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# Business development in Rail Maintenance

Evaluation of monitoring axle/wagon distance

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## **Preface**

This master thesis was produced over a period of 20 weeks during the winter/spring 2010, as the final part of the program for Industrial Engineering and Management at Lund Institute of Technology, Lund University. The project was conducted at the department of Industrial Management & Logistics and in association with EuroMaint Rail.

Many people have contributed to the final result, and we would like to thank all contributors for coping with our questions, e-mails and phone calls. Special thanks to our supervisors Bertil I Nilsson at Lund University and Trygve Engelbert at EuroMaint Rail, without whom this thesis would not have been possible.

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## **Abstract**

Due to recent accidents involving goods wagon axle failure, there is an increasing international focus on axle safety. One way of increasing the safety of goods wagon axles is monitoring the distance traveled by the axle and using this information to improve maintenance of the axle. This fact has sparked the belief that regulations regarding monitoring distance covered by goods wagon axles will become stricter in the future.

The belief in upcoming stricter rules together with the fact that EuroMaint Rail has recently moved into the German market for rail maintenance has resulted in a desire to be able to offer monitoring of goods wagon/axle distance to customers. The company has little knowledge about the concept of monitoring goods wagon/axle distance, and increasing this knowledge is the basic objective of this project.

To provide a basis for decisions regarding future actions in the field of goods wagon/axle distance monitoring, the project has been focused on identifying and evaluating different techniques as well as establishing the uses of goods wagon/axle distance information. Also, the suitability and possibility for EuroMaint Rail to incorporate this type of product/service into its portfolio has been evaluated.

Possibilities to monitor goods wagon/axle distance have been established by classifying and identifying techniques available and under development. The techniques identified have then been evaluated with respect to their suitability for the company. The most promising concept has been found to be a GPS-based solution where distance is approximated using registered positions of the wagon at different points in time.

To establish the demand for distance monitoring and the possibilities to offer the concept in the market, potential customers have been consulted regarding their potential use for the information, the willingness to pay and customer requirements on the product/service. Although there is a visible demand for distance monitoring in the market, the willingness to pay has been found to be very low.

Due to the availability of technical equipment in the market, the in-house competences, and the low willingness to pay for distance information, the recommended course of action for the company is to focus on customer specific offerings and not attempt to develop a tangible offering until a deal is made with a customer. This approach keeps risk at a minimum while at the same time keeping the window open for the possibility to offer a solution to the right customer.

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## Definitions

DB	Deutsche Bahn
ECM	Entity in Charge of Maintenance
FORD	Fordonsdatasystemet, a collection of information systems for control and monitoring of vehicle maintenance for the rail sector
GCU	General Contract of Use for wagons
GSM-R	Wireless communication system for railway communication based on GSM
MTTF	Mean Time To Failure
TPI	Technical Specifications for Interoperability
VPI	Vereinigung der Privatgüterwagen-Intressenten, a German association of private wagon stakeholders
VPILF	the VPI maintenance guide

# 1. Introduction

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*This chapter will introduce the reader to the background and reasons for carrying out this research. The problem will be discussed and specified, and the theoretical framework introduced. Also, the delimitations of the study will be discussed.*

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## 1.1 Background

### 1.1.1 International focus on axle safety

In June 2009, a serious train accident took place in Viareggio, Italy. A freight train with 14 goods wagons transporting Liquefied Petroleum Gas (LPG) derailed, resulting in gas leaking out from one of the wagons. This gas was likely ignited by a spark, and the resulting fire spread explosively 300m around, devouring cars and houses and killing 32 people<sup>1</sup>. Most likely, the derailment was caused by an axle failure in one of the wagons.<sup>2</sup>

Problems with goods wagon axles had been reported earlier during the spring of 2009 by EBA, the German railway inspection authority. It was feared that as many as 600 000 axles on wagons used to transport heavy loads are in the danger zone for axle failure<sup>3</sup>.

After the accident, discussions have been held on an EU-level about implementing a common system of control for the union as a whole. These discussions indicate that the demands regarding control over the maintenance of goods wagons will become stricter<sup>4</sup>.

The upcoming changes will likely lead to a need for changes in routines and control from the part of wagon keepers. One aspect that can give better control over the state of goods wagons (and in turn the need for maintenance) is monitoring the distance traveled by a goods wagon or more specifically a goods wagon axle.

### 1.1.2 EuroMaint Rail <sup>5</sup>

EuroMaint Rail was founded in 2001, when SJ Maskindivision became EuroMaint. The company provides comprehensive maintenance and refurbishment services for railway vehicles, both for passenger and freight, as well as infrastructure work.

Overall responsibility is taken for train maintenance and vehicle availability, with the aim to keep the vehicles available for service as much as possible. Ways of improving the

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<sup>1</sup> Il Tirreno: *Elisabeth, trentaduecima croce*, [iltirreno.gelocal.it](http://iltirreno.gelocal.it)

<sup>2</sup> Reuters: *Italy gas train derails and explodes, killing 14*, [www.reuters.com](http://www.reuters.com)

<sup>3</sup> Ny Teknik: *Skärpt kontroll av godsvagnar efter gasolyckan*, [www.nyteknik.se](http://www.nyteknik.se)

<sup>4</sup> *ibid*

<sup>5</sup> EuroMaint Rail: *About EuroMaint Rail*, [www.euromaint.se](http://www.euromaint.se)



services offered are continuously sought. To keep improving the services offered and add new services, there is a group working specifically with technical solutions and products within the company.

EuroMaint Rail has during 2009 acquired a number of workshops in Germany, in a step to widen their market and be able to attract German customers. German rules and regulations (primarily set by wagon keepers) are already strict. Offering products that can increase the safety and availability can lead to better being able to attract German wagon keepers as customers. Such improvements in services offered can naturally also be applied in other markets to increase the service level and potentially attract new customers.

Due to the discussions about train axle safety, EuroMaint Rail has seen the possibility to improve their services offered. Improving axle safety can be done in various ways. For example, the risk of deformation of the axle can be reduced by monitoring the heat in the axle box. Monitoring the relative position of the wheels in regard to the axle can also reduce risk of failure by identifying causes of stress at an early stage. A third alternative is monitoring the distance traveled by the axle in order to make sure that the axle is subject to maintenance at short enough intervals.

The possibility to add the service of monitoring distance traveled by train axles to the portfolio of EuroMaint Rail is what will be explored in this thesis. As this could have implications for other things than axle safety, these will also be investigated and discussed.

## **1.2 Problem discussion**

There are several potential gains to be made from monitoring the distance traveled by a goods wagon and/or axle. The important thing to establish before evaluating a system for goods wagon/axle distance monitoring is what purpose the information gathered is intended to serve. The problem must allow for a wide interpretation of the potential use for such information, as well as for a wide interpretation of the possible ways to technically address the solution of the problem. It is important that the focus is kept wide initially to allow for input from all conceivable stakeholders. Because of these demands, the proposed problem will have to be held relatively non-specific.

The proposed problem for this thesis is:

“How can the distance covered by a goods wagon be monitored and can this information be used to gain competitive advantage for a railway maintenance company?”

### **1.3 Purpose**

The purpose of this thesis is to identify and evaluate different techniques by which the distance covered by a goods wagon and/or axle can be monitored, as well as establishing the uses of this type of information. Furthermore, the purpose is also to investigate if and how this information about possible techniques can be used by EuroMaint Rail to increase their competitive advantage, possibly making the company better equipped to take contracts in for example Germany.

The purpose is for the report to serve as a basis for the company to move forward within the area of monitoring goods wagon and/or axle distance. This can be done either by adapting a solution to a tangible offering to current or potential customers, or by discarding the idea of simply monitoring vehicle distance and concentrating on other, possibly closely related, products or services. The most appropriate path for the company to choose will depend on the findings and conclusions presented in this report.

### **1.4 Objective**

The objective of the research is to lead to recommendations for further actions to take for EuroMaint Rail when it comes to the area of monitoring goods wagon/axle distance. The objective includes specifying the recommended way of monitoring wagon/axle distance as well as establishing whether or not the concept is suitable for EuroMaint Rail to offer its customers.

In addition, part of the objective is to recommend further studies to conduct in order to progress within the area of goods wagon/axle distance monitoring. The goal is for the findings and recommendations to be presented to the company both in a report as well as in the form of a seminar for EuroMaint Rail employees who are concerned by or interested in the subject.

### **1.5 Theoretical framework**

The theoretical framework used in this thesis is limited. The basis of the conclusions drawn will be opinions and knowledge shared by stakeholders and experts in the rail freight industry and other related companies. However, different maintenance concepts will be discussed, as well as theory regarding different aspects of quality. Also, a selection of strategy concepts will be introduced. These will form a basis for discussions regarding the strategic suitability of incorporating wagon distance monitoring in the product/service portfolio of the company.

## **1.6 Delimitations**

Delimitations of the thesis include:

- The study will only include the service of monitoring the distance traveled by train axles and/or wagons, as mentioned before (see 1.2).
- The service/system itself will not be developed.
- The study is limited to measuring applications for goods wagons, thus passenger vehicles and locomotives will not be dealt with. However, the findings may be interesting for rail vehicles in passenger traffic as well.
- The case study is limited to applications suitable for EuroMaint Rail, but the findings and recommendations can be used as a source of information for other stakeholders as well.
- Testing of the different technical solutions available on the market and evaluated in this report will not be made.
- Although potential customers will be consulted, the performance of a comprehensive market research is beyond the scope of this study.

## **1.7 Target groups**

The target groups are mainly business developers and other employees at EuroMaint Rail, as well as people within the academic world (including professors, teachers and students, especially in last year studies towards a MSc in Engineering). Other target groups are organizations and people in general that are interested in the concept of monitoring the distance traveled by goods wagons.

## 1.8 Report outline

The report is made up of the following parts:

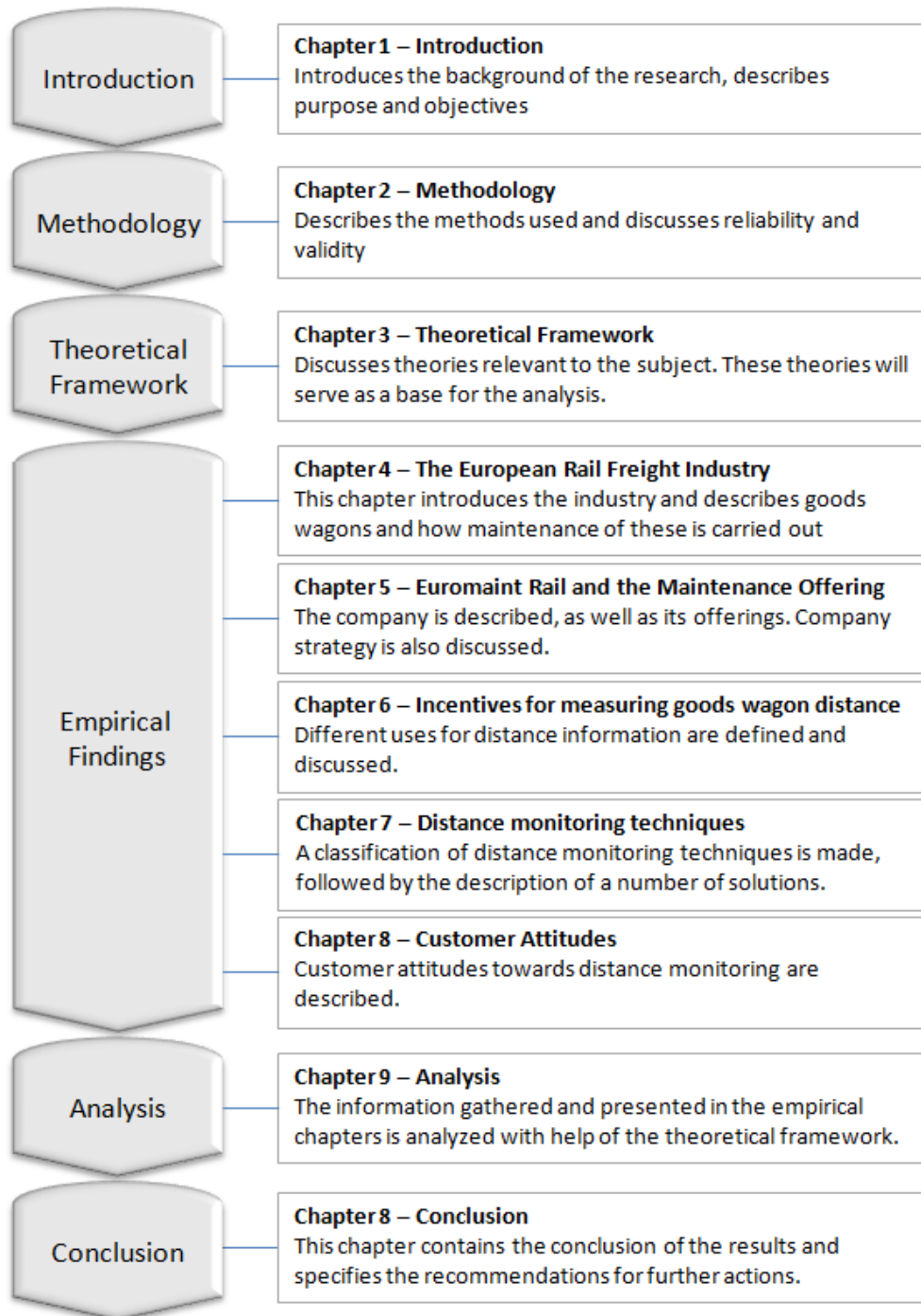


Figure 1.1, Report outline

## 2. Methodology

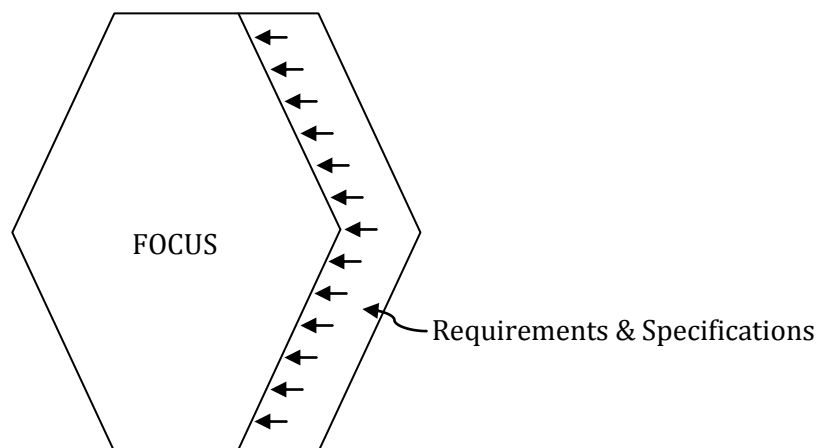
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*This chapter will present the methodological approach to the thesis, as well as discuss the quality and validity of the data gathering and analysis. Understanding the underlying methodology used will make it easier for the reader to fully grasp the work done and in turn the conclusions made.*

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### 2.1 Approach to the problem

The purpose of this thesis is to investigate different ways of monitoring the distance covered by a train axle used in cargo traffic. Initially, the focus is kept wide to allow for diverse influences. All conceivable means of measuring the distance covered will be considered and all leads to different solutions will be examined, allowing for the focus to widen initially. As a parallel monitoring of the specifications and requirements from both EuroMaint Rail and its current as well as potential customers will be conducted, the focus will progressively narrow. As the study progresses, the scope will narrow and a more specific focus will form the basis of the final report and recommendations. The progress of the focus and effect of requirements and specifications on the width of the focus is illustrated in Figure 2.1 below.



*Figure 2.1, the progress of the focus and effect of requirements and specifications on the width of the focus*

## 2.2 The structure of the study

The research is divided into two main parts. First, an exploratory study will be conducted to gain a deeper understanding of the problem and the conceivable technological solutions. Second, a problem solving study will be conducted in an attempt to find a suitable solution to the problem.<sup>6</sup>

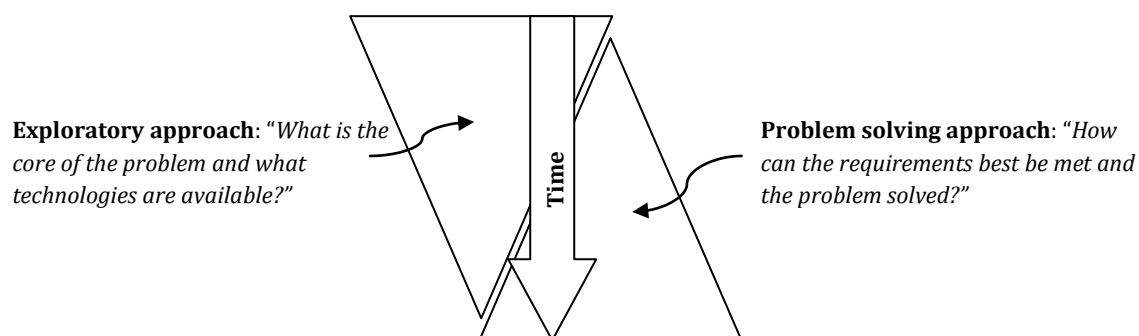


Figure 2.2, the distribution of the work over time

As seen in Figure 2.2 above, these two parts will be performed more or less simultaneously, even though the work will begin with a strong focus on establishing the core of the problem through applying an exploratory approach and end with the focus on solving the problem.

### 2.2.1 Exploratory approach

To effectively work in an exploratory way, it is essential to practice flexibility in searching for data, and open-mindedness about where to find this data<sup>7</sup>. Conducting exploratory research requires a willingness to change the direction of the research as a result of new findings and insights<sup>8</sup>. This flexibility does not mean that there is an absence of direction, but rather that the focus starts out as broad initially and narrows progressively with the progression of the research<sup>9</sup>.

Using an exploratory method, information will be gathered and form a base for conclusions about the nature of the problem at hand and the factors that are necessary to take into consideration when attempting to solve the problem. This method is more flexible and dynamic than descriptive research<sup>10</sup>. During the work with this thesis, it has been important to allow for widening of the focus due to new ideas and questions that

<sup>6</sup> Hst M, Regnell B, Runeson P, *Att genomfra examensarbete*, 2006, p29

<sup>7</sup> Stebbins R, *Exploratory research in the social sciences*, 2001, p6

<sup>8</sup> Saunders M, Lewis P, Thornhill A, *Research methods for business students*, 2009, p140

<sup>9</sup> Adams G.R, Schvaneveldt J.D, *Understanding research methods*, 1991, p106

<sup>10</sup> Saunders M, Lewis P, Thornhill A, *Research methods for business students*, 2009, p140

have appeared during the collection of data. This flexibility is valuable for the problem at hand as the scope and focus are not fixed at the onset.

The exploratory part will serve both to deepen the understanding of the problem, as well as to identify possible techniques that could be used in this context. Also, needs and wants of different stakeholders will be identified.

### **2.2.2 Problem solving approach**

The problem solving part of the study will be concentrated on evaluating the techniques that have been identified in the exploratory part of the study. This evaluation will be concentrated on evaluating these techniques with regard to the demands and specifications that have been proposed, and to recommend a solution.

There are several possible approaches to problem solving. The approach depends on for instance who takes initiative to the research (client or researcher) and what result the research aims for (for example implementation or recommendations). The approaches can be divided into five different groups that range from pure to applied research, and that show an increasing contribution from the client. Group A, *The traditional approach: "science only"*, is focused mainly on theoretical (or to a lesser extent practical) problems but not generally on application. Group B, *Building bridges between researcher and user*, is more practically oriented and some collaboration with the client is made. Group C, *Researcher-client equality*, is characterized by active collaboration. Group D, *Client-professional exploration*, is based on the researcher's past experience and knowledge and collection of new data is minimal. Group E, *Client dominated quest*, is completely client driven and takes help from an outsider to examine a problem, interpret the "best current knowledge" and suggest actions to take.<sup>11</sup>

In this thesis, the problem solving approach used is part of group C. The initiative to the study is taken by the client who has identified the problem. This problem is presented to the researcher and it is considered early on whether there are other issues that should receive primary attention. The attention can be focused mainly on either research or implementation or a combination of the two.<sup>12</sup> This thesis will focus on research rather than implementation.

## **2.3 Research methods**

The research method or research design can be seen as the blueprint for the research, specifying how it should be conducted. More specifically, it is "*a logical plan for getting from here to there*"<sup>13</sup>. In other words, it is a work plan, but even more it serves the

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<sup>11</sup> Robson C, *Real world research*, 2002, pp13-15

<sup>12</sup> *ibid*, p14

<sup>13</sup> Yin R.K, *Case study research. Design and methods*, 1994, p20

purpose of avoiding that the evidence presented does not address the initial research questions<sup>14</sup>.

This thesis will use a flexible methodology, something that is suitable given that the research questions are likely to be underdeveloped and tentative initially<sup>15</sup>. More precisely, the focus will be on using the case study method. This entails an in-depth study of one or more cases, where the aim is to affect the studied object as little as possible<sup>16</sup>. This will be combined with the survey method, which will be used initially to produce a description of the current situation<sup>17</sup>.

Alternatives initially considered include conducting a literature study to get a better idea of the concept of measuring vehicle distance. This would have been beneficial to the study as a whole, but due to the scarcity of published literature on the subject the idea had to be discarded. Conducting tests of the techniques studied was also considered but had to be excluded due to the complexity of conducting such tests and the limited amount of time available for the study. When it comes to extracting information about customer attitudes, the construction and distribution of a survey to numerous wagon keepers was considered. However, as the information desired is mainly qualitative, personal interviews were opted for. This means less wagon keepers were contacted but consulted more in-depth.

### 2.3.1 The Case Study method

Case studies are generally the preferred research method “when “how” or “why” questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context”<sup>18</sup>.

A case study describes a specific case and the intention is to acquire in-depth knowledge that cannot be acquired through surveys. The design is flexible, allowing for changes in focus and questions as the study progresses.<sup>19</sup>

The characteristic of a case study is that it focuses on a specific situation rather than trying to be general. It aims to be deep rather than wide and to focus on understanding the whole picture in the limited area of the case study, rather than isolated factors. Multiple sources are investigated rather than applying only one specific research method. Case studies have mainly been conducted to discover new information by following an inductive logic.<sup>20</sup>

When, as in this study, the case study method is principally driven by the desire to discover something new, it can be focused on *describing*, *exploration* or *comparison*. Describing deals with explaining what is actually happening within the scope of the case

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<sup>14</sup> Yin R.K, *Case study research. Design and methods*, 1994, p21

<sup>15</sup> Robson C, *Real world research*, 2002, pp163,165

<sup>16</sup> Höst M, Regnell B, Runeson P, *Att genomföra examensarbete*, 2006, p30

<sup>17</sup> *ibid*

<sup>18</sup> Yin R.K, *Case study research. Design and methods*, 1994, p1

<sup>19</sup> Höst M, Regnell B, Runeson P, *Att genomföra examensarbete*, 2006, p34

<sup>20</sup> Denscombe M, *Forskningshandboken*, 2009, p62



study, for example processes or relations. Exploration is used to investigate key issues that affect the actors within the scope of the study. Comparison is the method used to compare different frames to learn from the similarities and differences between them.<sup>21</sup> This study will mainly focus on exploration.

## **2.4 Methods for data collection**

The three principal ways of conducting exploratory research are literature search, interviewing experts and conducting focus group interviews<sup>22</sup>. The two former are the main methods for data and information collection used in this thesis, due to the nature of the problem. The main sources of information are people with deep knowledge in the field of goods wagon maintenance and safety, and extracting this knowledge is best done in an interview situation. The views and opinions of these experts will be backed up by data retrieved from written sources such as guidelines for maintenance etc.

### **2.4.1 Selection of techniques**

The selection of techniques will be made in an exploratory way. As the company has limited knowledge of techniques available and their specifications, information search will be conducted with a general and wide focus. To identify solutions available in the market, the internet will serve as a valuable source of information. Also, people in the industry (for example wagon keepers) will be consulted and asked for their knowledge of solutions available.

### **2.4.2 Interviews**

Interviews are an appropriate means of data collection in a research context when the researcher needs to gain insight into for example people's views, perceptions, feelings and experiences<sup>23</sup>. In this thesis, most of the information regarding the current situation and the problem will be collected through interviews. These are held with people from both inside the organization and stakeholders and experts on the outside. Internally, valuable information is possessed by for instance maintenance managers and engineers, business developers and technical experts. Externally, it is important to interview people from the customer side as well as technology providers and government representatives.

When holding a research interview, it is important to meet certain conditions. First, there must be consent to participate. The interviewee must be aware of the intention to produce material that will be used for research purposes and must agree to it. Second, what the interviewee says should be considered as documented (however, the

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<sup>21</sup> Denscombe M, *Forskningshandboken*, 2009, p63

<sup>22</sup> Saunders M, Lewis P, Thornhill A, *Research methods for business students*, 2009, p140

<sup>23</sup> Denscombe M, *Forskningshandboken*, 2009, p232

interviewee may request to not be mentioned by name). Third and final, the researcher sets the agenda for the discussion and controls the approach and direction.<sup>24</sup>

To extract the qualitative data needed, personal interviews will be the data collection method of choice whenever possible. For geographical and time planning reasons, experts that cannot be interviewed in person will be consulted with the help of for example telephone and e-mail.

## 2.5 Qualitative and quantitative data

Qualitative data can be described as “words”, and quantitative data as “numbers”<sup>25</sup>. In other words, qualitative data is more aimed at describing something, whereas quantitative data simply puts a measure to a certain attribute. In this thesis, the majority of the data collected will be qualitative. However, some quantitative data will also be collected when applicable and serve as a support to the quantitative part.

There are a couple of important reasons for the stronger focus on qualitative data in this research. First, the question is such that it cannot be answered without putting a strong weight on personal opinions and experiences from the people that are involved in one way or another. Second, there is no feasible way to quantify all of the main properties that are important to take into account when attempting to solve the problem. Also, qualitative data is often seen as more rich, full and real than just a number<sup>26</sup>. However, qualitative data also has its drawbacks. The main difficulty associated with qualitative data is the difficulty to analyze it.

The quantitative data gathered will mainly serve as a support to the qualitative analysis. It will concern areas such as basic profitability calculations and analyses of the dependability of the different technical solutions evaluated.

## 2.6 Criticism

A big part of the data will be collected from German sources, something that will lead to challenges in communication due to the language barrier. Neither of the researchers speaks German, so the language of use in the contact with foreigners will be English. As this is not the mother tongue of researchers or interviewees, misunderstandings may arise.

As most of the data is qualitative and dependent of the views and opinions of the interviewee, it is impossible to objectively verify all of the findings. The nature of the information gathered will be more or less subjective. It is important to consider the

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<sup>24</sup> Denscombe M, *Forskningshandboken*, 2009, pp231-232

<sup>25</sup> Robson C, *Real world research*, 2002, p455

<sup>26</sup> *ibid*, pp455-456

nature of the information gathered in an interview situation, as some of the data will be primary (experiences or opinions) and some secondary (recounted information from another origin). The secondary data will have to be verified from its original source whenever possible.

Some of the information gathered deals with assumptions and speculations regarding future rules and regulations. Such data is highly questionable as it is not possible to know what the final outcome will be. This type of information has to be treated with special caution.

### **2.6.1 Reliability**

Reliability is a term that deals with the extent to which the data collection or analysis will produce consistent findings. To assess the reliability of a research method, the following three questions can be posed<sup>27</sup>:

1. Will the same results be found on other occasions?
2. Will other observers reach similar observations?
3. Was sense made from the raw data in a transparent way?

There are a number of general threats to reliability. First, subject or participant error may occur. This deals with the risk for different results depending on when the questions are asked, and can be dealt with by choosing a “neutral” time for questioning when the interviewee can be expected to be neither on the high or low in respect to the questions asked.<sup>28</sup>

Second, there is risk for subject or participant bias. This can result in people telling you what they think that their boss would want them to say, and must be considered when the research design is developed. Also, it is important to consider this factor when analyzing the data.<sup>29</sup>

Third, there is a risk for observer error, where for example different observers ask questions in different ways. To deal with this, it is important to highly structure the interviews to ensure that the results are independent of the interviewer.<sup>30</sup>

Finally, observer bias may occur. This has to do with different observers interpreting the findings in different ways.<sup>31</sup>

One measure that will be taken to increase the reliability for this thesis is conducting all qualitative interviews with both researchers present whenever possible. This will reduce the threat of observer error and bias.

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<sup>27</sup> Easterby-Smith M, Thorpe R, Lowe A, *Management research: an introduction*, 2002, p53

<sup>28</sup> Saunders M, Lewis P, Thornhill A, *Research methods for business students*, 2009, pp149-150

<sup>29</sup> *ibid*

<sup>30</sup> *ibid*

<sup>31</sup> *ibid*

## 2.6.2 Validity

Validity deals with whether findings are actually “real” in respect to what they aim to describe, and if the relationship between a set of variables is causal or not<sup>32</sup>. To ensure validity in a research it is essential that it is reliable, but reliability does not guarantee validity<sup>33</sup>.

To determine whether a research has construct validity, that is measures what it is intended to measure, is not easy. One way of ensuring that the negative effects of individual shortcomings of different ways of measuring or gathering data are minimized is to use multiple methods. Combining and comparing results from different methods of gathering data increases the validity of the findings.<sup>34</sup>

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<sup>32</sup> Saunders M, Lewis P, Thornhill A, *Research methods for business students*, 2009, pp149-150

<sup>33</sup> Robson C, *Real world research*, 2002, p101

<sup>34</sup> *ibid*, p103

### 3. Theoretical Framework

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*This chapter provides a description of the theoretical framework that serves as a foundation for the research. The aim of the chapter is to explain some fundamental theories that are beneficial to understand in order to understand the objective and concluding reasoning of the thesis.*

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#### 3.1 Maintenance concepts

One of the aspects of the service considered is increasing the efficiency of maintenance. To be able to evaluate potential advantages gained through implementing the service, it is crucial to understand the different aspects of maintenance. Maintenance can roughly be divided into corrective, preventive, and predictive maintenance, the latter two being closely related. Table 3.1 below provides a simplified description of the three different concepts using the case of car maintenance.

*Table 3.1, maintenance concepts*

<b>Corrective Maintenance</b>	repairing your car when it breaks down due to problems caused by lack of oil
<b>Preventive Maintenance</b>	changing the oil every 50000 km or every year whether it is necessary or not
<b>Predictive Maintenance</b>	checking the oil level on a regular basis to be sure you refill when needed (but not before)

##### 3.1.1 Corrective Maintenance

Corrective, or run-to-failure, maintenance is maintenance that is performed to correct a problem that has already occurred. It is performed on units that are, with regard to reliability or safety, failed or malfunctioning. Since it is impossible to establish the exact time until a specific unit's failure ahead of time, corrective maintenance is performed at uncertain intervals<sup>35</sup>.

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<sup>35</sup> Kececioglu D, *Maintainability, availability, and operational readiness engineering handbook*, 2002, p40

The purpose of corrective maintenance is to restore a failed or malfunctioning unit to satisfactory and safe function within the shortest possible time. This is done by preparing the unit for maintenance, diagnosing the anomaly, and implementing the suitable corrective action.<sup>36</sup>

A problem with corrective maintenance is the uncertain time intervals at which maintenance is performed. This unpredictability can cause severe problems if failures or malfunctions occur at unfavorable times, causing potentially highly costly stops in operations. By knowing in advance when maintenance will be performed, downtime could be planned to make as little negative impact on operations as possible. Furthermore, corrective maintenance is associated with high spare parts inventory costs, high overtime labor costs, significant downtime and low availability<sup>37</sup>.

### **3.1.2 Preventive Maintenance**

Preventive maintenance is maintenance that is performed with the aim to prevent failures or breakdowns and avoid unplanned downtime. The objectives are to increase a unit's reliability, decrease failures, decrease nonproductive time, decrease spare parts requirements, decrease maintenance man-hours and decrease the life-cycle cost. Ultimately, the goal is to increase the availability of a unit (total output or production) and decrease total maintenance man-hours per operating hour as well as total maintenance cost.<sup>38</sup>

The concept of preventive maintenance is both an engineering issue and a management issue, in the way that the tasks performed are as important as the procedures and preparations. In fact, efficient preventive maintenance entails four distinct areas, all of which need to be given proper attention for the maintenance program to be successful. The four areas, namely Engineering, Economic, People-Psychological and Management, are described in Table 3.2 below.<sup>39</sup>

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<sup>36</sup> Kececioglu D, *Maintainability, availability, and operational readiness engineering handbook*, 2002, p40

<sup>37</sup> Mobley K, *An introduction to predictive maintenance*, 2002, pp2-3

<sup>38</sup> Kececioglu D, *Maintainability, availability, and operational readiness engineering handbook*, 2002, p40

<sup>39</sup> Levitt J, *Complete guide to preventive and predictive maintenance*, 2003, pXI

Table 3.2, *The four areas of preventive maintenance*<sup>40</sup>

<b>Engineering</b>	The right tasks have to be performed using the right techniques and at the right frequency. The key is to perform tasks that are designed to detect or correct critical wear. The engineering pillar entails analysis of statistics of failure, uptime and repair.
<b>Economic</b>	There must be economic incentives to perform the tasks. One economic incentive may be furthering the business goals of the organization. It is also important to consider the value of the failure in comparison to the cost of the tasks.
<b>People-Psychological</b>	The people performing the preventive maintenance must be motivated enough to perform the tasks properly. Proper training to ensure an understanding of what they are looking at and why is also crucial, together with attention to the proper level of detail.
<b>Management</b>	Preventive maintenance must be integrated into the systems and procedures that control the business. These systems must in turn be designed to ensure good preventive maintenance. The information collected in the preventive maintenance processes must be integrated into the general flow of business information.

Preventive maintenance is scheduled to make failures or malfunctioning unlikely. Maintenance activities are scheduled based on MTTF (mean-time-to-failure) statistics<sup>41</sup>. Depending on the safety desired, i.e. the accepted risk for failure before maintenance, the statistics are used to set a shorter or longer time period between maintenance activities.

### 3.1.3 Predictive Maintenance

Predictive maintenance is based on the premise that regular monitoring of for example the actual mechanical condition and operating efficiency will provide the data necessary to ensure the optimal (maximum) interval between maintenance activities and minimize the number and cost of unscheduled downtime created by failures or malfunctions<sup>42</sup>.

Predictive maintenance can be described as condition-driven preventive maintenance. Information about the actual operating condition of equipment and systems is used to optimize total operation. Instead of relying on industrial or in-plant MTTF-statistics to schedule maintenance activities, the timing of maintenance activities in predictive maintenance are based on direct monitoring of the condition, efficiency and other indicators that help determine the actual MTTF or loss of efficiency for each unit. Information about the condition of a unit can be gathered using various different techniques, such as vibration monitoring, thermal imaging, lubricating oil analysis, ultrasound examination and other nondestructive testing techniques (there are at least

<sup>40</sup> Levitt J, *Complete guide to preventive and predictive maintenance*, 2003, pXI

<sup>41</sup> Mobley K, *An introduction to predictive maintenance*, 2002, p3

<sup>42</sup> *ibid*, p4

50 different techniques in use). The schedules used are ultimately based on a combination of condition information together with intuition and personal experience.<sup>43</sup>

The objective of predictive maintenance is to improve productivity, quality, and overall efficiency. A predictive maintenance program can minimize unscheduled breakdowns as well as identify unit problems before they become serious. By detecting and repairing mechanical problems early, these problems can be minimized. Detecting anomalies at an early stage can help prevent major repairs. In extension, including predictive maintenance in the maintenance program leads to optimal availability and greatly reduces cost of maintenance.<sup>44</sup>

## 3.2 Quality

Improving quality is an activity that is often regarded as leading to higher costs. On the contrary, it usually leads to lower costs by making it possible to produce less faulty products with the same amount of effort or cost<sup>45</sup>.

Furthermore, previous research on quality has made it clear that a quality advantage can lead to improved market share and better profitability. It is clear that businesses offering a superior product or service outperform those with inferior quality. Businesses that offer superior perceived quality enjoy several benefits, for example connected to customer loyalty, repeat purchases, resistance to price wars and ability to command a higher relative price. High quality gives double benefit; it ensures lower costs as well as enables charging a higher price in the marketplace. The result is that high-quality organizations enjoy both greater market share and greater profitability.<sup>46</sup>

Given the focus of this thesis on the surrounding environment and possible implementation of a new product/service, it is beneficial to explore the impact of a certain level of quality on the customer. This is done in the following section.

### 3.2.1 The Kano Model<sup>47</sup>

The Kano model (Figure 3.1 below) illustrates how customers perceive quality. This model is made up of three key elements: Basic Quality, Spoken Performance, and Excitement Quality.

*Basic Quality* has to do with items where customers take the appropriate performance levels for granted. In other words, these characteristics are “must haves”. The fulfillment of all these requirements by the product will generate no significant positive

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<sup>43</sup> Mobley K, *An introduction to predictive maintenance*, 2002, p5

<sup>44</sup> *ibid*

<sup>45</sup> Dahlgaard J.J, Kristensen K, Khanji G.K, *Fundamentals of Total Quality Management: Process analysis and improvement*, 2005, p3

<sup>46</sup> Pyzdek T, Keller P.A, *Quality engineering handbook*, 2003, p120

<sup>47</sup> Antony J, Preece D, *Understanding, managing, and implementing quality*, 2002, pp60-62



satisfaction. However, if the product fails to satisfy one of the assumed characteristics this may result in high levels of dissatisfaction. An example of basic quality is for example crashworthiness in cars.

*Spoken Performance* characteristics are what give the customer a desired performance level. If this desired performance level is met or exceeded, the customer will be satisfied in that respect. If it is not, dissatisfaction will result. An approximately linear relationship between performance against the specified criteria and satisfaction on that issue is assumed in the model. An example of spoken performance might be acceleration performance in cars.

*Excitement Quality* refers to unexpected perks, specifically giving the customer something they didn't know they wanted. By definition, this can never lead to dissatisfaction due to the fact that the customers are unaware of the desirability of the characteristic and thus are not affected if not offered it. However, providing such characteristics or performance may generate substantial customer satisfaction. An example is the introduction of new features in technical products (for example mobile telephones) that customers wouldn't have asked for but eventually can't do without.

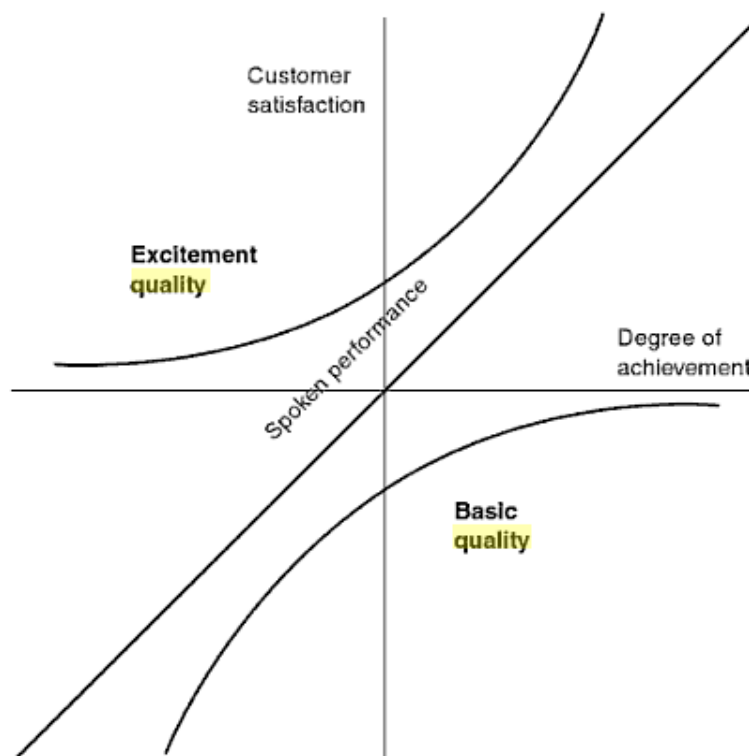


Figure 3.1, the Kano model<sup>48</sup>

The Kano model is hierarchical in nature. The basic quality has to be fulfilled in order for it to be possible to increase satisfaction by meeting the spoken performance level. A customer whose basic needs are not fulfilled will not care about the spoken performance

<sup>48</sup> Antony J, Preece D, *Understanding, managing, and implementing quality*, 2002, p60

level of quality. Correspondingly, the spoken performance requirements must be met in order for the customer to care about the excitement quality factors. Returning to the case of a car, a model that meets all the expressed requirements as well as provides exciting extras like an advanced entertainment system will not sell if it fails in the basic quality department by for example being unsafe, something that is a basic requirement for most car users.

For an organization to be considered the first choice by its customers, all of the requirements in the basic quality category have to be met. Also, the organization should be competitive with market leaders in the spoken performance category, as well as offer some features that belong in the excitement quality category. By offering elements from the excitement quality category, pressure is put on competitors to match or exceed these features. Until they accomplish this, the features provide the organization with unique selling points.

The categorization of features or characteristics is not fixed over time. Excitement quality features will with time move into the spoken performance category as customers become aware of the features and start desiring them. Eventually, as a feature becomes a part of the standard offer and is offered routinely across suppliers, it becomes part of the basic qualities. Due to this migration over time, excitement quality features must be early to market in comparison to other products in order for them to be beneficial. If they are not, they may drop down the hierarchy before the customer is able to experience them.

### **3.3 Strategy concepts**

In order to better understand the suitability of the possible addition to the product/service portfolio of the company, it is beneficial to understand some basic strategy concepts. In the following, the definition of a business and its goals and aspirations will be described. Furthermore, general strategies for growth and competition will be defined.

#### **3.3.1 Vision and Mission**

##### ***Vision***

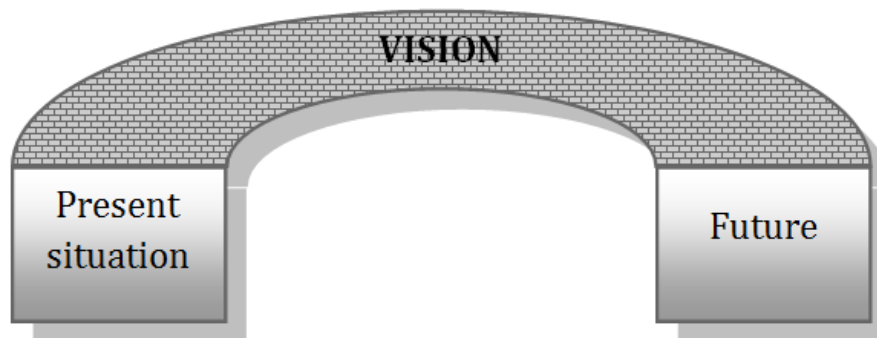
The vision of an organization deals with its aspirations, what it seeks to be. It can be said to be concerned about “where we are going and why”<sup>49</sup>. Furthermore, the purpose of the vision is to clarify the view of the future so as to enthuse and motivate<sup>50</sup>. The vision can

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<sup>49</sup> Thomson A.A, Gamble J.E, Strickland A.J, *Strategy: winning in the marketplace*, 2004, p12

<sup>50</sup> Johnson G, Scholes K, Whittington R, *Exploring corporate strategy*, 2008, p164

thus be said to act as a bridge between the present situation and the future goals<sup>51</sup>, as illustrated in Figure 3.2 below.



*Figure 3.2, Vision as a bridge between present and future*

A well-stated vision is kept distinctive and specific to the organization. Generic language that applies to countless organizations (for example to “become a global leader” and “the first choice of customers in every market we serve”) is best avoided. A strong vision excites strong emotions and is challenging, and will only arise from an organization led by a demanding and determined leader.<sup>52</sup>

### ***Mission***

In contrast to the strategic vision, the mission statement deals with the present purpose and business scope. The mission of the company should explain “who we are, what we do, and why we are here”<sup>53</sup>, and thereby express the purpose of the organization. The mission statement itself in turn serves the purpose of building an understanding and confidence for employees and stakeholders about what the purpose of the organization is<sup>54</sup>.

A good mission statement is designed to pinpoint the unique and fundamental purpose of the organization, which sets it apart from other organizations of its type<sup>55</sup>. Also, it should identify the scope of the organization’s operations with respect to markets served as well as goods and services offered<sup>56</sup>.

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<sup>51</sup> Dransfield R, *Corporate strategy*, 2001, p46

<sup>52</sup> Thomson A.A, Gamble J.E, Strickland A.J, *Strategy: winning in the marketplace*, 2004, p12

<sup>53</sup> *ibid*

<sup>54</sup> Johnson G, Scholes K, Whittington R, *Exploring corporate strategy*, 2008, p164

<sup>55</sup> Thomson A.A, Gamble J.E, Strickland A.J, *Strategy: winning in the marketplace*, 2004, p13

<sup>56</sup> Dransfield R, *Corporate strategy*, 2001, p39

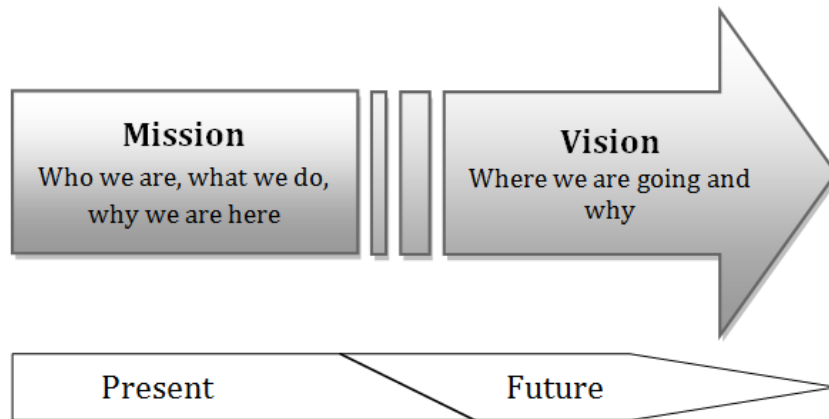


Figure 3.3, Mission and Vision

### 3.3.2 Business definition and diversification

Related to the concepts of strategic vision and mission, the business definition of an organization serves as a starting point for strategic planning and management in the way that it provides a means of evaluating the effects of planned changes. Defining the business is made by answering the question “what is our business?”, and the answer should cover three perspectives: *who* is being satisfied, *what* is being satisfied, and *how* the customer needs are satisfied. In other words, the markets served should be identified, as well as the functions provided in these markets and what resources and capabilities are used by the organization to provide these functions. The third perspective, how customer needs are satisfied, can be extended to defining what products or services the organization more specifically offers.<sup>57</sup>

The scope of an organization deals with the breadth of its activities across the markets it is present on, the functions it provides and the products or services it offers. Some firms with a very broad scope have businesses in areas that are completely unrelated to each other. This type of strategy is called *unrelated diversification*. When the scope is broad but the products or services offered are closely related to the organization’s core competence, the strategy is called *related diversification*. Related diversification can happen in two ways. Either, an organization concentrates on reaching backwards or forwards in its industrial supply chain by becoming additionally involved in business activities either forward towards the final customer or backwards toward the raw materials, a strategy known as *vertical integration*. Or, the organization focuses on *horizontal integration* by engaging in activities that are complementary or close to present activities.<sup>58</sup>

Incentives for diversification include benefits of synergy, increasing market power, stretching corporate parenting capabilities to include new markets and products/services and spreading risk. In the case of unrelated diversification, exploiting dominant logistics can be a source of value creation.

<sup>57</sup> Harrison J.S, St. John C.H, *Foundations in strategic management*, 2009, pp75-76

<sup>58</sup> Johnson G, Scholes K, Whittington R, *Exploring corporate strategy*, 2008, pp265-267

However, diversification also has its drawbacks and risks. Even if the diversification attempted is related, it does not automatically mean that the capabilities of the organization can support the new areas and succeed in creating value. Absence of relevant capabilities can far outweigh the potential from the value network links. Identifying synergies is often harder and any positive effects can be more costly to extract than expected. The relationships themselves can also bring disadvantages by adding to the business unit complexity and burdening corporate level time and cost.

### 3.3.3 Porter's Generic Strategies<sup>59,60</sup>

The generic strategies model is based on the notion that each and every strategy has competitive advantage at its core. For an organization to attain a competitive advantage, it must first make a choice about what type of competitive advantage to attain as well as about the scope within which to attain this advantage.

Basically, the generic strategy choice involves deciding to compete either on the basis of price/low cost or through some kind of differentiation. The latter involves competing in factors that accentuate the uniqueness of the individual organization's product or service.

Any one organization's position within the industry in which it operates is determined by its competitive advantage as well as its competitive scope. The scope refers to the width of the organization's target market. Simplified, the scope is in the model seen as broad (a mass market) or narrow (targeting a specific market niche or segment). The combination of competitive scope and competitive advantage is illustrated in Figure 3.4 below.

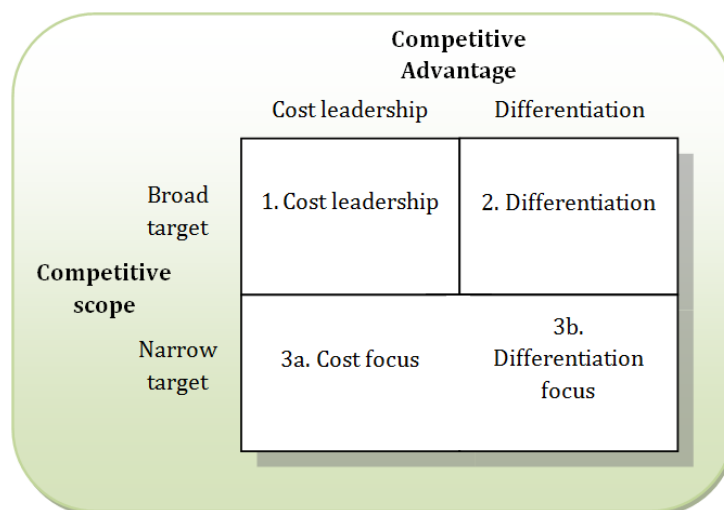


Figure 3.4, Porter's generic strategies

<sup>59</sup> John R, Ietto-Gillies G, Cox H, Grimwade N, *Global business strategy*, 1997, pp214-215

<sup>60</sup> Faulkner D, *Strategy: critical perspectives on business and management*, 2002, pp313-323

### 3.3.4 The Ansoff strategies for growth<sup>61,62</sup>

The Product-Market growth matrix explains how the development of an organizations markets and products come about in four main directions. The factors that define the direction are market (current or new) and product (current or new). Thus, four growth strategies are possible depending on the status of the product and market. The grid, shown in Figure 3.5 below, can be used by an organization to select appropriate strategies for each strategic business area<sup>63</sup>.

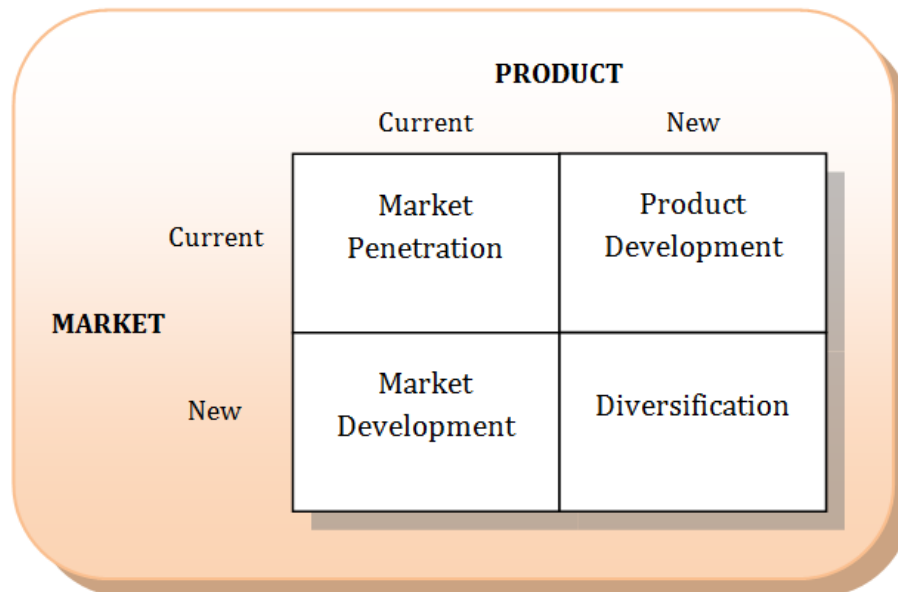


Figure 3.5, the Ansoff Product/Market growth matrix

Market penetration, the top left box, involves offering existing products in current markets. In order for an organization to grow using this strategy, a growth in product sales in line with market growth must be ensured. If the market is not growing, growth with this strategy can only be achieved by increasing market share. Furthermore, growth can be organic (for example by simply selling more units), or achieved through acquisitions. This is the strategy associated with the least amount of risk.

Market development, the bottom left box, is the strategy of diversifying into new markets with existing products. This strategy can be approached in various ways, including moving into new geographical markets and creating new market segments for example by creating new pricing policies.

Product development, the top right box, relates to selling new products in existing markets. Implementing this strategy may give rise to a need for developing new competencies. Growth using this strategy can be achieved either by product

<sup>61</sup> Proctor T, *Strategic marketing: an introduction*, 2000, p260

<sup>62</sup> Witcher B.J, Chau V.S, *Strategic Management*, 2009, pp180-182

<sup>63</sup> Harris N, *Business economics, theory and application*, 2001, p132

augmentation (further developing and/or modifying existing products) or by developing distinctly new products that can be either related to the ones originally offered or completely unrelated. The important thing is for the organization to ensure that these modified or new products can appeal to the existing markets in which the organization is active.

Diversification, the bottom right box, is the strategy of developing both new products and offering these in new markets. The lack of experience both in the new market and the new product means that this strategy is inherently risky. Therefore, a comprehensive assessment of the risk involved is important when attempting diversification.

## 4. The European rail freight industry

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*This chapter maps the European rail freight industry and serves to facilitate the understanding of the market. First, the structure is explained, followed by a look at the specifics of the vehicles used and the rules and regulations that govern operations and maintenance activities in the market.*

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### 4.1 Industry structure

Europe has a well developed infrastructure for rail transport. The rail network is an important logistical net for import and export. Today over 10 % of the transports of goods in the EU is made on rail<sup>64</sup>.

To allow for international traffic, part of the infrastructure and design of vehicles has been standardized. Some of the important parameters to standardize are gauge (the distance between the two rails forming a track), cargo weight, couplers and safety systems. Despite the standardization there are still discrepancies between countries. For example, the gauge is the same in most European countries, but Finland, Spain and Portugal among others have different measurements.

To facilitate the use of the railway infrastructure, a number of organizations have been formed. The overall purpose of most of these is to facilitate the use of the European rail network and to make rail transport more competitive in comparison to other means of transport. These organizations also contribute to improvements in the infrastructure and development of rail vehicles. They play an important role in tying together different stakeholders and users. These organizations become even more important when the rail network is international. More stakeholders will need to be connected as the rail industry becomes even more international and large scale projects are conducted in several member states.

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<sup>64</sup> Statens institut för kommunikationsanalys: *EU:s första järnvägspaket – erfarenheter från genomförandet*, [www.sika-institute.se](http://www.sika-institute.se)



*Table 4.1 Selection of European railway organizations*

<b>EBA</b> – Federal Railway Authority	The supervisory and authorizing authority for railway infrastructure companies in Germany
<b>ERA</b> – the European Railway Agency	Promotes safe and compatible rail systems. Develops common technical standards, safety measures and targets.
<b>ERFA</b> – the European Rail Freight Association	Works to remove material or legal hindrances and obstacles that prevent carriers from rapidly establishing international rail freight services.
<b>UIP</b> – the International Union of Private Wagons	Represents owners and users of the app. 180,000 private rail wagons that are operated in Europe.
<b>UIC</b> – the international union of railways	Promotes rail transport at world level.

There is, as stated above, numerous different types of players on the European rail transport market. Many of these operate nationally or within a certain region. However, there is also a large number of big players who operate internationally. The key types of players when it comes to rail cargo transport are:

**Railway undertakings** – Conduct traffic on the rail network, either with their own vehicles or with vehicles leased from other owners. The big players are usually formerly or presently state owned (for example Green Cargo in Sweden, Deutsche Bahn in Germany and SNCF in France) with strong ties to the infrastructure itself. In addition there are various smaller private operators that carry out transports on European railways.

**Wagon keepers** – Own wagons but do not necessarily operate them. They often lease wagons to railway undertakings that conduct transport, or to other customers who then in turn contract a railway undertaking to carry out the transport of the wagon. These lease agreements can be assignment-specific but most commonly the vehicles are leased for longer periods of time. During the time of the lease the vehicle is fully at the railway undertaking’s disposal and can be operated in most of Europe as desired. Maintenance is the responsibility of and handled by the wagon keeper. When a vehicle is in need of inspection, the wagon keeper contacts the railway undertaking and collects information about the whereabouts of the vehicle. The vehicle is then sent to the appropriate service workshop, as decided by the wagon keeper. Examples of this type of organization are Transwaggon, Nacco and VTG.

**Vehicle manufacturers** – Manufacture rail vehicles. Due to the complexity of construction of rail vehicles, there are few but large corporations focused on manufacturing these. Kockums Industrier and Bombardier are examples of vehicle manufacturers.

**Service companies** – Maintain and serve rail vehicles. Examples of this type of organization are EuroMaint Rail, SweMaint and Nedtrain.

The different players often play more than one role. For example, Green Cargo operates both as a wagon keeper as well as a railway undertaking. Bombardier is a rail vehicle manufacturer but also offers service agreements for its locomotives. Kockums Industrier which is the only Nordic goods wagon manufacturer bought SweMaint in 2007 in an attempt to take a step into the service market. Many of the players in the rail freight market have a more or less complex relationship to each other, as many serve as both customers and competitors to each other.

Around these large players there are numerous enterprises that offer additional services and complimentary products. Some of these additional services and products, more specifically technical solutions for monitoring goods wagon distance, will be discussed in chapter 7.

## 4.2 Goods wagons<sup>65,66</sup>

There is no universally used term for wagons transporting cargo on rail. In this report, the term goods wagon will be used. In this report, the term refers to any type of wagon that is used to transport cargo on rail.

Railway plays a central role in European logistics and is used to transport many types of cargo. Various different types of goods wagons have been developed over the years to meet the demand for different types of transports. Among the most common types are container wagons, tank wagons, timber wagons, open and closed wagons.



*Figure 4.1, Examples of container wagon<sup>67</sup>, tank wagon<sup>68</sup>, timber wagon<sup>69</sup>, open wagon<sup>70</sup>, closed wagon<sup>71</sup>*

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<sup>65</sup> Järnväg.net: *Vagnguide*, [www.jarnvag.net](http://www.jarnvag.net)

<sup>66</sup> Hansen, Bengt, Site Manager, EuroMaint Rail

<sup>67</sup> Photobucket, [media.photobucket.com](http://media.photobucket.com)

<sup>68</sup> Lostr, [www.lostr.cz](http://www.lostr.cz)

<sup>69</sup> Rail Express, [www.railexpress.co.uk](http://www.railexpress.co.uk)

<sup>70</sup> Remtechstroy Group, [www.remtechnology.eu](http://www.remtechnology.eu)

<sup>71</sup> SBB CFF FFS Cargo, [www.sbbcargo.com](http://www.sbbcargo.com)

The manufacturing of goods wagons is carried out on order. The wagons are designed according to planned use. With the basis in standard models, smaller changes can be made to maximize the functionality of the goods wagon. The price of a goods wagon varies depending on type, but is normally within the interval € 80000-250000<sup>72</sup>.

Goods wagons are usually equipped with two or four axles / wheel sets, but discrepancies exist for wagons used for extra heavy transports. The axles / wheel sets come in different diameters and design. Wheel discs are mounted on the axles. These are pressed onto the axle. When a wheel disc is worn out, it is processed by lathing or replaced.

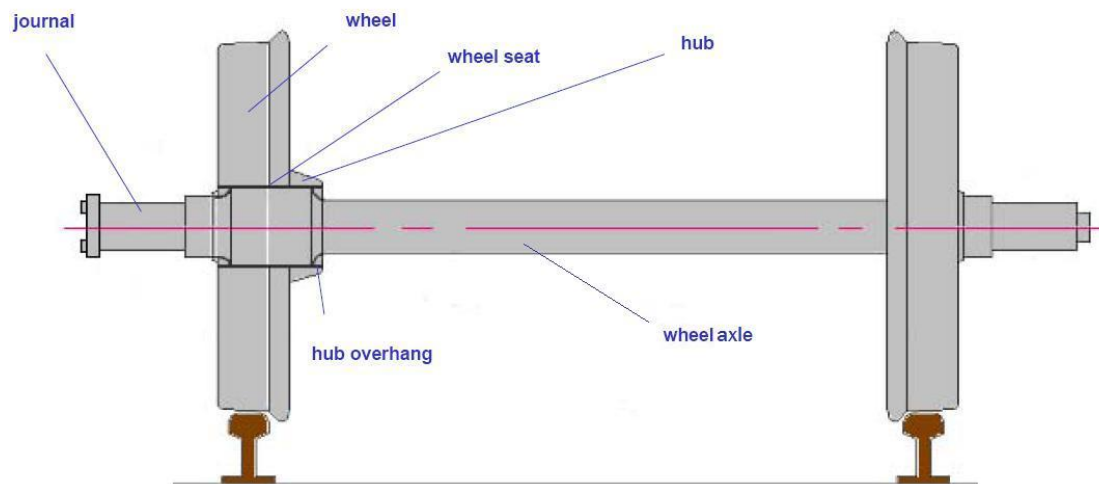


Figure 4.2, Wheel set with axle and wheel discs<sup>73</sup>

The axles are mounted in a spring system either individually or in bogie (a framework carrying at least two wheel sets, see Figure 4.3). The ball bearings of the axles are protected in the axle box by the wheel set bearing cap. The axle box is one of the most delicate areas of the wagon. As ball bearings are moving parts, they have to be free from moisture and dirt in order to function properly. Therefore, it is important for the wheel set bearing cap to be fully closed and robust and protect the content in a satisfactory way. An occurring problem is overheating of the axle box. For different reasons the temperature can rise to levels high enough to damage the bearings and axle. This phenomenon does not occur suddenly but is rather caused by the bearings being heated up over time. Therefore, the problem can easily be discovered in time by manually checking the axle box or by monitoring the axle box with special heat sensors that are placed along the track.

<sup>72</sup> Jönsson, Roger, Sales, Kockums Industrier

<sup>73</sup> Era, *European Visual Inspection Catalogue JSSG V10*

Since gauge is standardized in most parts of Europe, wagons operated in these parts have the same distance between the wheels. However, wheel and axle diameter and way of connecting the wheel sets to the wagon can vary between different types of wagons. Goods wagons are in general relatively simple constructions without electricity or other high-tech equipment. They are robust and designed to withstand the high amount of strain they are subject to.

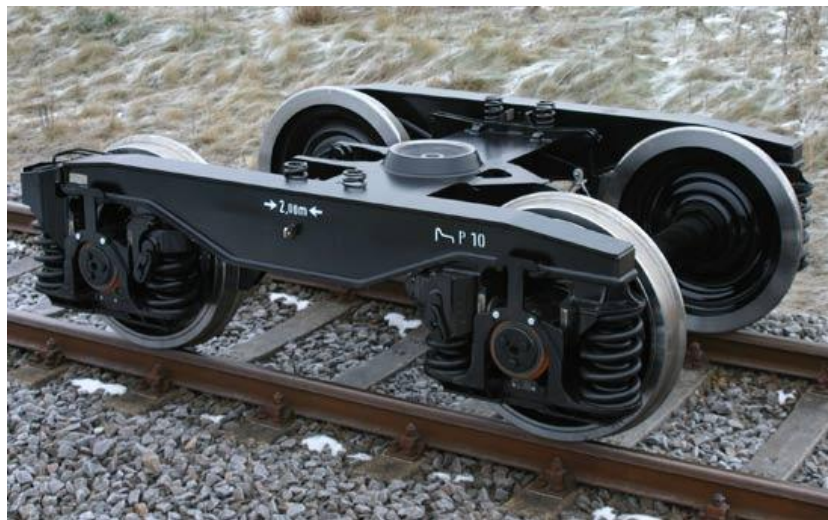


Figure 4.3, Example of a bogie for goods wagons<sup>74</sup>

The strain put on goods wagons has become larger over the years. This is partly due to cargo transported on rail becoming heavier. The new ore wagons that are operated between Kiruna and the ports of Luleå and Narvik carry up to 100 tonnes per wagon<sup>75</sup>. The wagons that are used around Europe typically carry loads of around 65-70 tonnes. The increased efficiency and optimization of rail transport (which for example enables the rail to be used more extensively) has also led to more frequent use of the wagons. Furthermore, goods wagons are basically always outside, something that makes them heavily exposed to weather and changes in temperature.

Despite the strain, a goods wagon has a life span of approximately 35-40 years. To be able to use the wagon during all this time the wheels, brake blocks and other parts that are regularly subject to wear have to be replaced as needed.

The continuous introduction of new rules regarding rail cargo traffic makes it common for wagons to be rebuilt and change appearance over time. Wagons can also be in need of rebuilding if and when they are to be used for new purposes. Every time a wagon is rebuilt it is re-registered and given a new id-number that corresponds to the new properties of the wagon. This means that the same wagon may have different id-numbers over the course of its lifetime. It is not uncommon that a wagon has up to five different id-numbers during its lifetime.

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<sup>74</sup> railway-technology.com, [www.railway-technology.com](http://www.railway-technology.com)

<sup>75</sup> LKAB, *Logistik*, [www.lkab.com](http://www.lkab.com)

As information about axle lifetime is limited, it is difficult to give a reliable estimation of it. Approximately, the lifetime of an axle is as long as a goods wagon as the disposal rate of axles does not appear to be high<sup>76</sup>. Axles may even last longer than the wagon itself. Naturally, the lifetime depends on how free from damage a wagon and its axles are. If damage occurs, both wagon and axles may need to be scrapped.

The lifetime of the wheel discs used on goods wagons is completely dependent on the type of wagon it is mounted upon. Wheel discs that are mounted on wagons transporting heavy loads in general have a shorter lifespan than wheel discs used on wagons subjected to lighter loads. For example, a wheel disc that is mounted on the “steel commute” between Luleå and Borlänge rarely last longer than 3 years.

High traffic intensity and unfavorable climatic conditions also decreases the lifetime of wheel discs. In favorable conditions, a wheel disc can last for 12-15 years before being discarded. Lifespans of up to 25 years have been reported but are not common. During the life of a wheel disc it is processed by lathing (turning) from time to time to ensure proper performance.

Due to the way goods wagons are operated today, wheel disc lifespan has decreased. This is due in most part to the increased utilization of rail and higher level of operation of goods wagons. Goods wagon fleets are decreased and cycle times are shortened. Wheel discs are consumed in a shorter time.

### **4.3 Goods wagon maintenance<sup>77,78,79,80</sup>**

As goods wagons are used, they are subject to different types of wear. Regular revisions are therefore made to ensure the vehicle’s reliability. The frequency at which these revisions are carried out is controlled by the wagon keeper who is ultimately responsible for maintaining his wagons. It is the wagon keeper’s responsibility to establish a plan for the regular revisions and the rest of the preventive maintenance and to specify the activities this revision should include. This plan is drawn up following guidance from wagon manufacturers as well as applicable rules and regulations on the subject of goods wagon maintenance and safety. Due to this, revisions can be significantly different for goods wagons with different owners. In general, goods wagons registered in Germany are subject to more thorough revisions than goods wagons registered in other countries. Also, German wagon keepers often require maintenance workshops to be certified according to strict standards (for more information about certification see section 4.4.1).

Different parameters control when a goods wagon must be submitted to a workshop for revision. Often, the parameters used are time since the last revision and the

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<sup>76</sup> Eriksson, Ulf L, Technical expert, EuroMaint Rail

<sup>77</sup> Hansen, Bengt, Site Manager, EuroMaint Rail

<sup>78</sup> Nilsson, Per Håkan, Sales, Interfleet Technology

<sup>79</sup> Hillman, Reinhard, Head of Technical Customer Service, VTG

<sup>80</sup> Eriksson, Ulf L, Technical expert, EuroMaint Rail

performance in km. When one of these parameters is approaching critical levels the vehicle is located and booked into a suitable workshop. In practice, due to the lack of distance information for many wagon keepers, the most common parameter used is time.

Performance is measured more or less arbitrarily. Green Cargo for example has its vehicles registered in the Swedish rail vehicle database FORD. This database handles vehicles as well as some components and keeps track of for example maintenance activities as well as vehicle distance if applicable and possible. FORD can be connected to a system that manages rail traffic in Sweden. The system registers all rail traffic and can therefore supply the wagon keeper with vehicle distance information (systems like this exist in other countries as well, for example there is a German system managed by DB and a French that is controlled by SNCF).

Some problems arise when a vehicle leaves Sweden. Since the rail traffic system mentioned above only contains distance information about the Swedish railway it cannot be used in Europe. Instead, the distance is estimated from charts over travel distance from A to B. A problem is that in continental Europe a trip from A to B can often be covered using several different routes. Using this system, the distance covered by a vehicle outside of Sweden is therefore potentially subject to a bigger margin of error than a wagon operated exclusively in Sweden.

Goods wagons that are in need of maintenance or are to be sent for revision are sent to workshops with a strategically good geographic location. This is determined depending on the state of the wagon and the coming assignments. In order to get a good geographical distribution of possible workshops to use, it is common for vehicle owners to contract numerous different maintenance operators. Only very rarely, for goods wagons used in very limited geographical areas, are the wagons served consistently by one single maintenance operator.

During a revision, service personnel access the vehicle register (which is controlled by the wagon keeper). This details the history of the wagon and the service book, with information about all maintenance activities that have been performed on the wagon as well as the history of the parts of the wagon. The wagon is inspected according to the specific revision specification issued by the wagon keeper. When it comes to interchangeable parts, these are processed or replaced as needed.

The most commonly replaced components on goods wagons are the wheels. Common reasons for changing wheels are wear, damage caused by brake dragging or indentations. Brake dragging is when an applied brake fails to disengage causing the wheel to be locked in position. This leads to the formation of a wheel flat, something that is seen as a serious anomaly due to the damage it causes on the rail it travels on. Indentations can occur when the wheel rolls over small rocks or other obstacles on the rail.

When a wheel needs to be processed, the wheel set is usually removed from the wagon and replaced. One reason for this is that some maintenance workshops do not have access to wheel lathes, something that makes processing on location impossible. Also,

replacing the wheel set rather than waiting for the wheel to be processed reduces the downtime of the wagon and enables it to be quickly returned into operation.

A goods wagon wheel set is made up of an axle and fixed wheel discs that have been heeled onto the axle (see Figure 4.2). When such a wheel set is defect it is as described above normally dismantled from the wagon and replaced. In this way the wagon can be quickly returned into operation. The defect wheel set is re-lathed and can later be used again. If the wheel set has been lathed so many times that further lathing is impossible due to insufficient remaining diameter, the wheel discs are dismantled and replaced by new discs.

Every axle/wheel set has its own unique identity. The dismantling and mounting of a wheel set is always registered and recorded in the maintenance documentation. Thereby, it is possible to identify which wheel sets that have been mounted on a wagon at a specific time, as well as which wagons a wheel set has been mounted on and when. Even if wheel sets change wagons, traceability of the wheel sets is ensured. This means that theoretically it does not matter whether wheel set or wagon distance is monitored, as the information is the same and can be applied to the respective parts.

To reduce the workload for wagon keepers and to make the service more efficient, a Swedish cooperation around cargo wagon wheel sets has formed. The vehicle owners that are part of this cooperation share a stock of wheel sets, the so called "hjulpoolen" (the wheel pool). Each service workshop can keep a stock of wheel sets that are ready for use on wagons that belong to companies that are part of the wheel pool. Companies that are not part of the pool have to send wheel sets from their own stock to the concerned workshop or to the wagon location on track if the wheel set has to be changed during operation.

## **4.4 Rules and regulations**

### **4.4.1 Present situation<sup>81</sup>**

European maintenance of railway vehicles is subject to rules and regulations from both governmental/EU instances as well as private industry associations. Guidelines from manufacturers also have an impact on the way maintenance is carried out.

On an EU level, the rules are mainly safety related and of a relatively broad nature. Among the objectives of the current EU legislation is to define common rules for safety investigations, coordinate and homogenize the use of safety certificates and to ensure the presence of an authority responsible for supervising safety in each member state. EU legislation also states that the responsibility for safe operation and control of risks associated with rail transport is borne by the infrastructure managers as well as other railway undertakings.<sup>82</sup> A practical meaning of this is that each and every operator has

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<sup>81</sup> Fehr, Karl-Heinz, Lawyer, VPI

<sup>82</sup> Summaries of EU legislation, *Railway safety*, europa.eu

responsibility for ensuring the safe operation of his own vehicles. Similarly, each wagon keeper is responsible for ensuring the safety of his wagons.

On a national level, each member state has previously had the possibility to set its own national safety rules. These have often been based on national technical standards, and the goal is for these rules to be gradually replaced by rules based on common standards. EU wide technical specifications for interoperability (TSIs) serve as a basis for these common standards.

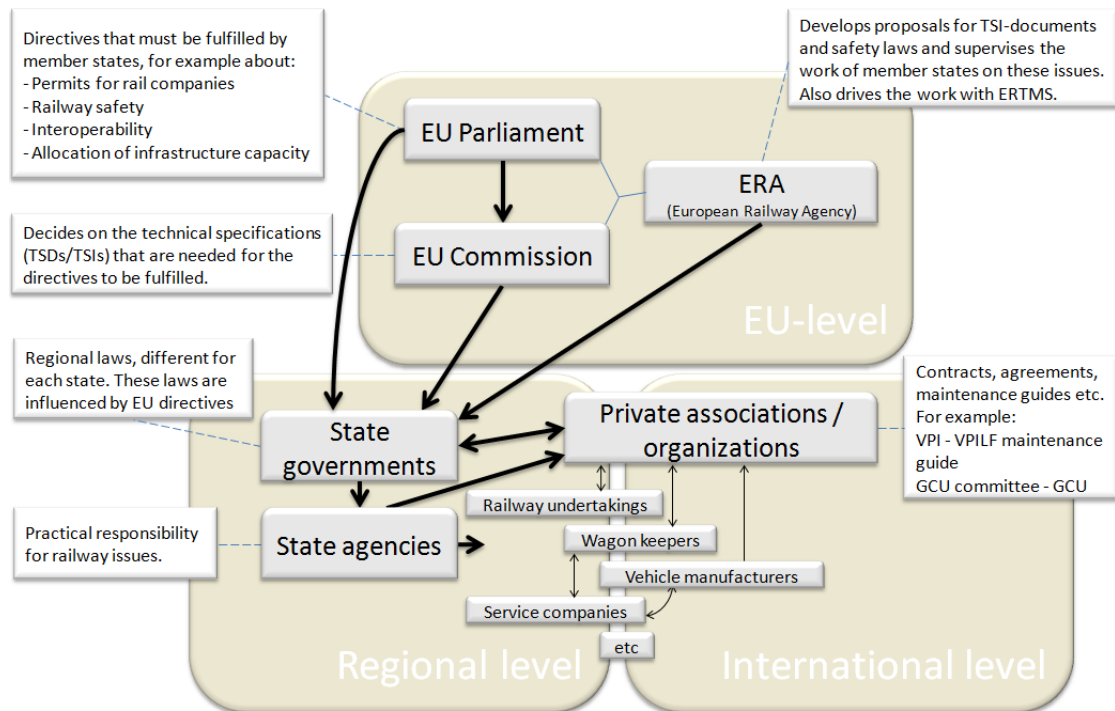


Figure 4.4, Overview over influences on rules and regulations<sup>83</sup>

In practice, the governmental rules do not always directly affect vehicle owners. This is due to the presence of regulations issued by independent associations such as VPI, a Germany-based private wagon keepers association. This organization presently has some of the strictest and most extensive regulations on railway undertakings. The guidelines issued by VPI are called the VPILF (VPI Maintenance Guide). Although the guidelines in the VPILF are not legal requirements, they are used extensively both in Germany as well as in other European countries where German owned vehicles are operated.

VPI are working continuously with updating the VPILF. New issues of the guidelines are issued every couple of years and smaller updates are entered in between. The changes are driven both by legal changes (both on an EU-level as well as national rules) and by

<sup>83</sup> Figure adapted from information supplied by Karl-Heinz Fehr, Lawyer, VPI



requests from users of the guide. Also, VPI are constantly working to increase the safety of rail cargo transport so own initiatives also drive the development forward.

The guidelines set up by VPI most certainly affect EuroMaint Rail's operations. Not only do the German workshops need to be up to the task of performing maintenance actions according to the guidelines. Also, the workshops in Sweden need to be able to fulfill the requirements stated in the guide in order for VPI affiliates to send their vehicles to the workshop in question. A maintenance provider therefore needs to be certified by VPI to be able to perform maintenance activities on wagons connected to the VPILF. In order to become certified, high standards have to be fulfilled and the fulfillment of the demands is tested by regular inspections. Due to the relative strictness of the VPILF in comparison to EU-regulations, there is a focus on fulfilling the requirements in the VPILF.

Another organization that has a large impact on the behavior of the European rail freight industry is the GCU Committee. This is an association of railway related organizations (UIC, UIP and ERFA, short information about these is provided in Table 4.1) that issue the GCU, the General Contract of Use for wagons. By signing up with the GCU Committee, wagon keepers and railway undertakings agree to comply with the requirements of the contract and to use this contract in business agreements with other rail companies. The contract is designed to protect the interests of both the wagon keeper and the railway undertaking.

The GCU clearly regulates the monitoring of vehicle distance. Article 15.2 in the contract states that "The RUs [railway undertakings] shall provide the keepers of the wagons they use with information from their operating and data recording systems on the kilometric performance actually carried out by the wagons"<sup>84</sup>. However, the wording of the rule is such that it has weak practical meaning. The railway undertakings only need to supply vehicle distance information if they have access to this information in their operating and data recording systems. Thus, the rule is easy to get around. In practice, if the wagon keeper cannot get the distance information from the railway undertaking that has been in charge of the transport, he is not forced to monitor the distance in another other way.

It is also important to remember that this rule only applies to organizations that have signed up for the GCU. However, 50% of all ERFA members (plus a number of non-members) had already signed up for the GCU in 2006 and it is expected that more or less all market actors will join eventually<sup>85</sup>. Three years after the publishing of the GCU, in 2009, it could be pointed out that "More than 600 signatories, including all relevant wagon keepers and railway undertakings in Europe have joined the GCU. 700 000 rail freight wagons, the vast majority of the European fleet of rail freight wagons are covered by the GCU"<sup>86</sup>.

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<sup>84</sup> GCU Bureau, *Updated GCU as of 13 October 2009*, [gcubureau.org](http://gcubureau.org)

<sup>85</sup> European Commission, *The General Contract of Use (GCU) – Position of the Private Rail Freight Operators*, [ec.europa.eu](http://ec.europa.eu)

<sup>86</sup> UIP, *UIP Information, nr1 April 2009*, [www.uiprail.org](http://www.uiprail.org)

#### 4.4.2 Future changes<sup>87</sup>

Speculations about upcoming rules and regulations should be handled with great care as this type of information is highly uncertain. However, prognoses from knowledgeable organizations in the industry can provide valuable indications about the changes that could possibly take place in the future. The most prevailing indication in the industry is that monitoring of distance will become more practically mandatory in the future.

Changes in rules and regulations concerning distance monitoring could come from different directions. For one thing, the industry is constantly working to improve the way maintenance is carried out and controlled. The level of safety when it comes to maintenance is already high, but there is a lot of potential in working with and improving maintenance efficiency.

When it comes to improving maintenance safety, the organization ERA (see Table 4.1) is currently developing the concept of ECM, Entity in Charge of Maintenance. This is a kind of certification that is designed to ensure that maintenance of goods wagons meets high standards. The project of developing this new certification is in its final phase and the final proposal will be presented in the end of June 2010. The certification means that each and every unit (wagon) must have an entity in charge of maintenance assigned to it. This entity will bear the full responsibility for maintenance of the vehicle, and can theoretically be not only wagon keepers (who are the responsible entity today by owning the wagon) but also for example undertakers or maintenance companies. Furthermore, the certification will be made up of four different parts:

*Management function* – aimed to ensure a high and consistent standard in the organizations that are affected. There are requirements when it comes to organizational learning, competence management, and risk assessment. Also, there will be requirements regarding how documentation is to be carried out as well as a predefined definition of responsibilities.

*Maintenance development function* – contains requirements regarding continuous development of the maintenance documentation, both maintenance plans and technical documentation.

*Fleet maintenance management* – standards for how maintenance is to be carried out. Routines regarding how a goods wagon is to be taken out of operation and sent to a workshop will be described. Also, the sharing of maintenance documentation between the different parts involved is described as well as how the wagon is to be put back into operation.

*Maintenance delivery* – description of the tests that are to be performed in connection to maintenance and how they should be performed.

ERA has suggested that all goods wagons should be certified in mid 2013, however no decision has yet been made by the EU commission.

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<sup>87</sup> Fehr, Karl-Heinz, Lawyer, VPI

Aside from maintenance safety, there is a lot going on an EU level in the field of noise reduction that will most likely affect the industry in the future. The issue of noise reduction is related to the fact that a significant part of the European rail infrastructure passes through densely populated areas. Rail transport is associated with high levels of noise. This is true especially when it comes to braking goods wagons. There are initiatives taken on an EU level to reduce the level of noise by developing a system of charging railway undertakings for transports depending on the level of noise produced by the wagons as well as on the vehicle distance. Loud wagons would have to pay more per kilometer and quiet less. The level of noise depends on for example which type of brakes the wagon is equipped with. To be able to apply this type of charging model, the monitoring of vehicle distance is fundamental.

## 5. EuroMaint Rail and the Maintenance Offering

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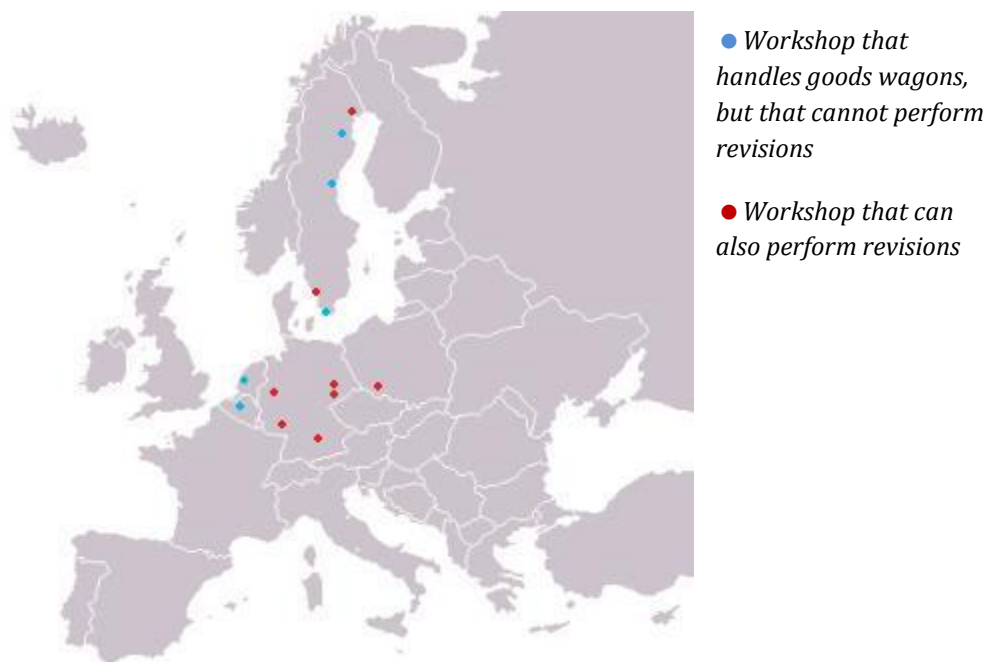
*This chapter describes the company and how it offers and supplies maintenance services for rail vehicles.*

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### 5.1 Facts about the company

EuroMaint Rail was formed in 2001 when SJ Maskindivision became EuroMaint. The operations of the organization are centered around maintenance and refurbishing of rail vehicles. These services are designed to help the customers to increase the availability, reliability and life span of their rail vehicles.

Today the company has workshops in a total of 13 locations in Sweden and is also present in Germany, Belgium, Poland, the Netherlands and Latvia. With more than 1500 employees, EuroMaint Rail is the largest independent European maintenance company in the rail transport industry. The turnover for 2009 was over € 215 million. Among the customers are Green Cargo, SJ, Veolia and Transwaggon.



*Figure 5.1, EuroMaint Rail goods wagon maintenance geographical presence<sup>88</sup>*

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<sup>88</sup> Figure adapted from [www.euomaint.se](http://www.euomaint.se) in combination with information supplied by Gunnar Melkersson, Sales Director, EuroMaint Rail

The services offered by the company can be divided into three basic categories; preventive maintenance, corrective maintenance and daily maintenance and conversion/modifying. The services are further offered as framework agreements or in the form of availability agreements. The former entails offering maintenance on a “per request” basis, where the customer is free to serve his vehicles at other maintenance workshops as well, while in the case of the latter EuroMaint Rail takes care of all of the planned/preventive maintenance needed for a vehicle.

Aside from maintenance and refurbishment, the company also offers some technical products. The responsibility for the technical products is held by a specialist development group.

## **5.2 Maintenance offerings**

### ***Preventive Maintenance***

Preventive maintenance is carried out on locomotives and railway wagons according to the maintenance plan that is specific for the vehicle. This specific maintenance plan is issued by the vehicle owner, and the timing of maintenance is normally based on the number of vehicle kilometers or time. The vehicle owner is the one who takes initiative to the service action. Furthermore, the content of the maintenance revisions is affected by the vehicle’s country of affiliation.

When a vehicle is taken in for inspection, it is inspected according to a schedule of revision (specific to each vehicle owner) after which unsatisfactory components are replaced.

### ***Corrective Maintenance***

Corrective maintenance is carried out either in one of the company workshops or out on the track with the help of a mobile maintenance unit. When a vehicle brakes down rapid access to components and spare parts is essential to getting the vehicle quickly back into traffic. To minimize handling time, the company has warehouses and workshops strategically placed around Sweden and northern Europe.

### ***Daily maintenance and conversion/modifying***

Railway vehicles are in general used during a very long time and must occasionally be renovated or rebuilt. This type of service action is mainly carried out on passenger vehicles. Aside from renovations and conversions, daily maintenance in the form of for example vehicle washing, graffiti removal and system testing is offered.

### ***Availability agreements***

For vehicles with good traceability, the company offers availability agreements where they assume full responsibility for the planned /preventive service of the vehicle. Maintenance is carried out on a regular basis and the owner is charged a fixed fee based on the number of vehicle kilometers. Currently this type of service is only offered for vehicles for which travel distance can be monitored.

SJ's X2000 passenger trains are currently served with this type of availability agreement. This type of agreement causes EuroMaint Rail to prioritize vehicles with availability agreement when it comes to giving fast service since they need to be in traffic for the agreement to be profitable.

Due to this, availability agreements can be an advantage for the vehicle owner. At the same time the agreement creates a security in the way that the cost for maintenance is known before hand. On the other hand, it can be harder for SJ to change to another workshop to get faster service if the workshops of EuroMaint Rail are busy. Entering an agreement like this and committing to one maintenance provider requires great confidence in the maintenance provider from the vehicle owner.

EuroMaint Rail is positive about this type of agreement as it locks the customer to the company. It has potential to generate good profits and creates a regular and even flow of capital. Availability agreements are currently not offered for goods wagons, as the traceability for such vehicles is limited. However, there is an aspiration to implement such agreements for goods wagons as well.

## **5.3 Strategy**

EuroMaint Rail has a well developed strategy to use its combination of experience and skills to strengthen the competitiveness of its customers. High technical competence and good geographical spread are strong competitive advantages. In order to ensure good geographical availability to customers the company has workshops in strategically good locations. The aim is for a customer who needs to send a vehicle to maintenance to always have a workshop within reasonable distance. In case a wheel is damaged and the wagon cannot get to a workshop the company can offer the service of lathing the wheel in location with the company's portable lathing equipment.

The company does not primarily compete in costs/low prices but rather aspires to offer their customers a high level of technical competence. Thereby the aim is to differentiate themselves from the competition by offering advantageous deals rather than offering the lowest prices.

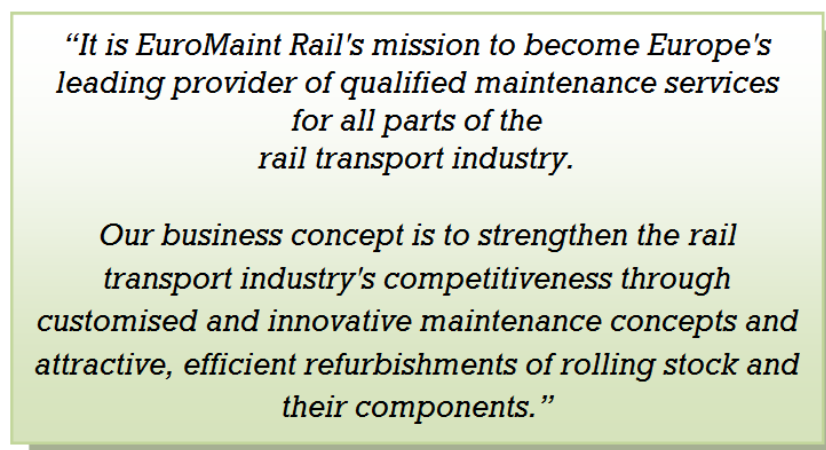
EuroMaint Rail operates within a specific niche, service and refurbishment of railway vehicles. At the same time the focus of the company is broad from a customer's perspective. The offering includes a comprehensive expertise in maintenance for all railway vehicles, including locomotives and different kinds of wagons. A customer can

use the services of the company for service, maintenance and refurbishment of all their railway vehicles.

In relation to the generic strategies defined by Porter (see section 3.3.3), the strategy of the company would fall under type 2, Differentiation. The competitive advantage of the company is the comprehensive service offering and the high level of technical expertise. This together with the broad scope of the offering that entails services for all railway vehicles contributes to the classification of the strategy as type 2.

The last couple of years the company has employed an offensive strategy. From being a strictly Swedish enterprise with all its activities located within the same country, the market was enlarged by the acquisition of workshops in for example Germany, the Netherlands and Lithuania. This growth opened up possibilities to offer service deals to the European market. The strategy has been to cover a larger part of the European rail network by acquiring workshops in locations previously not served.

This type of geographical market expansion has been beneficial for several reasons. For one thing, several of EuroMaint Rail's existing customers were using their vehicles internationally. Also, the expansion has made it possible to take market share in a new market.



*“It is EuroMaint Rail's mission to become Europe's leading provider of qualified maintenance services for all parts of the rail transport industry.*

*Our business concept is to strengthen the rail transport industry's competitiveness through customised and innovative maintenance concepts and attractive, efficient refurbishments of rolling stock and their components.”*

*Figure 5.2, EuroMaint Rail Vision and Business concept<sup>89</sup>*

One of the coming objectives is to take more deals in Germany. The type of growth strategy the company has employed can be classified as market development (see section 3.3.4), as the company has entered in a new market with existing services.

The addition to the portfolio of vehicle distance monitoring for goods wagons can be seen as a method for growth either as a product/service of its own (in which case it would entail offering a new product in an existing market) or as a means for offering availability agreements for goods wagons (which could be considered as offering an existing product on an existing market). There is a desire to increase the offering of availability contracts as these tie customers to the company for longer periods of time.

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<sup>89</sup> Figure adapted from [www.euromaint.se](http://www.euromaint.se)

The company has a separate group working with technical solutions, both for internal use as well as for customer use. The marketing of additional technical solutions is seen as very beneficial, as it not only ties current customers closer to the company and enables the selling of additional products or services to existing customers but also enables the company to reach new customers. These new customers can either be sold only the unique product/service but also potentially be attracted to the other maintenance solutions the company offers. There is a potential to attract customers by offering own technical solutions, as this type of solutions is offered by wagon manufacturers but often at very high prices.

Examples of products that are currently offered by the company are a portable wheel lather that can be used out at location on the track to process damaged wheels and an information system that will be used on X2000-trains (high speed trains) to keep track of among other things the position of the wagon (although there are many more uses for the system). The back-end of the system has the potential to be customized for use in goods wagon distance monitoring that is based on interval positioning (for more information about this distance monitoring concept, see 7.2.2).



## **6. Incentives for measuring goods wagon distance**

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*This chapter will discuss the incentives for implementing the concept of measuring the distance covered by goods wagons/axles.*

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There are several incentives for measuring the distance covered by goods wagons/axles. Information about vehicle and/or axle distance can be used for various purposes. Aside from the obvious purpose of complying with any laws that may be in effect, there are also practical uses for this type of information. Examples of use of vehicle distance information is for timing and increasing efficiency of maintenance, calculation of charge for long term wagon lease and increasing traceability. These uses of the information will be discussed in the following sections. Also, potential uses for infrastructure organizations as well as for enabling the offering of availability contracts for goods wagons will be mentioned.

### **6.1 Distance monitoring for maintenance timing purposes**

In maintenance planning, the timing of planned maintenance actions is usually based on either time or distance (see 4.3). Planning with time as the basis has the obvious advantage of being easy to perform. However, basing inspections and revisions on time also has significant drawbacks. One of the most important shortcomings is that by looking at time alone, there is no way of knowing how much wear the vehicle has been subject to. To make the intervals between inspections/revisions short enough to guarantee safety, it will be necessary to plan according to the highest expected level of wear. This means that all vehicles that are used to a lesser extent will be sent for inspections/revisions more often than necessary, resulting in higher maintenance costs than optimal.

Following the reasoning above, it is evident that the ideal basis of maintenance planning would be actual wear the vehicle has been subject to. However, monitoring actual wear is considerably difficult, seeing as it is affected by such a variety of parameters (for example load, speed, operational temperature and weather conditions).

The use of distance traveled as a basis for maintenance planning moves closer to monitoring actual wear than simply relying on time. By using distance as a basis rather than time, the negative effects caused by the shortcoming of maintaining all vehicles regardless of level of use can be reduced. Vehicles that spend a lot of time in an inoperative state will then be subject to less frequent inspections/revisions, while vehicles that are constantly in operation will be sent to the workshop more often. Intuition provides that this leads to a more efficient maintenance planning and execution where safety can still be guaranteed but costs can be lowered compared to costs with time planning. Wagon keeper's opinions about the use of vehicle distance to improve maintenance efficiency are discussed in section 8.2 on page 59.

## **6.2 Distance monitoring for long term wagon leasing<sup>90,91,92</sup>**

When wagon keepers lease their goods wagons to operators on a long term contract the price is usually based on leasing time (calendar time). Together with the leasing time, there is most often a maximum distance that is included in the contract. If the customer operates the wagon more than allowed in the contract, an additional fee is levied. However, the wagon keeper has little or no chance of knowing if the wagon is used in excess. Once the wagon is in the hands of the customer, the responsibility for tracking the whereabouts of the unit is transferred to the customer. Presently, the owners are mostly dependent on the honesty of their customers when it comes to providing information about excess use.

This type of excess use by the customer is seldom reported to the wagon keepers (see section 8.2 for more information). However, it is not uncommon for the owner to observe high levels of wear in a returned wagon, indicating that excess use may have occurred even though it has not been reported. By monitoring the distance traveled, the wagon keeper could prove excess use and thus charge the customer for this use in a straightforward way. Wagon keeper attitudes towards the use of vehicle distance for this type of purpose are further discussed in section 8.2 on page 59.

## **6.3 Distance monitoring for axle safety**

Currently, the most common basis used for planning preventive maintenance is time (for more information about this, see section 4.3). This is due in most part to the lack of other meaningful ways of evaluating the supposed wear. Using time as the basis for planning requires setting the time to a level that is low enough to make it unlikely that the axle will be subject to more wear than acceptable before revision. The current interval of 6 years that is implemented for most wagons throughout the industry is held short and most axles/wheel sets could in fact be revised less frequently since they are used less than the expected amount in 6 years<sup>93</sup>. Although it is very rare that axles/wheel sets are subject to more wear than calculated for with the use of these intervals<sup>94</sup>, the use of time as the basis for maintenance planning is associated with some risk of excess wear occurring. By monitoring distance and using this information for maintenance planning purposes, the danger of excess axle distance before revision could be reduced.

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<sup>90</sup> Hillman, Reinhard, Head of Technical Customer Service, VTG

<sup>91</sup> Engdahl, Bo, Sales Representative, NACCO Scandinavia

<sup>92</sup> Flügel, Peter, Head of Technology Department, Transwaggon

<sup>93</sup> Hillman, Reinhard, Head of Technical Customer Service, VTG

<sup>94</sup> Hansen, Bengt, Site Manager, EuroMaint Rail

If and when monitoring of distance will become mandatory for wagon keepers (see 4.4.2), there will be a need for ways for these organizations to accurately enough measure the distance traveled of their vehicles.

## **6.4 Distance monitoring for infrastructure organizations**

Aside from the advantages for wagon keepers discussed above, there are also potential benefits for other types of organizations. For example, railway infrastructure organizations (such as Swedish Trafikverket, the authority in charge of managing the Swedish railway track network) could with a distance monitoring system charge operators for the actual use of the railway tracks<sup>95</sup>. A problem with this kind of use is the information access, as it requires information to be collected and controlled by the infrastructure organization itself rather than by the individual operators. In Sweden, there is a project underway which is investigating possibilities for Trafikverket to track vehicles with the help of RFID-readers placed along Swedish railway tracks. This project is part of the EU-level Dryport project<sup>96</sup>. The Dryport project works to increase incentives to transport goods on rail and sea rather than road within the EU<sup>97</sup>.

## **6.5 Offering availability contracts for maintenance of goods wagons**

One of the main reasons for EuroMaint Rail to be interested in the concept of monitoring vehicle distance is the desire to have the possibility to offer availability contracts for goods wagons. In short, this type of contract means taking care of all the maintenance a wagon needs and charging the wagon keeper not per maintenance action performed but for the actual distance the wagon has traveled (for more information about this type of contract see section 5.2).

There are two main problems associated with the offering of availability contracts for goods wagons. First of all, the wagons are usually operated in a widespread geographical area (more information about the geographical use of wagons can be found in section 4.1), something that puts high demands on geographical availability of maintenance workshops. Secondly, it is necessary for the maintenance company to be able to get reliable information about the vehicle distance in order for the company to have the possibility of charging the correct price for the service.

The problem of geographically widespread use of the wagons is perhaps the most difficult to truly get around. A wagon keeper wants to be able to send his wagons to

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<sup>95</sup> Udikas M, *Tillförlitligare transporter med RFID-märkta tågvarnar*, TransportNytt

<sup>96</sup> *ibid*

<sup>97</sup> Sjöholm, Per, Technical consultant, Starbright Consulting

service workshops that have a suitable geographical location given the position of the wagon at the time of planned or needed maintenance. If the wagon is being operated by a railway undertaking on a long term lease, the wagon keeper has little or no control over where the wagon is operated. Wagons on this type of lease contract therefore will have to be possible to serve in maintenance workshops in a variety of locations. It will not likely be possible to serve this type of wagon with an availability contract unless the maintenance company has workshops strategically located close enough to all the geographical areas in which the wagon is operated. For example, if the wagon is situated in southern Italy at the time of planned maintenance and the maintenance company's closest workshop is in Germany, a considerable amount of time will be used to get to and from the maintenance workshop. Following the reasoning above, availability contracts can only easily be used for wagons operated within the reach of workshops belonging to the maintenance company in question. More information about wagon keeper attitudes towards availability agreements for goods wagons can be found in chapter 8.

When it comes to the problem with monitoring vehicle distance, there are two aspects to consider. Firstly, the vehicle distance has to be actually monitored in some way (for more information about monitoring of vehicle distance in general, see chapter 7). Secondly, this information has to be possible for the maintenance company to access with high accuracy. Distance that is reported from the wagon keeper (and possibly in the prolonging from the railway undertaking operating the wagon) has to be reliable.

## **7. Distance monitoring techniques**

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*This chapter describes different technologies available in the market for monitoring distance traveled. These are either already adapted for goods wagon use or are possible to adapt to such use.*

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### **7.1 Monitoring wheel set or wagon?**

The monitoring of vehicle distance can be done either by monitoring the distance traveled by the wagon itself or by monitoring the distance covered by one (or more) wheel sets. If monitoring the wagon, the distance covered by the unit as a whole is monitored and the same distance is assigned to the separate components. The advantage of monitoring the wagon is that only one piece of monitoring equipment is needed which stays on the same unit even though wheels or wheel sets are replaced.

The second alternative is to monitor the distance of a specific wheel set (and thereby axle). The monitoring equipment is then mounted on the wheel set. The problem with this is that the equipment follows the wheel set if it is removed from the wagon. This means that every wheel set will need its own piece of equipment to ensure that the distance of the wagon is always monitored (unless there is a way to easily move the equipment from one wheel set to another to ensure that it stays with the same wagon, in which case it would resemble measuring the distance of the wagon itself). Customer (wagon keeper) thoughts about the possibility of monitoring individual axles are described in chapter 8.

A relevant question when trying to determine whether it's most appropriate to monitor the wheel set or the wagon as a whole is what the distance information will be used for. The best alternative may vary from situation to situation.

### **7.2 Classification**

#### **7.2.1 Wagon based mechanical measuring**

The concepts that use precise measuring are based on mechanical measurement of the distance. This type of measuring is conducted by mounting an odometer adapted for goods wagon use on the wheel set. This odometer counts the number of turns of the wheel. Together with information about wheel diameter the vehicle distance can then be calculated.

One problem with this type of measuring is the fact that wheel diameter changes over time due to lathing being performed on the wheel when needed. The measuring will

therefore not be exact unless there is a way to easily change the wheel diameter that is used as a base for distance calculation in the system. Another drawback is the addition of another component to the wagon that has to be maintained and monitored to ensure that it is working properly. Any equipment that is placed on a wagon also needs to be securely fixed and discrete enough to ensure a low likelihood of theft and vandalism.

### **7.2.2 Wagon based approximate measuring**

This type of measuring constitutes an approximation of the true distance a wagon has traveled. It is based on the idea of approximating the distance by registering the position of the wagon at regular intervals. By combining this information with the knowledge of the rail network structure, the distance can be approximated. In other words, the distance itself is not measured but rather calculated based on known railway distances. For this type of system to work, the position has to be registered frequently enough for it to be possible to determine the route taken. This can be a challenge in places like Germany where an extensive railway network means that changes of track can happen often. The equipment used for this type of measuring is mounted on the wagon itself.

Using this type of system for distance monitoring has other potential benefits. The information about the whereabouts of the wagon can be used by companies that transport their goods in the wagon. These companies can thereby predict delivery times and optimize the handling of the goods.

Disadvantages of this type of solution are the risk for inaccurate measuring, the addition of a component to the wagon and the fact that an expensive information system is needed to manage the information collected. As the system is wagon based it is also important to consider making the equipment secure when it comes to theft and vandalism.

### **7.2.3 Infrastructural approximate measuring**

By implementing new technology along the railway tracks, wagons can be registered when they pass. Information about the id of a wagon and the time of positioning is collected and stored. Like wagon based approximate measuring, the distance can then be approximated with the help of already known distance information. The responsibility of the wagon keeper extends only to the placement of a RFID tag on the wagon. The placement and maintenance of readers along the tracks is managed by private or state owned infrastructure managers.

A solution that involves changes or additions to infrastructure is often associated with large costs. The placing of readers in large scale can be exceptionally expensive and extensive. Enough readers have to be placed along the track to ensure that the system covers all possible routes. Such readers are relatively expensive and require mounting and connection to a central database. For the system to be possible to use internationally, infrastructure managers from different countries must cooperate.

Information from this type of system has several possible uses. The system can give information about which transponder that a certain wagon last passed and calculate expected arrival times at the final destination. The system can also give information about the order of the wagons in a train. This information can be used by personnel at the final destination for planning the unloading of the cargo before the train has arrived.

#### **7.2.4 Real time delivery of data**

In all of the concepts mentioned above, the information about vehicle distance is gathered and stored in some way. This information can then be made available to stakeholders in different ways. One of the ways of supplying information is by more or less real time delivery of data. Wagon keepers, infrastructure and logistics companies and other stakeholders (depending on who has permission to access the information) who are interested in knowing the vehicle distance of a wagon can access the information by connecting to a central database. This database is continuously updated as new information about the wagons is received. The intervals at which data is sent from the wagons to the database differ.

There are several advantages of being able to access the information about a wagon regularly. For example, continuously monitoring the vehicle distance makes it possible to use the vehicle distance information for maintenance planning purposes, something that can potentially increase axle safety as well as decrease maintenance cost (for more information about these benefits see sections 6.1 and 6.3). Also, being able to access the information in more or less real time allows for positioning of the train and information about wagon order in the train as discussed above in section 7.2.3.

#### **7.2.5 Manual reading of data**

The alternative to regular transfer of vehicle distance information to a central database is manual reading of the information. This can be done either by physical or wireless connection to the monitoring equipment and therefore has to be done in close proximity to the wagon. This can for example be done by maintenance personnel during revision or at return of a wagon to a wagon keeper. The drawbacks are that the information about vehicle distance cannot be accessed while the wagon is in operation and that it therefore cannot be used as a preventive measure. However, it can be used for example as a basis for charging the correct fee for a long term lease (see 6.2) for statistical purposes.

### **7.3 Studied techniques**

Numerous technical solutions have been found, however most of the ones identified have been discontinued due to low interest and weak sales. In this report, the solutions found that are at present possible to acquire will be investigated and evaluated.

### 7.3.1 Concept 1: Lenord + Bauer<sup>98</sup>

Lenord + Bauer is a German company specialized in automation and measurement technology. Their unit GEL 2510 is a wagon based mechanical measuring system. The measuring equipment is mounted inside the axle box of the wheel set. Magnets are mounted on the end of the wheel axle. When the wagon starts to roll the magnet rotates with the wheel axle. A sensor detects the magnet motion and stores the information of the distance traveled. This information together with information about the temperature in the axle box is stored in a memory.

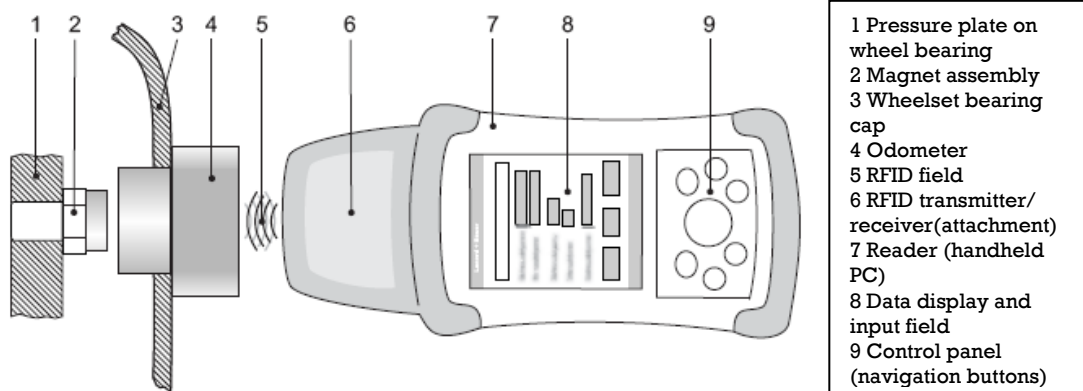


Figure 7.1, System design, Lenord + Bauer solution<sup>99</sup>

The advantage of measuring the temperature is that service personnel can see if the wheels and wheel system has been subject to high temperatures and thereafter perform actions as needed. In almost 80% of the accidents that occur due to axle failure, the cause of the failure is overheating of the axle box<sup>100</sup>. Today the temperature is normally controlled by using temperature sensitive paint. The paint indicates heat by peeling when subjected to high temperature.

The solution and its components are classified for safety and can be used on goods wagons carrying flammable cargo.

<sup>98</sup> Redding, Jonathan, Sales Manager, Lenord+Bauer

<sup>99</sup> Lenord + Bauer, *Operating manual GEL 2510*

<sup>100</sup> ERA, *Results of the survey on broken axles - Follow up*





Figure 7.2, Collecting the information from the Lenord + Bauer solution<sup>101</sup>

There is no external power supply; the whole system is powered by electricity generated by the magnet when the axle rotates. The advantage of this is that no battery is needed and the system requires less maintenance. The sensor is mounted on the wheel set bearing cap and has no physical contact with the magnet.

The transfer of data to a computer is manually operated with a hand held RFID reader. The information that is stored details mileage, serial number, wheel set type and number, and mileage traveled where the temperature threshold was exceeded.

The price of this solution is from € 200 per unit, assembly not included. A very simple information handling system (spreadsheet-based) is included.

### 7.3.2 Concept 2: Franz Kaminski Waggonbau<sup>102,103</sup>

This like the previous is a wagon based mechanical measuring system. Mounting of the unit LLZ-FK V2 simply replaces the wheel set bearing cap with a new custom-made model. Inside this new larger model there is a rod that is pressed against the wheel axle with the help of a spring. The interface between the rod and the axle is made of rubber. The pressure of around 200N applied by the spring keeps the rubber bud pressed against the axle and guarantees a reliable motion transfer. The rubber knob is axially adjustable and has no negative effect on the durability of the axle. A sensor registers the rotations of the rod and stores the information in a memory. The rotations are registered in the same way regardless of the direction of movement of the wagon. Daily vehicle distance for up to 6 years of transport is stored. Apart from distance information, the system also stores information about wagon keeper, id of the wagon, id of the wheel set and date of coming planned maintenance.

<sup>101</sup> Lenord + Bauer, *Information brochure, GEL 2510*

<sup>102</sup> Elstner, Karsten, Head of Sales, Franz Kaminski Waggonbau

<sup>103</sup> Franz Kaminski Waggonbau, *the LLZ-FK V2*, [www.kaminski-hameln.de](http://www.kaminski-hameln.de)

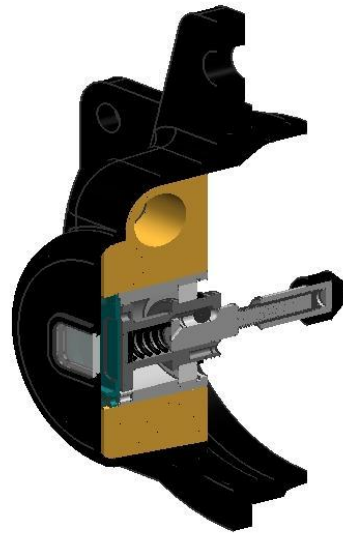


Figure 7.3, The Franz Kaminski Waggonbau customized Bearing Cap<sup>104</sup>

There is no power generated by the unit itself, which means that the system requires a battery. The battery can supply the system with power for at least six years and can then be replaced as needed during service. All electronics are placed well protected by the wheel set bearing cap and are adapted to meet current requirements regarding mounting of equipment on goods wagons. The batteries are classified for ATEX zone 1, which enables mounting on wagons carrying flammable goods. ATEX is a standard that contains technical requirements regarding equipment used in explosive environments<sup>105</sup>.

Data transfer is performed manually using a hand held RFID reader with a range of 1,5 meters. When a wagon arrives at a maintenance workshop, service personnel can easily read the information. The information is then sent to a computer that is connected to the central service system of the wagon keeper.

The price per unit is from € 550 and includes software for read and write.

### 7.3.3 Concept 3: ElectroTech/Pilotfish<sup>106</sup>

The unit PU 100 is a development based on an earlier system for monitoring of container levels. Here a GPS is mounted on the goods wagon and periodically saves its positions. The different positions are saved in a memory and sent in to a central system using GSM/GSM-R once a day. The user can choose between using the normal mobile net GSM or GSM-R which is specific to railway use. At the central computer the positions are compared to a map of the rail network and software can determine the route and

<sup>104</sup> Franz Kaminski Waggonbau, *the LLZ-FK V2*, [www.kaminski-hameln.de](http://www.kaminski-hameln.de)

<sup>105</sup> European Commission, *Utrustning som är avsedd för användning i explosionsfarliga miljöer (ATEX)*, [www.ec.europa.eu](http://www.ec.europa.eu)

<sup>106</sup> EuroMaint Rail, *Information brochure, PU 100*

thereby calculate the distance. Wagon keepers and other stakeholders can not only get information about the vehicle distance but also about the whereabouts of the wagon at different points in time.



*Figure 7.4, The Electrotech/Pilotfish wagon mounted equipment<sup>107</sup>*

The system is powered by a battery. Since both the positioning system and the data transfer system require relatively large amounts of electricity, different power management features have been developed. The system has a built-in accelerometer that can tell if the car is in motion. The system can then wait to start the GPS search until the vehicle has stopped. A satellite search requires significantly more power when it is not standing still. The accelerometer can also detect if the vehicle has been stationary for some time and if so, the system can wait to start the GPS search until the wagon has changed position. This is useful as a means to save battery while still not decreasing the accuracy of the monitoring as goods wagons are sometimes left standing in railway yards for weeks while awaiting loading.

A built-in thermometer prevents the GSM/GSM-R transmission if the temperature is below -25C as transmission requires more power at low temperatures. Thanks to this power management, the battery can last for more than five years with one GPS search every hour plus one additional every time the wagon stops, and one daily report with GSM/GSM-R.

The price of this solution is between € 350-580 per unit, depending on order number. GSM/GSM-R traffic is not included. Apart from this there is also the cost of developing the software and mapping system, with a cost of about € 50'000. A solution based on this concept has recently been offered to the Norwegian national rail administration Jernbaneverket who wish to position as well as calculate vehicle distance for a number of vehicles.

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<sup>107</sup> EuroMaint Rail, *Information brochure, PU 100*

### 7.3.4 Concept 4: Eurotrack/I-LOC8<sup>108,109</sup>

Eurotrack is a Norwegian company that offers tracking of trucks, boats, containers and different types of machines. The equipment comes from the British company I-LOC8 and is made up of a GPS receiver and a GPRS transmitter. The GPS receiver regularly registers the position of the wagon and sends this to a central system via GPRS. Aside from position, velocity is also registered. By combining the different positions the distance can be calculated. The drawback of the performance today is that only one position per day is saved. This limits the reliability of the distance measuring.

When the positioning system is mounted on a vehicle it can be powered by the vehicle electrical system if such exists. When mounted on for example a container the system is equipped with a rechargeable battery and a solar film. GPS, GPRS transmitter and battery are placed in a waterproof box that is mounted on the container. The solar film which regularly recharges the battery has the measures 44\*28\*1,4 cm and is also mounted on the container. For positioning boxes mounted on containers it is also possible to monitor temperature. This is used to ensure an even temperature in for example a refrigerating container.



Figure 7.5, Eurotrack solar panel<sup>110</sup>



Figure 7.6, Eurotrack battery and transmission unit<sup>111</sup>

<sup>108</sup> Eurotrack, *Information brochure, Containersporing*

<sup>109</sup> Audun Tandberg, member of the board, Terje Tandberg Transport AS

<sup>110</sup> Eurotrack, *Information brochure, Containersporing*

The system and its uses are under development and Eurotrack has conducted tests where the system has been mounted on goods wagons. During the tests which were commenced in November 2009, the equipment was mounted on a number of wagons belonging to the Norwegian mail. The wagons were used around Norway with satisfactory results. Although the number of hours during which the solar cells can generate power in northern Norway during the winter is very limited it turned out to be enough to power the positioning system.

The price for the Eurotrack positioning system is from € 23 per unit per month including hardware and software system.

### 7.3.5 Concept 5: Infrastructural RFID monitoring<sup>112,113</sup>

A RFID-based system is presently tested by Trafikverket (former Banverket) on the route between Gothenburg and Falköping. The aim of the project is to create a possibility to trace cargo from the port to the factory and in this way create better management in general when it comes to rail cargo transport. The project is part of the European Dryport project and the goal for the Swedish part of the project is to create an open system that keeps track of goods wagons and that can be used by all stakeholders in Europe. In the starting phase of the project that is currently underway, different standards have been developed that are to be used and implemented throughout Europe. The aim of the Swedish project is to develop a reliable RFID based system that will be possible and desirable to implement in more European countries in the future.

The system is built up of passive RFID-tags and readers. Two passive RFID-tags are mounted on the goods wagon, one on each side. These can be mounted somewhere in the yellow areas in Figure 7.7 below. The advantage of these tags is that they are very small and require no external power supply. Instead, they are powered by induction when a tag passes a reader. When the tag is hit by radio waves from the reader, part of the tag is transformed into an electrical circuit which supplies the reading of data with power.<sup>114</sup> Tests during the project have shown that reading of the information in the tag can be performed at speeds as high as 200 km/h.

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<sup>111</sup> Eurotrack, *Information brochure, Containersporing*

<sup>112</sup> Per Sjöholm, Starbright Consulting, Project leader Dryport

<sup>113</sup> Udikas M, *Tillförlitligare transporter med RFID-märkta tågvarnar*, TransportNytt

<sup>114</sup> Ny Teknik, *Så funkar rfid-tagarna*, [www.nyteknik.se](http://www.nyteknik.se)

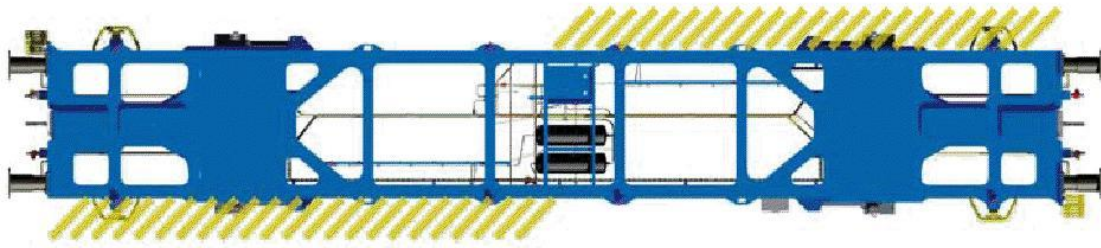


Figure 7.7, Possible areas for placement of RFID tags on the wagon<sup>115</sup>



Figure 7.8, Two different RFID readers and tags<sup>116</sup>

During the test period a dozen readers will be deployed. These will be placed in strategic spots along the rail, primarily in connection to already present other types of monitoring units that are connected to a central system. This connection can then be used to send the information from the RFID reader about the wagons that have passed. In places where no such connection exists, a new connection will be created by cable.

<sup>115</sup> ITS Sweden, *Freightwise*, [www.its-sweden.se](http://www.its-sweden.se)

<sup>116</sup> *ibid*



*Figure 7.9, Two independent RFID tags/readers are tested and evaluated<sup>117</sup>*

The information that is transferred from the tag consists of identity of the wagon only.

The price of an RFID-tag is low, around € 3 a piece. However, establishing a network of readers is significantly more expensive. The placing of one reader has a total cost of approximately € 6000. Due to the amount of readers needed for the system to function properly the investment cost is high. In Sweden around 500-700 transponders are expected to be needed.

## **7.4 Other ways of monitoring vehicle distance**

Measuring vehicle distance with the help of different kinds of equipment as described above in section 7.3 is not the only way of obtaining information about the distance traveled by a goods wagon. Vehicle distance information can also to some extent be obtained without any investments in equipment. This can be done in two main ways; by receiving information from railway undertakings and by calculating the distance by knowing the route traveled.

Obtaining information about vehicle distance from railway undertakings is fairly straightforward. If the railway undertaking that has been transporting the wagon has access to information about the vehicle distance, it is generally obligated to supply the wagon keeper with this information (these rules are discussed further in section 4.4.1). In practice, most big railway undertakings do register this information and it is therefore readily available. An approximation from one of the wagon keepers consulted in this study is that 85-90% of the transports made are made by undertakings that store vehicle distance information (this is discussed further in section 8.4). The fact that the rules regarding vehicle distance information are expected to become stricter suggests that the number of railway undertakings that collect and store vehicle distance information will increase in the future.

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<sup>117</sup> ITS Sweden, *Freightwise*, [www.its-sweden.se](http://www.its-sweden.se)

When it comes to calculating the distance by knowing the route of the wagon, it can easily be used in practice for wagons that are used in  $A \rightarrow B \rightarrow A$  transports or equivalent situations. This could for example be wagons that are operated in shuttle traffic between a production site and a harbor or other transport hub. It is then easy to calculate vehicle distance by simply multiplying the number of travels made with the (known) distance of the route. Apart from vehicles in shuttle service, vehicle distance can also be monitored for wagons used in unique transports as opposed to long term contracts. The control the wagon keeper has over the whereabouts of the wagon can potentially be used to manually calculate the distance traveled.



## **8. Customer Attitudes<sup>118,119,120,121,122</sup>**

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*In this chapter, customer (wagon keeper) attitudes towards wagon/axle distance measuring will be described. The information discussed in this chapter aims to give an understanding of the wishes and requirements on a measuring system from a customer point of view.*

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The attitudes towards distance measuring among wagon keepers in the industry seem fairly homogenous. In general, there is a positive attitude towards monitoring vehicle distance and an eagerness to be able to fully receive this type of information. All wagon keepers contacted in this study have already been investigating the possibilities for implementing vehicle distance monitoring on their wagons in one way or another. From a customer point of view, there are rather strict requirements on this type of product/service. Furthermore, vehicle distance information is to some extent already available.

### **8.1 Attitudes towards placement of equipment**

When it comes to the type of monitoring equipment, the wagon keepers are in general more positive towards concepts that are placed on the wagon as a whole rather than on individual wheel sets. The main argument for this is that the handling of equipment and replacement of it in connection with replacement of wheel sets would be inconvenient. To ensure continuous monitoring, equipment will need to be placed on each wheel set on the wagon. Access to “spare parts” (monitoring equipment) in the workshop has to be ensured.

### **8.2 Incentives**

All wagon keepers that have been contacted during this study see a need or desire for the possibility of monitoring vehicle distance. In general, most wagon keepers have the same business model when it comes to renting out wagons to railway undertakings or other operators. Most keepers have short term rentals, in which a wagon is made available for a specific transport from A to B, as well as long term rentals where the leaser disposes of the wagon during a longer period of time. During these long term leases, the leaser is free to transport the wagon wherever preferred.

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<sup>118</sup> Hillman, Reinhard, Head of Technical Customer Service, VTG

<sup>119</sup> Engdahl, Bo, Sales Representative, NACCO Scandinavia

<sup>120</sup> Flügel, Peter, Head of Technology Department, Transwaggon

<sup>121</sup> Behrens, Oliver, Technology Department, GATX

<sup>122</sup> Sandgren, Magnus, Technology Department, Peterson Rail

For short term contracts the wagon keeper knows where the wagon is transported, and thus has good possibilities to estimate the vehicle distance for each transport without using any specific distance monitoring technique. For long term leases, however, the control over the whereabouts of the wagon is very limited. The leaser/operator is the one controlling this information.

In the case of long term leases, the leasing cost is based on calendar time but with a maximum distance allowed (see also section 6.2). The wagon keepers contacted in this study state that excess usage of their wagons on long term contracts is believed to be uncommon. However, since actual vehicle distance is not monitored, this is only an educated guess. Nevertheless, the wagon keepers also state that it is fairly easy to tell at the time of return of the wagon if it has in fact been used more than allowed in the contract. The distance allowed is quite high and with normal use it will not be exceeded.

One keeper with a lot of experience in long term leases states that a wagon that has been used significantly more than allowed shows clear signs of wear and that they are fairly sure that they almost always notice if a wagon has exceeded its allowed distance. In the case of such excess use, the leaser is contacted and asked about whether or not the wagon has traveled further than allowed. The leasers have quite good information about the actual distance traveled and charging them for the excess distance does not pose a problem.

In general, the attitude among the keepers is that the benefit of monitoring the distance themselves in order to be able to charge leasers for excess distance on long term contracts is very limited. For one thing, the keepers trust their customers to be honest about how much they use the wagons leased. Also, this type of distance information is generally supplied upon request.

There are indications that long term contracts could be based on actual distance rather than time in the future with better possibilities of accurate vehicle distance monitoring. However, there is no information about the possible monetary gains from this type of contract as opposed to contracts based on time, something that makes it difficult to estimate the willingness to pay for the possibility of monitoring vehicle distance for this purpose at this moment in time.

Some of the wagon keepers contacted in the study see a potential value in the optimization of maintenance. By monitoring vehicle distance it would potentially be possible to serve a vehicle less frequently if it is used less, something that would decrease maintenance cost. For more specific details of these advantages, see section 6.1.

### **8.3 Current situation**

Even though the monitoring of vehicle distance is more or less required (see section 4.4.1), none of the wagon keepers consulted in this study fully control this information. Some of them are currently gathering vehicle distance information by requesting it from the railway undertakings operating their vehicles. Also, vehicle distance when it comes to short term leases (for example transports from A to B) where the route of the vehicle is known is naturally easily monitored within the own organization. However, this information is not widely used. In general, the information is gathered for statistical/informational purposes and used more for getting an idea of to which extent the vehicles are operated.

All larger railway undertakings have systems that control and monitor the operations carried out by the undertaking. As many European railway undertakings use the GCU (in which supply of information to wagon keepers is regulated, for more information, see 4.4.1) they also agree to provide the wagon keepers with this information upon request. Three years after the publishing of the GCU, in 2009, it could be pointed out that “More than 600 signatories, including all relevant wagon keepers and railway undertakings in Europe have joined the GCU. 700 000 rail freight wagons, the vast majority of the European fleet of rail freight wagons are covered by the GCU”<sup>123</sup>. The goal for the GCU Committee is for all European railway undertakings to use the GCU, and it is likely that the number of railway undertakings that monitor vehicle distance as well as are willing to supply wagon keepers with this information will increase in the future.

### **8.4 Requirements**

In general, the main requirements on the monitoring technique from the part of the wagon keepers are that it should be cheap and sufficiently accurate. The cost of the service should be weighed up by either the reduction in maintenance costs or increase in lease charges or a combination of both, depending on what the information will be used for.

As an approximation of the willingness to pay, one wagon keeper in the study has made own calculations of the potential gains from monitoring distance for maintenance optimization purposes. These calculations have shown that the maximum cost they will be willing to pay for the service is less than € 0,16 (sixteen Euro cents) per wagon per day (for calculations, see Appendix 3). Even at this price, it is not certain that the use of the service will be profitable, as this depends on the use of the wagon. It will only be profitable if the wagon is used little enough to make it possible to delay wheel set revision with at least four years (since wagon revisions of the tank wagons owned by the wagon keeper are carried out every four years and no other scheduled maintenance is conducted between these revisions due to the desire to keep wagons in operation as much as possible), something that according to the wagon keeper is not likely to be the

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<sup>123</sup> UIP, *UIP Information, nr1 April 2009*, [www.uiprail.org](http://www.uiprail.org)

case for most levels of use. Consequently, the real value of the service and thus the price that would be possible to charge for the service is even lower, depending on the likelihood of being able to delay wheel set revision to the next revision occasion. However, it is important to note that the calculation above concerns tank wagons that must be revised every four years for safety reasons (more specifically safety of tank valves). This interval cannot be extended even if the wagon travels less. The only difference is that wheel set revision may be possible to perform at less than every third tank valve revision (wheel set revisions are made every 12 years by this wagon keeper). However, in the case of other types of goods wagons where the interval time between planned revisions is originally based solely on expected vehicle distance over the interval time, there may be possibilities to extend all planned maintenance intervals and thereby reduce overall maintenance costs, something that would increase the willingness to pay correspondingly. On the other hand, such extensions of interval time may not currently be in accordance with maintenance regulations depending on the type of wagon. No estimation can be given for the possible savings that could potentially be made by performing maintenance for other types of wagons less frequently as the wagon keepers in this study are skeptical about the possibilities to extend maintenance intervals.

When it comes to accuracy of the information provided by the monitoring, the requirements are basically that the information supplied should be accurate enough to serve the purpose. In practice, this means that the difference between actual vehicle distance and measured distance should not be big enough to threaten the safety of operation of the vehicle or produce misleading information.

If the information is to be used as a basis for maintenance planning, the wagon keeper needs to be sure that any deviations do not lead to maintenance being performed too seldom. It is impossible to put a fixed number on the standard deviation that would be acceptable, but the wagon keepers consulted agree that the difference that would be caused by differences in wheel diameter would be acceptable. The maximum difference caused by this type of difference in the case of mechanical measuring is 8,7 % (see Appendix 1). The risk that this type of deviation will cause excess use of the wheel set before revision can be eliminated by calculating with the maximum wheel diameter (before any lathing has been performed). However, doing so will somewhat decrease the potential benefits from using the vehicle distance information for maintenance planning purposes as the distance calculated will always be on the high side provided that lathing is performed.

When monitoring the distance by obtaining information about vehicle distance from railway undertakings, the accuracy of the distance is considered to be very high. This level of accuracy is accepted by wagon keepers as well as in general as stated in for example the GCU (see section 4.4.1). The problem with this type of distance monitoring is that some railway undertaking cannot supply the information. These undertakings are usually small and privately owned. One of the wagon keepers in the study estimates that the proportion of operation carried out by such undertakings amounts to approximately 10 – 15 % of all transports. This number likely differs considerably between different wagon keepers, but due to the market structure (with a presence of many small railway undertakings) it is not likely for a wagon keeper that is in need of accurate vehicle

distance to be able to fully rely on information being supplied by railway undertakings at the present time.

When it comes to the accuracy of approximate measuring techniques, it is difficult to give a general estimation of the deviation. The accuracy depends on for example how often the position of the wagon is checked and how the distance is approximated (if the positioning is combined with information about the rail network or if it is approximated linearly). However, this type of measuring has proved to be rather imprecise. One of the wagon keepers in the study has conducted experiments where this type of distance measuring has been compared to mechanical measuring. These experiments led to the conclusion that the margin of error of the approximate measuring in question was around 10 %. This is considered quite large and not sufficiently accurate. In the case of the solution offered to Jernbaneverket, there is a maximum deviation of 5 % specified by the customer. By adjusting the interval between registration of the position of the wagon, the margin of error of wagon based approximate measuring can be reduced to suit the needs of the user.

## 9. Analysis

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*In the following chapter, the theory and empirical findings from the preceding text will be examined and analyzed to provide a solid base for the conclusions that will be drawn and the recommendations for further actions that will be made.*

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### 9.1 Possibilities to measure vehicle distance

Technique	Equipment type / classification	Delivery of data	Power supply for wagon based equipment	Approximate cost for equipment per wagon	Approximate cost for system / additional costs	Limitations	Additional functionality
Lenord + Bauer	Wagon based / mechanical measuring	Manual reading	No power supply needed	From € 400 (2 axles, € 200 per axle)	Depends on complexity of system (simple system included)	Inconvenient handling (replacement at wheel change)	Wheel system temperature information
Franz Kaminski Waggonbau	Wagon based / mechanical measuring	Manual reading	Battery (lasts for >6 yrs)	From € 1100 (2 axles, € 550 per axle)	Depends on complexity of system (simple system included)	Inconvenient handling (replacement at wheel change)	
ElectroTech/ Pilotfish	Wagon based / approximate measuring	"real time"	Battery (lasts for >5 yrs depending on performance)	€ 350-580 depending on order quantity	€ 50'000 for system.		Information about position
Eurotrack/ I-LOC8	Wagon based / approximate measuring	"real time"	Rechargeable battery + solar panel	€ 23 per month	Included in monthly fee	Somewhat delicate, long interval between positioning	Information about position
Infrastructural RFID	Infrastructure based / approximate measuring	"real time"	No power supply needed	€ 6 (2 tags, € 3 per tag)	N/A (central system, cost for information unknown)	No control over the system	Information about position (predefined positions only)
Collection of RU data	N/A (no equipment)	On request	N/A (no equipment)	N/A (no equipment)		Time consuming + not all RU's provide information	

*Figure 9.1, Overview over distance monitoring techniques (a larger version is available in Appendix 2)*

There is already a number of techniques available on the market for monitoring vehicle distance, summarized in Figure 9.1 above (the specifications of these were discussed in chapter 7).

In general, it is advisable to monitor the wagon as a unit instead of wheel sets. This is due to the fact that wheel sets are occasionally replaced. Monitoring the wheel sets would then require either monitoring each wheel set to avoid discontinued measuring if the wheel set equipped with the monitoring equipment would be removed from the wagon, or having the possibility to easily move the monitoring equipment from one wheel set to another. In general (with the techniques evaluated in this report) the moving of equipment from one wheel set to another is not easy. Due to this, the use of

wheel set based monitoring equipment would likely require the use of monitoring equipment on each wheel set. This also means that there is a problem with replacement of monitoring equipment when wheel sets are removed. Wheel sets equipped with monitoring equipment would need to be readily available for placement on the wagon independent of the location at which replacement would take place. This fact together with the fact that wheel set placed solutions require more monitoring units than wagon placed solutions is a drawback of the mechanically functional wheel based solutions for vehicle distance monitoring.

For wagon based solutions, the only possibilities of monitoring distance are approximate (no mechanically based solutions are wagon based). The way they work involves calculating the distance traveled based on positions at which the unit has been located at different points in time. Although this way of measuring the distance will never be 100% exact (unless the interval between positioning is infinitely small), neither is mechanically monitoring due to differences in wheel diameter due to lathing and wear.

Also, the monitoring of distance through positioning has the added benefit of gathering information about the geographical position of the wagon, information that can potentially be used for other purposes (such as tracking cargo, calculating estimated arrival times etc). This applies to both wagon based as well as infrastructural approximate measuring, but the positions naturally differ depending on if the monitoring locations depend on time (which is the case when it comes to wagon based monitoring) or geographical position (for infrastructural monitoring where the readers are located in fixed places). Information about the position of the wagon can be offered to the customer in combination with distance monitoring as a function they do not expect and don't know they desire. This is called "excitement quality" in the Kano model (described in section 3.2.1), and can significantly increase customer satisfaction.

An important thing to consider when investigating the possibilities to offer a product/service of monitoring vehicle distance is the substitutes for the offering that are already available to the potential customers. Currently, most of the information about vehicle distance can be obtained from railway undertakings at no cost for the customer (the wagon keeper). However, this information is currently not consistently collected due to the collection of data being rather time-consuming as it is stored in different formats by different undertakings. Thus, room is still left for filling the demand for distance monitoring.

Future possible solutions that may be available from other sources and that may reduce future demand for solutions offered by the company must also be considered. There are indications that information supplied by railway undertakings will be more widely available in the not so distant future. With a more readily available source of free information, the demand from wagon keepers for the monitoring of vehicle distance will be limited. Also, the possibility that a European wide RFID system will be implemented needs to be considered. With such a system, wagon keepers would have access to vehicle distance information in an easy way and to a low cost.

## 9.2 Willingness to pay

There is a recognized interest in the business for ways to monitor the distance traveled by a goods wagon. The fact that there are solutions available on the market is widely known but in most cases the willingness to pay is lower than the cost of the solutions available. The different types of players in the industry have different potential use for the information about vehicle distance and thereby different willingness to pay depending on the utility.

A wagon keeper could potentially use the distance information to make maintenance more efficient. Service intervals that today are based on estimated maximum use can both be lengthened and made more reliable. At the same time, it is not obvious that implementing wagon distance monitoring will lead to the possibility of lengthening service intervals. It is only guaranteed to create an opportunity to establish whether or not it would be possible to lengthen an interval. A wagon keeper can therefore not assume that a distance monitoring system will lead to decreased maintenance costs. This in turn makes the demand and willingness to pay for such a system very limited.

A distance monitoring system can also be used to enable correct charging for rental of wagons. Although no comprehensive market research has been made to establish the demand for such use of the system, there are indications that the willingness to pay is low as the charging model that is in use today is seen as sufficiently accurate and excess use of wagons is either insignificant or easy to detect and charge for. Nevertheless, there are indications that some wagon keepers may wish to use wagon distance information to allow for short rentals charged on mileage base. There is also some interest in being able to make random distance checks at some occasions. This could for example be done if it is suspected that a certain customer systematically fails to report excess use of a wagon on long term lease.

The research made in this study indicates that the only real reason for a wagon keeper to be willing to pay the current cost for implementing a system for wagon distance monitoring is if rules or regulations would make it mandatory for wagon keepers to keep track of wagon distance. However, this distance information can possibly be collected from operators. Also, due to the relative complexity of implementing monitoring systems for all wagon keepers, it is not likely that it will become mandatory anytime soon.

There are more players that can benefit from a monitoring system although maintenance companies and wagon keepers are the main ones. Distance monitoring systems that are based on positioning (for example RFID and GPS solutions) can potentially appeal to more players. Potentially, the cost for a system could then be split between several parties. Railway undertakings can use the information gathered to keep track of the whereabouts of the wagons they operate and make operations more efficient. Companies that transport cargo by rail can be willing to pay extra for transports where they can follow their cargo to and from for example factories and warehouses. The higher the total utility that a system contributes to, the bigger the chance that the costs can be covered by the total willingness to pay.



There are clear indications that there is a low likelihood that the willingness to pay for a pure distance monitoring system will exceed the costs of implementing the system at the present point in time. The cost for the system is simply higher than the perceived customer value.

### **9.3 Possibilities to offer availability contracts**

The demand for availability contracts for maintenance of goods wagons is low. The main apparent problem is geographical presence of maintenance workshops when it comes to serving vehicles that operate internationally. Wagon keepers that only have wagons on long term leases also have less to gain from increasing the availability of the wagons as they do not suffer when the wagon is out of service for reasonable amounts of time. The time that is considered reasonable differs from case to case. However, using normal maintenance agreements (where several different maintenance companies are used depending on geographical location of the wagon) does not normally cause any significant down time. As the wagon keeper is ultimately responsible for maintenance of the wagon during this type of use, the main selling point would be offering availability contracts that would decrease total maintenance costs while still not causing trouble for the customer who is renting the wagon. This could be done by being flexible with timings of planned maintenance and timing these maintenance activities with regard to the planned operation of the wagon and at the same time allowing for corrective maintenance to be performed at external maintenance workshops. This would theoretically be possible but poses problems when it comes to communication between wagon keeper and railway undertaking to ensure that the timing of maintenance activities is suitable for both parties.

One reason for the low demand and weak interest in availability contracts for goods wagons can be the fact that the service is completely unheard of in the industry and wagon keepers have difficulties to assess the benefits of such a solution. It is possible that this interest can be aroused through marketing of the service, however determining the possibilities for this is beyond the scope of this research.

### **9.4 The addition of goods wagon distance monitoring to the portfolio**

For EuroMaint Rail, the offering of a product or service that can produce vehicle distance information can create new customer contacts and be a good complement to the rest of the product/service range. This new product/service also has the potential to tie customers to the company with the potential possibility to offer availability contracts for goods wagons.

The evaluation of the suitability of adding goods wagon distance monitoring to the product/service portfolio of EuroMaint Rail depends mainly on two factors: the technique in itself and the functionality of it.

#### **9.4.1 Suitability of the technique as a part of EuroMaint Rail operations**

When introducing a new product or service to a company's portfolio, it is important to consider whether the company has the expertise needed to produce and offer this new addition. Adding a product that cannot be produced and offered to meet the specifications and demands is not recommended.

When it comes to the technique in itself and its suitability for the company, there are no apparent problems. The company has a department working exclusively with technical solutions, and has sizeable experience in dealing with both hardware/tangible products as well as software and information systems. The mechanics of the monitoring systems described in chapter 7 that could be considered as an addition to the company (wagon based solutions, either mechanical or approximate) are not complicated. However, these need to be combined with an information system that can transform the data from the monitoring equipment into meaningful information.

The development of a system can of course be done by the customer (in case the monitoring equipment is offered as a product only), but the margin on this kind of offering would likely be low due to the extra work the customer would have to perform in order to extract the information in combination with the availability of alternatives in the market. Instead, and in part due to the fact that there is already a back-end system available in the company that could be customized to work with goods wagon monitoring, the company can consider to offer the monitoring equipment in combination with a system solution to give the customer a complete solution for monitoring wagon distance. The customization of the system would not be cost free but cost significantly less than developing a completely new system. In addition, the fact that the company already has a system to show its potential customers can be an exploitable selling point. An important thing to note is the fact that the current back-end system is adapted for monitoring with the help of geographical positions. Consequently it would only really be appropriate for use with approximate measuring techniques.

#### **9.4.2 Suitability of the concept of goods wagon distance monitoring**

Not only does the internal suitability of a product/service matter to the overall aptness of a new product/service to a company' portfolio. It is also crucial to consider the expected response to the addition in the market.

The suitability of monitoring of goods wagon distance as a concept depends on whether it should be used in development of maintenance or as a tangible way of monitoring the distance traveled by a goods wagon. The difference of these two will be described in the following.

### ***Development of maintenance***

As a way of developing maintenance, the addition of the service is suitable given that the willingness to pay of the customer is high enough to cover the cost of offering the service. As the company has a mission to supply the market with customized and innovative maintenance concepts that can strengthen the competitiveness of the rail transport industry, the addition would go well in line with company aims and goals. Being able to offer unique maintenance supplements can potentially have a higher value than the immediate monetary profits – it can be a way to attract potential customers to the company by showing innovativeness and width in the technical expertise. Thereby company reputation can be strengthened.

The use of vehicle distance monitoring in combination with maintenance planning, mainly in the way of serving wagons with availability contracts, is already available on the passenger train side and extending this to involve goods wagons as well would likely be reasonably straightforward given the possibility of monitoring goods wagon distance. The main issue involved in the addition of goods wagon distance monitoring for maintenance development purposes is the demand for availability contracts in the market. Although it has been beyond the scope of this study to perform a comprehensive market research, there are nevertheless possibilities to draw some conclusions regarding the demand for availability contracts for goods wagons. The research made in this study indicates that there is a very low demand for availability contracts for goods wagons due in most part to the geographical limitations and the fact that wagon keepers are not familiar with the concept. The geographical limitations can be hard to get around when it comes to for example wagons on long term lease but for wagons operating in more limited geographical areas (or even more strictly from A to B), there is potential to make availability contracts attractive and worthwhile for the customer.

### ***Monitoring of goods wagon distance as a complement***

The addition of the product/service as a complement to the rest of the portfolio can appear more uncertain than using it to enable availability contracts as described above. According to the Ansoff growth matrix, offering the monitoring of goods wagon distance as an independent product/service means attempting growth through product development. The product is new but will be sold in existing markets. As the offering is distinctly different from the products currently offered, it will more specifically entail developing a distinctly new product. However, the product will be related to the ones originally offered.

Growing by means of product development may induce the need for developing new competencies. In this case, there may be a need for this when it comes to ensuring that the wagon based equipment is developed to meet the demands. However, as there is a variety of hardware solutions available in the market, incentives to develop an in-house solution are relatively weak. When it comes to the back-end system, there is sizeable

existing competence in-house as the company already has a system that can likely be customized to suit the needs of a monitoring solution.

For product development to be successful as a growth strategy, the organization must ensure the appeal to the market of the new or modified products offered. On the whole, the experience, reputation and weight of the company in the industry makes for the possibility to reach more customers than a pure technology provider could as the company already has an in on the customers and can market the solution in relation to supplying other services. The company also has good knowledge of and contact with the customers.

On the other hand, the marketing of a pure goods wagon distance monitoring product/service has not yet been successful in the industry. Many companies have tried to market various different solutions among them, but no attempt seems to have been truly successful. The demand is not insignificant but willingness to pay is low, indicating the difficulty of successfully marketing a pure distance monitoring system for goods wagons.

The existing back-end system serves several other purposes aside from pure distance monitoring and there is therefore a potential to extend the possible goods wagon solution to incorporate other features as well. The evaluation of other features and functionalities is beyond the scope of this research. However, it is likely that willingness to pay increases with the addition of other useful and desirable features aside from pure distance monitoring.

## **9.5 Trends**

When researching part of the rail transport industry it is easy to come to the conclusion that the industry is in general slow-moving and not very open or positive to change. This means that changes tend to take time to be accepted and to be implemented. Wagon keepers also in general have a skeptical attitude towards new technical solutions, as these are seen as unreliable and expensive applications that lead to higher cost of maintenance.

There are no signs that wagon keepers are moving towards a more accepting and positive attitude towards innovations when it comes to wagon mounted equipment. Products that cannot be shown to have a direct cost-saving effect or increase revenues are dismissed at an early stage.

Accidents like the one in Viareggio may however mean that the industry has to adapt to new conditions to improve rail safety. One type of adjustment that may need to be made in the future is better traceability and maintenance control in general of goods wagons to reduce the risk for serious accidents.

Rules and regulations seem to be moving towards a more consistent collection of wagon distance data for all railway undertakings. Also, this information will likely be at the free disposal for wagon keepers. The problem when it comes to utilizing this free

information supplied by the undertakings is the different formats used by undertakings, resulting in treatment of the data into meaningful information being excessively time consuming.

It seems unlikely that it will become mandatory for the wagon keepers themselves to produce information about wagon distance. Because of this, the selling of the service of monitoring wagon distance to wagon keepers has to be made on the basis of benefits for the customers that are not only regulation-based.

Although obeying rules will not likely be the main selling point of a wagon distance monitoring system, there is a visible demand for this service among wagon keepers. The wagon keepers see the access to distance information as very attractive; however at this moment in time the willingness to pay for the service is low.

## 10. Conclusions

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*This chapter describes the recommended actions to take as a result of the findings of the study. Also, recommendations will be given regarding areas that can be studied further.*

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The current situation of EuroMaint Rail in relation to monitoring goods wagon distance is summarized in Figure 10.1 below.



*Figure 10.1, Summary of current situation*

Figure 10.1 describes factors to be taken into consideration when evaluating possible courses of action. These factors have been discussed over the course of this report.

### 10.1 Recommendations

In general, the overall picture shows clear internal suitability for the company to incorporate goods wagon distance monitoring into its portfolio due to competence, resources and congruence of the concept with the overall strategy of the company. However, due to the state of the market, in particular regarding willingness to pay, but also with respect to future solutions, substitute sources of information and competition,

a cautious approach is recommended. The details of the recommendations, both with respect to recommended technique as well as regarding recommended course of action will be described in the following sections.

### 10.1.1 Recommended technical solution

	what?	why?
<b>Recommended technique</b>	Wagon based approximate measuring (GPS-based solution)	<ul style="list-style-type: none"> <li>• Gives added information about position</li> <li>• Access to information during operation</li> <li>• Easier to ensure continuous monitoring</li> </ul>

*Figure 10.2, Recommended monitoring technique*

If the company wishes to move forward towards offering a goods wagon distance monitoring system in the market, the most promising technical solution is a GPS-based monitoring system. This type of solution is better than mechanical monitoring (where the wagon based equipment is mounted on the wheel sets) for a number of reasons.

For one, the system can more easily be used when it comes to ensuring continuous monitoring. With mechanical monitoring, problems may arise when changing wheel sets as there needs to be access to equipped wheel sets at location. Also, this type of system automatically gives access to information during operation (albeit at intervals), enabling the distance information to be used for more than the information supplied by mechanical systems (where distance information is accessed when in contact with the wagon, at for example maintenance or return of the wagon). Also, information about the position of the wagon can significantly increase customer satisfaction through providing an “excitement quality” that the customers do not know they desire.

Although mechanically based systems can potentially also be equipped with GSM/GSM-R transmission to enable more frequent access to distance information this has not yet been implemented for any solution that has been identified in this research. Adding this function will raise the cost significantly for each wagon as every wheel set has to be equipped for the system to work properly according to wagon keepers. With a GSM-based solution, only one unit per wagon is needed.

Of the two GPS solutions mentioned in the report our recommendation is to use the one without solar cells. Wagons are frequently subject to harsh conditions. The use of a relatively fragile component such as solar cells increases the risk of malfunction. Also, the Eurotrack/I-LOC8 concept only registers the position of the wagon once per day as

opposed to several times (normally 5) for the ElectroTech/Pilotfish concept. As the number of positions used for distance calculation affects the accuracy of the measuring, more frequent positioning is preferable. The Electrotech/Pilotfish solution is expected to have a margin of error of maximum 5%, which is in the same magnitude as the error for mechanical measuring (which has been established to be acceptable for the wagon keepers in the study).

There may be a problem when it comes to power supply of the ElectroTech/Pilotfish solution, but it has become apparent that there are battery solutions available in the market that can supply a GSM-based system with enough power to ensure proper functionality of the system at the same time as not needing replacement more often than operationally suitable.

### 10.1.2 Recommended offering

	what?	why?
<b>Recommended action</b>	<ul style="list-style-type: none"> <li>• No investments without deal</li> <li>• By request: GPS-based solution in combination with customized back-end system</li> </ul>	<ul style="list-style-type: none"> <li>• Very low willingness to pay</li> <li>• Possibility to customize offering (increase/identify willingness to pay)</li> <li>• Low risk</li> <li>• Utilize in-house expertise (system)</li> </ul>

*Figure 10.3, Recommended offering*

At the onset, the expected result or conclusion of this research was a recommendation to either offer a specific solution to the customers or to discard the idea of pure distance monitoring. Although it has become apparent that there is a very low willingness to pay for pure distance monitoring, the conclusion cannot be drawn that the company should discard the possibility of offering a distance monitoring solution in the market. Due to the availability in the market of technical monitoring equipment combined with the in-house access to a back-end system that could potentially be customized to fulfill the requirements of a goods wagon distance monitoring system, the recommendation is that the company keeps the option open to offer a goods wagon monitoring system on demand. This means that no investments need to be made before a deal is made and the risk is thereby significantly reduced. This also keeps the option open to identify and reach customers that may have higher willingness to pay than the ones consulted in this study. As no comprehensive market research has been made, there is no possibility to conclude that all potential customers have a low willingness to pay for the service.



Another benefit of focusing on customized customer driven solutions is the fact that the effect of potential future changes in the area (for example the introduction of an EU-wide infrastructure based RFID system) will have a limited negative impact on the company. Basing the offering on making the individual deal profitable means that there will be no risk for a one time investment becoming unprofitable if the demand drops due to other substitutes in the future. In fact with the focus on offering a solution as a specific deal where costs are borne by the customer and not incurred until the deal is final rids the company of the need to consider future changes when deciding on whether or not to go ahead with the offer. Naturally, future changes in the industry will have an impact on the future possibility to market the solution; however these changes do not have to affect an individual deal entered before the changes take place.

When it comes to the offering of availability contracts with the help of distance monitoring, the research shows no demand for such a maintenance concept. However, since no comprehensive market research has been made it is impossible to draw the conclusion that there are no potential customers interested. Also, the fact that the knowledge about availability contracts is very low among wagon keepers opens for the possibility to raise the demand by marketing the concept in a good way.

## **10.2 Further studies**

There are numerous areas that could preferably be examined further. Some of the most relevant areas of interest are:

- Conducting a comprehensive market research to establish the true willingness to pay for the concept of goods wagon distance monitoring as well as identify specific potential customers.
- Researching add-ons that can be integrated into a goods wagon distance monitoring system to increase the demand for the solution as well as increase the willingness to pay. This could for example be different troubleshooting functionalities.
- Actual testing of a GPS-based monitoring system to establish the performance of the system.
- Evaluating the possibility of developing a system for processing distance data supplied by railway undertakings.

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## Appendix

### 1. Margin of error for mechanical measuring

Wheels with a diameter of 92 centimeters (standard size):

Wheel diameter, cm	Circumference, cm	Margin of error %	
92	288,88	0,00%	← New wheel
90	282,6	2,17%	
88	276,32	4,35%	
86	270,04	6,52%	
84	263,76	8,70%	← Fully lathed wheel



## 2. Overview over distance monitoring techniques

Technique	Equipment type / classification	Delivery of data	Power supply for wagon based equipment	Approximate cost for equipment per wagon	Approximate cost for system / additional costs	Limitations	Additional functionality
Lenord + Bauer	Wagon based / mechanical measuring	Manual reading	No power supply needed	From € 400 (2 axles, € 200 per axle)	Depends on complexity of system (simple system included)	Inconvenient handling (replacement at wheel change)	Wheel system temperature information
Franz Kaminski Waggonbau	Wagon based / mechanical measuring	Manual reading	Battery (lasts for >6 yrs)	From € 1100 (2 axles, € 550 per axle)	Depends on complexity of system (simple system included)	Inconvenient handling (replacement at wheel change)	
ElectroTech/ Pilotfish	Wagon based / approximate measuring	"real time"	Battery (lasts for >5 yrs depending on performance)	€ 350-580 depending on order quantity	€ 50'000 for system.		Information about position
Eurotrack/ I-LOC8	Wagon based / approximate measuring	"real time"	Rechargeable battery + solar panel	€ 23 per month	Included in monthly fee	Somewhat delicate, long interval between positioning	Information about position
Infrastructural RFID	Infrastructure based / approximate measuring	"real time"	No power supply needed	€ 6 (2 tags, € 3 per tag)	N/A (central system, cost for information unknown)	No control over the system	Information about position (predefined positions only)
Collection of RU data	N/A (no equipment)	On request	N/A (no equipment)	N/A (no equipment)		Time consuming + not all RU's provide information	

### 3. Calculation of possible savings for distance monitoring of tank wagons

According to a wagon keeper every wheel set gets a maintenance after the:	Here are the costs for maintenance on 4 wheel sets:
Mileage:	2.800,00 €
We are calculating an average mileage and a time interval as follows:	total
Mileage/year:	
time interval: 600000km/50000km/y=	233,33 €/y
	per year
when we measure a smaller mileage, we get a new time interval:	0,64 €/d
	per day
Mileage/year:	
time interval: 600000km/37500km/y=	175,00 €/y
	per year
Savings per day, but only if we have less mileage than expected:	0,48 €/d
	per day
	0,16 €/d
	per day