "Problems per 10.000 miles", we can identify some brands whose customers are generally less demanding and some that are more demanding. The brands that are located above the regression line, have customers that are more satisfied than those brands that are locate below, when looking at the same reliability for both groups.

The study also measures the expectations of customers relative to other brands on the market. This reveals that customers that expect more of their brand also seem to be more satisfied with reliability than customers who expect less for comparable reliability levels.

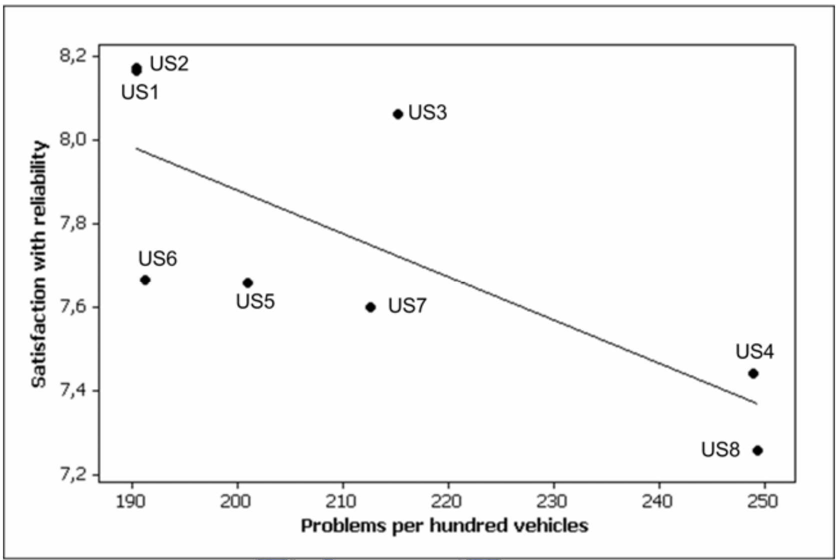

***Figure7**: Cross-sectional relation between Y, customer satisfaction with reliability and dependability and X_1, Problems per 100 vehicles.*

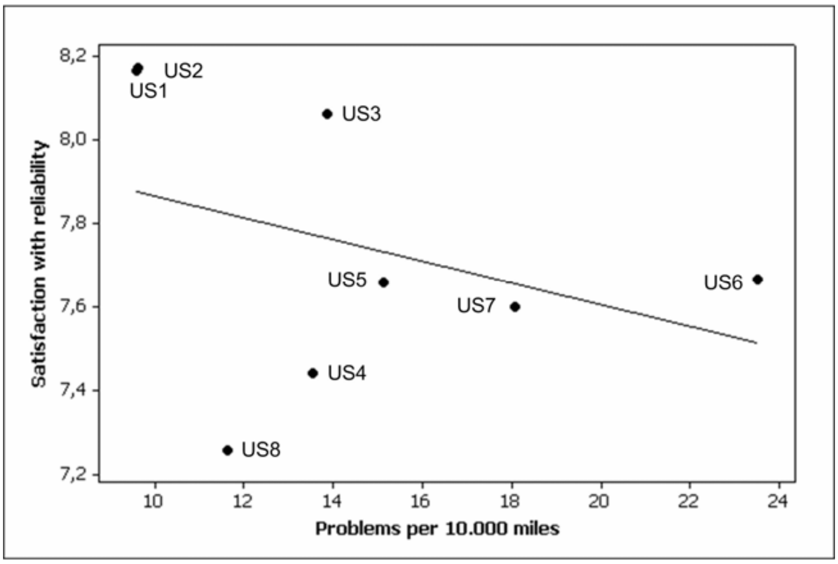

***Figure 8:** Cross-sectional relation between Y, customer satisfaction with reliability and dependability and X_2, Problems per 10.000 miles.*

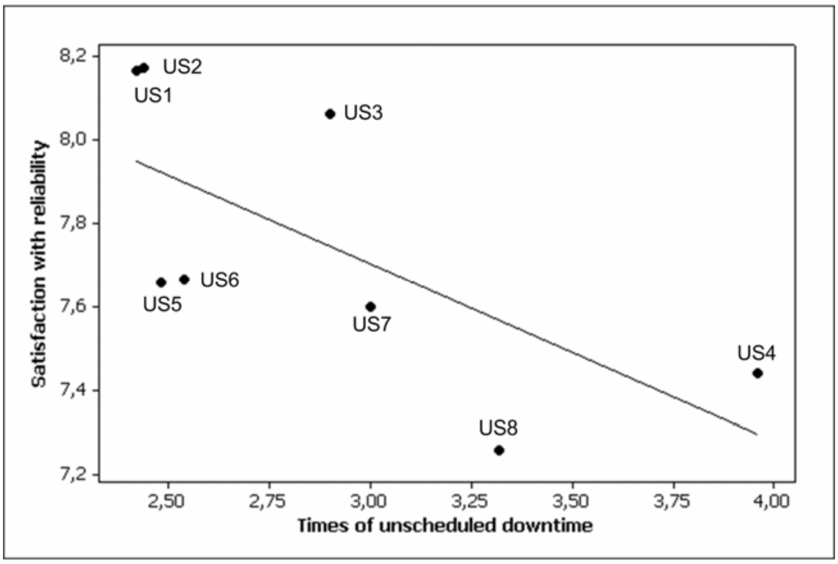

Figure 9: *Cross-sectional relation between Y, customer satisfaction with reliability and dependability and X_3, Times with unscheduled downtime.*

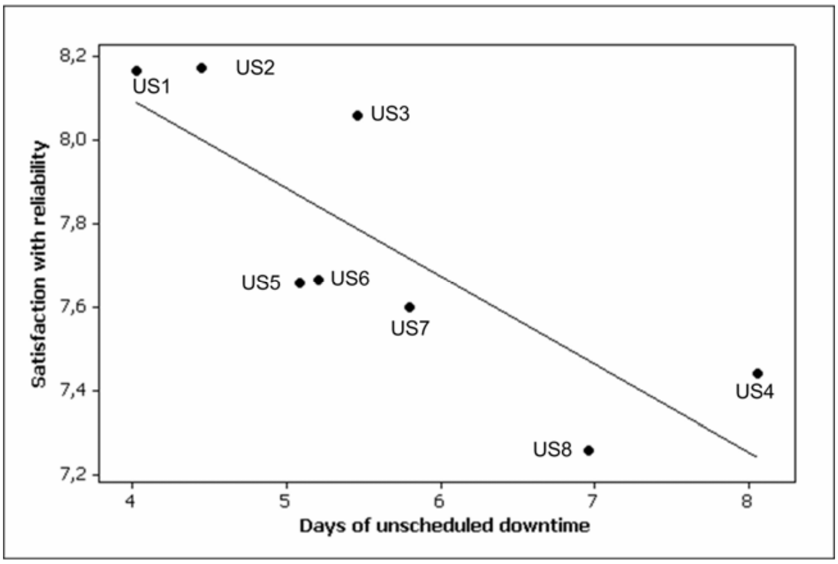

Figure 10: *Cross-sectional relation between Y, customer satisfaction with reliability and dependability and X_4, Days with unscheduled downtime.*

Dynamic relation

The dynamic relation is studied by offsetting all annual brand averages by the grand brand mean, i.e. the brand mean that we get from taking the mean for all years together for each respective brand. This means that we compensate for the cross-sectional relation and the figures that we get reflect how the different reliability measures are related to the satisfaction with reliability when looking at development over time. The scatter plots (Figure-Figure), provide a first impression of the strengths of the relationships between measures and the satisfaction with reliability and dependability, our response. The coefficients, presented in Table-Table, provide a more precise description of the relations.

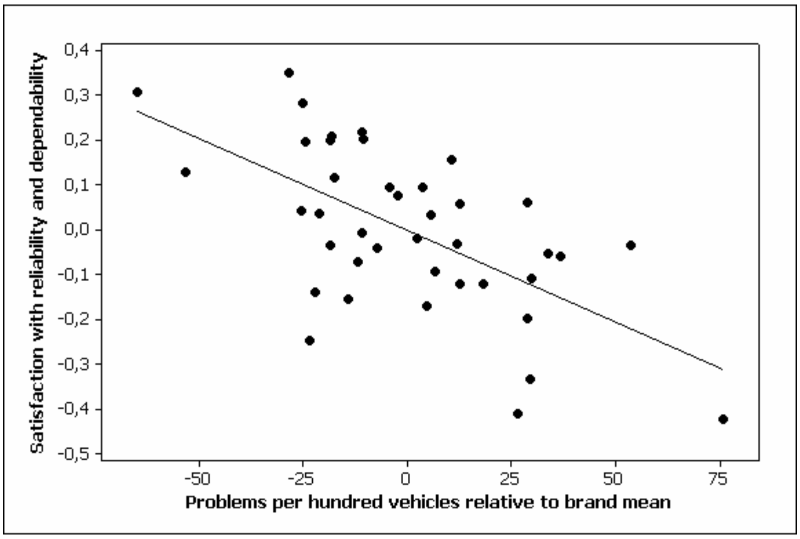

Figure 11: Dynamic relation between customer satisfaction with reliability and dependability and problems per hundred vehicles. Each data point represents a specific brand and year relative to the brand mean for all years.

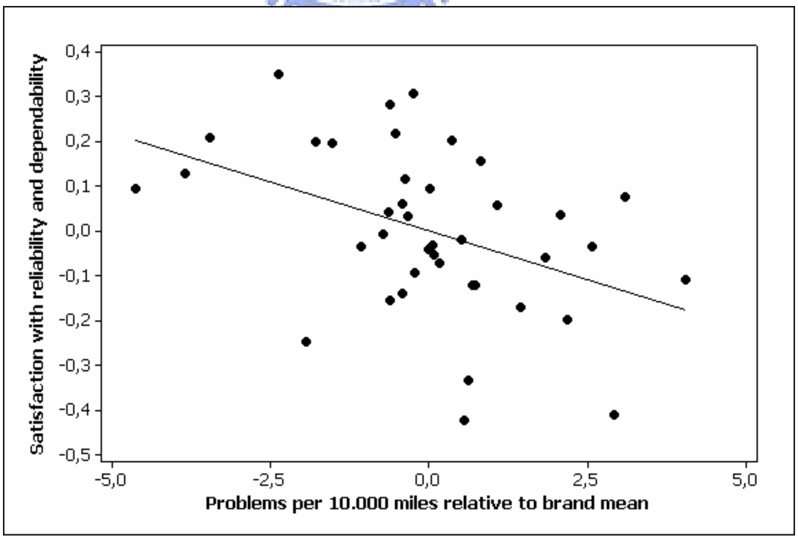

Figure 12: Dynamic relation between customer satisfaction with reliability and dependability and problems per 10.000 miles. Each data point represents a specific brand and year relative to the brand mean for all years.

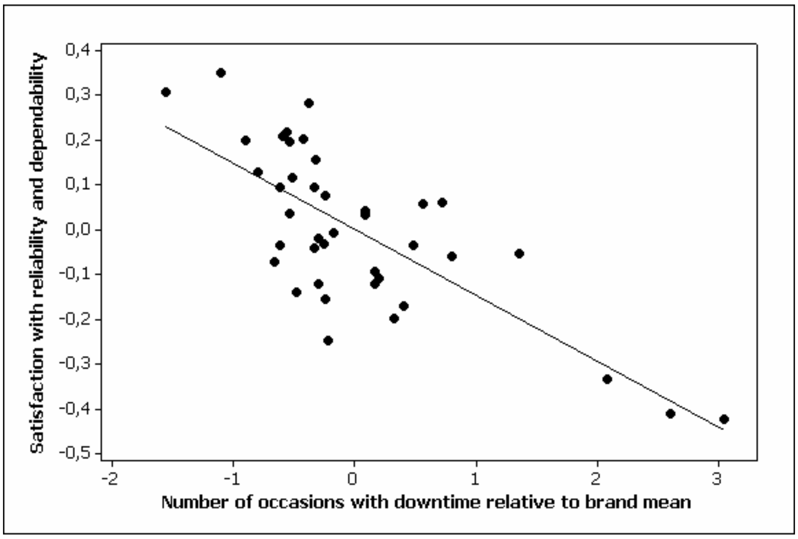

Figure 13: Dynamic relation between customer satisfaction with reliability and dependability and times with downtime. Each data point represents a specific brand and year relative to the brand mean for all years.

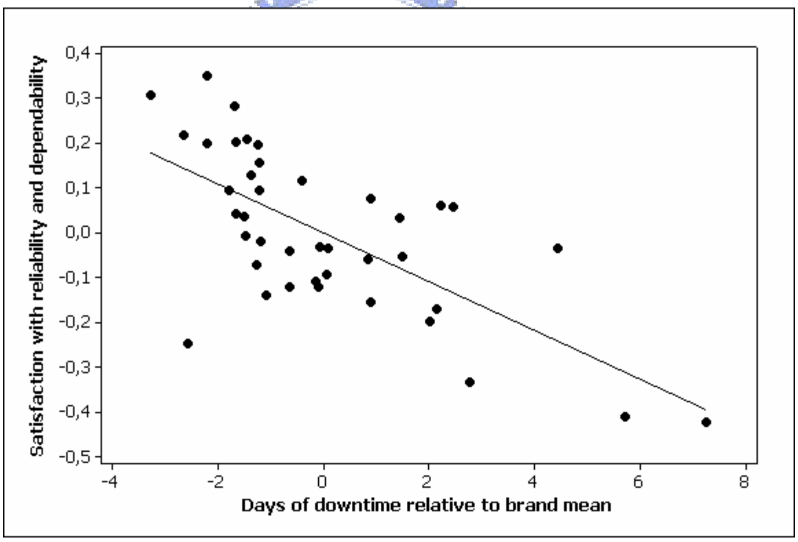

Figure 14: Dynamic relation between customer satisfaction with reliability and dependability and days with downtime. Each data point represents a specific brand and year relative to the brand mean for all years.

Looking at the coefficients in Table, we can first note that the number of times with unscheduled downtime seems to have the strongest relationship with the satisfaction with reliability. As we have previously mentioned we must be very careful not to believe that a strong correlation implies causality. In this case, however, we have a very rational reason to believe in causal relationships. We expect that satisfaction with reliability depends heavily on the actual reliability. Factors that might limit the correlation we see are other causes of satisfaction, like expectations and previous experiences, but also inaccuracies that come from the quantification of experiences of people; Respondents with the same experiences might rate factors differently. Returning to the coefficients, we can continue our analysis by noting that the number of times with unscheduled downtime shares a considerable amount of variation with Y; Variation of which a considerable portion is not shared with the other predictors. In more qualitative terms, we may say that it seems that the number of times with unscheduled downtime is a powerful measure of the kind of reliability that is important to customers. The number of problems is important, and it is more relevant to measure it per time period than per distance, but what really matters is if the problems create downtime or not. As we can see in the lowermost entry in Table, the simple correlation coefficient between X_3 and X_4 is almost 0.9, which is relatively high, suggesting that X_3 and X_4 are strongly connected. The explanation is probably that the total number of days of downtime is an effect of the number of times down. The amount of downtime varies from time to time, but in general, the more occasions with downtime, the longer the accumulated downtime is. It seems that the amount of downtime each time is less important than the number of times itself. It might be so that most unscheduled breakdowns with downtime causes major obstructions to business and in many cases one has quite soon after the breakdown either managed to get hold of a replacement vehicle or the problem has already caused consequences for the receiver of the goods. In either of those two cases, it might not make such a big difference if the truck is down for a half day or a full day. An exception to that would of course be if one can not replace the dysfunctional truck and one has to cancel or delay several transports while waiting for the truck to get fixed. Each transportation company has their own operating conditions and the consequences of breakdown vary greatly between firms. Therefore it is hard to conclude why the number of times down in general on the US market seems to have a greater effect on the satisfaction of customers than does the amount of downtime measured in days. Also the difference in correlation is not extremely large, so one should not trust too much that there is actually a difference in the importance of these factors, measured as the correlation between the measures and the measure of satisfaction, which in itself has many sources of inaccuracy.

One thing that is important to remember is that, as mentioned earlier regarding methodological reliability, these studies cover only trucks that are relatively new and most of them are covered by warranties from the manufacturers. Therefore, it is understandable that problems that do not cause unplanned visits to the workshop and that might not even incur a repair cost, will not be a very big issue. As the truck get older, the warranties cease to be valid and all repair costs is on the owner. There is one other circumstance that might also explain why problems causing breakdowns is worse than problems that can be solved at planned workshop visits. Many owners of trucks have service contracts, through which they have an agreement with the manufacturing organisation where they pay some monthly fee, but instead do not have to pay for service or repairs (the coverage of the contracts may vary). Naturally, as in the case of the warranty periods, if covered by a service contracts that protects you from repair costs, minor repairs that do not cause breakdowns might be acceptable, at least when comparing to breakdowns, causing major obstructions to the business.

This picture that we get that it is the problems causing breakdowns that are the most important is supported by the study of Ivarsson and Johansson (1996) for Scania. That study can provide important support for the hypothesis that it is really the breakdowns that matter the most and that measuring them is more important than measuring just the number of problems. Furthermore, an advantage for us with their study is that it is made on a totally different part of the truck lifetime. Ivarsson and Johansson's sample contains 90 responding customers from a group of 200 customers asked for input. All customers own Scania trucks of model R143 6x2 delivered in 1990, running in long-haul traffic. Thus, when their study was performed in 1996, the trucks had been in service for 6 years. Their sample was confined to Swedish owners and only heavy trucks running in long-haul traffic. However, we believe it to be rational to believe, even if it can not be confirmed, that their results hold for most markets.

Table 4: Correlation coefficients of dynamic relation between measures of reliability and measured customer satisfaction with reliability

Predictor	r_{Yi}	r_{Yi}^2	pr_i	pr_i^2	sr_i	sr_i^2
X_1, Problems per 100 vehicles	-0.618	0.382	0.043	0.00185	0.028	0.000784
P-value	0.000		0.793		0.865	
X_2, Problems per 10.000 miles	-0.432	0.187	-0,179	0.0320	-0.118	0.0139
P-value	0.005		0.270		0.469	
X_3, Times with unscheduled downtime	-0.750	0.562	-0.424	0.180	-0,304	0.0924
P-value	0.000		0.006		0,057	
X_4, Days of total unscheduled downtime	-0.684	0.468	-0,044	0.00194	-0,029	0.000841

P-value	0.000	0.788	0,861

Table 5: Correlation coefficients (Pearson r) between the X's.

	X_2	X_3	X_4
X_1	0.543	0.802	0.801
P-value	0.000	0.000	0.000
X_2		0.423	0.502
P-value		0.007	0.001
X_3			0.874
P-value			0.000

Table 6: Multiple correlation coefficients

Unadjusted	Adjusted
$R^2_{Y.1234} = 57{,}9\%$	$\tilde{R}^2_{Y.1234} = 53{,}1\%$
$R^2_{Y.234} = 57{,}9\%$	$\tilde{R}^2_{Y.234} = 54{,}3\%$
$R^2_{Y.134} = 56{,}5\%$	$\tilde{R}^2_{Y.134} = 52{,}9\%$
$R^2_{Y.124} = 48{,}7\%$	$\tilde{R}^2_{Y.124} = 44{,}4\%$
$R^2_{Y.123} = 57{,}8\%$	$\tilde{R}^2_{Y.123} = 54{,}3\%$

4.1.2 Western European market

The following analysis is based on data from a survey of Western European markets performed annually during 2000-2007. There are seven brands included in study and these seven brands are all included in my analysis. While we for this analysis use means per brand and year, there are 7*8=56 data points.

The measures that are compared are 'Share of trucks with problem(s)', 'Number of problems among trucks with problem(s)' and 'number of problems among all trucks'.

Cross-sectional relation

The cross-sectional relations are here represented by scatter plots of the brand means (Figure-Figure). Due to secrecy reasons, the brand names can not be disclosed. We can see that for all three studied measures, there is strong correlation between predictors and response. The closeness to the regression line in Figure is striking, but we have no explanation to why the correlation between the average number of problems among trucks with problems and the satisfaction with reliability is stronger than the other correlations. One answer might simply be that it is a random effect. Looking at many scatter plots is always dangerous. Sooner or later it becomes likely to see something unlikely, while there are so many unlikely events that would be seen if occurring. We stay with concluding that when comparing brands, it seems that the satisfaction of customers is largely based on the performance of the trucks in terms of failure frequency. Some customers have higher expectations than other and some are harder to satisfy than others, which might explain why some brands seem to get a little more satisfaction for their reliability level than other at the same reliability level get. EU1, EU2, EU3 and EU5 are brands whose customers in average have a relatively high satisfaction reliability compared to the actual reliability. EU 4, EU6 and EU7 on the other hand have to achieve better reliability than others to get satisfied customers.

With a few exceptions, brands with a good reliability image generally get higher satisfaction ratings for reliability than others, even when having the same reliability levels.

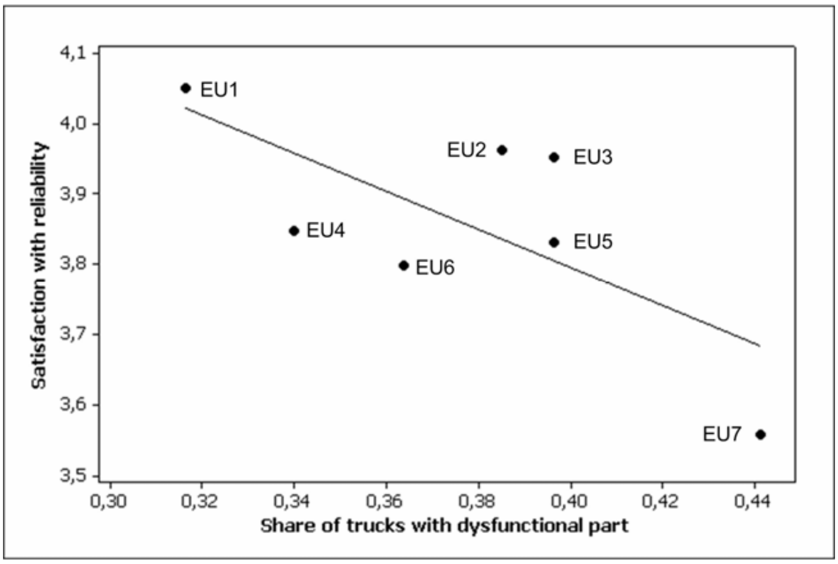

Figure 15: *Cross-sectional relation between customer satisfaction with reliability and share of trucks with dysfunctional part*

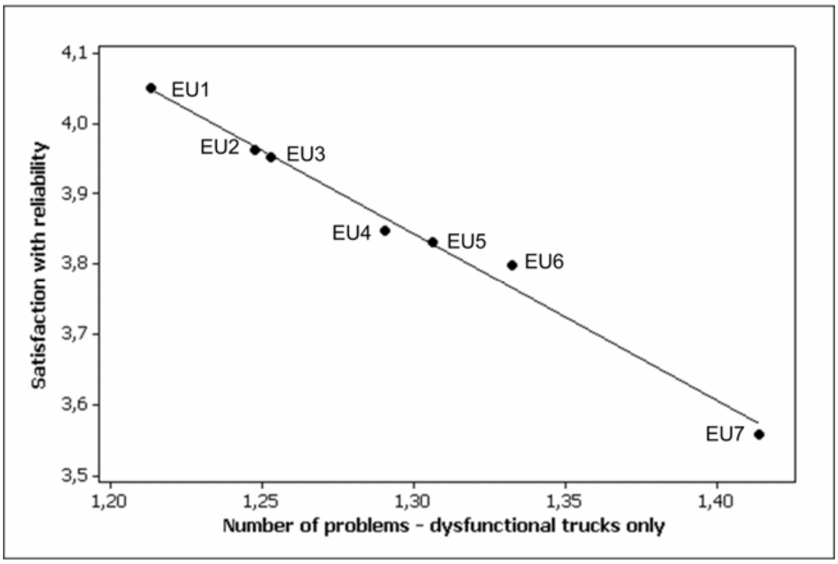

Figure 16: *Cross-sectional relation between customer satisfaction with reliability and average number of problems among trucks with problem(s)*

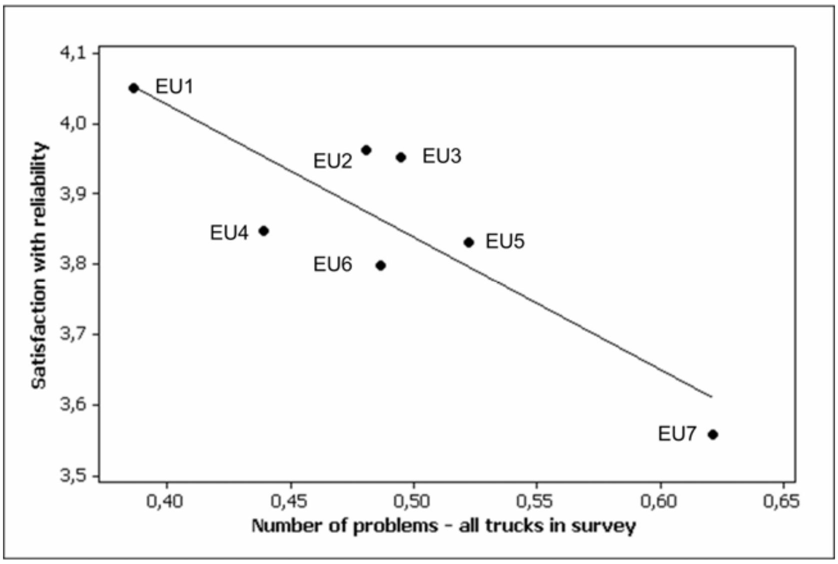

Figure 17: *Cross-sectional relation between customer satisfaction with reliability and average number of problems among all trucks*

Dynamic relation

When studying the dynamic relation (comparing years) between reliability measures and satisfaction with reliability it is important to try to minimize the effects of structural changes in the sample. In the study from which we have acquired secondary data, individual respondents are not followed over time. Rather, a unique sample is created each year and by employing weights it is supposed to reflect the population at that time as well as possible. By using weights one can represent the population quite well even if one sometimes can not get access to people in the exact right proportions considering for instance distribution of customers over countries. However, even if the weighted secondary data has the right properties for qualified conclusions each year, it does not necessarily have good properties for longitudinal studies, i.e. studies of several "objects" (in this case brands) over time. The problem is that as the population changes its characteristics, the answers in the surveys will probably change as a result of that, even if the opinions of all individuals would be unchanged. What we are interested in looking at in this section and in RQ2 is how the satisfaction among customers changes when the reliability of their trucks changes. While we are not having the same individuals each year, we can not rightfully claim to look at changing opinions of customers. However, if we for each year look at groups that have very similar characteristics then we can expect that the change in opinions between years is an approximation of the changed opinions of individuals in those groups. In order to try to get a fair picture of how satisfaction with reliability is affected by changes in reliability over time, we have chosen to look at a reference population which has the same distribution over countries every year. It is not the same individuals that are studied every year, but when creating means per brand we use the same weights that decide the importance of each country for every year. The weights we use are based on registrations of trucks from quarter 1, 2003 to quarter 2, 2005. In the scatter plots below we can see the dynamic relation between the three reliability measures and the satisfaction with reliability. In order to get only the dynamic relation, we have taken each data point, both the measure dimension and the reliability dimension and I have subtracted the corresponding brand means for all years collectively. The scatter plots suggest that there is some, although very limited, correlation between each of the measures and the satisfaction. To be able to say something about which correlation that is strongest we must refer to the correlation coefficients which can be found in Table-Table.

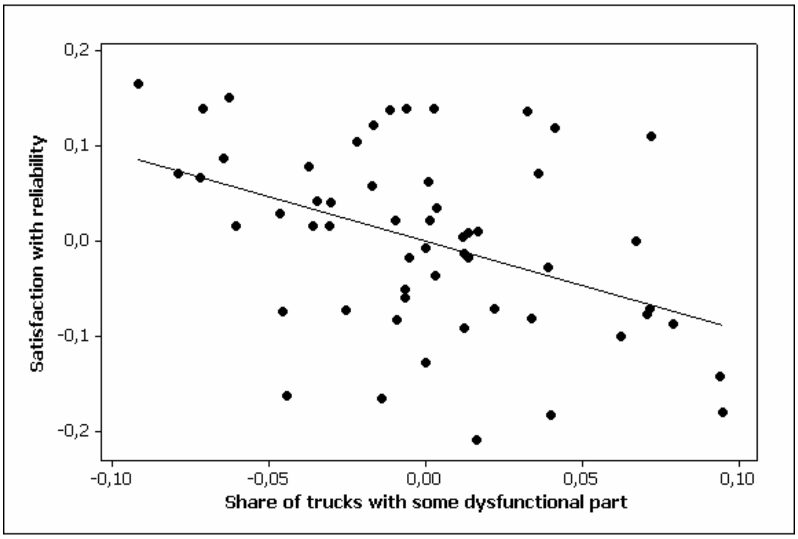

Figure 18: Dynamic relation between customer satisfaction with reliability and share of trucks with some dysfunctional part. Each data point represents a specific brand and year relative to the brand mean for all years.

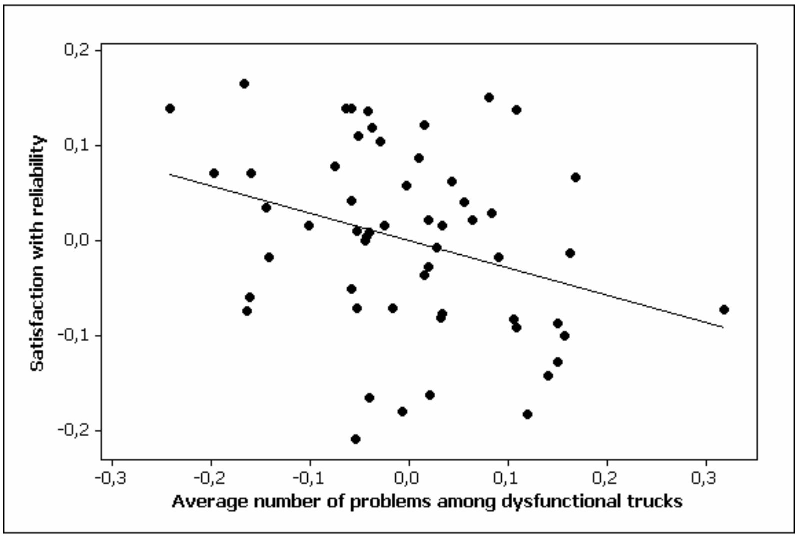

Figure 19: Dynamic relation between customer satisfaction with reliability and the average number of problems among dysfunctional trucks**.** Each data point represents a specific brand and year relative to the brand mean for all years.

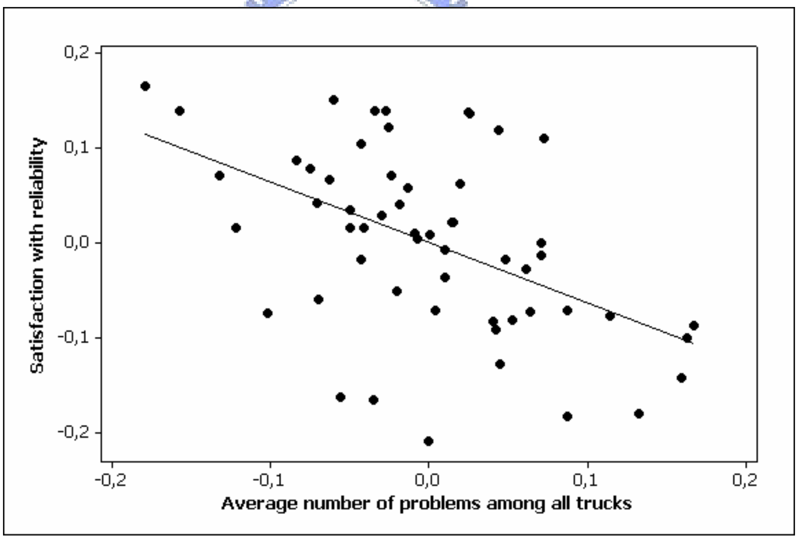

Figure 20: Dynamic relation between customer satisfaction with reliability and average number of problems among all trucks. Each data point represents a specific brand and year relative to the brand mean for all years.

Table 7: Correlation coefficients of dynamic relation between measures of reliability and measured customer satisfaction with reliability.

Predictor	r_{Yi}	r_{Yi}^2	pr_i	pr_i^2	sr_i	sr_i^2
X_1, Share of trucks with dysfunctional part	-0.430	0.185	0.004	0,000	0,004	0,000

P-value	0.001		0.976		0,979	
X_2, Average number of component categories with problems (trucks with problems)	-0.319	0.102	0,001	0,000	0,000	0,000
P-value	0.017		0,997		0,997	
X_3, Average number of component categories with problems, (all trucks)	-0.496	0.246	-0,079	0,006	-0,069	0,005
P-value	0.000		0,564		0,615	

Table 8: Correlation coefficients (Pearson r) between the X's.

	X_2	X_3
X_1	0.200	0.876
P-value	0.139	0.000
X_2		0.629
P-value		0.000

Table 9: Multiple correlation coefficients

Unadjusted	**Adjusted**
$R^2_{Y.123} = 24{,}6\%$	$\tilde{R}^2_{Y.123} = 20{,}2\%$
$R^2_{Y.23} = 24{,}6\%$	$\tilde{R}^2_{Y.23} = 21{,}7\%$
$R^2_{Y.13} = 24{,}6\%$	$\tilde{R}^2_{Y.13} = 21{,}7\%$
$R^2_{Y.12} = 24{,}1\%$	$\tilde{R}^2_{Y.12} = 21{,}3\%$

By studying the correlation coefficients we find that X_3 is the measure that has the strongest (or least weak) correlation with the satisfaction factor. We find it positive, while we find it to be the measure that is rationally supposed to be the best representation of the reliability that customers experience. However, the difference in correlation from the other measures is small and it is not certain that this difference can be trusted to be significant. The correlation between the measures is strong except for the correlation between the share of trucks that have some problem and the average number of problems among trucks with problems. This we expected before seeing the coefficients; while X_3 is constructed from the other two it has a strong correlation with both of them and the only relation that is weak is the one between the independent variables X_1 and X_3. Worth noting here is that the picture of the dynamic relation is quite different from the cross-sectional relation. The measure that has the strongest cross-sectional relation with satisfaction has the weakest dynamic relation with it and vice versa. This was not expected and we have no explanation to it. Also, the overall conclusion of this section must be that the measures have a very small ability to predict satisfaction. This might be largely due to the large categories of components for which customers are to state any problems.

4.2 Satisfaction sensitivity (RQ2)

Is there a difference in the sensitivity of customer satisfaction with reliability between reliability improvements and reliability deterioration? There is a traditional view that worsened quality will have a huge effect on satisfaction and image, whereas improved quality takes time to generate improved image and customer satisfaction. We want to test this for satisfaction with reliability in the specific case of reliability fluctuations on the US and European markets of heavy duty trucks.

Section summary

US

We have looked at reactions in customer satisfaction with reliability to changes in the number of problems per 100 vehicles and the average number of times with downtime per year.

For decreases in times with downtime that are smaller than about 0.5 times per year (or about 20%), the corresponding changes in satisfaction are more or less impossible to predict. Larger decreases seem to substantially improve satisfaction, but there is not enough data to support it strongly. Similarly, increases in downtime up to 1.5 times per year (corresponding to about 75%) correspond to totally unpredictable effects on satisfaction. During the surveyed period, large increases in downtime (around 2.7-3.5 times per year) have been accompanied by decreases in the satisfaction ratings of about 0.25-0.4 points on the 5 point scale. The data can not support any comparison of strength between reactions to increased and decreased amounts of failure and downtime.

If we relate changes in satisfaction with reliability to changes in problems per 100 vehicles, the variation among reactions is also great. There is a quite reliable, although not very strong correlation between the reliability improvements and the satisfaction with reliability. We can not say much except that there seems to be a negative relation between the failure frequency and the satisfaction with reliability. A conclusion that our data can only support for increases in failure frequency and that essentially adds no new knowledge.

Western Europe

For instances where the average failure frequency for a brand has decreased, it seems that the corresponding changes in satisfaction are unpredictable. Increases in average failure frequency up to 1.5 problem per year (or 30%) come with greatly varying changes in satisfaction that leave us no clear patterns. Two instances exist where the failure frequency have increased dramatically (both over 80%). Such increases have been accompanied with decreases in satisfaction ratings of over 6%. Neither for this market do we have appropriate data to draw conclusion regarding whether reactions to reliability deteriorations are stronger than to improvements.

4.2.1 US market

For the analysis of reactions to changes in failure frequency on the American market, we have used data from the same study as in the previous research questions. Each year customers are asked, among other things, how satisfied they are with the reliability and dependability of their truck and how many problems they have had. We have looked at survey answers for owners of eight different brands in five annual studies, carried out 2002-2006. Each year the size of the sample for all the brands together consisted of between 1596 and 2865 respondents. We have taken means for each brand each year and looked at how the means have developed over time. While we have looked at five years, we have four year-to-year (YtY) changes of means to look at per brand. Having eight different brands gives 8*4=32 changes of means. For these 32 changes We have plotted the change in satisfaction with reliability vs. the change in reliability (as it is measured in the studies). We have then made two regressions, one for the changes where the failure frequency have increased and one for the changes where it has decreased. The plots are made for both absolute changes (e.g. y_2-y_1) and change factors (e.g. $\frac{y_2 - y_1}{y_1}$) in separate graphs, while we found it very difficult to know which one would be more appropriate. The graphs are presented together with tables that briefly describe the characteristics of the regression model. One issue when tracking changes in a population over time is that there are always changes in both the population and the samples. The samples do, in this case as in most samples, not contain the same individuals from year to year. This means that we could never track how the opinions of individuals change over time. We can look at changes in opinions for the entire population, but we must then consider if there are major changes in the sample from year to year. One such change could be if the distribution of the sample over countries or cultural regions changes. In the case of the US market there is a clear advantage that there are large studies that are made for the US market separately. This sample will always cover the same country. However, there can also be changes in the way the sample is distributed over different parts of the country or different types of driving conditions. In the case of the survey I have studied there are weights that make sure that the results for the sample are transformed into results valid for the target population. The main problem remaining is then that the population itself changes. However, such changes will to some extent also exist in a study where individuals are tracked over time, it simply cannot completely be avoided. It is relevant however to try to avoid, to highest possible extent, that known structural changes in the sample constitute main reasons for the change in reliability satisfaction. One purpose of research question 1, where we compared the strength of the relationships that different reliability measures had with reliability satisfaction was to give input to which measures to use in this research question. While we want to see how effects on satisfaction differ between reliability improved and worsened reliability, we need to look at the measure that has the strongest relation with satisfaction. For the US market, it turned out that the number of times with downtime was the measure that best predicted the satisfaction with reliability. Therefore this measure qualifies for being included. We have chosen, however, to include one more measure, the number of problems per 100 vehicles. This measure is commonly given much attention and we believe that it adds some basis for our conclusions to also look at that measure.

Number of times with downtime

We start by looking at the number of times with downtime and its effect on the satisfaction, as is it suggested by regression analysis. How do we interpret the scatter plots and regression coefficients below? The first thing worth emphasising is that each point says something about the relation between a change in reliability (horizontal axis) and the corresponding change in satisfaction (vertical axis). If we want to draw overall conclusions about this relation, we must not only focus on the slope of the regression lines but also their position. For instance, the slope for negative absolute changes in the number of times with downtime is twice as steep as the line for positive changes (Figure). However, there is a difference in the constants in the regression equation. In this case the lines do not meet in the point (0,0), as would be expected in the ideal case.

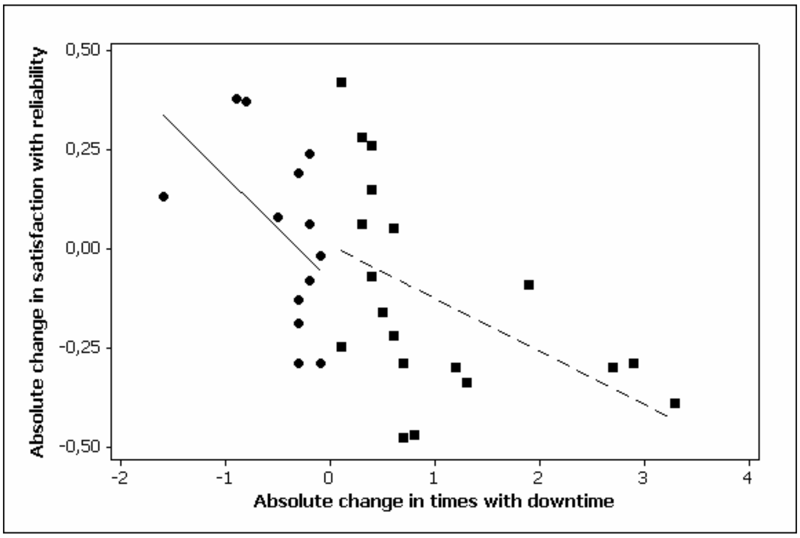

Figure 21: *Absolute change YtY of satisfaction with reliability and dependability vs. change factor of times with downtime*

For the change factor, the difference in constants in the regression equations is very large. From the scatter plots (Figure and Figure) we can learn that in many cases, small decreases of the number of times with downtime are accompanied by considerable decreases in satisfaction, contradicting our rational expectations. For decreases in times with downtime that are smaller than about 0.5 (or 20% in the change factor case), the corresponding changes in satisfaction are more or less impossible to predict. The average change in satisfaction associated with such small changes in times with downtime is very close to zero and the variation is large. Just looking at the regression coefficients we would be led to believe that decreases in downtime have a stronger ability to increase satisfaction ratings than the ability of downtime increases to lower the satisfaction ratings. However, the coefficients can not tell the full story. A painting example of how regression coefficients alone are not enough is provided by the so called Anscombe´s quartet (Anscombe, 1973) (Figure). All four plots visualise unique sets of data that all have the following attributes (among others) in common: Number of observations = 11, mean of the x's = 9.0, mean of the y's = 7.5, regression equation: $y = 3+0.5x$, $R^2=0.667$.

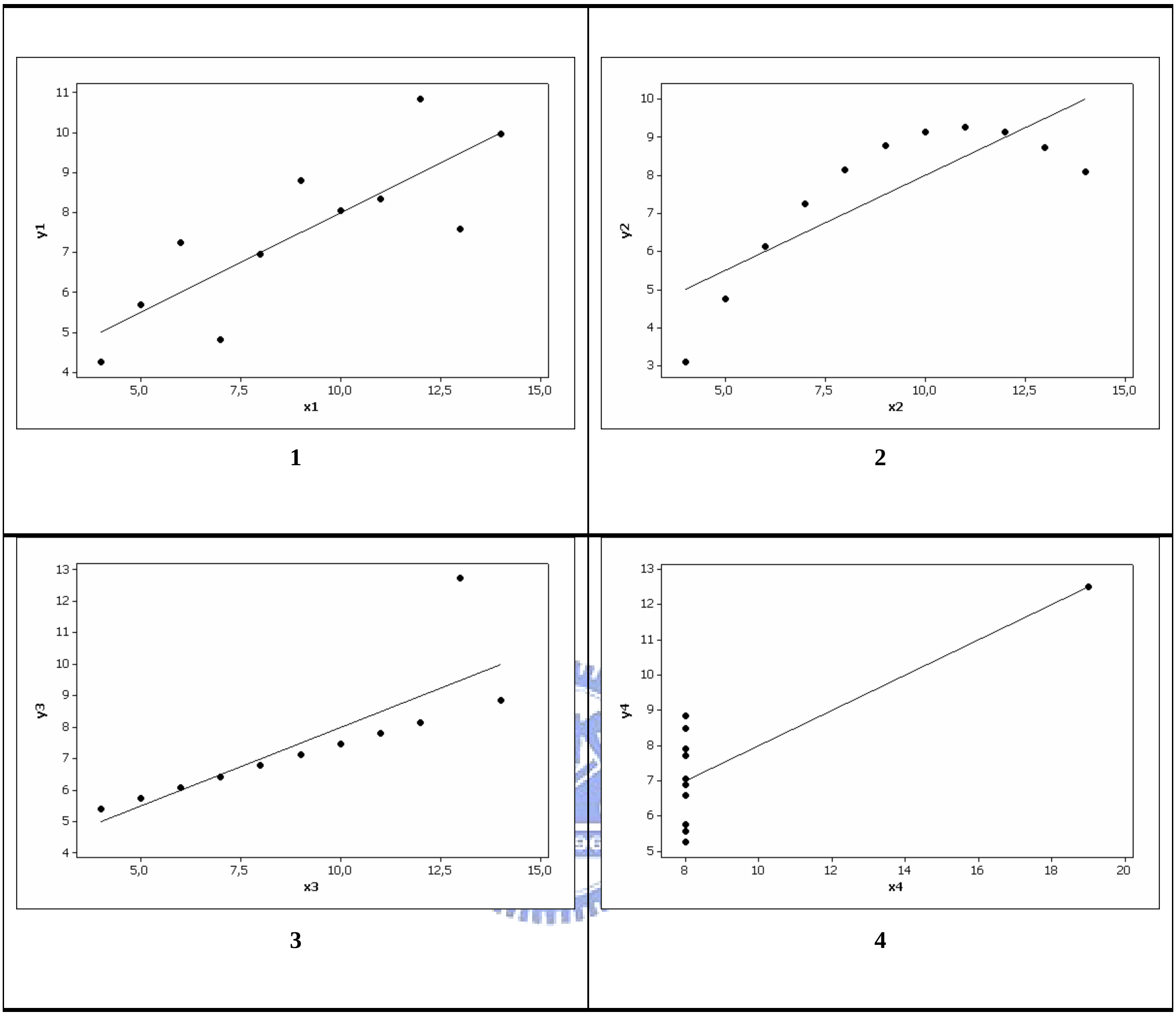

Figure 22: Anscombe´s quartet. (Graphs based on data from Anscombe, 1973)

Looking at the decreases in times with downtime (Figure and Figure), we can see similarities with plot number 4 in Anscombe´s quartet (Figure). What we have for decreases in times with downtime is essentially an area with changes between 0 and -0.5, where the corresponding changes vary immensely. We also have a few points representing larger changes that correspond to changes in satisfaction so that the regression coefficients look quite “good”. We must be aware though that in the area where we have many points there is almost no predictability and around the few point that represent larger changes, we have so few points that we can not safely trust them to be representative.

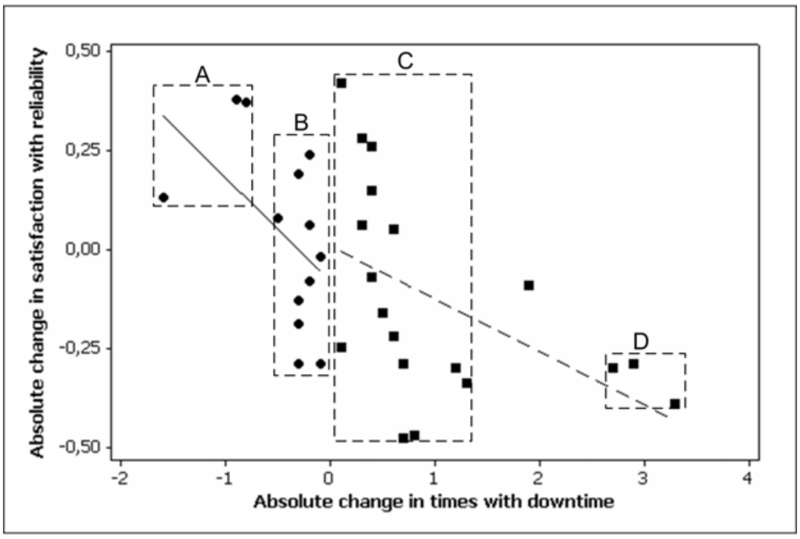

Figure 23: Grouping of data points, absolute changes.

The conclusion is that we can not on the basis of the regression equation give some rule for how decreases in downtime correspond to increases in satisfaction. We might say that decreases in downtime that are smaller than about 0.5 times (or 20%), have no clear impact on satisfaction (group B in Figure). Larger decreases (group A in Figure) seem to have a substantial impact on satisfaction, but the there is not enough data to support it strongly. Similarly, for increases in times with downtime, we have an interval (increase in times with downtime of 0-1.5) in which the corresponding changes in satisfaction are varying greatly and in which there are many data points that are counterintuitive, in this case representing increases in downtime and simultaneous increases in satisfaction. The conclusion is that we can not predict changes in satisfaction that correspond to changes in downtime that are smaller than 1.5. We can never safely predict changes in satisfaction for larger changes in downtime either, but it seems that historically large increases in downtime (around 2.7-3.5) have been accompanied by decreases in the satisfaction ratings of about 0.25-0.4 points on the 5 point scale.

Table 10: Regression of absolute changes

	Decreased failure frequency	**Increased failure frequency**
Regression equation $\Delta CS_{rel} = b + a\Delta N_{down}$	$\Delta CS_{rel} = -0.0829 - 0.263\Delta N_{down}$	$\Delta CS_{rel} = 0.0071 - 0.134\Delta N_{down}$
R^2	24.5%	24.4%
$\tilde{R}^2$	17.7%	20.0%
$P\{a = 0\}$	0.085	0.032
$P\{b = 0\}$	0.346	0.930

N_{down} is the number of times with downtime

CS_{rel} is the customer satisfaction with reliability

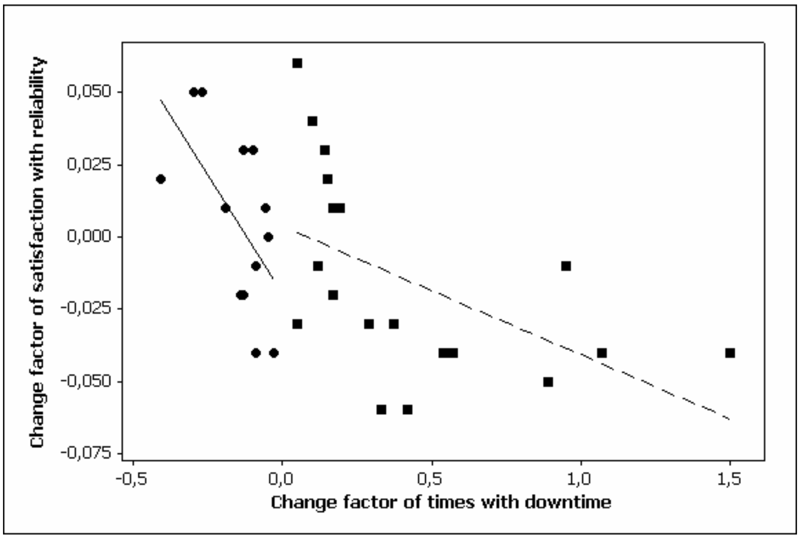

Figure 24: *Change factor YtY of satisfaction with reliability and dependability vs. change factor of times with downtime*

Table 11: Regression of change factors

	Decreased failure frequency	Increased failure frequency
Regression equation $\frac{\Delta CS_{rel}}{CS_{rel}} = b + a\frac{\Delta N_{down}}{N_{down}}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = -0.020 - 0.16\frac{\Delta N_{down}}{N_{down}}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = 0.0036 - 0.044\frac{\Delta N_{down}}{N_{down}}$
R^2	35,6%	26,9%
$\widetilde{R}^2$	29,7%	22,6%
$P\{a=0\}$	0,031	0,023
$P\{b=0\}$	0,142	0,730

Problems per hundred vehicles

The first thing we want to study for this measure is the accuracy of the regression models. How much do the models actually say about the behaviour of Y, the satisfaction with reliability and dependability? First of all, let us look at the adjusted multiple correlation coefficients $\tilde{R}^2$ and the probability that the estimated coefficient a is actually only an effect of randomness ($P\{a=0\}$), for decreases in failure frequency. These coefficients tell us that the change in the failure frequency measure (number of problems per 100 vehicles) can not explain any of the variation in the satisfaction with reliability and there is a good chance that the slope coefficient of the regression model is completely made up of randomness. We must therefore conclude that we can not describe how customers react to decreases in the number of problems other than saying that the reactions vary a lot. Also, with such a weak connection between the x and the Y, we should be careful talking about reactions while we see that there must be other things than the changes in failure frequency that decides how the satisfaction of customers is changing. Looking instead at increases in failure frequency, there are statistically significant slope coefficients for both absolute changes and change factors suggesting that in average an increased failure frequency of 50 problems will be accompanied by a decrease in satisfaction of about 0.25 points on the 5 point satisfaction scale. The relatively low multiple correlation coefficient makes us aware though that even though we can say something about the average "reaction", many times the individual changes fall quite far from the average (this is easily seen in the right half of Figure). Due to the poor fit of the data to the regression line for decreases in failure frequency (left half of Figure), we can not make any relevant comparison between the slope coefficients of decreases and increases, which was essentially the objective of this research question.

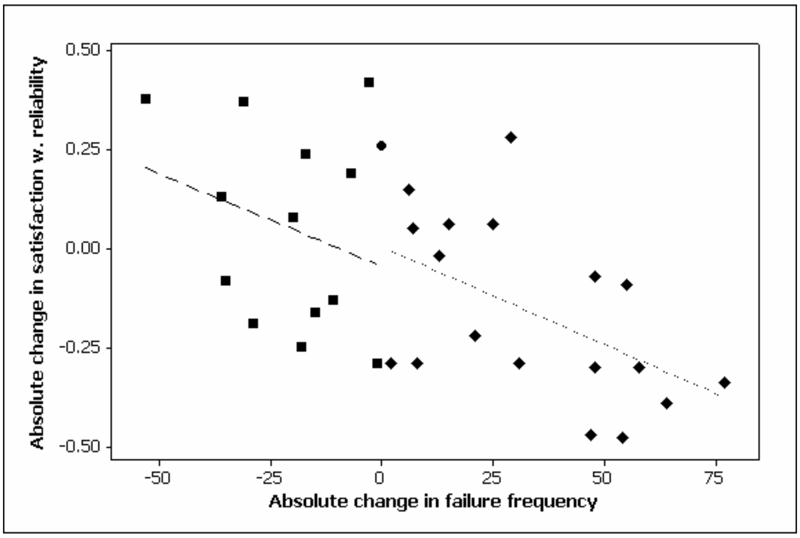

Figure 25: *Absolute changes YTY in satisfaction with reliability and dependability vs. absolute changes YTY in problems per 100 vehicles.*

Table 12: Regression of absolute changes

	Decreased failure frequency	**Increased failure frequency**
Regression equation $\Delta CS_{rel} = b + a\Delta FF$	$\Delta CS_{rel} = -0.0044 - 0.0047\Delta FF$	$\Delta CS_{rel} = 0.0031 - 0.0049\Delta FF$
R^2	7.6%	26.2%
$\tilde{R}^2$	0.0%	21.6%
$P\{a = 0\}$	0.361	0.030
$P\{b = 0\}$	0.730	0.971

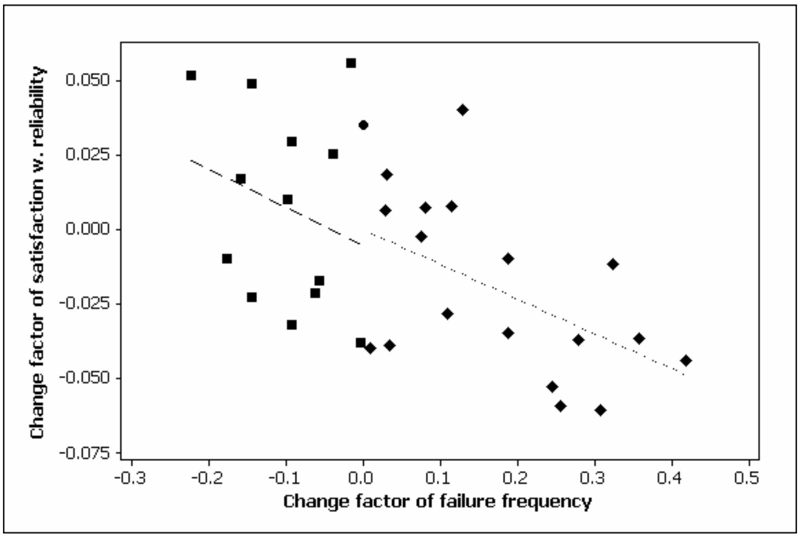

Figure 26: *Change factor YTY of satisfaction with reliability and dependability vs. change factor of problems per 100 vehicles.*

Table 13: Regression of change factors

	Decreased failure frequency	**Increased failure frequency**
Regression equation $\frac{\Delta CS_{rel}}{CS_{rel}} = b + a\frac{\Delta FF}{FF}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = -0.0055 - 0.129\frac{\Delta FF}{FF}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = 0.0003 - 0.117\frac{\Delta FF}{FF}$
R^2	6.5%	26.4%
$\tilde{R}^2$	0.0%	21.8%
$P\{a = 0\}$	0.400	0.029
$P\{b = 0\}$	0.757	0.980

4.2.2 Western Europe

We study seven brands for eight years (2000-2007). Each brand thus has seven changes of survey measures of failure frequency and satisfaction with reliability. This gives us 7*7=49 changes in failure frequency for which we can study the impact on satisfaction.

To limit the impact of structural changes in sample between years, we have in this analysis, as in research question 1 used a reference sample, that has a distribution over countries that is based on truck registrations from quarter 1, 2003 to quarter 2, 2005. The weighting that is used to give the samples this attribute is used for every year, but the set of individuals is not the same from year to year.

All brands have their unique characteristics and the customers that own each brand might have some commonalities. However, we do not have the data necessary to make time series analysis for each brand. Rather, we assume that there are substantial commonalities between the brands in how their customers react to changes in reliability and based on this assumption we use longitudinal analysis to analyse changes in time.

As in the case of failure frequencies for the truck on the US market, we can note that there is almost no pattern to the reactions of decreased failure frequencies. Whether we look at absolute changes or change factors, we have almost no reflections of decreased failure frequency in the corresponding changes in satisfaction with reliability. The mean of all changes in satisfaction for years where the failure frequency have gone down are slightly positive, but there is no pattern such as larger decreases in failure frequency giving larger improvements of the satisfaction with reliability. This can be seen by looking at the R^2's and P's of decreases in failure frequency. The very low R^2's indicate that there is very little correlation between the data points and the regression line and the high P´s indicate that there is a very high probability that the slope of the line could actually be zero which would mean that the slope coefficient in the regression equation would be nonzero only due to random errors. It is tempting to compare the slope of the regression lines for decreasing failure frequencies between the US market and the Western European, but with such poor fit as we have in these two cases it is completely irrelevant to look at the slope of those lines.

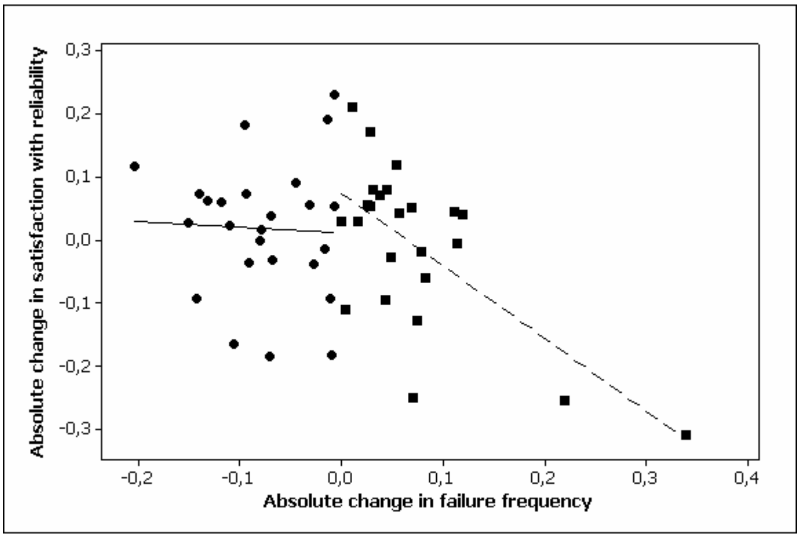

Figure 27: *Absolute changes YTY in satisfaction with reliability vs. absolute changes YTY in number of problems per vehicle.*

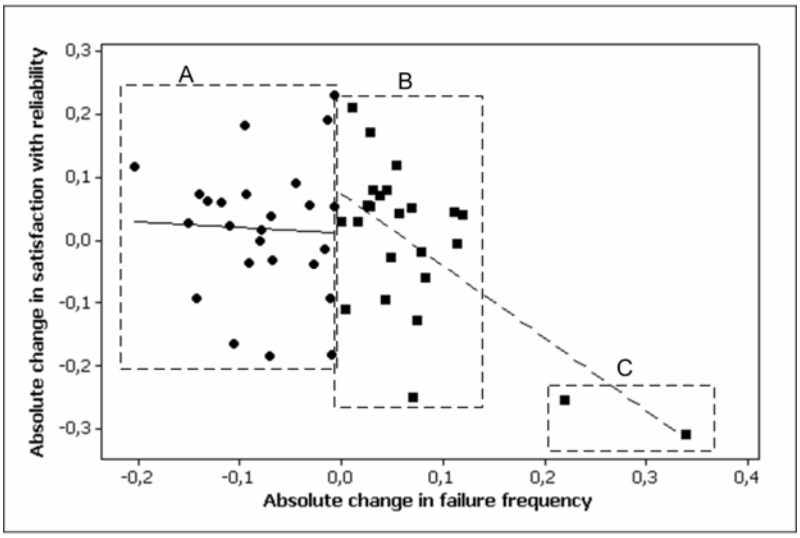

Figure 28: *Grouping of data*

Table 14: Regression of absolute changes

	Decreased failure frequency	**Increased failure frequency**
Regression equation $\Delta CS_{rel} = b + a\Delta FF$	$\Delta CS_{rel} = 0.0112 - 0.089\Delta FF$	$\Delta CS_{rel} = 0.0741 - 1.15\Delta FF$
R^2	0.2%	43.8%
$\tilde{R}^2$	0.0%	41.2%
$P\{a = 0\}$	0.832	0.000

	Decreased failure frequency	Increased failure frequency
$P\{b=0\}$	0.776	0.016

Increases in failure frequency have reactions that are slightly more predictable. The R^2's and P's indicate that there is a something similar to a linear relationship between increases in failure frequency and decreases in satisfaction with reliability. The R^2's indicate that the relationship is substantial although not very strong, whereas the P's indicate that we can be quite certain that it is not only randomness. It seems quite clear though that it is the two points in the lower right corners of Figure and Figure that cause these low P-values and the graphical representation of the data tells us that based on these historic events it seems likely that a very large increase in failure frequency will yield a large decrease in satisfaction, whereas the reaction of a failure frequency change within the region of (-25%,25%) have reactions that can not be predicted solely by the failure frequency. Having just two occurrences of a very large increase in failure frequency means that we have to be careful with relying too much on the data. The fact that the conclusion that very large failure frequency increases causes large decreases in satisfaction is very logical and expected makes it more sound to trust it, but we do not have a solid foundation in the data to support it. We do not have data that can tell us anything about the reactions to decreases in failure frequency that are larger than about 25% while it has not been accomplished by any of the studied brands during the studied period.

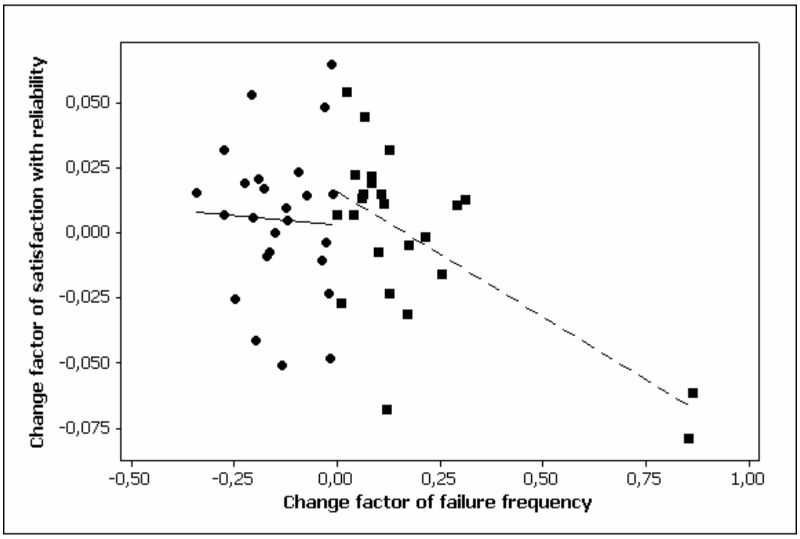

Figure 29: Change factor YTY of satisfaction with reliability vs. change factor of problems per vehicle.

Table 15: *Regression of change factors*

	Decreased failure frequency	Increased failure frequency
Regression equation $\frac{\Delta CS_{rel}}{CS_{rel}} = b + a\frac{\Delta FF}{FF}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = 0.0033 - 0.0133\frac{\Delta FF}{FF}$	$\frac{\Delta CS_{rel}}{CS_{rel}} = 0.0158 - 0.0966\frac{\Delta FF}{FF}$
R^2	0.2%	42.5%
$\tilde{R}^2$	0.0%	39.9%
$P\{a = 0\}$	0.837	0.029
$P\{b = 0\}$	0.764	0.001

4.3 Image sensitivity (RQ3)

Different customers have different images of the ability of truck manufacturers to provide reliable trucks. How are these images affected by changes in truck reliability?
Is there a difference between reliability improvements and reliability deteriorations concerning the size of the effects that they have on image?

Section summary

We do not have access to data for the US market on this aspect, while it is not included in the survey from which we have acquired data. For the Western European markets and brands, there seems to be very little connection between changes in image ratings and changes in my measure of failure frequency based on the secondary data. There are substantial changes in both reliability and image, but there seems to be no correlation between them. The lack of correlation and a number of very strange data points suggest that there are other factors that influence the image ratings much stronger and/or the changes in image ratings have a lead time. It might also be so that the failure frequency measure is too inaccurate. An important characteristic of the image ratings is that they come from all respondents in the survey, not only those that own a truck of the respective brands. Therefore, it is quite understandable that the reliability changes can not yield predictable effects in image; Only a portion of the respondents have experienced the reliability change. Sometimes of course, changes in reliability spreads to others, but that probably requires large quality deteriorations and probably also has a lead time. We have one instant of a very large increase in failure frequency and a simultaneous large decrease in image, but we can not be sure if that image change is connected to that reliability change.

There is a traditional view that worsened quality will have a huge and immediate effect on satisfaction and image, whereas improved quality takes time to generate improved image and possibly also for satisfaction. We want to see if this seems to be true for reliability image in the specific case of reliability fluctuations on the markets of heavy duty trucks.

In the studies of the US market that we have access to, there is no factor called image. They ask all respondents how their expectations of the overall performance of their brand will relate to the industry average. This is hard to connect to reliability image, both because it measures many other aspects outside reliability, but also because expectations are not the same as image. We have therefore limited this analysis to the Western European market.

We are basing our analysis on the studies of 2000-2007, for seven brands, altogether 20,472 responses. This means that we have in average about 400 responses per brand each year.

To limit the impact of structural changes in sample between years, we have in this analysis, as in research question 1 and 2 used a reference sample, that has a distribution over countries that is based on truck registrations from quarter 1, 2003 to quarter 2, 2005. The weighting that is used to give the samples this attribute is used for every year, but the set of individuals is not the same from year to year.

The regression coefficients (Table) reveal that there is very little fit between the regression model and the data. The lion share of the data points are located in "clouds" around (0,0) and there is little connection between their horizontal and vertical distances from (0,0). Beside these clouds, we have a few outliers. Two of them, A and B, are relatively easy to understand. A represents a major decrease in failure frequency and a corresponding large increase in image. D represents a major increase in failure frequency and a corresponding major decrease in image. The other two outliers, B and C, on the other hand represent a major increase in satisfaction without a change in reliability (B) and a major increase in failure frequency together with a relatively large improvement of average image rating (C). These points may support, which we already expected, that there are other things than the actual reliability that decides to what extent a brand is perceived as reliable. It could be a new model being introduced, a major advertising campaign, the presentation of a study in trade press etc. It might also be so that the reliability measure is too inaccurate or that the effects on image have a lead time. A major difference between image ratings and satisfaction ratings are that the image ratings for each brand are given by all respondents, while the satisfaction ratings are only given by each respondent for the brand of which he owns a truck. This makes it easy to understand that image ratings will be more dependent on other factors than the actual performance, while most respondents do not have any experiences to base their image ratings on for all or even most brands. The regression of change factors provides more or less the same information as that of absolute changes.

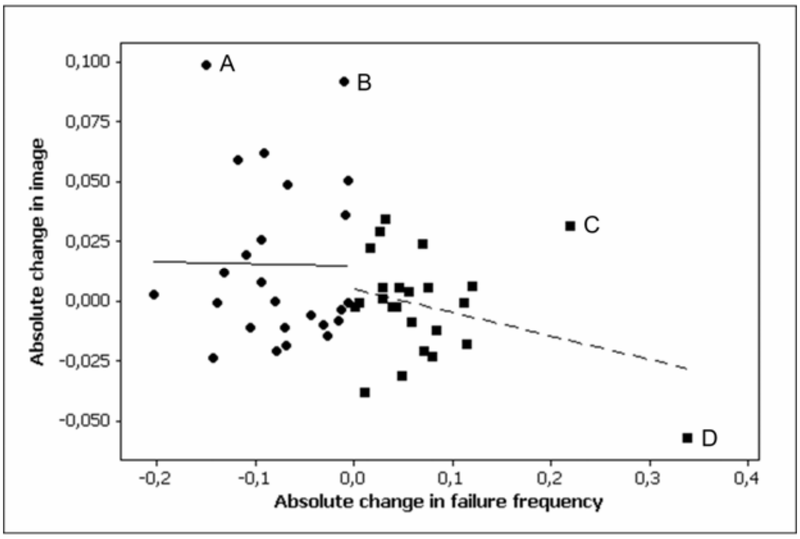

Figure 30: *Absolute changes in image vs. absolute changes in failure frequency (as estimated by the measure "Average number of problems among all trucks")*

Table 16: *Regression of absolute changes*

	Decreased failure frequency	**Increased failure frequency**
Regression equation $\Delta I_{rel} = b + a\Delta FF$	$\Delta I_{rel} = 0.0145 - 0.011\Delta FF$	$\Delta I_{rel} = 0.0487 - 0.0976\Delta FF$
R^2	0.0%	10.6%
$\tilde{R}^2$	0.0%	6.5%
$P\{a = 0\}$	0.935	0.121
$P\{b = 0\}$	0.260	0.436

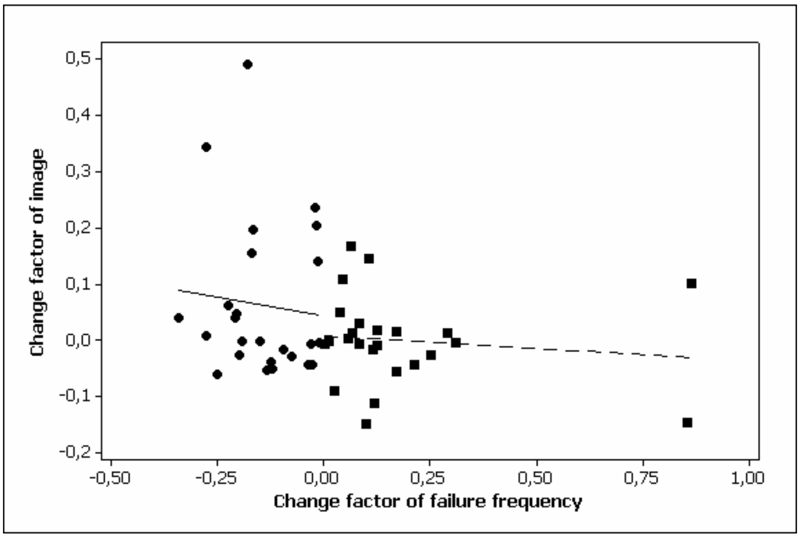

Figure 31: *Change factors of image vs. change factors of failure frequency (as estimated by the measure "Average number of problems among all trucks")*

Table 17: *Regression of change factors*

	Decreased failure frequency	Increased failure frequency
Regression equation $\frac{\Delta I_{rel}}{I_{rel}} = b + a\frac{\Delta FF}{FF}$	$\frac{\Delta I_{rel}}{I_{rel}} = 0.0442 - 0.133\frac{\Delta FF}{FF}$	$\frac{\Delta I_{rel}}{I_{rel}} = 0.0078 - 0.0452\frac{\Delta FF}{FF}$
R^2	0.8%	1.6%
$\tilde{R}^2$	0.0%	0.0%
$P\{a=0\}$	0.665	0.553
$P\{b=0\}$	0.400	0.717

4.4 The role of service satisfaction (RQ4)

Can good service compensate for poor reliability?

Section summary

We wanted to test the hypothesis that it can be acceptable with some problems as long as the service organization is good, so that the issues cause no major obstructions to business, which was suggested by several interviewed fleet managers. We have created four groups of respondents from a large survey of transportation firms in Western Europe (2006-2007): one that is satisfied with both reliability and the service organization, one that is dissatisfied with both and two that are satisfied with one of them, one satisfied only with reliability and the other only with service. Respondents who were satisfied with reliability but not with the service provided at authorized workshops were more satisfied than those that were dissatisfied with reliability but satisfied with the service organization. Our interviews strongly suggests that a good service organization could make quite a few problems acceptable, but the small sample size for the interviews should make us cautious to trust it to much, especially since it ca not be backed up with this quantitative analysis. We do believe that the hypothesis can be true, but it might not be possible to measure it quantitatively. There are many conditions specific for each fleet that makes the analysis complex.

Based on input from truck fleet owners in Sweden, my supervisors at Volvo and we had a hypothesis that the quality and availability of the service organisation when problems occur is crucial to overall satisfaction and that a relatively high number of problems can be acceptable as long as they are solved well and rapidly, thereby avoiding major obstructions to the business. That it is positive with a capable service organization is obvious and that it is important is also barely needed to be said. The point that is less clear is if a relatively high number of problems can be accepted as long as they are solved in a good manner. The statements that we have heard over and over when talking to Swedish fleet owners are almost identical and would be translated to something like

"Problems happen to everyone, the important point is how they are solved"

Saying that problems happen to everyone is to some extent saying that one may have some tolerance for defects and maybe it is not even necessary to strive for zero defects as long as the service can make sure that there are no major obstructions to business. It would be interesting to see if customers that have experienced quite a few problems but are satisfied with the service organization actually are have a higher overall satisfaction than those who are less satisfied with the service, but that have not experienced as many problems. We will look at this by analyzing data from a large sample of European truck owners. This quantitative analysis is made on data from the 2006 and 2007 editions of a survey purchased by Volvo.

While incorporating service quality takes us into a wider area than just reliability of the truck, we have chosen to measure the satisfaction of customers through their repurchase intention and their willingness to recommend the truck make to others.

A suitable start of this analysis seems to be a simple regression analysis to see if there seems to be some direct or indirect connection between the service satisfaction and the repurchase intention. The result, which is based on 4061 responses from owners of seven major European truck brands in seven countries[20] during 2006 and 2007 is presented below.

Regression equation:	Repurchase intention = 2.88 + 0.325 Service satisfaction
P {slope coefficient = 0}	0.000
R^2	10.7%

The P tells us that the probability that the slope coefficient of the regression line is actually zero is very small. The R^2 shows that there is quite a weak correlation and the fit of the data to the regression model is not very good. This is not very strange, because the repurchase intention is expected to depend on a large number of different variables of which service satisfaction is just one.

Satisfaction with the workshop service is measured through the sum of several service ratings. They are:

[20] The included countries are Germany, the United Kingdom, the Netherlands, Belgium, France, Spain and Italy

- Quality of service/repairs
- Availability of the workshop service when needed
- Solving the problem at the first time
- Total amount of time needed to bring you back to business
- Emergency breakdown services

To get a hint whether good service can compensate to a substantial extent for poor reliability we have created four groups into which the respondents are divided. The groups are based on the ratings given by customers for service satisfaction and reliability satisfaction (Figure).

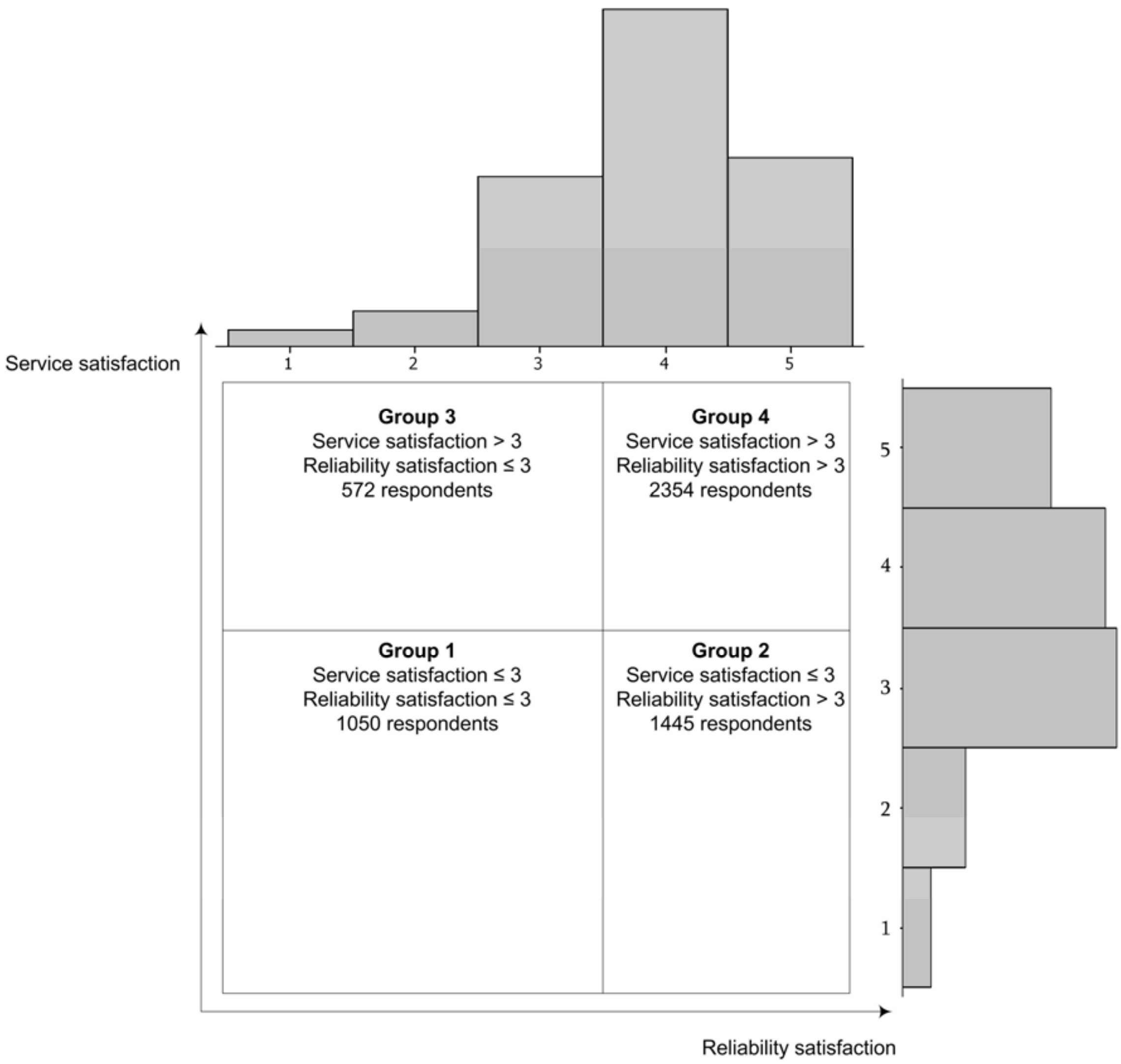

Figure 32: Groups of ratings for service satisfaction and reliability satisfaction.

The intention is to look at groups that are defined in a rational way so that the results are possible to interpret. However, there seems to be no unique best way to draw the lines. Both factors are evaluated on a scale from 1 to 5, with the following meaning of the numbers.

1 = Completely dissatisfied
2 = Fairly dissatisfied
3 = Fairly satisfied
4 = Very satisfied
5 = Completely satisfied

Just by looking at these wordings, we could say that 3-5 are positive ratings, whereas 1-2 are negative ratings. However, if we look at the histograms for the distributions of answers, as can be seen in the uppermost and rightmost ends of Figure, we see that the ratings 3-5 include the lion's share of all answers for both reliability satisfaction and service satisfaction. We could therefore say that those who give a 3 are relatively dissatisfied compared to the mean. We want to see how those who are not very satisfied with their reliability in average rate their repurchase intention if they are satisfied with the service provided by authorised workshops. We therefore choose to count 4-5 as high ratings, whereas 1-3 are low ratings[21]. The mean values of the ratings for repurchase intention and willingness to recommend for the respective groups respectively is presented in Table and visualised in Figure and Figure.

Table 18: Mean ratings of repurchase intention and willingness to recommend per group

Group 3		**Group 4**	
Repurchase intention	3.89	Repurchase intention	4.40
Willingness to recommend	4.25	Willingness to recommend	4.75
Group 1		**Group 2**	
Repurchase intention	3.26	Repurchase intention	4.09
Willingness to recommend	3.67	Willingness to recommend	4.49

[21] Results from Xerox (McCarthy 1997, see Szwarc 2005) showing that those who give a 5 in overall satisfaction ratings are many times more loyal than those who assign a 4 suggest that one should not make categories of several grades while they may be very different when it comes to loyalty. However, for my purposes I believe that the division 1-3 and 4-5 is viable.

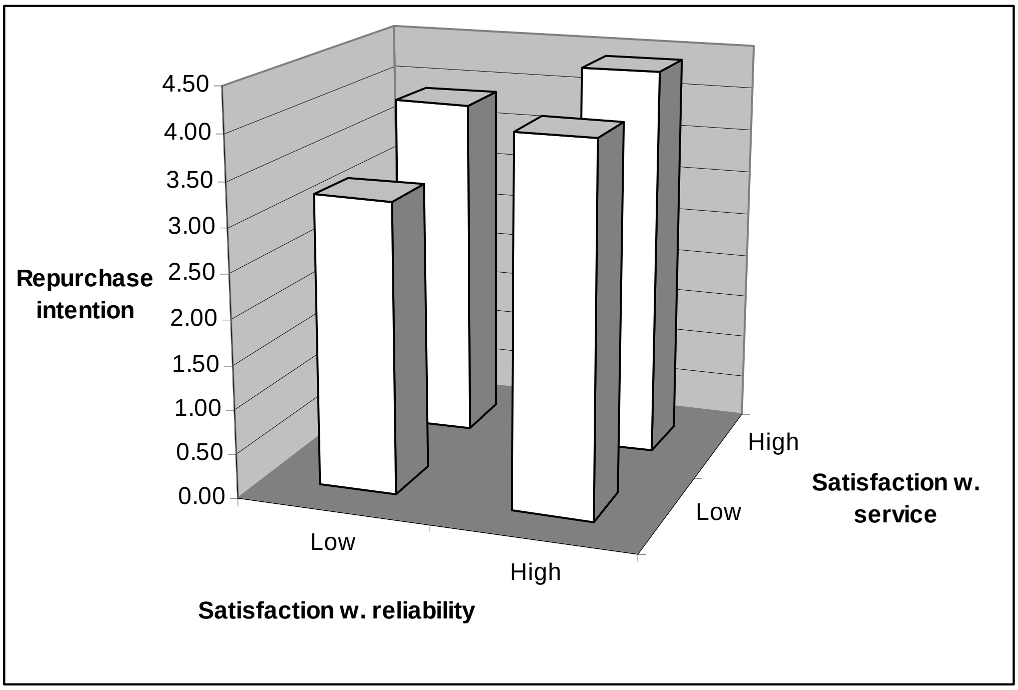

Figure 33: *Mean ratings of repurchase intention per group*

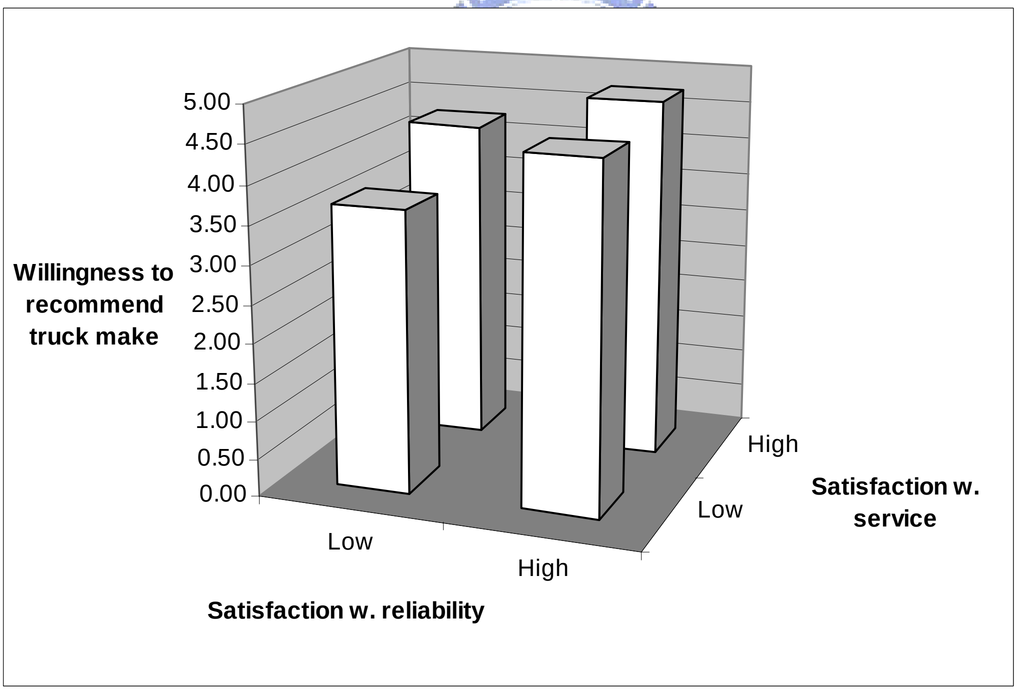

Figure 34: Mean ratings of willingness to recommend per group

By studying the mean ratings for the different groups we have to conclude that it seems that reliability is more important for the overall satisfaction than the service quality is. It might be so that some customers that are dissatisfied with their workshop can switch to another workshop and therefore they do not consider it necessary to change truck make to get better service. It might also be so that they are not satisfied with their service but that they do not believe that there are other trucks makes with better workshops. In that case the dissatisfied customers have no choice but staying and considering that there are no alternatives, they might even recommend the make to others, especially if they are satisfied with other aspects, such as other dimensions of truck performance. One possible explanations is also that the customers that are satisfied with the reliability have had very little contact with the workshop. Their impression of the workshop might be negative, but maybe it does not influence their satisfaction too much while they have had little need to go there. We can not support the hypothesis that it is acceptable with some problems as long as the service is good, while the customers who are not satisfied with their reliability but relatively satisfied with the workshop service, seem not as inclined to repurchase as expected. It might be so that if the customers who have had problems but that have been served well at workshops do not consider themselves dissatisfied with reliability. This could cause them to be included in group 4 instead of group 3, which was my intention. Our interviews with customers give a clear support for the hypothesis, but that result is valid only for Swedish truck fleets and due to the small sample of seven fleets it is quite unreliable even for that population.

4.5 Generation and diffusion of knowledge and impressions (RQ5)

How is knowledge about the reliability and durability of truck models generated and diffused among truck customers? What importance does it have when making decisions about replacements of trucks?

Section summary

Firms with their own workshop seemed to have a good system for following up problems with the trucks, whereas other firms barely kept any structured records of repairs. Strategies for replacing trucks were in some cases built on rules of thumb that were adjusted for the conditions of individual trucks. Surprisingly though, a large share of the owners used the trucks until they were completely "worn out". When purchasing a new truck, most of the respondents did not look at any summaries of performance of previous trucks, they based their decision largely on a general feeling. Many of the respondents reflected clearly that they were the only ones who could make purchasing decisions and they did not base it on any facts, neither about reliability or durability nor about other factors. Rather, they purchased vehicles from companies they had always purchased from and they often mentioned the relation to the sales organization as the most important factor for the purchase decision. They even trusted the sales representative when he said that a specific model is very reliable etc.

The personal relations to representatives of the manufacturer were far more important than any facts. This very high importance of personal relations might be extra high for our sample, in which almost all firms were family businesses with one person who was both major owner and CEO. Few respondents said they would call other peers to ask about their experiences of specific models, but it did happen and there was absolutely some communication within the industry, event though one claimed it is clearly decreasing. Mentioned occasions when communication occurs frequently are trucker meetings, meetings within some cooperative of transportation firms and sales promotion trips that are arranged by truck manufacturers. Impressions about the reliability and durability of trucks from different manufacturers were built on a huge variety of inputs, such as rumours in the industry, statements from family members, drivers, workshop staff, what brands they see on the roads and of course trucks they experience themselves through purchases, leasing, renting etc.

This section deals with knowledge and impressions among truck customers about reliability and durability of truck models. How is the knowledge generated and how is the diffusion within the transport industry working? How are the fleets following up their own repairs and are they discussing their experiences with persons in other transportation firms? Or are they keeping it to themselves?

4.5.1 Sample

The number of trucks in the fleets varied greatly, with the smallest fleet having only five trucks and the largest having almost 300 trucks. In average, about 60% of the trucks in these fleets were made by Volvo, almost 40% by Scania, 1-2% by Mercedes and then one single truck from MAN (not even noticeable in Figure) Almost 60% of the trucks worked in long haul traffic, about 40% were distribution vehicles and a few were timber trucks. In the figures for distribution and long haul there are some special transportation types included such as petroleum and milk. Important to note is that all respondents except one were both CEOs and main owners of the firm they worked for. The remaining one was a merely a manager employed by one of the fleets. All fleets were based in the South of Sweden.

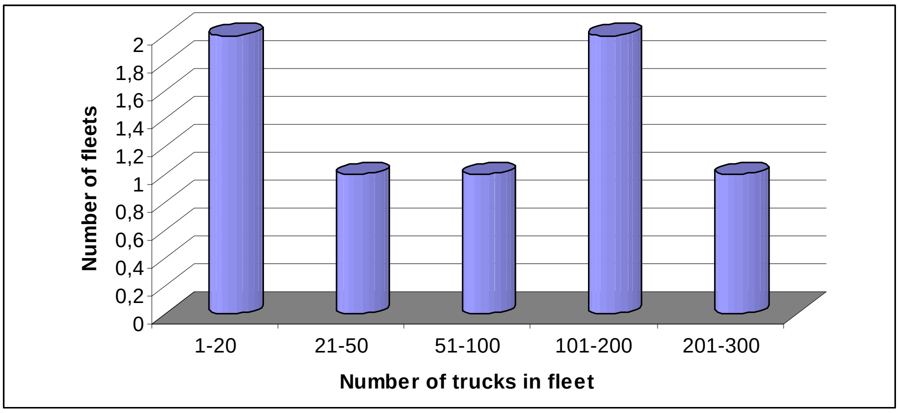

Figure 35: Fleet sizes

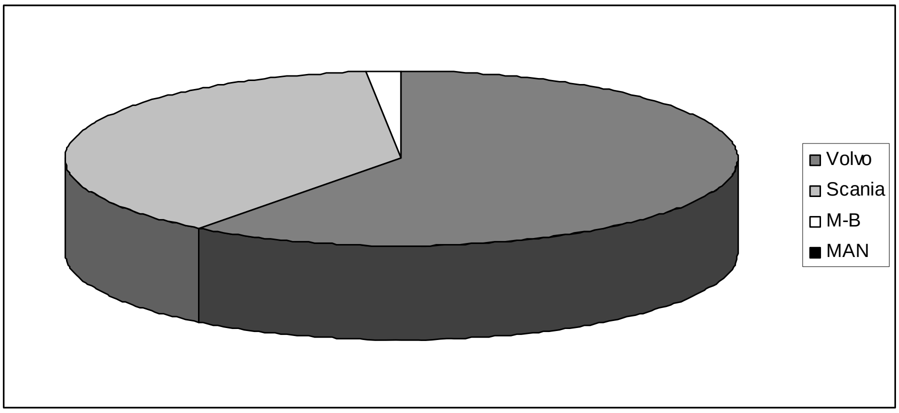

Figure 36: The shares of different brands of all trucks in the fleets of our interviewees

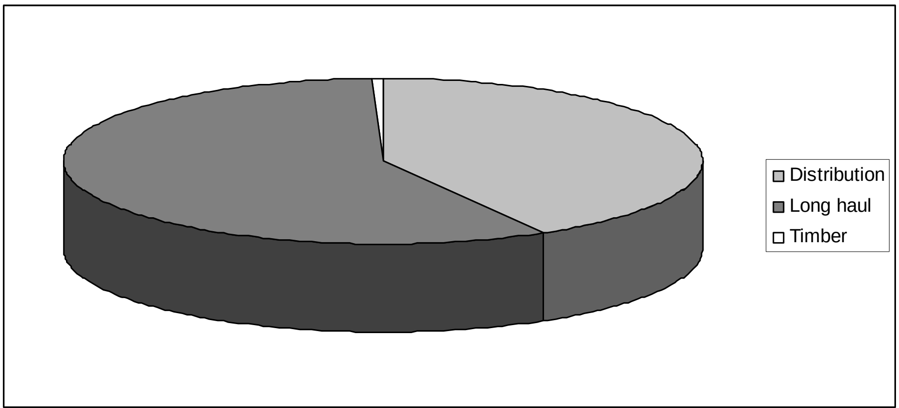

Figure 37: Approximate shares of fleets per transportation type

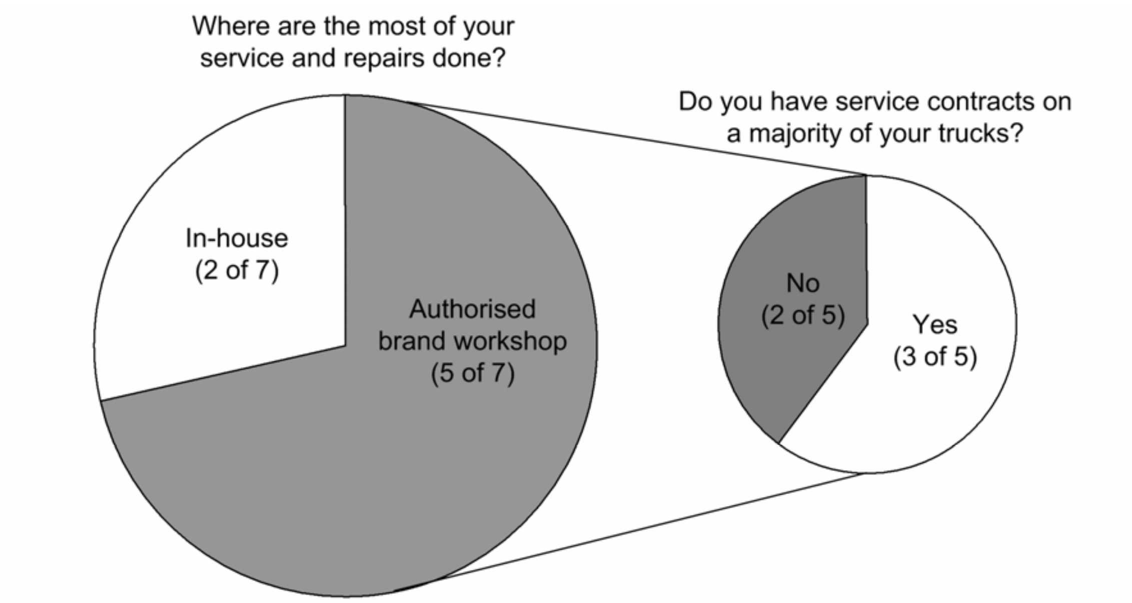

Figure 38: Service and repairs location and service contracts

4.5.2 Tracking problems

The first issue that we wanted to explore in this part of the thesis was whether the companies keep track of problems they have with their trucks so that they can compare different models and make fact-based decisions regarding buying, selling etc. It turned out that the two companies that had their own workshops and made most repairs themselves kept records of all the repairs that were done and they seemed to have a good view of problems and a good system that could support them when they wanted to check something up. Among the others, most companies had little control of what was done on their trucks. One of them, who made some minor repairs in-house, claimed that his workshop staff kept good records, but it was unclear if there was an organizational support for this and the owner seemed to think that his workshop manager, who kept track of the repairs, was too picky and he gave the impression that he found it unnecessary to keep detailed records. The remaining four companies had no structured way of following up problems. Some records were kept of costs, but none of what repairs that were actually done. One important factor explaining their lack of follow up was that most of the companies that did not have their own workshop had some kind of service contract on their trucks and therefore did not pay for all repairs. There were some possibilities for them to track through the internet what had been done on their trucks at authorized brand workshops, but not all of the workshops were connected to the system so in most cases they could not get the full picture. One manager of a large fleet said straight out something that we feel is probably valid also for most of the other interviewees.

> "I can not really see the use of following up the repairs of each individual truck."
>
> Fleet manager (101-200 trucks)

What we can conclude from this is that even though there is knowledge about reliability and durability among the interviewees of the trucks they own, the knowledge is not exact or structured but rather at a "sense level". For fleet managers that do not keep structured records of the repairs done, we might expect that the issues leading to downtime will have a big impact on their satisfaction, whereas they might not even know of all the repairs that are done together with planned service. For those that have their own workshops, more or less all problems will probably be noticed and be reasons for dissatisfaction. Problems leading to the truck braking down on the side of the road will of course be major problems to all owners, although less of a problem for those that have contracts for good action services that swiftly can help out. Problems that do not cause immediate breakdowns but that need to be fixed within a day might be less of an issue for those that have their own workshop than those who do not, while having your own workshop allows you to prioritise among vehicles, you may have an influence over the open hours of the workshop and you can yourself plan your stock of spare parts, whereas those that turn to authorized workshops might need to wait for some time before getting the attention of service personnel to their truck. In some cases of course the advantages of the authorized workshop will outweigh those of the in-house one and may allow for quicker solutions to problems. Such advantages may for instance be competence regarding some special technical problems, access to support from other workshops, diagnostic tools etc.

4.5.3 The use of knowledge about reliability and durability

Occasions where knowledge about reliability and durability of specific models could be especially valuable is when one is thinking replacing an old truck with a newer one, adding a new truck to the fleet in order to increase capacity or selling an old truck to decrease capacity. For the selling or replacement decision, we expect that many truck owners have some kind of rules of thumb that they use for judging when it is time to change a truck. However, there might also be some adjustment to the state of each individual truck. A truck that should be replaced according to some rule of thumb might be kept if it has a good track record and is in good condition. Knowing when it is most clever to replace each truck clearly demands a good knowledge about the state of the trucks that are currently in the fleet.

Firstly we tried to see how our customers reason regarding the timing for replacing and what defines the appropriate time to sell a truck. Then we tried to go deeper into how the fleet owners/managers acquire information about reliability and durability of different models and how they communicate their knowledge to others.

First of all, it seems that we can state three main positions or strategies regarding replacement of trucks.

1. Replace trucks at a specific mileage or age in years with minor adjustments for the current states of the individual trucks.

2. Replace trucks before their reliability gets "too low". At some approximate mileages, start to be more observant and start thinking about replacing, but always use the state of each truck as the guideline.
3. Use the trucks until they are considered to be worn out, which among our interviewees seem to be when you get an expensive failure when the truck is in such a state that they next failure is likely to be imminent.

Quite surprisingly four of the seven surveyed firms had a strategy close to no. 3 above. The trucks where sold when they got into a situation where a repair was needed but not an attractive option. For these firms the residual value of the trucks was considered unsubstantial and the trucks where often sold to less developed countries or even to junkyards. The other firms tried to replace trucks before the reliability of the trucks got too low and their strategies can be positioned at different points between 1 and 2 above. Selling the trucks before the reliability was too low allowed them to get relatively high prices when selling, but the reason for selling at this time was more than anything else to make sure that the trucks that were used were reliable and would not cause any obstructions to business. For firms running both long haul and distribution traffic, it was as expected most important to keep the long haul trucks new and in a good condition, while it is more problematic to get a breakdown on a long haul truck than a distribution truck, which most of the time runs in proximity to workshops.

Two of the firms that replaced the trucks before the reliability got too low were really proud to say that they had such a good reputation for taking care of their trucks that they got much better prices than others on the market for used trucks. One of them talked about people cueing to get hold of one of their used trucks and he claimed that they could get 100% more than some other firms when selling comparable trucks (comparable apart of course from the condition of them). The firms that seemed to take less good care of their trucks and drove them until their were totally broken down said that the pricing of used trucks was very standardized and it was only factors such as model, engine, axle configuration, mileage etc. that made a difference for the price.

4.5.4 Communication within the industry

To know which of your trucks to replace and when to do it you need to have information about your own trucks as previously noted. But in order to know what to replace your truck with or what truck to buy when you need more capacity, information about your own trucks is not enough. You also need to know some things about the new truck, which is especially hard if you have not previously owned the models you are considering. Let us start with the case that a manager of a truck fleet wants to buy a truck of a model that is already represented in the fleet. In that case the most important base for the impression about the reliability and durability of that model is, according to the interviews, that persons own experiences. One of our interviewed owners states that he checks the internal records of repairs before he buys a truck of the same model, but most of the others seem to depend merely on their feeling of that model. We believe that people in general tend to give their own experiences very high importance no matter what the issue is. If one thinks about it from a statistical perspective, it is of course not very wise to base the conclusions about a brand or a model on just one or a few units. If it is possible to acquire more information from others, that seems to be a good alternative. However, it seems that most of our interviewees do not do this and, without support for it, I personally think it applies to most other fleet managers too. Having the experience your self makes it real and important. If they have had an experience themselves, they seem to find it unnecessary to ask others.

We would have expected that the owners of these fleets would state other fleet owners as an important source of information before buying a truck, at least if buying a model not currently in the fleet, but this was quite rare. Only one owner stated clearly that he would call other owners and ask them about their experiences. One interviewee said, after being specifically asked about it, that he might sometimes ask others. Many stated though that they would not. One person gave the explanation that some find it embarrassing to call others on this errand and another manager had a feeling that the communication among truck fleet owners/managers had decreased and the business had become more "professional". He explained that before it used to be very common that truck owners talked to everyone about their own trucks and about how good they were. They just did not want to admit that sometimes they might have made a bad purchasing decision. Two owners stated that they did not have any contact with other fleets and that they did not want to help others out while they are competitors.

4.5.5 The importance of personal relations

Worth noting is that, in most cases, the person taking the purchasing decision is not the person with the best knowledge about the repairs of their trucks. For most of the firms that we have interviewed, there has been one person who is both CEO and major owner of the business and this person makes all the purchasing decisions. In the firms that are not very small, they usually have someone else who is responsible for maintenance and usually this person has the best knowledge about the actual reliability of the trucks. A striking feature of these leaders, the CEO/owners, was that most of them had very strong wills and opinions and when it came to purchasing decisions it was their call. If they felt like asking others in the company about their view, they sometimes did, but in general they just did what they felt like themselves. It was clear that most purchasing decisions where based more on feelings than on facts. As is suggested by the statements below, different managers have different proportions of feelings and facts as a base of their purchase decision. The first statement suggests a very high share of feelings, whereas the second one represents a decision where the facts are considered before the feelings.

> "I buy trucks from the one that I think is the most fun to make business with. I do not care what others think about the trucks."
>
> Owner and manager of a fleet (101-200 trucks)

> "I add together the purchase price and the cost of the service contract. If there is a large difference in total cost between manufacturers, I might buy the cheaper truck. Otherwise I prefer to buy one that I know is good and from a manufacturer that I have a relation with."
>
> Owner and manager of a fleet (201-300 trucks)

Several interviewees spoke warmly about customer events they had been invited to as customers. During these events they got the chance to discuss various issues with the manufacturer as well as with other customers. The relations between the interviewed customers and the manufacturers seem to be very important and in most cases very positive. However, a few of the interviewees told us about personal conflicts they have had with representatives of the manufacturers and how these conflicts had made them change brand or at least consider doing it. The brand loyalty of the customers we have interviewed is extremely strong and in most cases it is built, to a very large extent, on personal relations.

Quite surprising to me was that two of the seven interviewees said that when buying a new truck, the absolutely most important input is the seller. If the seller says that the truck is reliable then he is trusted. One of them was the owner of a business with eight trucks, whereas the other was a manager taking purchasing decisions for a fleet of almost 200 vehicles. For the larger business, the turnover of trucks must be quite large, so the buyer must have seen that the seller actually does not give false promises, but rather delivers what is promised. Trust is, as we all know hard to build up but easy to destroy, so if this buyer, after numerous trucks coming in and going out still trusts the buyer, there must be a good balance at the dealership between promising and delivering.

Also when buying a model of which you have no previous experiences, the previous experiences of specific manufacturers are very important. In the absence of a clear picture of how a specific model performs, the best thing one can do is often to consider previous performance of that manufacturer. Buying a truck from a manufacturer that has proved before to build reliable trucks naturally feels safer than to try a new manufacturer. However, one owner stressed that a new truck equals new problems. Only one of the interviewees mentioned the internet as a source of information about new truck models. When asked if trade press or advertising campaigns were interesting sources of information for them, most gave a very clear negative answer. One reason for the seemingly small role played by quantitative input, especially from external parties when taking purchasing decisions, probably is, as mentioned before that the decisions are made by persons who want to decide themselves and who are not very inclined to listen to others, but also that the firms that we have interviewed have a very high loyalty to brands. Most drivers are very clear with which brand they want to drive and they seem to be very resistant to changing. Most of the managers also seem to accept and adapt to these strong preferences among drivers, as long as they are only concerning brand of the trucks and as long as the brand they want to drive is Volvo or Scania. The drivers often also have requests regarding engine power, extra lights, exclusive interior etc., but these requests are not considered as important as brand preferences. Putting a driver in a truck of a brand he does not like, is believed to cause the driver to treat the truck abusively. For most of the interviewed fleets, there is a very strong preference for the two Swedish brands, Volvo and Scania. The bases for the purchasing decisions can be expected to be different in countries where there are not any local firms that are so dominant.

4.5.6 Building an impression

To get an idea about how these owners or managers of fleets viewed the reliability and durability of different brands, and even more importantly to get more ideas about what they based their impressions on, we asked them to rate the reliability and durability of brands and to explain how they believed that they had built up their impressions of the different brands.

When discussing the information that owners/managers base their purchasing decisions on, we have already mentioned that some of them would call others in their situation for input. When we asked what things that might have built up their impression of the reliability and durability of trucks of certain makes, we got some more specific information about internal and external parties that might influence them.

Mentioned occasions when communication occurs frequently are trucker meetings, meetings within some cooperative of transportation firms and customer events that are arranged by truck manufacturers.

A number of mentioned sources of input for the respondents' impressions of manufacturers can be found in Figure 39.

Figure 39: Inputs to impressions about the reliability and durability of truck brands and models.

An interesting phenomenon that was mentioned in several interviews was that they used the number of trucks they saw of each make on the streets as an indicator of how good the make is. Now that they for instance started to see more MAN on the streets they concluded that probably the reason is that they are quite good. With the same logic they concluded that the brands that have a small market share in Sweden are not very reliable, but added that if they would start seeing more of them they might gradually change their attitude. When you think about it this is not very strange. If there are lot of trucks of some brand that must mean either that they have large volumes of sales to people who buy their trucks for the first time or they have very satisfied and thereby loyal customers or a combination of the two. We did not expect though that several would state it explicitly as a response to the quite open ended question about the inputs to their impression of the reliability and durability of trucks. Wherever this "habit" of using the volumes of trucks of a brand on the streets as a quality indicator is present, we should expect that upcoming brands have some critical market share they need to obtain and then their presence will help them growing thanks to the improved quality that is assumed to explain their market share growth. This market mechanism is probably not this simple though and it still remains unclear to me, apart from the fact that this is only suggested by a small sample of people, whether it is the market share itself or the market share growth that indicates quality.

Whereas the opinions about the reliability and durability of the previously mentioned brands must be considered similar among most of the interviewees the opinions about the development of the different brands varied greatly. We asked in a quite unspecific manner if their impressions about the reliability and durability of the brands had changed in any specific way over time or if it was more or less the same as it always had been. One felt that Scania and Volvo had increased their gap to the other brands, whereas two others contrasted this; One by saying that most other brands had improved and decreased the gap to Volvo and Scania and one by saying that MAN had moved up and were now competing on the level of Volvo and Scania. Furthermore, one said that overall, the reliability of trucks has improved, whereas another one said the exact opposite. How can we explain this? Well first of all, these are just answers of a few individuals and it is not strange if they have different experiences and mindsets. Generally, my impression from most of the interviewees is that the reliability and durability has improved meaning less repairs and longer lifetimes of trucks. However, many seem to feel that the large increase of electronics in trucks has kept the number of minor problems quite high and often the problems are such that would never happen in older trucks, while the now failing components did not even exist in them.

4.5.7 Acceptance

We asked the interviewees if they had a larger acceptance for failures that are due to new technology being applied than those happening in mature technology or if it was the same for all problems. If they would accept problems due to new technology to a larger extent than for problems with mature technology then that could suggest that it might be worth taking risks with new technology that is not indisputably necessary but that might add a competitive edge. Often new technology increases the risks of having failures but at the same time the benefits of the technology might be appreciated by the customers, so there is clearly a trade-off between having cutting edge technology and maximizing reliability in the short term. The replies from the interviewees were almost unanimously that they do not accept problems to a higher extent just because they are due to new technology. Just one of the seven interviewees claimed to accept failures due to new technology more than other failures. The others clearly marked that all problems give them trouble and that the new components must be properly tested before being pushed to the market. Something they did not feel was done today. One of the persons that showed little acceptance for failures in new technology said that even though he did not accept such problems, he believed that he was less critical to it now than before, while he saw the great need for new technology in the industry. The truck industry really is in a situation that makes it different from many other industries. The amount of new technology brought into the new vehicles is to some extent decided by the manufacturers, but all of them are also forced to make massive innovations in the area of emission technology and the time to market for these new technologies is constraint strongly by the environmental regulations of different unions of nations, individual nations, states and cities. Due to this fact, one might have expected that the acceptance for failures related to engine and emission technologies would be at least higher than before. It is suggested though, by our interviews, that at least in Sweden, the fleet managers do not have a high acceptance for these failures and they do not want to act as some kind of testers unless they are explicitly asked to. A clear message from the interviewees is that it is not only important not to get problems with new technology but that it is also crucial how it is handled by the manufacturer in the event that such problems do occur. In situations where some new technology is creating problems for many owners it is important that the workshops have good capacity so that the problems can be found and solved swiftly. It is also important that the workshop staff is humble and have as a starting point the hypothesis that there is a production defect rather than assuming that the driver has misused the truck in some way. A manager of a fleet that has its own workshop mentions also that problems due to new technology often have worse consequences than conventional problems while they are more difficult to diagnose.

Although all this lack of acceptance for failures it seems that most of our interviewees choose to buy a newer model rather than an older one when they have the choice, even if the opposite strategy is also represented. Except for the advantages that new technology can bring for the drivers, having a newer model can also give a higher price when the truck is sold and this latter advantage is stated by several as the main reason for buying new models rather than old ones. In times where having a newer model can give lower fees on some European highways and access to some European cities not open for older trucks, the model and most noticeably the EURO emission classification can make a substantial difference for the price.

4.6 Economical aspects of durability (RQ6)

The main question that will be penetrated is

What are possible economical effects for Volvo of a changed durability of driveline components?

Future research that is needed to be able to evaluate these potential effects is presented in section *5.4 Suggestions for future research.*

A simplified model of how we have come to view the issue of driveline durability is shown in Figure. What we mean with the different boxes and connectors is presented in the following quite extensive section. While the issue is very complex, it is not possible to describe it briefly without missing the point.

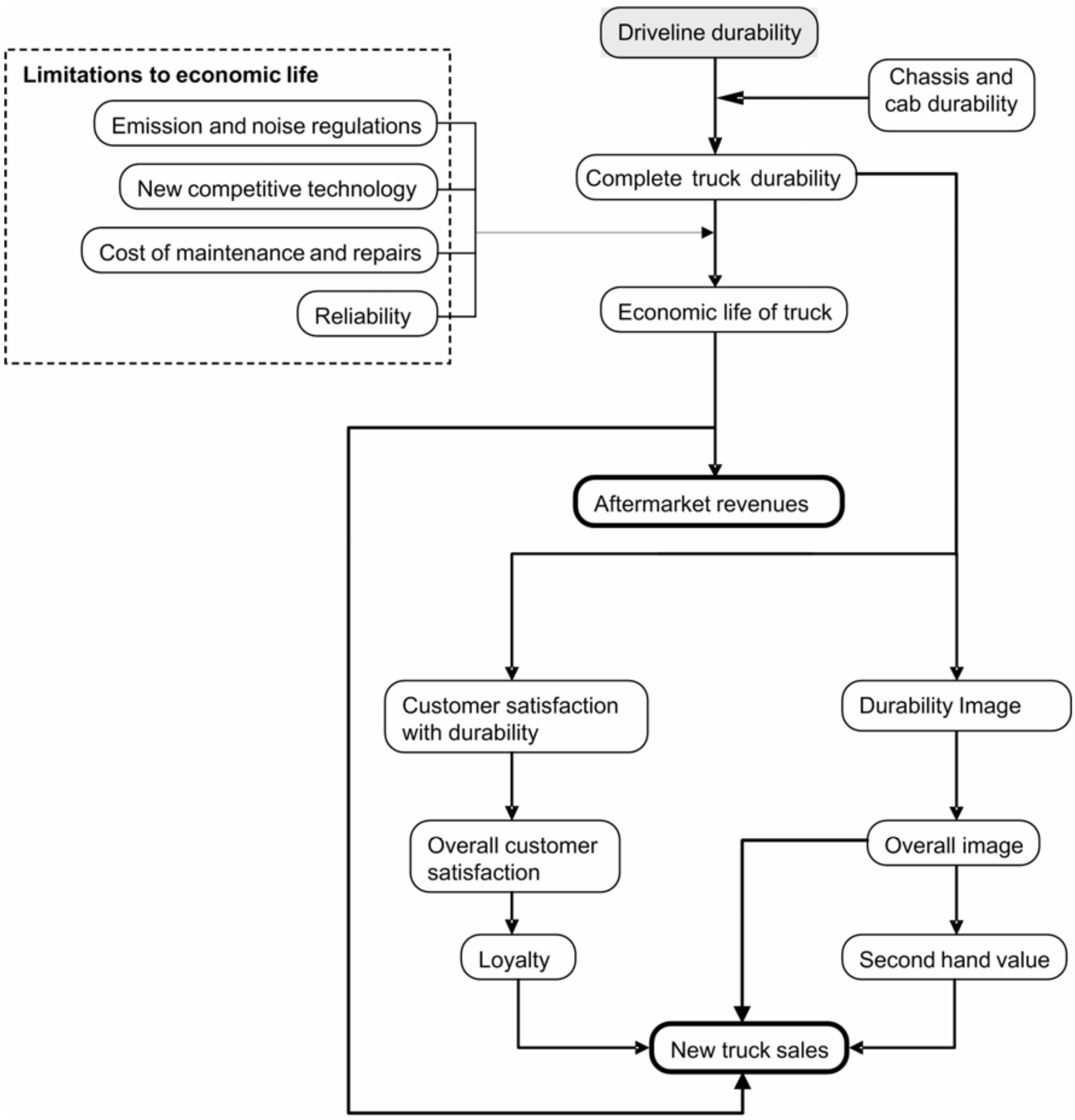

Figure 40: Driveline durability and some possibly affected attributes from a manufacturer's perspective.

Saleh discusses implications of changing the intended lifetime of a spacecraft, and in his article all the conclusions are based on the assumption that the actual durability is as intended. We can discuss strategic aspects of setting the durability targets of different components or entire products, but we must be aware that what really matters is how the product really performs on the market. Thinking about real durability rather than just targets has the implication that we do not have all facts. We do not fully know the durability of the entire trucks and neither do we know the durability of the driveline components, even though there are some estimates. Would increased driveline durability substantially increase the durability of the entire truck? This question is very important in order to judge the end implications of a changed durability for the driveline and depends of course of the current relation between the durability of the driveline and the durability of the rest of the truck. Even if we had all the facts about all failures on all trucks that presently are or have been on the market, there would be no simple answer. Sometimes the driveline fails at a point in time so that it is judged unprofitable to replace it and instead the truck might be sold as it is (example B in Figure). Sometimes a major part of the driveline fails, but does so when the rest of the truck is in such a condition that it is considered worth investing in for instance a new engine (example A in Figure). On the other hand, sometimes it might be so that the durability of the cab and chassis is so low that the complete truck is considered as worn out even though the driveline components are still in good shape (example D in Figure 41).

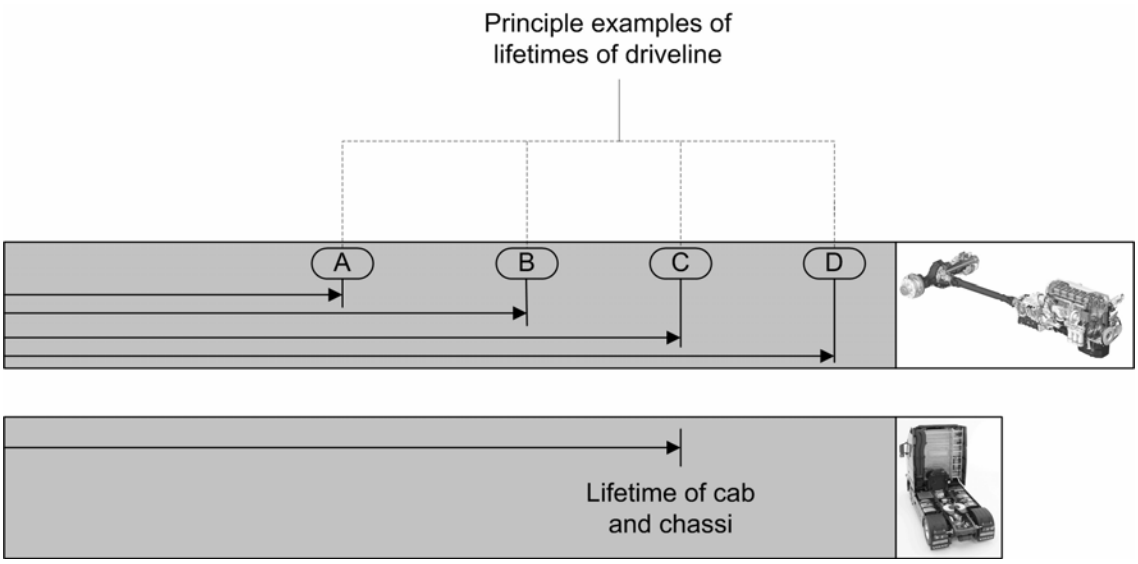

Figure 41: Principle examples of driveline lifetimes in relation to lifetime of chassis and cab

The ideal case from a customer perspective is probably that all components have their unrepairable breakdown at the same time (example C in Figure). What we mean by that is that the driveline components last equally long as the cab and the chassis, so that it is never the case that you have recently invested in an expensive repair, when some other major part breaks down and you are forced to take the truck out of use. The examples of Figure are to be seen as principle examples that represent a range of driveline lifetimes that are such that they share the same properties in terms of their relation to the lifetime of cab and chassis lifetimes. Shorter lifetimes than A are of course possible, but definitely not desirable. Around A is not optimal for the customer, but the decision to replace or renovate the engine or whatever it is that has failed is probably easier at this point than later. For the manufacturer, a major driveline failure might be good, if accepted by customers, while it generates after market revenues. If competitors offer trucks with considerably more durable drivelines however, this level of driveline durability might be detrimental to satisfaction and image. Having the driveline failing around the beginning of the last quarter of the cab and chassis lifetime is probably undesirable for the customer. The main alternatives are then selling the entire trucks and get quite a low price or spend a considerable amount on buying a replacement engine. If replacing the engine, this is done with the background that the complete truck might be getting “worn out” and a main issue is that the owner can never know when the next major problem will occur. This alternative is detrimental to the after market business of the manufacturer, while they miss out on a large revenue, that might have been realised if the problem occurred slightly earlier. On the other hand, if the truck is sold due to the failure, this will increase the potential of new truck sales. The relation between the lifetimes of driveline and the complete vehicle will be different in each market and for each model, making it hard to say what design lifetime for the driveline that is optimal. Clearly an important conclusion is that for the driveline durability, the relation to the durability of the rest of the vehicle is at least as important as the durability of the driveline itself.

Our interviews with owners and managers of Swedish truck fleets provided some input on this issue, even if it was not a planned part of the interviews. Durability was discussed in a general sense rather than through questions that were meant to provide quantitative results. Still, we obtained some input about the durability of their Volvo trucks that is worth mentioning. If we try to see some common features among the answers it seems that for the distribution vehicles, most interviewees did not feel that there was any substantial value in improving the durability of the driveline. The drivelines served them well until the trucks became too old and were replaced for other reasons. For long haul vehicles there was more value in an improved durability than for the distribution vehicles. Several mentioned that what limited the durability of the driveline was not the engine but rather the things that are mounted on the engine, such as compressors, turbo chargers, sensors and actuators. Some said that an improved engine durability could extend the vehicle lifetime a bit, but it was clear that in general interviewees were satisfied with the durability of the driveline and the complete vehicle, so it did not seem like they would be willing to pay a lot extra to get it improved further, if that would be found to be a necessity. We do not have enough information to draw any conclusions about how improved driveline durability would affect the durability of the complete vehicle; Rather we must keep this as an issue to investigate in the future.

Let us remember that we do not yet have enough data to say whether improved driveline durability would improve the durability of the truck substantially. If the case would be that the driveline already today is not a substantial limitation to complete truck durability, then there is no business case for improving the durability of the driveline. While the durability always varies between individual trucks, we can be sure that there are cases where the driveline is the limitation of the complete truck lifetime. Therefore, We will continue this analysis based on the assumption that improved driveline durability improves the overall truck durability.

A major limitation to the value of an improved durability for vehicles that travel through cities are environment zones and road tolls. Therefore, the business case for improved truck durability from a customer perspective is depending on the development of such regulations. To get a picture of the regulatory environment that today applies to trucks that are already in use, an investigation has been done, which is available in Appendix 4. A short summary follows here. Currently there are several sources of potential extra costs for users of relatively old trucks. There are road tolls that discriminate between technologies making it expensive to use old trucks. In countries like Germany and the Czech Republic there can be increased toll costs of about 20% already when the truck is a few years old and while they charge by the kilometre it can become costly for fleets driving long distances. Furthermore there are regulations for access to many European city centers as well as cities in Japan, demanding owners to perform costly retrofits with particle filters or catalysts, sometimes as soon as 4 yrs after the truck was registered. Looking at the development over time in the number of cities that create so called low emission zones, it seems reasonable to believe that they will increase further and discussions are ongoing in cities like London and New York. To forecast how the emission related regulations will look in the future is of course difficult, but it is clear that the debate over human impacts on the environment is growing ever larger, making me believe that the incentives for using low emission technology will increase as will the costs of using old technology. This will clearly have an impact on the economic life of trucks. How large the effect will be depends largely on the development of the regulatory environment.

Regulations that are supposed to limit the environmental impact are not very likely to be taken out of use once they have proved their efficiency. However, they are based on emission standards and sooner or later there might be a point where the emissions are so low that there is no need for introducing yet another emission standard. Then that could mean that after that point, the drawback of the ageing of the truck would be less than today. It is expected by many though, that when the emissions contain so small amounts of NO_x and particulates that it is getting really difficult to measure, the authorities will turn to CO_2 in line with the trend in society at large.

Emission regulations are not the only issue based on technological advances that might restrain the benefits of improved durability. There are also other factors that might make usage of old trucks less attractive. For instance, if the fuel efficiency would improve dramatically, then it might be more profitable to buy replace an old truck than to keep it in service, while the savings thanks to lower fuel consumption outweighs the potentially increased purchase cost. However, it is not clear that this is the case right now and what is important is of course the future.

For slightly more than a decade, there have been demanding regulations on trucks, especially regarding nitrogen oxides (NO_x) and particulates. The efficiency of the engine is increased with higher combustion temperatures, but higher temperatures create higher concentrations of NO_x (Andersson, 2005). Therefore, there has been a conflict between fuel efficiency and environmental standards for emissions. Furthermore, the time and effort spent on keeping emissions down has reduced the focus on fuel efficiency. Major improvements in the area of fuel consumption could create an incentive to replace trucks before their technical life is over, thereby reducing the benefit of increased durability. We can not know for sure, whether there will be any substantial improvements in the area of fuel efficiency in the relatively close future, but there are several areas of potential improvements that seem very promising.

In a report for the American National Commission on Energy Policy, Therese Langer of the American Council for an Energy-Efficient Economy presents an interesting analysis of previous research on the future of fuel efficiency for trucks (Langer, 2004). She provides estimates of fuel efficiency increases and lifetime cost-savings for tractor-trucks and short-haul trucks respectively. Langer claims that there is general agreement on the categories of technologies that can contribute substantially to raising truck fuel economy, but that estimates of the potential for increases vary widely.

In her analysis, she starts with defining reasonable pay-back periods, after which the additional cost of the technology should have been paid back through fuel savings. For tractor-trucks, she refers to a list of potential sources of fuel efficiency improvements compiled by Vyas, Saricks and Stodolsky (2002). Estimated introduction dates, costs and potential fuel economy gains are listed and used to rank different means of fuel economy gains. The length of the payback period decides which technologies that are profitable enough to applied and this in turn defines the total fuel economy savings for that payback period. Assuming for instance a 3 year payback time, an average fuel price of $1.60 and a 8% discount rate for the fuel savings, Langer predicts a 35% increase in fuel efficiency, an increased purchase cost of $8,000 and fuel savings of almost $19,000, yielding net savings of almost $11,000[22].

Table 19: Some technological advances with potential effect on fuel efficiency
Source: Vyas, Saricks and Stodolsky (2002)

	Fuel economy gain	Year of introduction	Cost
Aerodynamics			
cab top deflector	2.0%	current	$750
gap closing	2.5%	2005	$1,500
trailer edge curvature	1.3%	2005	$500
pneumatic blowing	5.0%	2010	$2,500
Rolling resistance			
low RR tires	3.0%	2005	$1,098
super singles	3.0%	2008	$1,098
pneumatic blowing	1.2%	2015	$500
Transmission	2.0%	2005	$1,000
Auxiliaries			
electrical auxiliaries	1.5%	2005	$500
fuel-cell auxiliaries	6.0%	2012	$1,500
Engine			
friction reduction	2.0%	2005	$500
increased peak cylinder pressure	4.0%	2006	$1,000
improved injectors etc	6.0%	2007	$1,500
thermal management, etc.	10.0%	2010	$2,000
vehicle mass	5.0%	2005	$2,000

[22] Assuming that all the listed technologies are available.

To promote the development and use of technologies improving fuel efficiency, standards for fuel efficiency could be adapted by authorities. That would however be challenging due to the need of testing fuel efficiency, which largely would depend on aerodynamics and therefore testing the engine alone would not be enough (Langer, 2004).

The potential for fuel efficiency improvements is largely dependent on the duty cycles that the trucks are used in. For duty cycles with a lot of braking, hybridisation has a potential, while the concept is based on brake energy being stored and used for propulsion. For long-haul trucks this technology does not have a great potential, making fuel efficiency savings harder in that segment.

Langer (2004) estimates that over half of all trucks in classes 3-6[23] and straight trucks in Classes 7-8[24] could through hybrid technologies experience lifetime savings; Modest in the near future, but substantial (several thousand dollars) for vehicles purchased after 2015.

An important issue to bear in mind that makes any predictions even more complex is that the fact that a technology would have a short payback period does not necessarily mean that it will reach the market and the customers.

> "Manufacturer risk, low fuel prices, lack of fuel economy information on individual models, and undervaluation of fuel economy all limit the introduction of better technologies."
>
> Langer (2004)

By this final remark we wish to clarify that we can not expect any predictions like these to be anything but predictions. Also, a few years have already passed making the conclusions less reliable than necessary, taking into consideration that some part of development that was unknown at the time that the article was written is now known. We dare not draw any final conclusion regarding the development of fuel efficiency other than saying that many of the mentioned technological advances seem promising and it does not seem unlikely that we will

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[23] Class 3-6 =from SUV's up to three-axle single unit, short-haul delivery truck.
Source: US Department of Transportation. FHWA Vehicle Classes (Electronic).
Available: <http://tmip.fhwa.dot.gov/clearinghouse/docs/accounting/appendix_e.stm> (2007-11-18)
[24] Class 7: Four-axle single unit, short-haul delivery truck, concrete truck. Class 8: Less than five-axle tractor/single trailer, medium-haul delivery. Same source as above. Straight truck = Rigid truck. Refer to appendices 1 and 3 for more information if needed.

see future increases in fuel efficiency that are rapid enough to affect the replacement behaviour of at least some truck owners.

Another issue that affects the use of an improved durability is reliability. If the reliability is constant and one just improve the durability, then probably one will experience poor reliability in the end of the lifetime. On the other hand, it does seem likely that improved durability will increase the reliability, at least in the early part of the life time, which could be a great benefit. If we define durability as the amount of use that we get from the truck before we end up in a situation where the truck is taken out of use while it is not considered worth repairing it, then we can say that in most cases, durability is limited by components that are expensive to repair. It could of course happen that an owner feels that there are so many small problems that the downtime and accumulated repair costs get too expensive. However, if it is just small problems, there is often someone who is interested in buying the truck and we consider the life of the truck to continue. If we accept this reasoning, then the question of how durability is connected to reliability boils down to how big problems are related to small problems, although simplified a bit. In order to answer this question, we need to know what problems that are the main limitations to durability and reliability for different models. Some things that could limit durability might be closely connected to many small problems, whereas some other main problems are relatively isolated from other issues. We can not give a clear answer in this issue, but it seems reasonable to believe that in general durability and reliability have a connection in the sense that products with a good reliability generally have a better durability than products with a poor reliability. There are many exceptions though. Without a proper investigation we would expect that an improved durability would improve reliability and thereby also lower the costs of maintenance and repairs. Maybe it is so that an improved durability requires an improved reliability rather than gives it.

How would the sales of new trucks be affected by improved truck durability?

The answer is quite obvious if there is only one owner for the entire lifetime. A longer durability would allow the owner to buy new trucks less frequently, as is argued by Saleh (2006). This assumes though that the economic life is extended as a consequence of improved durability, meaning that there are no aspects such as emission tolls, fuel efficiency, poor reliability etc. that causes the owner to replace the truck even though it does not have a major breakdown. In the case of heavy duty trucks, my impression is that it is not very common with just one owner for a truck, which makes it necessary to look at the consequences of an improved durability for several different owners. We have found it necessary to look at three principal kinds of owners, defined by the order in which they own the truck: the first owner, the intermediary owner and the last owner.

First owner

If the first owner sells the truck well before its lifetime is over, he will not necessarily have very large benefits of extended durability. Possibly, he will have economic gains through increased second hand value. It is possible that the first owner will keep the trucks for a longer period when the durability is better, but this would, as would an increase in second hand value demand that the owners are aware of the improved durability.

Intermediary owner

The effect on costs for intermediary users ought to be minimal. They might have to pay a slightly higher price if buying trucks at the same mileage as with the earlier lower durability. But in that case, it is probably so that they would also get a higher price when selling it. The net change will probably be small.

Last owner

The one who owns the truck until the end of the lifetime is the only one who directly will experience the benefit of being able to use it for a longer time than is possible with the original durability. However, if the last user would buy the truck at the same mileage as before, the increased period of service could be accompanied by an increased purchase price. If the truck is bought at the same price as before but at a higher mileage, then the effect for the last user would be small and for the entire system a possible but quite irrelevant effect is an increased number of owners per truck.

Whether improved durability leads to lower operation costs for the owners collectively depends on if the increased durability saves more money than the potential increase in purchasing price due to increased development and production costs. Whether the second hand value of trucks will be affected by an improved durability depends largely on the market's general impression of the model. Nobody knows for sure which models are the most durable so what will decide the price is the impression of the market. If second hand buyers think it is a durable truck, the demand will increase, as will the price. It might be so that it takes several successful models in a row before the market will perceive a model as durable.

The massive time delay that exists before anyone in the market can say anything about the durability of a new model makes me doubtful that changes in durability from one model to another would be clearly reflected in second hand prices. However, we definitely believe that trucks of makes that are perceived as durable loose their value on the second hand market slower than trucks of other makes. If the second hand value would be improved thanks to the improved durability, would that then have a large effect on sales of new trucks? My impression is that it would not. Both for Western Europe and the US, customer satisfaction surveys show that the customers do not value the second hand value when stating important factors.

How is the aftermarket affected by the durability of the driveline components?

Now we have to go back to the level where we separated driveline durability and complete truck durability. When starting to analyse this issue, we have the input which is a changed driveline durability. In the other end of a relatively large system, we expect to have a response in the form of changed conditions for the aftermarket business. If we start in the response end of the system, we will see that several questions arise.

There are several ways in which the aftermarket business could be affected by a changed durability.

1. A more durable truck means that the truck can be kept in use for a longer time, raising the potential for sales of spare parts and charging for preventive maintenance and repairs.

2. A better durability might be accompanied by a higher reliability, decreasing the need for repairs, thereby decreasing the volumes of sold parts and services but at the same time making service contracts more profitable and/or competitive[25].

There are some basic conditions that make evaluations of these possible effects a little extra complex. First of all, the increased durability will in most cases increase the time period in

[25] Service contracts are signed between the distributor of the truck and the customer. A common setup is that the customer, for a fixed monthly amount, gets preventive maintenance and/or repair service at some specified level without further payments. If there would be less need for repairs thanks to an improved reliability, the seller of the service contracts can keep the contract prices and increase margins through decreasing costs. He can also reduce prices and increase the competitiveness of the contracts without decreasing the margins. Obviously anything in between these extremes is also possible.

which a truck is used, but it does not necessarily mean that the aftermarket revenues increase substantially. A common problem in the aftermarket business is that the older and more used the truck gets, the less willing the owner is to have major expenses. Therefore it is commonly so that during the life of the average truck, the probability that it is serviced at authorised work shops, or at least with original parts decreases. For the aftermarket revenues to grow thanks to an extended lifetime, the time in which the owner uses authorised services and/or original parts must be extended. This is, however, not at all certain. It might be so that an extended lifetime of the truck only or mainly extends the time during which very small aftermarket revenues are generated for the Volvo Group. So the potential of point 1 above depends on the behaviour of customers when it comes to maintenance and repairs. Their behaviour in turn, depends on the offerings of the manufacturers.

A common situation is that most owners whose trucks are used for long haul transportation, only keep the trucks for a 3-4 years, as long a the reliability is very high. When these years have passed, the truck is sold according to some rule of thumb. The truck is sold in a sequence of owners where the demands on reliability continuously decreases and the sensitivity to purchase price increases. After a while, the trucks that have been used in rich countries, like those of Western Europe, commonly end up in Eastern Europe or South America. When the trucks reach less developed countries, the chances of aftermarket revenues for the Volvo Group decreases rapidly. It seems that for a change in durability to have an effect on the aftermarket revenues through extending the time in which services can be provided, the second hand market must become aware of the change and change its patterns. For instance, if we see it from the first owner perspective, he/she could choose to keep the truck for a longer time if he/she knows that the model is more durable than previous models. If the time that the truck is owned by the early customers is extended, the aftermarket revenues should consequently increase. However, if the owner does not believe that the durability is better than earlier, the replacement intervals might be kept as before and the extended usage time will appear at the end of the owner chain. Although it is a fact today that the aftermarket revenues are very limited in the end of the lifetimes, we should not assume that this will be the case also in the future. Instead of just offering replacement engines for instance, one could also offer renovation engines, which would be a cheaper alternative which might catch some of the customers that judge the replacement engines to costly and therefore sell the truck.

How would an increased economic life affect customers' satisfaction and image of the brand?

A rational way to explore this issue would be to monitor customer satisfaction with durability and durability image to see how it changes when the durability of the driveline and thereby possibly of the truck changes. This is hard, because durability is as described earlier a products ability to keep providing services over time, i.e. its lifetime. For a truck, the lifetime is usually measured as a mileage. If we look at it in terms of years, it would in many cases take at least 10 years before a truck is taken out of use completely due to being worn out and in need of repairs. Thus, not until about a decade after a new model is launched can we start to get data on durability and to make a good estimate we need to include also the trucks that survive a long time, increasing the delay further. The massive time delays do not make it worthless to ask customers about durability, but it makes the answers hard to interpret. This problem with durability data is accompanied by a problem with gaining data on how customers feel about the durability. Most trucks have several owners, so who is to judge the durability? It is also likely that many customers base their answers about durability on their perception of reliability, assuming that a good reliability corresponds to a good durability, which logical reasoning says that it often does.

While durability takes time before it can be seen, we must not focus only on the effects that we can see in the short term. If the durability of a new model would be superior to previous models and/or to competitors, it would in some way lead to savings for some customers and thereby increased customer satisfaction. In the long term, improved durability of a model could improve the image of Volvo as a brand of durable trucks. This might give Volvo new customers. Currently there are a few European brands that have very similar image when it comes to reliability and durability. By improving durability it might be possible to single yourself out as the best brand. If the case is that the main competitors make efforts to improve their durability, it might be necessary to improve durability not to loose ground on them. If improved durability creates customer satisfaction, which we expect it to do sooner or later, would that have any impact on the financial performance of the Volvo Group. Yes! Customer satisfaction feeds loyalty, this can be considered a fact, and the more loyal the customers, the more profitable the manufacturer. Acquiring new customers is hard and expensive so retaining current customers is really crucial to be competitive.

"When product attributes are difficult to observe prior to purchase, consumers may plausibly use the quality of products produced by the firm in the past as an indicator of present or future quality. In such cases a firm's decision to produce high quality items is a dynamic one: the benefits of doing so accrue in the future via the effect of building up a reputation. In this sense, reputation formation is a type of signalling activity: the quality of items produced in previous periods serves as a signal of the quality of those produced during the current period."

(Shapiro, 1983)

5 Discussion

5.1 Conclusions

Through RQ 1, we investigated what market research measures that have the strongest explanatory power for satisfaction with reliability. We found that on the US market, measures of downtime, especially the number of occasions with downtime, are more relevant than failure frequencies like the number of problems per time or distance unit.
The results for the US market indicate that one should be careful with putting to much focus on the number of problems experienced, which is a much emphasised measure today. The amount of downtime seems to deserve more focus.

For the European markets, we do not have access to measures of downtime through the studied survey. The measure with the strongest explanatory power available is the average number of problems among all trucks. It is important to note is that the data from the survey of the European markets does not seem to support analyses to be made based on the number of problems, the way we have measured it. Measuring reliability is not a prioritised objective of the European study as I have understood it, so I am not criticising the work of the survey supplier. It is rather a matter of what is ordered. Problems are tracked in multiple ways throughout the corporation already, but I think it adds additional value to get indications on the customer satisfaction, repurchase intentions etc. of those who state what problems they have had. The survey of the US market shows that this can be done, so I would suggest that more accurate measures of failure frequency and maybe more importantly downtime are incorporated into a slightly extended study for the European markets.

In RQ 2 and 3, we looked at the strength of reactions to changes in reliability. The reactions were studied as changes in both satisfaction with reliability and reliability image. The strength of the reactions to improvements and deterioration of reliability were to be compared. The analysis shows that the reactions are, at least for most changes in reliability more or less unpredictable. For large changes, the reactions are quite as expected, but the number of occurrences supporting this is low. The unpredictability of reactions yields a poor fit for our regression model and comparing the average strengths of reactions to changes in reliability is not relevant neither for satisfaction nor image. This means that we can not answer whether satisfaction and image are path dependant features or not. Having much stronger reactions to deteriorations that to improvements, which we would expect, would stress manufacturers to be careful with introducing technology that could generate poor reliability.

We tested in RQ4 if good workshop service could compensate substantially for poor reliability. The analysis shows that good workshop service generally improves satisfaction, but those customers who are dissatisfied with reliability but satisfied with workshop service are less satisfied than those who are satisfied with reliability but dissatisfied with workshop service. The overall satisfaction was measured through repurchase intention and willingness to recommend. This does not mean that there is no meaning with trying to provide excellent service. The analysis shows that good service clearly improves satisfaction. However, it suggests that we can never ignore reliability no matter how good service we can provide. Also, it is probably cheaper for the manufacturer to do it right the first time, i.e. building trucks with few problems, rather than building low quality trucks and provide excellent service.

RQ 5 is a qualitative analysis of how customers reason regarding reliability. Interviews with seven Swedish fleet managers revealed among other things that personal relationships between customers and sales staff are immensely important, that statistics is not frequently used by customers to evaluate trucks and that the impressions of brands among customers are based on a large variety of inputs. One of the managerial implications of these results is that the staff in the organisation must be trained well so that they are equipped to be able to build relationships with customers.

Another conclusion from the interview sessions was that customers do not seem to have a large acceptance for problems that are due to new technology. This means that there is clearly a risk in introducing more new technology than one is forced to by legal requirements. What is then the rationale of introducing more technology than other competitors, when the deteriorated reliability will have consequences in the customer satisfaction? There are examples of brands that have produced reliable trucks that have been based on more mature technology than that of competitors. This has given them a very good customer satisfaction. However, not providing state-of-the-art technology has hindered them from getting a premium image, and without a premium image it is impossible to charge as much as the premium brands can do. In spite the risk of losing customer satisfaction, premium brands must probably continue applying new technology not to loose their status.

In the last research question a model is created to create an initial understanding of how a changed durability of the driveline might affect the business performance of the Volvo Group. The connections between the constituents can at this point not be deeply analysed, while there is a lack of data in the organisation. This finding stresses that the area of durability must be explored better and measuring field durability must be done in a more consistent and systematic way than is currently done. Also, it is not always a lack of knowledge that is the problem. In many cases, knowledge exists somewhere in the organisation, but while the organisation is very large and the communication between departments could be better, the knowledge available is not diffused as would be appropriate.

As we have stated before, the interviews have been a very interesting part of this thesis and we think that they provide many valuable points even if it comes from a small number of people. The interviewees make purchasing decisions for some of the largest fleets in Sweden and satisfying these customers as well as other customers is integral to Volvo. A striking feature of the overall results is that the quantitative analyses are sensitive to validity of the measures and some of the most important results overall are concerned with personal relations, which is almost impossible to measure quantitatively. An overall conclusion is therefore that Volvo and other truck manufacturers must continue to keep a good communication with their customers in order to really understand why customers are satisfied or dissatisfied and also to be able to follow changes in needs and wants of its customers.

A general recommendation, that is not based on the results of my analyses but rather something I have realised when talking to people within Volvo is that if Volvo wants to stand out even more when it comes to reliability and durability, there are two prerequisites:

- Obtain superior quality.
- Make the customers understand and believe it.

The customers in Sweden that we have interviewed claim not to care much about advertising, but rather listen to people. For improved durability or reliability to be worthwhile, one must have a strong strategy for communicating it.

5.2 Methodological validity and reliability

5.2.1 Validity

The data on how many problems that customers have experienced is collected in similar manners in both surveys from which we have used secondary data. Both have the weakness that they can not take into accounts that some parts sometimes fail more than once for the same customer in the same year. The measures of the number of problems that we have created for the Western European market are have a lower validity than those for the US. The number that is acquired is actually the number of component categories that have had at least one failure rather than the total number of failures. For the US, the breakdown of components is very fine, whereas for Western Europe it is very rough. Using data that reflects how many customers that have had at least one problem with a component category and presenting it as the number of problems decreases the internal validity, i.e. that the measures actually measure what they are intended to. The reason for asking if a component category has had a problem rather than how many problems there have been with such components is not completely clear to me, but we suppose that it is thought to be easier for the respondent to answer if the question is asked in that way. We still want to use the number as an approximation of the number of problems, while we think it has acceptable validity and while the number of problems is in many cases a useful measure. However, we do believe that one should be as clear as possible with this weakness.

One problem with the surveys that I have analysed is that they are carried out quite early in the lives of the trucks. The trucks in the American study have been in service for about 24 months and the ones in the Western European study have been in service for 6-30 months with an average around 15 months. During the first 15 or 24 months, there are generally warranties covering most repairs. This means that the factors that are important for customer satisfaction during the period prior to the study, when the warranty period is not yet over, might not be the most important ones later on. For instance, repairs that can be done together with preventive maintenance should not be a big issue during the warranty period, while they cause neither downtime (except for some minor repair time) or repair costs. Later on, however, such problems may cause substantial costs. Therefore, this analysis does not provide an explanation of what measures that reflect factors important for customer satisfaction during the entire life of a truck. Rather, it only provides us with knowledge about the relative importance of the measures during the period that the studied vehicles have been in service, i.e. approximately the first two years. We expect that if we would look at a point in time when the warranty is not valid any longer, the importance of direct costs such as repair costs, would increase to some extent.

We believe that the results for Western Europe (RQ1-4) are valid for that region even though not all countries are included in the survey. My impression is that the included countries are a fair representation of Western Europe.

In RQ4, we try to quantitatively test the hypothesis that a considerable number of problems can be accepted as long as the service organisation is good. The analysis is based on a large sample of responses and we believe that there are no major threats to reliability. The validity might be threatened though by the grouping of ratings, for which there is no clear best solution. The value of the comparison is founded on the assumption that the groups represent combinations of 'satisfied' and 'not satisfied'.

There is probably very limited external validity for the results of RQ5, which is based on interviews of seven Swedish fleet managers. The results could be seen as indicative for Swedish fleets with mainly Scania and Volvo trucks and where a major owner is also CEO.

5.2.2 Reliability

In the survey of the US market, the average time of use differs substantially between brands and years. The largest differences are, both when comparing between brands and between years about 10-15% (ranging from 22 to 25 months of service), creating a potentially substantial source of error. There are several factors in the studies that we can expect to be more or less linearly dependent of time. For instance, the number of failures per vehicle should increase with an extended studied period.

The sample sizes for the secondary data suggest that the reliability data used in RQ1-4 should be fairly high. This is however, not only a matter of sample sizes but also of how the interviews were carried out. We do not have enough information to give a statement about the reliability and general quality of the methodologies used for the generation of data. This is the common drawback of using secondary data.

An issue which might commonly be forgotten is the risk of the researcher making mistakes when compiling data. It would be unrealistic of me to say that there is no such risk considering that we for the quantitative analyses have handled data files with enormous amount s of data.

The limited reliability of the methodology for RQ5 is an issue that my supervisor at Volvo and I have been aware of all the time. We need to accept it and be cautious with how the results are used. They do provide valuable input to how fleet managers might reason even if the sample might not be a very reliable representation of all Swedish fleet owners. Apart from the reliability limitation in the small sample size, there is also one in the fact that qualitative data requires compilation and classification, allowing for interpretations by the researcher. This issue is however nothing specific for this research, but rather common for all qualitative research.

Another important issue when employing regression analysis is that of *collinearity* between predictors. Collinearity is sometimes referred to as ill-conditioning and it means, in connection to regression analysis, that predictors are so highly correlated that it becomes difficult or impossible to distinguish their individual influences on the response variable (Dallal, 2001). While there is a large degree of covariation among the predictors in my study, the variation that each predictor uniquely shares with Y will be small. This means that the reliability of our measures decreases and it makes it hard to make reliable comparisons between the predictors. Simply speaking, while the measures have so much in common, the impact of randomness becomes higher and our evaluations of the predictive abilities of the measures loose in reliability. This is an issue we must be aware of and which raises a concern of the reliability of the results to Research Question 1. Criticism on this point has been rightfully presented and there would be a great value in confirming the results with a future study, preferably made with an improved research method. We must be cautious especially with focusing on the small differences that exist between some variables. That the measures of downtime on the US market have a stronger predictive ability than the measures of failure frequency is an indicative result that I find quite reliable, but it would be valuable confirming it in a second study and we must be very cautious with for instance the difference between 'Number of times with downtime' and 'Total days with downtime', which is very small considering the relatively poor reliability of the results.

5.3 Using correlation for rating importance

During the course of this research, which to a large extent has been done by studying customer surveys made by others, we have come across some different methods for evaluating different aspects of products and services and also for rating the importance of each aspect. I have found that sometimes conclusions are based to a too high extent only on correlation studies. For instance, when trying to rate the importance of about 15 aspects of a truck, the correlation between the satisfaction rating of each aspect vs. the overall satisfaction rating is checked. High correlation is interpreted as high importance. There are also instances where the correlation between the satisfaction rating for some aspect and the stated repurchase intention is used. Then this is compared to the importance stated by customers for each factor. Finally, if the correlation with repurchase intention is strong but the customers state the factor not to be very important, then the correlation is given the higher power and it is generally considered that the factor is important, without the customers knowing it. These kinds of conclusions are in my view very risky. I believe that looking at the correlation with repurchase intention or overall satisfaction can give some support about whether a factor is important or not but it can never be the only argument for it. As in all cases, where correlation is used as a means of showing a relation between two factors, it can never be that single argument, it can only be one of several facts pointing in the same direction. Why do I think that it is so bad to use the correlation between a factor and the overall satisfaction or repurchase intention to show its importance? Is it not true that if customers who are more satisfied with a factor have a higher retention rate or overall satisfaction, then that factor must be important? No, it is not necessarily true! To show how this kind of thinking can give us the wrong idea I will give a simplified example.

Say that we have 4 types of trucks, we call them T1, T2, T3 and T4. Their characteristics are presented below.

T1	T2	T3	T4
Very good fuel efficiency	Poor fuel efficiency	Poor fuel efficiency	Good fuel efficiency
High price	High price	Moderate price	Low price
High quality	High quality	Moderate quality	Poor quality
Very spacious cab	Very spacious cab	Moderately Spacious cab	Not spacious cab

The customers are asked to rate their satisfaction with the truck they own for each factor: fuel efficiency, price, quality and how spacious their cab is .They are also asked to rate their overall satisfaction.

Let us assume that the actual importance looks following way[26] (might be same as stated by customers but not necessarily):

Quality	Most important
Price	↕
Fuel efficiency	
Spacious cab	Least important

Let us assume that T1 gets the highest rating for overall satisfaction and that the types happen to be rated for overall satisfaction as they are named. T1 is the best, T2 second best. etc.

If we now look at the correlation we probably find that customers that are customers with truck types T1 and T2 are satisfied with quality and have a good overall satisfaction whereas customers of T3 and T4 are less satisfied with quality and are less satisfied overall. Hence, quality would be concluded as very important. If we look at price, it is likely so that customers, when judging how satisfied they are with the price, take into consideration what they get for the money. Therefore, based on the specifications above, let us assume that all customers give a similar rating for price. That would be interpreted as the price being totally unimportant, while it would have no correlation with the overall satisfaction. This interpretation would be wrong. Spacious cabs would also be given an importance rating based on correlation that would be totally wrong. There happens to be a correlation between the factors spacious cabs and quality and there is, as assumed before a strong correlation between quality and overall satisfaction. If we look at the correlation between spacious cabs and overall satisfaction it will be very high and it could be interpreted as spacious cabs being important for overall satisfaction whereas it is very unimportant and where the correlation simply comes from the factor being correlated with factors that are important.

[26] Obviously different customers have different needs and priorities, hence the variation in the types that they buy. However, if we want to find factors that are more important than others, then we must assume that there are some factors that in average are more important than other.

Factors that are positively correlated with important factors will (sometimes wrongly) be perceived as important. For instance, it might be that high quality trucks often have spacious cabs, which can fool you into thinking that spacious cabs in itself is important.

5.4 Suggestions for future research

5.4.1 Customer reactions to changes in reliability

- Include questions about downtime in the surveys of the Western European markets.
- Improve the measures of reliability so that they are more accurate. This demands a substantial extension of the survey, while one needs to ask the respondents about many parts of the truck. However, it provides great value to know what problems that have occurred among the customers whose satisfaction and image ratings we look at.
- Investigate deeper the rationale of introducing new technology and the possible advantages and disadvantages in terms of satisfaction and image related to reliability.

5.4.2 Economical aspects of durability

This section deals with future research that we would recommend in order to facilitate deeper conclusions regarding economical aspects of durability. These are issues that have arisen when we have looked into this issue, limiting the possibility to proceed into a deeper analysis without substantially extending the time needed.

- **Issue**: It takes a very long time before the durability of a truck can be seen, delaying durability estimates.

    - This is an integral issue without solution due to the nature of durability.

Issue: We need to know if customers would change their behaviour of buying and selling thanks to changed durability.

- **Possible approach**: Create suitable question(s) and try to get them integrated into some current survey. Alternatively, one could form a network of customers that provide input through focus groups or similar.

- **Issue**: If a brand wants to stand out when it comes to reliability and durability, one issue is to actually obtain superior quality. The other is to make the customers understand and believe it. The customers in Sweden that we have interviewed claim not to care much about advertising, but rather listen to people. If it should be worth improving for instance durability, this has to be in line with company strategies so that there is commitment to emphasize this in communication

  - **Possible approach**: Take into consideration whether a further emphasis on durability is in-line with the company strategies. Investigate what would be needed to influence the marketing strategies and discuss with marketing departments the fact that advertising might not be the most suitable media for communicating quality to truck customers. Maybe the training of sales and workshop staff for instance is more important.

- **Issue:** We do not know how much impact the customer perception of durability has on the second hand price. We do not have very reliable estimates of truck durability and we have not been able to find statistics on second hand prices that are useful, while there are so many details of a truck that makes it hard to create homogenous groups. What is needed when looking at how durability affects second hand price is not only the second hand price, but also the original new truck price so that one can obtain the share of the trucks value that remains. Otherwise, one will mainly get the result that trucks that are expensive when new also have a high second hand value, and this is not what we are interested in.

  - **Possible approach**: Ask customers that regularly buy used trucks of several different brands how they decide what different trucks are worth.

- **Issue**: The regulatory environment and the technological advances that affect how long it is economically sound for different owners to keep trucks changes continuously.

  - **Possible approach**: Follow development of regulations closely and analyse how this affects the strategies of truck fleets. Keep track also of technological advances such as major improvements in fuel efficiency and become aware of how this affects the needs and benefits of reliability and durability.

- **Issue:** How would the reliability of the trucks be affected if the durability was improved?

    - **Possible approach**: Likely, truck durability could be improved by improving the durability of some expensive components that today, when failing, “force owners” to take trucks out of use. Look at components overall and identify components that usually do not have a lot to give when the truck is taken out of use. Consider if these could stand an extended usage time or if it might be so that many components would fail in the end of the new lifetime.

- **Issue:** How would the aftermarket revenues be affected by an improved durability

    - **Possible approach**: A good start would be to get a good understanding of how the aftermarket business looks today for trucks of different ages and different markets. When do customers in Sweden stop using authorised workshops, how do the flows of truck to different countries look and what about the aftermarket revenues on those countries. Some of this information is probably available at the aftermarket departments, but in that case probably the communication needs to improve between engine development and aftermarket dept. at Volvo trucks.

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(60)Pictures from the Volvo Trucks Image Gallery are used with permission. Available: <http://imagebank.vtc.volvo.se/> (2007-10-10)

Appendix 1: Abbreviations and Key concepts

Abbreviations

B2B – Business-to-Business

B2C – Business-to-Consumer

DOC – Diesel Oxide Catalyst

HDV – Heavy-Duty Vehicles

PPH – Problems per 100 vehicles

VPT – Volvo Powertrain

VTC – Volvo Truck Corporation

YTY – Year To Year

Key concepts

The following list contains explanations rather than formal definitions.

Driveline – The entire entity that supplies the wheels with power i.e. engine, gearbox, propeller shaft and driveshaft(s).

EURO – classes for emission levels, applied mainly within the European union, but also in some other countries.

Retrofit - The addition or removal of an item of equipment, or a required adjustment, connection, or disconnection of an existing item of equipment, for the purpose of reducing emissions

Distribution trucks – Trucks that are used for distribution of goods. Generally these vehicles are not very heavy and do not travel long distances. Rather, they operate within a smaller region.

Long-haul trucks – No common definition. Trucks that carry goods over long distances. Often, but not always tractor-trucks.

Semi-trailer - A trailer having a set or several sets of wheels at the rear only, with the forward portion being supported by the truck tractor or towing vehicle.

Tractor - Truck designed primarily to pull a semi-trailer and sometimes also a trailer

Rigid truck (or straight truck) - Truck which carries cargo in a body mounted to its chassis, rather than on a trailer towed by the vehicle.

Appendix 2: Important technical components

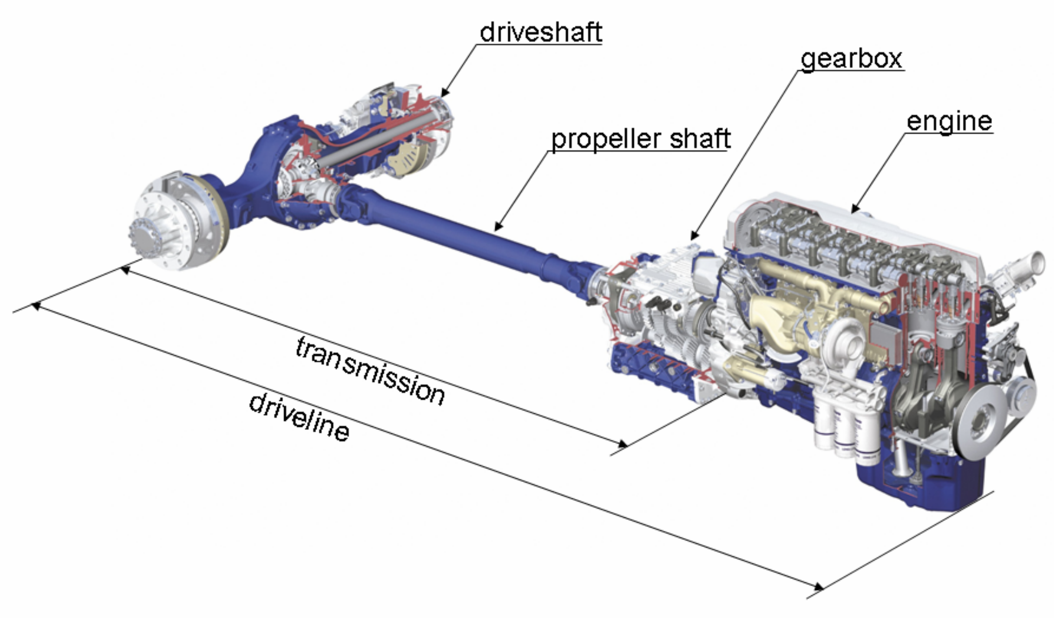

Figure 42: Driveline components. From Volvo Trucks Image Gallery. Printed with permission. Grouping and naming according to Volvo Corporate Standards.

Appendix 3: Basic types of trucks and trailers

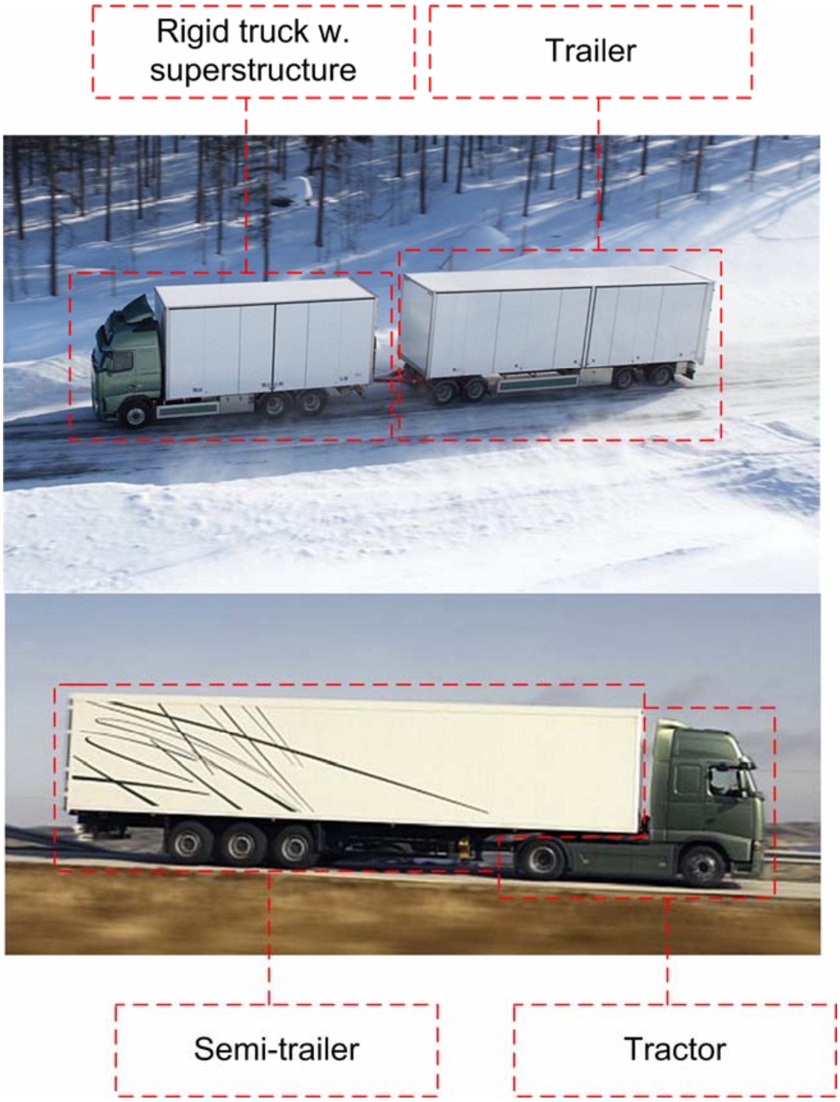

Figure 43: Types of trucks and trailers. Based on pictures from Volvo Trucks Image Gallery. Printed with permission

Appendix 5: Interview guide (English)

Respondent

Fleet/customer:

Respondent's name:

Respondent's position:

Date:

Background information

A1. Please give us a brief description of your company and the operations

____

____

____

____

____

A2. What is your distribution of trucks with respect to makes?

____

____

A3. What kind of driving do you do?

____

____

A4. How many employees do you have? ______________________________

A5. What is your annual financial turnover?___________________________________

A6. Spontaneous follow-up questions

____

____

____

A7. Do you have service contracts for your trucks? If yes, what type?

____

A8. Where are the most of your service and repairs of your trucks done?

- Authorised brand workshop
- By your own company
- Other ____________________________

Knowledge about problems

B1. Do you internally follow up the reliability and durability of the trucks that you own? If yes, how?

____

B2. What kind of information regarding reliability and durability do you have access to when buying a new truck? (If the question is not understood, ask "Do you ask other customers, read industry magazines etc?")

____

____

____

B3. Do you talk to people outside your company about experiences from different models. If yes, who and on what occasions? Who do you ask and who are you telling?

____

____

____

B4a. What is your opinion about the reliability of trucks from the following manufacturers? Please give a rating from 1 to 10, where 1 is very bad, 5 is average and 10 is excellent.

Volvo ___ Scania ___ Iveco ___

M-B ___ MAN ___ DAF ___

Renault ___

B4b. What do you base your opinion on?

____

B5a. What is your opinion about the durability of trucks from the following manufacturers? Please give a rating from 1 to 10, where 1 is very bad, 5 is average and 10 is excellent.

Volvo ___ Scania ___ Iveco ___

M-B ___ MAN ___ DAF ___

Renault ___

B5b. What do you base your opinion on?

____

____

B6. Has your opinion about these makes changed over time? If yes, when and how?

____

____

Buying and selling

C1. What are the main reasons for replacing a truck?

____

____

C2. Do you have rules of thumb for how long to keep a truck. If yes, what are the rules?

____

C3. When it comes to costs of downtime and repairs, how does it affect the decision to replace a truck? (If not mentioned in the previous question)

____

C4. When you sell a truck, is the price affected by the reliability shown so far?

Yes ◦

No ◦

If yes, how? ______________________________________

Acceptance

D1. Do you have a larger acceptance for failures when they are due to new technology?

Yes ◦

No ◦

Why? ______________________________________

D2. Has your distribution of trucks with respect to makes change over time? How come?

____

Thank you!

Appendix 6: Durability economics

Much of the early research that was done on economical aspects of quality was concerned with product durability and its impact on the profitability of manufacturing companies. However, most of it focused on the question of what durability a manufacturer should have in order to maximise profits in a monopolists market (see for instance Kleinman and Ophir, 1966, Swan, 1970).

Some models have also been made to explore optimal durability in a perfect market. Kleinman and Ophir (1966) conclude that an increased interest rate will decrease optimal durability but that the demand of service from the products has no effect on it. These results are though somewhat shadowed by the fact that Swan (1970) proved some assumptions and thereby conclusions in the article to be wrong.

A general feature of the research on durable goods theory is that it so far consists of numerous models, whose assumptions are often arguable and which limit the validity and applicability of the conclusions severely. One of these assumptions (employed in Swan, 1970 and Sieper and Swan, 1973 and criticised by Avinger, 1981 and Waldman, 2003) is that units of service are perfect substitutes in consumption irrespective of the age or durability of the product supplying the services. One can easily see how there could be a difference between the service supplied by a brand new truck and that of an old one. Driving comfort, safety, reliability and fuel consumption are only a few important aspects that could be age-dependent.

Planned obsolescence

One way to create planned obsolescence is to frequently introduce changes in style that increases the difference between new and used trucks (Waldman, 2003). With a bigger difference it is easier to increase the price of new units without having the old ones as competition that is limiting the price.

Adverse selection

The concept of adverse selection applied on the automobile second hand market was described in Akerlof (1970). It is founded on the assumption that there will always be an asymmetry in information when a used product is sold, meaning that the seller has more knowledge about the quality of the individual car than the buyer does. If we assume that the buyer only knows something about the group of cars defined by model, production year etc, this is what will define the price. The consequence is that the sellers that own cars with lower quality than the group average will have the most benefit from selling. The owners of cars with over average quality on the other hand have little incentive to sell while they probably will not be able to get a price reflecting the high quality. The essence of this market mechanism is thus that the majority of the second hand market turnover will consist of cars of relatively low quality and the asymmetric information will overall reduce the activity of the second hand market. The adverse selection, it should be noted, is not as applicable when there are warranties defining a minimum quality level. After the warranty period however, the mechanism is applicable as long as the buyer can not have as much knowledge as the seller about the individual item for sale.

If adverse selection is highly present, then the second hand market will be constrained, leading to a lower pricing of used cars (Hendel and Lizzeri, 1999). A lower second hand price and lower second hand market turnover will naturally effect sales of new goods, but the effect on the new car price from adverse selection is not absolutely clear. The lowered second hand price affects the new good price negatively, while it increases the cost of ownership for the buyer of the new car. On the other hand, a lower quality of the second hand market makes the used cars less substitutable for new ones which allows for higher pricing of new cars (Hendel and Lizzeri, 1999).

Appendix 7: Technology discriminating regulations on in-use trucks

It is clear that the emission tolls may have an impact on the economic life of trucks. If a user faces tolls that are up to twice as high with an older technology than with state-of-the-art technology, the cost of operations with an old truck will increase and the benefits of good durability will decrease.

Emission tolls

EU

Directive 2006/38/EC of The European Parliament and of the European Council of 17 May 2006 regulates the charging of heavy goods vehicles for the use of certain infrastructures. It is based on the principles 'user pays' and 'polluter pays', meaning that the charges are aimed only at users of the infrastructure and that the charges may discriminate between users of different technology. The motives of the tolls include financing infrastructure and creating incentives for users to invest in newer technology, which is more environmentally friendly. Regarding the size of the tolls, the directive states that the toll rates may be varied according to the so called EURO emission classes. The tolls on a truck may not be more than 100% over the tolls charged on equivalent vehicles meeting the strictest emission standards. The directive states that

> "Member States may vary the toll rates for purposes such as combating environmental damage, tackling congestion, minimising infrastructure damage, optimising the use of the infrastructure concerned or promoting road safety, provided that such variation:
> — is proportionate to the objective pursued;
> — is transparent and non-discriminatory
> particularly regarding the nationality of the haulier, the country or place of establishment of the haulier or of registration of the vehicle, and the origin or destination of the transport operation"[27]

[27] *Directive 2006/38/EC of The European Parliament and of the Council of 17 May 2006 amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures* (2006)

So far, a number of countries have applied road tolls that discriminate between emission classes. They are applied on highways and some other major roads. The countries and the additional costs of having an old technology are presented in Table 20[28].

Table 20: **Road toll charges**

Country	Emission categories	Charged unit	Additional cost of oldest technology compared to newest
Czech Republic[29]	Euro 0-2, Euro 3-5	Distance	29-35%
Germany[30]	None-Euro1, Euro 2, Euro 3, Euro 4, Euro 5, EEV 1	Distance	About 50%
Poland[31]	Euro 0-1, Euro 2 or newer	Time	10-19%
Romania[32]	None, Euro 1, Euro 2 or newer	Time	Up to 50%
Switzerland[33]	Euro 0-1, Euro 2, Euro 3-4	Distance	34%
Eurovignette countries[34]: Belgium, Denmark, Luxembourg, the Netherlands, Sweden	Euro 0, Euro 1, Euro 2	Time	About 25%

Even though there are still many countries that have not applied this kind of tolls, we can conclude that they exist in some countries with large markets and large traffic flows, most noticeably Germany, so the effect is still considerable. For operators registered in or with substantial presence in the mentioned countries, the effect should, the percentages suggest, be substantial.

[28] No information has been found regarding Cyprus, Lithuania, Greece or Malta. For other EU members not mentioned in Table, the European Car-Transportation Group of Interest (ECG, 2007) states that there are currently no emission-based tolls.
[29] ECG (2007)
[30] Toll Collect (2007)
[31] ECG (2007)
[32] UNTRR (2005)
[33] ECG (2007)
[34] Skatteverket

No tolls discriminating on the basis of emission class in other regions have been identified.

Restricted access zones and retrofit requirements and incentives

Europe

In an effort to harmonise the driving restrictions on heavy goods vehicles involved in international transport on some designated roads, the European Union has laid forward a proposal which allows member states to impose restrictions between 10 pm and 5 am on vehicles that do not comply with the noise emission standards that are in effect (Directive 96/20/EC). To give an impression of the current situation concerning implemented models to restrict access of heavy-duty vehicles based on emission or noise I will present some examples. There exist additional cases, which are not presented here.

One of the so far most efficient models for restricted access of heavy-duty vehicles with relatively old technology is the Swedish environment zones regulation. Since 1996 it has been effective in Stockholm, Gothenburg and Malmo and since 1999 also in Lund. Revisions on the regulations became effective Jan 1, 2007[35]. The new regulations applies to all heavy-duty vehicles over 3.5 metric tons and restricts access into some designated city zones for vehicles that were first registered more than 6 years ago (8 years for Euro 2 and 3). Trucks with Euro 4 or Euro 5 technology have access until 2016 and 2020 respectively, independent of when they were registered. No exemptions are made for retrofitted vehicles.

In Stuttgart there is from 2007 a year-round traffic ban for diesel vehicle that do not fulfil any Euro standard, with the exemption of those that are retrofitted with a soot particle filter[36]. From 2008 the demand will be Euro 2, but with the same retrofit exemption.

Regulations that will be implemented in the five largest cities in Denmark stipulate that particulate filters must be fitted to Euro 0-2 vehicles from July 2008 and to Euro 3 vehicles from July 2010 for access to be granted[37].

In the Netherlands, access to zones in 10 major cities will demand, by July 1st 2007, that the vehicle fulfils Euro 4 or fulfils at least Euro 2 and is fitted with a certified particulate trap. By

[35] Nyheter angående miljözon (2006)
[36] Policy options for access restrictions in Stuttgart (2006)
[37] Thomsen (2007)

January 1st 2010, the demand is tightened to Euro 4 or Euro 3 less than 8 years old with a particulate trap[38].

For all vehicles registered in the UK a vehicle tax needs to be paid. If one retrofits a particulate filter or a new engine, one might get the tax reduced by up to a third[39]. Furthermore, London is looking at creating a low emission zone. Investigations by government officials recommend demands on Euro 2 by 2006/2007 and Euro 3 by 2010[40].

In a very large number of European cities (Zürich, Geneva, Munich, Lyon, Berne, Hamburg, Marseille, Milan, etc.) there are retrofit efforts that are limited to waste collection vehicles and buses[41]. It seems reasonable to expect that such cities might consider applying retrofit demands also on other heavy duty trucks.

US

In California, a plan was developed in 2000 by the Air Resources Board (ARB) in order to limit diesel particle matter emissions[42]. It affects both new and in-use heavy duty vehicles but so far the requirements only apply to publicly owned or operated vehicles. The plan is however, that it should be applicable also on private vehicles. The regulations that are in effect stipulate that all public fleets must apply best available control technology (BACT) on their heavy-duty diesel-fuelled vehicles with model years between 1960 and 2006. BACT can be an alternative fuel engine, a diesel engine that is certified at a sufficiently low particulate matter emission level or application of some other control strategies such as retrofits of diesel particulate filters or certain catalysts.

There are no federal requirements of this type on in-use engines.

[38] Degenkamp (2007)
[39] Directgov
[40] Sadler
[41] Mayer (2004)
[42] California Environmental Protection Agency (2000)

Japan

Since 2003, all heavy duty trucks that were registered at least 7 years ago have to join a retrofit program to meet substantial decreases in particulate matter emissions (Walsh, 2001). Trucks that fail to meet the new demands are banned from Tokyo Metropolitan area as well as four additional prefectures. According to *Japan Auto Trends* the execution of the new regulations immediately had an effect on new truck sales. The increase of sales for the first half year of 2003 was 36.7 percent higher than the corresponding period the previous year. Japan Auto Trends elaborates that sale rose because fleet owners found it more economic to buy new vehicles than to retrofit the old ones they had. The timing of the market growth makes it possible that it could be explained largely by the new regulations while the general economy was not considered to support such growth.

Worldwide there are also a large number of voluntary retrofit programs, e.g. in Beijing, Hong Kong and many American states.

Appendix 8: Used translations

Table 21: Translations made for table 20

Original phrasing (Swedish)	Proposed translation
Få driftsstopp	Few breakdowns
Få reparationer	Few repairs
Lång komponentlivslängd	Durable components
Låg reparationskostnad	Low repair costs
Enkel att reparera	Easy to repair
Enkel felsökning	Easy to locate problems