Measuring the performance of a preventive maintenance programme for heavy trucks

-from a life cycle profit perspective

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Preface

This Master's thesis, conducted in the fall of 2010, marks the end of our four and a half year long education in *Industrial Engineering and Management* at *Lund University*, *Faculty of Engineering*.

The project was conducted at Scania CV in Södertälje at the department *Vehicle Service Information* in assistance with *Production Management* within *Department of Industrial Management and Logistics* at *Lund University*, *Faculty of Engineering*. We have gained great insights to the world of heavy truck maintenance and a whole new understanding of the life cycle profit perspective. The work has been intense and challenging, but at the same time very inspiring.

We would like to thank our supervisors at Scania CV, Anna Pernestål and Sven Egerhag for your support, feedback, and for always challenging us with new angles of approach. It has been very valuable for us that you have always taken time for discussions and questions throughout the entire project.

Professor Hans Ahlmann, our supervisor from *Department of Industrial Management & Logistics*, your experience and commitment to the field of study has been an invaluable asset to the project. The sources of information you have provided us with has been a great help and the inspiration and understanding you have given us has kept us motivated and on track. Thank you!

We would also like to thank Linda Helsing for the co-operation when conducting interviews. Last but not least, we would like to thank all of those who have contributed to the project through interviews, discussions, and feedback. Without your sacrifice we would not have been able to complete the project.

Södertälje, January 18th 2011

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Abstract

Title: Measuring the performance of a preventive maintenance programme for heavy trucks - from a life cycle profit perspective

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Problem: *Scania Commercial Vehicles* (Scania CV) initiated the project, as a result of a vision regarding future preventive maintenance (PM) programmes. This vision and its core concepts will impose great changes to the way PM for heavy trucks are viewed upon at Scania CV. Within this vision many questions have risen, one of which is: *How does one measure the performance of a preventive maintenance programme for heavy trucks?*

Purpose: The result of the project will work as a tool when evaluating PM programmes for heavy trucks within Scania CV. The foundation of the measurement system rests upon identifying crucial factors with emphasis on the life cycle profit (LCP) for heavy trucks. Quantifying crucial factors within the measurement system will result in a set of maintenance performance indicators (MPI:s), which will be decisive for the customer's, i.e. the hauler's, profitability. The objective of the project is to:

Develop a set of MPI:s, which forms a system that measures the performance of PM from a LCP perspective.

Inference on how to measure the set of MPI:s.

Evaluate Scania CV' present PM programme according to the developed measurement system.

Delimitations: For the projects feasibility two delimitations have to be taken into consideration. The first delimitation is that the design and customer specification of the vehicle is given. In other words, the vehicle has already been delivered and the specifications of the vehicle cannot be changed, even if it would be beneficial for the customer's LCP. The second delimitation is that only Scania CV' existing customers are considered and the study is confined to the Swedish market.

Methodology: As a foundation for this project the authors performed, among other things, theory studies of the life cycle concepts, internship at heavy truck workshops, interviews with specialists within the field of heavy truck maintenance and interviews with the end users, i.e. the haulers. The approach has been systematic and aimed at mapping the current situation in order to identify key performance indicators.

The main theoretical approach for the project has been action research based, with an initial case study as a foundation for the action research approach. However, several research strategies and methods were applied in order to have a broad approach to the study in question. Regarding the empirical collection of data, both quantitative and qualitative data has been collected.

Conclusion: In the development of the measurement system the project has found three main MPI criteria: economic, availability and customer satisfaction related MPI:s. Furthermore, the project has come to the conclusion that scrutinizing the MPI:s separately can result in sub-optimization or wrongful conclusions of the PM programme's performance. A comprehensive view is required when regarding the system. Moreover the MPI system has been ordered according to a multi-criteria hierarchical structure, in order to provide a better overview of the MPI:s, which allows management at different levels to focus on MPI:s that concern them directly. The project strived to have an unbiased approach when developing the MPI system. The project disregarded if the measures used in the MPI:s seamed difficult to measure, as long as they were not impossible to measure. The unbiased approach allowed the project to fully focus on the objective of the MPI system, developing a system that measures the performance of PM. The project found that there are crucial measures which will always have difficulties regarding their measuring process, irrespectively of resources or efforts invested in the measuring process.

Keywords: Maintenance performance indicator (MPI), life cycle cost (LCC), life cycle profit (LCP), preventive maintenance (PM), corrective maintenance (CM), maintenance management, heavy truck maintenance, maintenance performance measurement (MPM).

Abbreviations

3PL	: Third Party Logistics
BSC	: Balanced Scorecard
BULCC	: Best Uptime and Life Cycle Cost
CBM	: Condition Based Maintenance
CM	: Corrective Maintenance
LCC	: Life Cycle Cost
LCP	: Life Cycle Profit
LCR	: Life Cycle Revenue
MPI	: Maintenance Performance Indicator
MPM	: Maintenance Performance Measurement
MRD	: Maintenance and Reliability at the Design Phase
MRRD	: Maintenance, Reliability, and Redundance at the Design Phase
MSC	: Maintenance Scorecard
MTTF	: Mean Time to Failure
PDM	: Predetermined Maintenance
PI	: Performance Indicator
PM	: Preventive Maintenance
Scania CV	: Scania Commercial Vehicles

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1 Introduction

The aim of Chapter 1 is to provide the reader with a comprehension of the background of this project. This is needed in order to have an understanding for the purpose and delimitations.

1.1 The Company Scania Commercial Vehicles

Scania Commercial Vehicles (Scania CV), with its main office in Sweden (Södertälje), is today one of the leading manufacturers of heavy trucks, buses and engines for industrial and marine use. Besides vehicles and engines, Scania CV also offers comprehensive service and financing solutions for their products. Being a global player within its business areas results in operations in some 100 countries with the support of 32 300 employees. In addition, Scania CV' independent sales and service organization employ about 20 000 people. [1]

Being the leading company in its industry, both in terms of profitability and brand, is distinguishing for Scania CV. The company's philosophy, focusing on methods rather than results, is one of the reasons for its success. Result is a consequence of doing the right things the right way and this is the Scania CV motto. This combined with an active strive towards core values: *Customer first, Respect for the Individual*, and *Quality* characterizes Scania CV as a company.[(2,3)]

Only depending on the success of the past, in Scania CV' case being a brand defined by the equipment, could be devastating for any company in today's competitive environment. Scania CV' objective, to supply its customers with optimized vehicles providing the best total operating economy, is leading to a shift in focus. The development from being a traditional manufacturer of commercial vehicles to a total solution provider for its customers is confirmed by the increased share of employees working in sales and services. This is a result of customers increasingly wanting to focus on their core business. [4]

A new Scania CV is taking shape, where focus lies on increased and lasting profitability for its customers. This is achieved by offering products and services that give customers high life-time revenues combined with low life-time costs. Consequently, this new shape means that the brand is not only defined by the equipment, as in the past, but also by the life-time profit generated from this equipment.

[1] Scania, Scania Group, Scania in brief, retrieved 3 January 2011, <http://www.scania.com/scania-group/scania-in-brief/>
[2] Scania, Scania Group, Philosophy, retrieved 3 January 2011, <http://www.scania.com/scania-group/philosophy/>
[3] Scania, Scania Group, Core values, retrieved 3 January 2011, <http://www.scania.com/scania-group/core-values/>
[4] Östling L., "Customers profitability in focus", Scania World 3/2010, Appelberg Publishing Group, September/October 2010, p. 3

1.2 Purpose

Scania CV initiated the project, to measure the performance of a *preventive maintenance* (PM) programme for heavy trucks, as a result of a PM vision. This vision and its core concepts will impose great changes to the way PM for heavy trucks are viewed upon at Scania CV. Within this vision many questions have risen, one of which is: *How does one measure the performance of a PM programme for heavy trucks?*

The overall purpose of the project is to find an answer to the question above, i.e. to develop tools for measuring the performance of PM. This is done by studying the performance of PM from a *life cycle profit* (LCP) perspective. The LCP approach to the question above is in line with the new shape Scania CV is taking, as mentioned in Section 1.1.

The result of the project will work as a tool when evaluating PM programmes for heavy trucks within Scania CV. The foundation of the measurement system rests upon identifying crucial factors with emphasis on LCP for heavy trucks. Quantifying crucial factors within the measurement system will result in a set of *maintenance performance indicato*rs (MPI:s), which will be decisive for the customers profitability.

Crystallizing the goals of the project results in the following points:

- Develop a set of MPI:s, which forms a system that measures the performance of PM, from a LCP perspective
- Inference on how to measure the set of MPI:s
- Evaluate Scania CV' present PM programme according to the developed measurement system

1.3 Delimitations

For the projects feasibility a number of delimitations have to be taken into consideration.

The first delimitation is that the design and customer specification of the vehicle is given. In other words, the vehicle has already been delivered and the specifications of the vehicle cannot be changed, even if it would be beneficial for the customer's LCP.

The second delimitation is that only Scania CV' existing customers are considered and the study is confined to the Swedish market.

1.4 Target Groups

The project is intended for Scania CV employees at the departments *Vehicle Service Information* and *Service Operations* as well as the project *Best Uptime and Life Cycle Cost (BULCC)*.

Other parties which can have interest for this project are companies offering products and services similar to Scania CV'. Furthermore, an important target group is within the academic world, i.e. teachers, professors and students who want to gain knowledge about *maintenance performance measurement* (MPM) for heavy trucks.

2 The Organization of Workshops and Dealerships

The following chapter will present an overview of Scania CV' maintenance organization and the services they provide in Sweden. Since the project is performed at Scania CV it is important that the reader has a basic understanding of Scania CV' organization and service products.

2.1 Organization Map

Figure 2.1 illustrates in principle how the organization regarding maintenance and dealership looks like at Scania CV.

Scania CV is the parent company where R&D, production and other corporate functions exist. Every market or region, where Scania CV is active, is represented by a *distributor*. The distributor is the link between Scania CV and the *dealer companies*, who in turn can have one or several *dealerships/workshops*. The distributors, dealer companies and consequently dealerships/workshops are either independent or wholly owned subsidiaries of Scania CV. On a worldwide basis, approximately two thirds of the 1500 dealers and workshops are wholly owned subsidiary of Scania CV, which is unique in the industry.

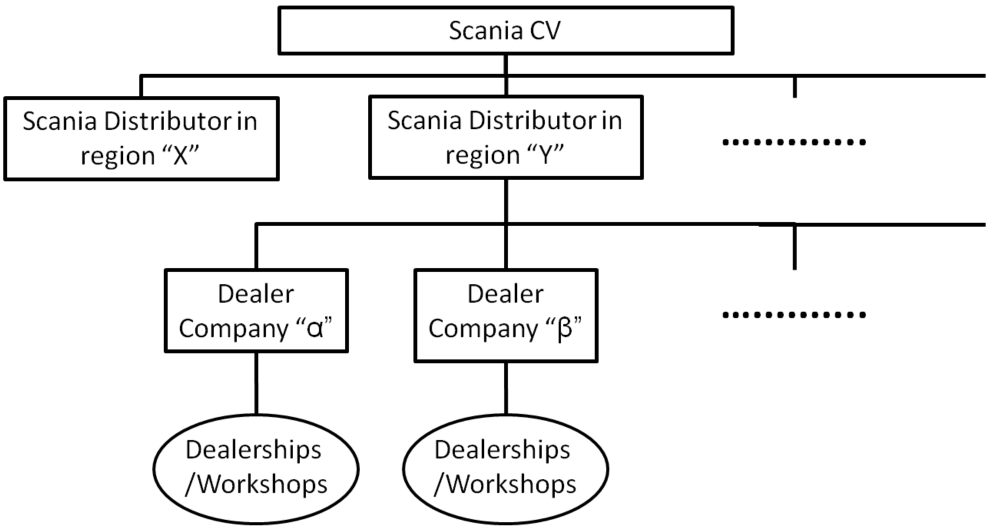

Figure 2.1 A principle sketch of the dealership and maintenance organization for Scania CV.

2.2 Scania CV' Workshops and Dealers in Sweden

In Sweden, Scania CV is represented by a total of 29 dealer companies. These dealer companies cover Sweden with a total of 96 dealerships/workshops, as seen in Figure 2.2. [5]

Figure 2.2 Map of Scania CV' dealership and workshop network in Sweden.

The extent of the services offered by the workshops vary from strictly truck repair and service to total service solutions, which include trailer service, transport refrigeration unit service, vehicle rental, tire service, vehicle washing etc.

The dealerships and workshops also offer maintenance contracts with different extent. In Sweden there are mainly three types of contracts offered; *Service contract*, *Powertrain contract* and *Green Card contract*. The contracts are beneficiary for the customers since the maintenance and service activities are discounted, compared to doing them standalone. Furthermore, the contracts are paid periodically or as a lump-sum in advance.

Service Contract

The service contract covers scheduled PM, including materials and labour costs. This contract can be signed from one to two years at a time and there are no restrictions on vehicle age or mileage.[6]

Powertrain Contract

A powertrain contract covers repairs on the powertrain as well as scheduled PM. The extent of repairs covered is decided upon signing the contract. This contract can be signed for a period of 3-5 years and there is both a mileage and vehicle age limit.[7]

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[5] Scania, Careers, Work areas, Sales & Service, retrieved 3 January 2011, <http://career.scania.com/work_areas/sales_service/>

[6] Scania, Tjänster, Verkstadstjänster, Avtal, Tillsynsavtal, retrieved 3 January 2011, <http://www.scania.se/tjanster/verkstadstjanster/avtal/tillsynsavtal.aspx,>

[7] Scania, Tjänster, Verkstadstjänster, Avtal, Drivlineavtal, retrieved 3 January 2011, <http://www.scania.se/tjanster/verkstadstjanster/avtal/drivlineavtal.aspx>

Green Card Contract

The whole chassis is covered by the Green Card contract, in terms of repairs and PM. As for the powertrain contract, the extent of repairs covered is decided upon signing the contract. The contract can run 3-7 years, usually five years with an option for two more years, and there is both a mileage and vehicle age limit. [8] The Scania CV distributor and dealer/workshop shares the risk in the contract, i.e. if the actual maintenance cost exceeds the pre-paid sum the customer does not have to cover the excess amount.

[8] Scania, Tjänster, Verkstadstjänster, Avtal, Grönt Kort-avtal, retrieved 3 January 2011, <http://www.scania.se/tjanster/verkstadstjanster/avtal/grontkortavtal.aspx>

3 Methodology

The choice of methodology lays the basis for the work methods in a research project. It is of importance that the reader has knowledge of the academic standing ground and approach applied within the project. Hence the reader can get a better understanding of the validity and reliability of the project, as well as forming an opinion about the quality of the data that has been collected.

3.1 Research Strategies

Research strategies set the basic framework for how to proceed with the research project at hand. It is not intended to describe in detail how the research should be conducted, but should instead show the direction.[9]

3.1.1 Exploratory Research

The aim of an exploratory research is to learn more about something that is new to the researcher. This strategy of research has great value in the early stages of a research project since, beside illuminating problems and opportunities it also elucidates the field of research. Furthermore the strategy can generate ideas and provide the researcher with insights relevant to the subject of study. In principle there are three methods to conduct exploratory research; *literature review*, *interviewing experts* within the field of the study and *interviewing focus groups*.[(10,11)]

3.1.2 Explanatory Research

The explanatory research aims at examining the relationship between cause and effect. By identifying certain variables the researcher can obtain explanations between cause and effect relations. Theories built by utilizing the knowledge gained through explanatory research allow the researcher to predict future effects, given similar circumstances.[12]

3.2 Research Methodology

The goals and the design of research consist of research methodology, which is the frame for the study. The methodology can be viewed as a general way to approach the research, more clearly the direction, scale and the underlying philosophy which lay the basis for the research project.[13]

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9 Höst M., B. Regnell & P. Runeson, *Att genomföra examensarbete*, Studentlitteratur AB, Lund, 2006

10 Wrenn B., R.E Stevens & D.L Loudon, *Marketing Research: texts and cases*, 2nd edn, The Haworth Press Inc., Binghamton NY, 2007

11 Saunders M., P. Lewis & A. Thornhill, *Research methods for business students*, 5th edn, Pearson Education Ltd., Harlow, 2009

12 MacNabb D.E, *Research Methods for Political Science: Quantitative and Qualitative Methods*, 2nd edn, M.E Sharpe Inc., Armonk NY, 2004

13 Denscombe M., *Forskningshandboken – för småskaliga forskningsprojekt inom samhällsvetenskaperna*, trans. P. Larson, 2nd edn, Studentlitteratur AB, Lund, 2009

3.2.1 Preparatory Research

In many cases researchers begin a research project with a preparatory research. This aims at providing the researcher with a deeper understanding of the subject in study. The review of literature and analysis of available information within the field of study is included in a preparatory research. This research method often generates many ideas for how to proceed further in the research project.[14]

3.2.2 Case Study

A case study attends one or a few special cases and tries to give a deep explanation of the underlying connections and processes associated with the case. [15] The goal of this strategy is to find general results in a specific case. It is suggested that by focusing on a specific case the researcher might come to conclusions which would not be possible with a wider strategy like surveys. The depth of a case study gives the researcher a possibility to make inference as to why certain results were achieved as opposed to only providing the results. A strength of the case study is that it not only allows but encourages the researcher to incorporate several different sources, research methods and types of data throughout the research. The choice of methods is based on what is suitable for the specific case.

A recurrent question the researcher has to ask himself is whether the results of the case study can be generalized or not. This often becomes a question of how the specific case was chosen or if there exists similar studies where there is accordance in results.

3.2.3 Action Research

The purpose of action research is to build and/or test theory, within the context of solving a practical problem in a real setting. Action research can be regarded as a research approach, rather than a specific method of research. The recognition as a research approach is a result of action research combining theory and practice, researchers and practitioners, and intervention and reflection.[16]

The action research approach is an iterative process consisting of several steps. It starts with the observation of a situation or phenomenon, in order to identify and clarify the problem which is subject for the research. For the first step the case study method can be used, according to Section 3.2.2. Step two is finding a solution, to the identified problem, and implementing the proposed solution. Following step two is the evaluation of the solution. This third step is of utmost importance, since it puts the solution in a context, providing an opportunity for analysis and reflection of the functionality of the solution. The steps above should be considered as an iterative process, repeated depending of the outcome from step

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[14] Haviland W.A, H.L Prins, D. Walrath & B. McBride, *Cultural anthropology: the human challenge*, 12th edn, Thompson Wadsworth, Belmont CA, 2008

[15] Denscombe (2009)

[16] Azhar S., I. Ahmad & M.K Sein, "Action Research as a Proactive Research Method for Construction Engineering and Management", *Journal of Construction Engineering & Management*, vol. 136, no. 1, 2010, pp. 87-99

three. If the solution is not satisfying or new problems have risen, the researcher needs to clarify the issues and find a satisfying solution.[17]

Action research approach has both strengths and weaknesses. One strength is that action research offers a wide explanation of *how* and *why* the problem under investigation occurs. This can sometimes be very hard or impossible to answer by statistical or regression models. Furthermore, the natural setting of the research problem can many times prove to be expensive, difficult or impossible to replicate in a restricted research location, e.g. a laboratory. One weakness of action research is that the conclusion derived from a single study has limited generalizability.[18]

3.3 Methods for Gathering Data

There are different methods for gathering data. None of the methods is completely perfect or completely useless. This is because each method deals with data gathering from certain conditions. The usability of the data, provided from a certain method, depends largely on what the researcher wants to achieve.[19]

3.3.1 Literature Review

It is of importance for any research project, especially in the beginning of it, to establish an overall perception of the present situation in the field of study. A thorough literature review gives the researcher a solid knowledge basis and reduces the risk to overlook existing knowledge in the field of study.[20]

3.3.2 Observations

Through observation the researcher has the possibility to collect data in a very tangible way. The observation technique focuses, by directly observing events, on what people actually do instead of only relying on what people *say* they done or would have done.[21]

There are two types of observation techniques: systematic and participating observation. Systematic observation is especially used when studying interactions and is characterized by quantitative data and statistical analysis. Participating observation is mainly used when the researcher wants to deeply penetrate an issue and is characterized by delivering qualitative data.

3.3.3 Interviews

Interviews can be used both as a way to gather background information and provide the researcher with information about the current situation. Furthermore, interviews can also provide ideas for solving the problems of the research project. An interview is basically a systematic hearing of a person, concerning a certain topic. Random selection of the

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[17] Höst et al. (2006)
[18] Hales D.N, & S.S Chakravorty, "Implementation of Deming's style of quality management: An action research study in a plastics company", *International Journal of Production Economics*, vol. 103, no. 1, 2006, pp. 131-149
[19] Denscombe (2009)
[20] Höst et. al. (2006)
[21] Denscombe (2009)

interview subjects is not essential if the research is of a qualitative nature and does not focus on representativeness. Instead it is important that the selection of the interview subjects reflect the variations in the population. As a consequence of non random selection of interview subjects, no general conclusions can be made based on the population which was used for selecting the interview subjects. On the other hand, the researcher is given the possibility to a deep qualitative exploration of the research area.[22]

The extent of how structured the interviews are can vary between *structured*, *semi-structured* and *un-structured*. Structured interviews are more or less an oral survey, where the researcher has a list of questions, each question having several predefined answer options. Furthermore, the order in which the questions have to be answered is fixed. When it comes to the semi-structured interview the researcher still has a list of questions but the order in which they are asked is not fixed. The interview subject is not bound by predefined answer options; instead he or she can give comprehensive answers. As for the un-structured interview the researchers role is to intervene as little as possible. Basically the researcher only starts the interview and introduces the topic, letting the interview subject elaborate his or her ideas.[23]

3.4 Quantitative and Qualitative Data

Quantitative data is defined as numerical data and data that can be classified. The analysis of quantitative data is attended to with statistical methods. Several different methods of research can be utilized in order to collect quantitative data. These comprise interviews, questionnaires, observations and different kinds of documents. All quantitative data are not numbers when they are collected and must be coded. It becomes important for the researcher to choose how and when to categorize and code the data. [(24,25)]

Qualitative data comprehends words, pictures and descriptions which are rich with nuances and detail. Qualitative data is attended to with categorization and sorting techniques. As with quantitative data, it can be obtained using several different methods of research. Qualitative data needs interpretation from the researcher in the process of analyzing the results. It is not sufficient to say that the data speaks for itself. The interpretation of the data involves a high demand on the researcher to be thorough when analyzing qualitative data. It is also important for the researcher to be free from prejudice and not to be locked to previously established theories within the field. [(26,27)]

[22] Höst et. al. (2006)
[23] Denscombe (2009)
[24] Ibid.
[25] Höst et. al. (2006)
[26] Denscombe (2009)
[27] Höst et al. (2006)

3.5 Validity and Reliability

Reliability concerns the trustworthiness of a research method. This includes both the collection and analysis of data. The reliability of a research method is characterized by its ability to reproduce data in a consistent way on repeated trials. However there will always be a presence of chance error no matter how reliable the method is. [28,29]

While reliability concerns the trustworthiness of a research method, validity addresses the issue of measuring what is intended to be measured. When concerning validity the following questions should also be raised: *Is the data relevant for the field of study? Was the data collected in the right way?* Failing to satisfy the questions raised above results in the information, although accurate, being useless. Using different methods of scrutiny for an object, that is triangulating, one can achieve higher validity. The combination of reliability and validity is essential for the outcome of the research quality. [30,31]

3.6 Practical modes of procedure

The practical modes of procedure describe how the research has been conducted and how conclusions are reach within the scope of the research project.

3.6.1 Participating Observation

The project was initiated with observations which entailed working at a Scania workshop, performing repairs and PM, during three days. It had the objective of illuminating how the delivery of the service products takes place.

3.6.2 Literature Review

The literature review has the focus of elucidating different aspects concerning maintenance, performance measurement as well as the LCP perspective. The theoretical foundation of this project lies in various books, articles and papers within relevant fields of research. The literature review is conducted as a desk study review and much effort will be made towards finding the theories which most adequately can be applied towards maintenance of heavy trucks.

Iterative methods will be applied when conducting the literature review and as the project precedes those fields of research which are of interest will be studied further.

[28] Carmines E.G, & R.A Zeller, *Reliability and validity assessment (Quantitative Applications in the Social Sciences)*, Sage Publications Inc, Thousand Oaks CA, 1979
[29] Höst et. al. (2006)
[30] Ibid.
[31] Denscomb (2009)

3.6.3 Interviews

The empirical data for the project is to a large extent based on interviews that have been conducted during the course of the project. Initially, internal interviews were made with different Scania employees in order for the project to grasp the scope of the problem at hand. As the project have preceded additional interviews with Scania employees, as well as maintenance and hauler industry organizations have been made. All of the interviews were conducted in co-operation with another master student, who carried out a similar project. The co-operation was initialized in order to rationalize the interview processes for both projects. Furthermore all of the interviews above where in the form of open discussions. The interview subjects were chosen based on their position within their respective organizations.

To seize the hauler perspective, twelve interviews with service sales representatives have been made. The service sales representatives each have a large customer portfolio and by interviewing them the opinions of several customers are brought to light. The service sales representatives work at the different workshops and the interview objects were chosen such that all of Sweden was represented. The interviews were semi structured with a fixed set of questions but without fixed answer alternatives. The questions can be found in Appendix 1.

Five haulers, representing different transport segments, have also been interviewed to validate the information received from other interviews. The project only gained access to a limited number of customers and the choice of interview subjects were based on which haulers that were able to conduct interviews. The interview questions can be found in Appendix 2.

All interviews have been conducted face to face with the exception of: one interview with a service sales representative and three of the customer interviews. In addition most of the interviews have been recorded. All of the interviews were conducted in Swedish.

3.6.4 Data Collection

Quantitative data has been collected from several sources. In those cases where primary data has been unable to collect secondary data as well as assumptions have been made. The assumptions made are based on the conducted interviews.

Financial statistics concerning hauler companies have been accessed through the database *"AffärsData"*. Data on cost allocations within the hauler industry have been collected from the Swedish hauler industry organization, *Sveriges Åkeriföretag*. Data on cost and time for maintenance is gathered from Scania CV' database.

4 Maintenance Theoretical Framework

The theoretical framework lays the foundations for the project. In the development of the MPI system it is of great value to study previous theoretical findings within performance measurement. General principles and terminology within maintenance theory are further explored to give the project an understanding of how maintenance can affect profitability.

4.1 Maintenance Strategies

The strict definitions of maintenance terminology presented in Sections 4.1-4.4 are based on the Swedish standard for maintenance terminology, SS-EN 13306:2010, which is also a European Union standard. The standard specifies generic terms and definitions for the technical, administrative and managerial areas of maintenance. Correct and formal definitions are required in order to give readers a full understanding of the maintenance terms used.

Maintenance is defined as[32]

> *"Combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function."*

The definition states that activities designed to either prevent an item from failing or correct the function of an item that has already failed is considered as maintenance. As seen in Figure 4.1 maintenance can be divided into two main strategies; corrective and preventive maintenance which will be further examined in the following sections.

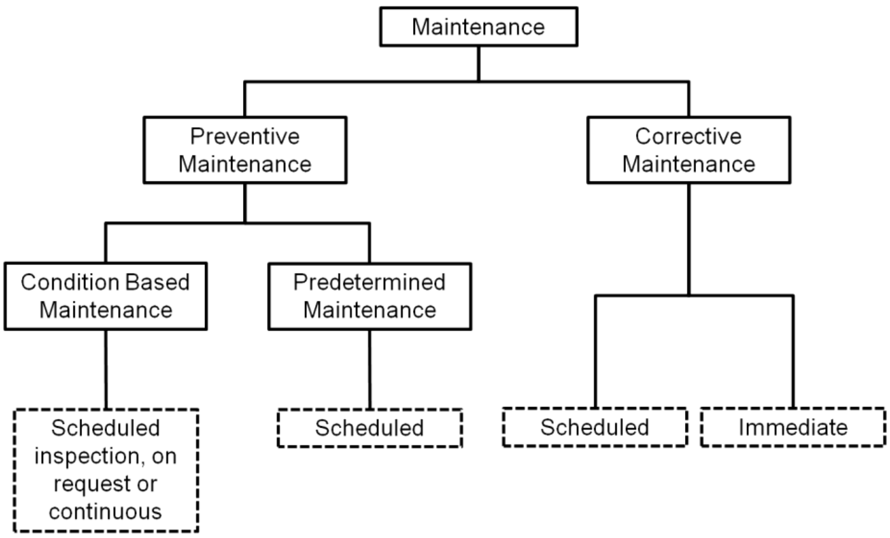

Figure 4.1 Maintenance overall view (SS-EN 13306:2010)

[32] SS-EN 13306:2010 Maintenance–Maintenance terminology, 2nd edn, Swedish Standards Institute, Stockholm, 2010

4.2 Preventive Maintenance

PM is defined as[33]

> *"Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item."*

PM comprises all maintenance activities performed on an already functioning item with the intention of decreasing its failure rate. The item to be maintained could either be replaced or reconditioned depending on the wear and tear of the item. The failure rate of an item is its probability to fail over a given period of time. As illustrated in Figure 4.1 PM can be divided into two sub categories, namely *condition based maintenance* (CBM) and *predetermined maintenance* (PDM).[34]

4.2.1 Condition Based Maintenance

CBM is defined as[35]

> *"Preventive maintenance based on performance and/or parameter monitoring and the subsequent actions."*

The use of CBM is dependent on the ability to monitor the condition of an item. There are two main strategies on how to monitor the condition of an item;

- Inspection – A person inspects the item at regular intervals and performs maintenance when needed or possible
- Condition monitoring – A parameter is measured and when it reaches a certain predetermined level, maintenance is performed

Condition monitoring is often followed by some sort of estimation of when the monitored item will fail. This method of scheduling maintenance is referred to as predictive maintenance. CBM is especially suited when the failure rate is dependent on operating conditions rather than time. When failure rate depends on operating conditions PDM is not optimal. [(36,37)]

[33] SS-EN 13306:2010 (2010)
[34] Coetzee J.L, *Maintenance*, Trafford Publishing, Victoria BC, 2004
[35] SS-EN 13306:2010 (2010)
[36] Coetzee (2004)
[37] Bengtsson M., *Condition based maintenance systems: An Investigation of Technical Constituents and Organizational Aspects*, Licentiate Theses no. 2004:36, Mälardalen University, Eskilstuna, 2004

4.2.2 Predetermined Maintenance

PDM is defined as[38]

> *"Preventive maintenance carried out in accordance with established intervals of time or number of units of use but without previous condition investigation."*

A requirement for PDM to be effective is that the item, on which maintenance is performed, has a failure rate which increases with the aging of the item. The maintenance intervals for the item are decided based on age, running hours, distance travelled or number of uses.[39]

4.3 Corrective Maintenance

Corrective maintenance (CM) is defined as[40]

> *"Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function."*

CM is the wait-for-failure strategy and does not entail any prediction of when an item will fail. Depending of the failed items impact on the functioning of the system it is in, maintenance could either be performed immediately or be scheduled at a later point in time as illustrated by Figure 4.1. This is a strategy applied most often when it is difficult or even impossible to make inference on when an item will fail. CM is commonly referred to as repair.[41, 42]

4.4 Scheduled Maintenance

Scheduled maintenance is defined as[43]

> *"Maintenance carried out in accordance with established time schedule or established number of units of use."*

By the pure definition of scheduled maintenance, PM is positioned as a scheduled maintenance activity. It should be pointed out that CM can also be positioned as a scheduled maintenance activity, depending on if the failing item is critical for the function of the system. When maintenance cannot be scheduled it has to be performed immediately and is thus called an immediate maintenance activity.

[38] SS-EN 13306:2010 (2010)
[39] Coetzee (2004)
[40] SS-EN 13306:2010 (2010)
[41] Bengtsson (2004)
[42] Coetzee (2004)
[43] SS-EN 13306:2010 (2010)

4.5 Maintenance Crucial Parameters

The total time an item is intended to be used is called the *planned operating time* and is denoted *T*. It is not to be confused with the total time it could be operating which for instance could be 24 hours a day. Whenever the item is inoperable for maintenance purposes a down state is imposed. The total time the item is in its down state is called *downtime* and is denoted *D*. Apart from maintenance purposes there could be other limitations preventing the item from being used. These include staff meetings, idling and set up times. These activities will be summarized into *waste* which is denoted *W*.

When the item is operable it is in an up state. The total time the item spends in its up state is called *uptime* and is denoted *U*. The relationship between planned operating time, downtime and uptime can be formulated according to Equation 4.1 and Figure 4.2. [44]

$$U = T - D$$

Equation 4.1

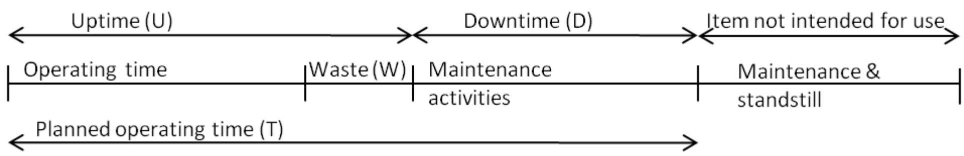

Figure 4.2 The relationship between planned operating time (T), downtime (D), and uptime (U) is illustrated.

Availability

Availability is a measure of the capability to keep an item in a functional state, such that it can perform its required task.[45] Availability is given as the ratio between the time an item could be utilized and the time it was planned to be utilized, as showed in Equation 4.2.

$$A = \frac{T - D}{T} = \frac{U}{T}$$

Equation 4.2

where *A* is the availability, *T* the planned operating time, *D* the downtime and *U* the uptime. The measure A gives the ratio between the actual operating time and the planned operating time. The measure is independent of the cause of the downtime and merely gives us the share of time which we could use an item for its intended purpose. [46]

[44] Coetzee (2004)
[45] Ibid.
[46] Nakajima S., *Introduction to TPM*, trans. Productivity Press Inc. Cambridge 1988, Japan Institute for Plant Maintenance, Tokyo, 1984

Failure

A failure is defined as[47]

"Termination of the ability of an item to perform a required function"

Failure is an event and describes when an item fails. The item will then be in a faulty state until its required function is restored. Failure can aim at both the failure of a specific component and the failure of a system that consist of a large number of components.

Mean Time to Failure

Mean time to failure (MTTF) is the average operating time between two consecutive failures of an item. [48] While the availability presents the average percentage uptime MTTF measures the regularity at which an item needs to be maintained. MTTF is often considered as a measure of reliability. It is given according to Equation 4.3.

$$MTTF = \frac{Operating\ time}{N},$$

Equation 4.3

where N represents the number of failures over a period of time. With an increase in MTTF the item will be able to operate over a longer period of time without failure.

4.6 Efficiency and Effectiveness

The clear definitions of efficiency and effectiveness depend largely on which context these measures are used in. In an economic productivity context, efficiency is defined as a ratio, consisting of what is produced to what is needed to produce it. As seen in Equation 4.4, the ratio can also be explained as the total output of e.g. goods, divided by the total input of e.g. labour or raw materials. In fact, any input can be used in the denominator. [49]

$$Efficiency = \frac{Total\ output}{Total\ input}$$

Equation 4.4

[47] SS-EN 13306:2010 (2010)
[48] Coetzee (2004)
[49] Frankel M. & J.W Kendrick, *Productivity (economics)*, Britannica Online Encyclopedia Academic Edition, retrieved 20 December 2010, <http://www.britannica.com.ludwig.lub.lu.se/EBchecked/topic/478036/productivity>

Effectiveness is derived from effective, meaning the ability of producing an intended result. The ability to achieve intended results can be measured, as illustrated in Equation 4.5, through dividing the goals set by the actual results achieved.[50]

$$Effectiveness = \frac{Goals\ set}{Goals\ achieved}$$

Equation 4.5

4.7 Performance Measurement Systems

An organization reaches its goals, according to the marketing perspective, by outperforming its competitors. The outperformance is accomplished through superior efficiency and effectiveness when it comes to customer satisfaction. So, in a business context, performance can be defined as the efficiency and effectiveness of actions. Using a set of metrics to quantify the efficiency and effectiveness of actions, results in a *performance measurement system*.[51]

A performance measurement system can be used for strategic and day-to-day operations of the organization, control and implementations of improvements, and monitoring of these. It is important that the performance measurement system has a clear orientation towards the organizational strategy.[(52, 53)]

Furthermore, establishing the relationship between the internal measures (causes) and the external measures (effects) is a significant objective of a measurement system.

From a maintenance perspective the performance measurement system can be adopted by the MPM concept. If linked to performance trends a MPM system can be used to highlight business processes, areas etc. within maintenance that need to be improved in order to fulfil the organizational goals. In other words MPM enables a solid basis for establishing where maintenance related improvements are most appropriate at any given time. Furthermore a MPM system can be utilized as a foundation for benchmarking and the data from a MPM system can also be used as a marketing tool. [54]

The concept of measuring maintenance process activity is not a new phenomenon; it has been around for a long time. Mainly in the form of scorecards or indicators measuring; maintenance cost per unit, maintenance budget, non-availability index due to maintenance

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[50] Miller G.A, R. Tengi, H. Langone, A. Ernst & L. Jose, *effective/effectiveness*, Princeton University: WordNet–A lexical database for English, retrieved 20 December 2010, <http://wordnetweb.princeton.edu/perl/webwn?o2=&o0=1&o7=&o5=&o1=1&o6=&o4=&o3=&s=effective&h=100001000000000000&j=7#c>

[51] Neely A., M. Gregory & K. Platts, “Performance measurement system design: A literature review and research agenda”, International Journal of Operations & Production Management, vol. 25, no. 12, 2005, pp. 1228-1263

[52] Parida A. & U. Kumar, “Maintenance performance measurement (MPM): issues and challenges, Journal of Quality in Maintenance Engineering, vol. 12, no. 3, 2006, pp. 239-251

[53] Parida A., *Development of a multi-criteria hierarchical framework for maintenance performance measurement – Concepts, issues and challenges*, Doctoral Theses no. 2006:37, Luleå University of Technology, Luleå, 2006

[54] Parida (2006)

etc. A shortcoming of these indicators has been the lack of linkage to the corporate level. Instead the indicators are often stand alone and isolated to the shop-floor or operational area only. [55]

4.7.1 Maintenance Performance Measures

Commonly used maintenance performance measures can be divided, depending on what they focus on, into three categories.[56]

I. Measures of equipment performance
II. Measures of cost performance
III. Measures of process performance

Availability, reliability and overall equipment effectiveness are all possible measures of equipment performance (I), while measures used for following up cost performance (II) can be maintenance labour and material costs. When measuring process performance (III) e.g. the ratio between planned and unplanned maintenance work can be used.

Often the reasons for keeping track of the measures I-III can be derived to habit or because the measures has always been used by the organization. Mimicking other organizations and because the data collection is easy are further reasons for keeping track of the measures I-III.

The measures I-III are of diagnostic character and they are mainly chosen to support operational control and benchmarking of maintenance performance. Being backward looking and introspective distinguishes these measures, besides being biased towards the financial and process perspective of maintenance.

In order to establish the benefits of maintenance to the success of the organization, performance measures must be linked to the strategy of the maintenance function.

4.7.2 Balanced Scorecard

Only focusing on the traditional performance measurement systems, like financial accounting which measures return-on-investment and earnings-per-share, is inadequate for the demands of today’s competitive environment. A specific shortcoming of the traditional financial measures is the fact that they report past events. This results in an inadequate tool for managers to improve present and future performance.

As illustrated by Figure 4.3, the *balanced scorecard* (BSC) emphasizes four perspectives which are crucial for any business. These perspectives reflect on *financial* and *customer* measures as well as on *learning and growth* and *internal business process* measures. While traditional financial measures give information on the happenings in the past, without

[55] Parida (2006)
[56] Tsang A.H.C., “A strategic approach to managing maintenance performance”, Journal of Quality in Maintenance Engineering, vol. 4, no. 2, 1998, pp. 87-94

indicating how managers can improve performance in the future, the BSC functions as the cornerstone of a company's current *and* future success. The information from the four perspectives balances the external measures, like operating income, and internal measures, like new product development. The BSC allows senior managers to focus on the above mentioned four perspectives, but at the same time avoids overburdening them with information by limiting the number of measures used.

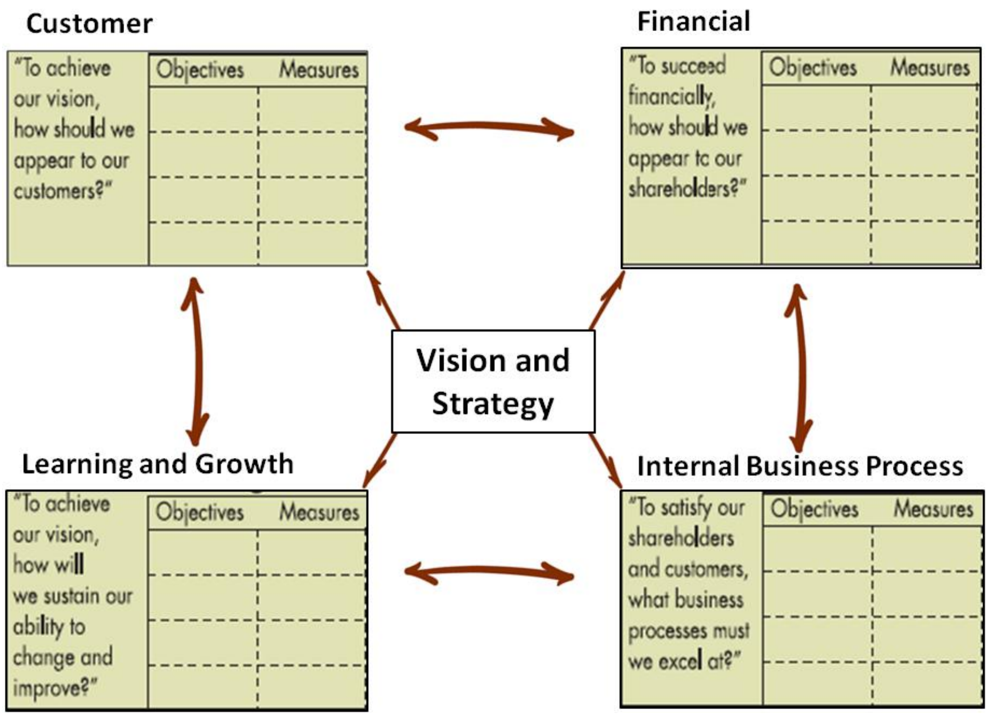

Figure 4.3 The four perspectives of the BSC (Altered from Kaplan and Norton 2007)

By gathering different factors the BSC results in a sole management report. The measures of the scorecard are also closely tied to the organization's strategic objectives. Furthermore, the BSC illuminates all the important measures together and diminishes thereby risks of sub-optimization in the organization, i.e. advocating an improvement in one area, which in turn will result in deterioration in one or several other areas.

It is important to point out that there is no general BSC template that is applicable to all business. Diverse product strategies, competitive environments and market situations demand different scorecards. The BSC should be developed so that it suits the business unit's mission, strategy and culture. De facto, a crucial test of the BSC's prosperity is its transparency. One should be able to observe the business unit's competitive strategy just by looking at the 15-20 measures of the scorecard. [57,58]

4.7.3 Maintenance Scorecard

The cause and effect interrelationship, from a maintenance angle, can be mapped by implementing the BSC concept with production and maintenance in focus, giving rise to the *maintenance scorecard* (MSC). The basis for the MSC is the leveraged effect of increased maintenance performance. The leveraged effect consists of the internal efficiency supporting the external effectiveness. Figure 4.4 illustrates the leveraged effect of maintenance performance. Increased maintenance performance results in less maintenance related disturbance in production, offering higher supply availability. Furthermore it leads to products with higher or consistent quality. Higher supply availability and increase in quality will act as value drivers for the market strategy, resulting in increased demand from customers. The leveraged effect of increased maintenance performance reflects the total effectiveness of the business, resulting in growing profitability.[59]

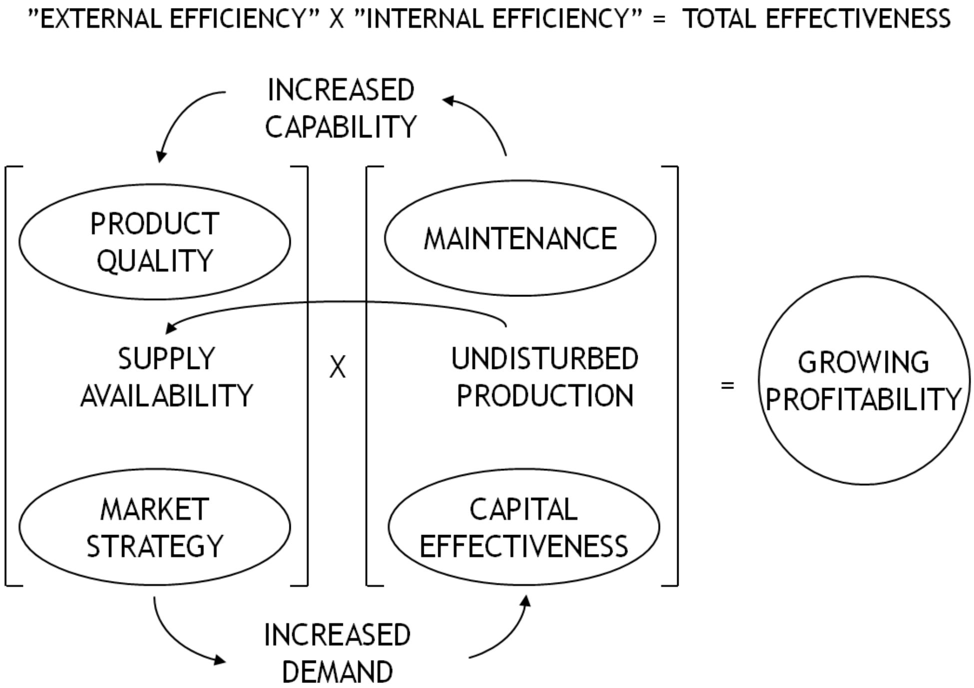

Figure 4.4 The leveraged effect of maintenance performance (Ahlmann 2002)

[57] Kaplan R.S. & D.P. Norton, “The Balanced Scorecard-Measures That Drive Performance”, Harvard Business Review, vol. 70, no. 1, 1992, pp.71-80

[58] Kaplan R.S. & D.P. Norton, ”Putting the Balanced Scorecard to Work”, Harvard Business Review, vol. 71, no. 5, 1993, pp.134-145

[59] Ahlmann H., “From traditional practice to the new understanding: the significance of life cycle profit concept in the management of industrial enterprises”, paper presented at the IFRIM Conference, Vaxjo, May 6-7, 2002

Improvements which affect internal efficiency and external effectiveness at the same time results in a multiplicative effect on total effectiveness. By contrast, improvements affecting solely internal efficiency or external effectiveness result in a graduate effect on total effectiveness.

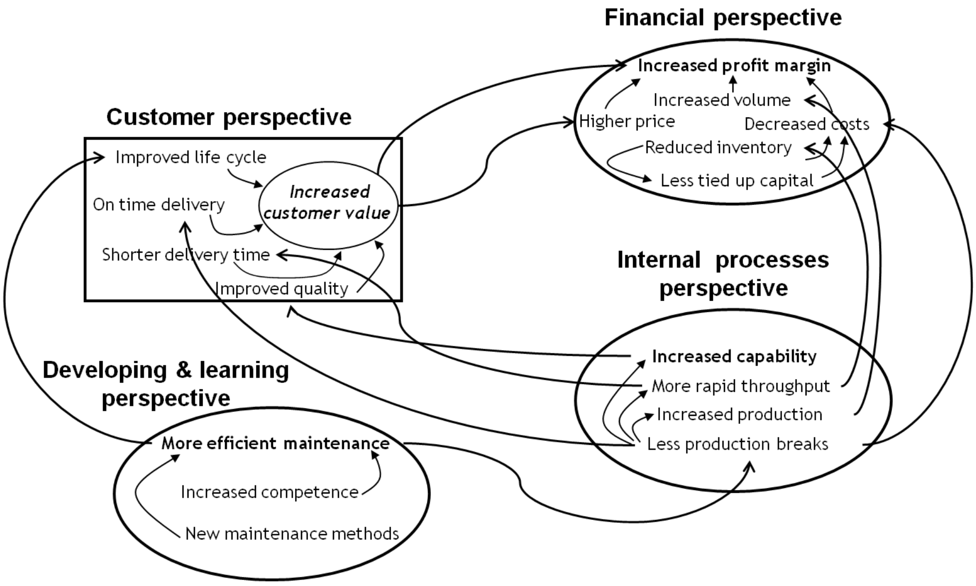

Figure 4.5 Maintenance Scorecard (Ahlmann 2002)

Figure 4.5 illustrates the four perspectives and the relationship between them in the MSC. These relationships are all possible to calculate or measure. These perspectives and relations affect the cost and income as well as the volume and price. Consequently the effect on the profit margin of the business is also possible to calculate. The four perspectives are essentially the same as for the BSC. The *Developing & learning perspective* deals with the future of the maintenance organization and how it should evolve to be able be competitive. The *internal process perspective* has the role of describing what is happening right now within the company. How efficiently resources are utilized and the quality of products are issues attended to in this perspective. The *customer perspective* also has the present in its focal point but focuses on external effectiveness. How the customer perceives the products offered is important in this perspective. The *financial perspective* is the rear view mirror and past performances are quantified here.[60]

[60] Ahlmann (2002)

4.7.4 Maintenance Performance Indicator

A measure that can generate a quantified value to indicate the level of performance, using single or multiple aspects, is called a *performance indicator* (PI). Consequently, the PI:s are the set of metrics used in a performance measurement system to quantify efficiency and effectiveness. [61]

An organization can use PI:s as an aid to focus its efforts on supporting the course of the corporation.[62]

> "*All performance indicators must be tied to the long-range corporate business objectives"*.

Each element of a strategic plan needs relevant and defined key performance indicators. The strategic plan as a whole can then be broken down into PI:s at the basic shop floor.[63] MPI:s are the tools for the organization to supervise the effectiveness of the maintenance carried out. [64]

4.7.5 Multi-criteria Hierarchical Framework for MPM

An MPM system incorporates a number of criteria or goal functions, which needs to be regarded from the different views of the stakeholders. These criteria can be broken down to several maintenance indicators, e.g. MTTF, downtime, maintenance cost etc. It is important that these indicators can be structured from the operational level to the strategic level.[65]

For an organization the foundation for developing and identifying MPI:s lies in the organizations vision, objectives and strategy as well as the requirements of external and internal stakeholders.

The perspective of the organizations multi-hierarchical levels has to be considered when contextualizing the MPI:s. Depending on the structure of the organization, the number of hierarchical levels can differ. With a three level structure, as illustrated in Figure 4.6, the first hierarchical level could correspond to the organizations corporate or strategic level. The second hierarchical level could correspond to the tactical level of the organization and the third level would then correspond to the operational/functional level. The MPI:s at the functional level, i.e. the level where the actual maintenance is performed, are integrated or linked to the tactical level in order to provide management with a base for analysis and decision making at the strategic or tactical level. It is beneficiary to break down the strategic goals into objective targets for operating maintenance managers, as these may act as performance driver for the maintenance group. If the objective outcome from the

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[61] Wireman T., *Developing performance indicators for managing maintenance*, Industrial Press, New York NY, 1998

[62] Ibid.

[63] Parida (2006)

[64] Wireman (1998)

[65] Parida A. & G. Chattopadhyay, "Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM)", Journal of Quality in Maintenance Engineering, vol. 13, no. 3, 2007, pp.241-259

operating level is linked back to the strategic goals, in the form of MPI:s, the subjectivity increases as the objective outcomes are integrated to prevail MPI:s at higher level.[66]

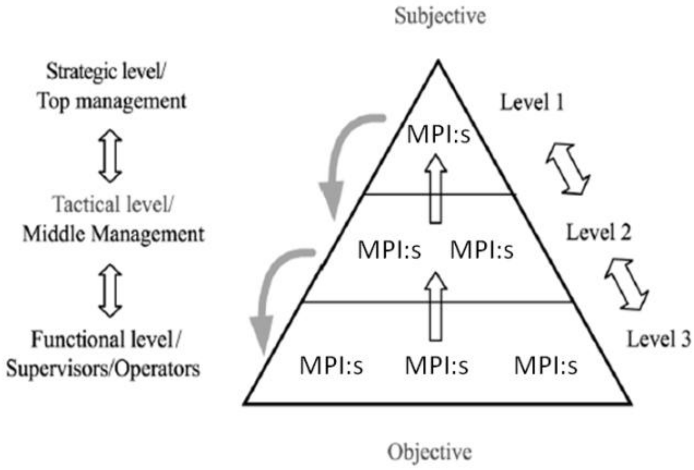

Figure 4.6 Hierarchical levels of MPM model (Altered from Parida and Chattopadhyay 2007)

4.8 Life Cycle Perspective

The life cycle perspective of owning and operating equipment entails looking at the entire life cycle when making investment decisions. The definition of maintenance from Section 4.1 clearly states that maintenance should be viewed upon from a life cycle perspective. As illustrated in Figure 4.7 the life cycle starts with the *Preproduction phase*, continues with the *Production phase* to finally end with the disposal of the equipment. The ability for a piece of equipment to generate profit for its owner during its life cycle is almost entirely decided in the *Preproduction stage*. To fully embrace the life cycle perspective a company is inclined to look at high availability and low maintenance costs in the projecting stage.[67]

4.8.1 Life Cycle Cost

The *life cycle cost* (LCC) of a plant, machine or vehicle is the total cost associated with that unit. The LCC concept emphasizes that one should not only look at the initial investment cost but also at the cost of ownership. Costs associated with LCC are typically acquisition, operation, maintenance, conversion, and disposal. The cost of ownership is often several times greater than the initial investment. When performing LCC analysis the net present value of all future costs must be taken into account since value of money changes over time. As can be seen in Figure 4.7, a large portion of the LCC is decided in the

[66] Parida et al. (2007)
[67] Ahlmann (2002)

preproduction phase of the life cycle. In the early stages of the production phase, costs are usually higher due to running in costs.[68, 69]

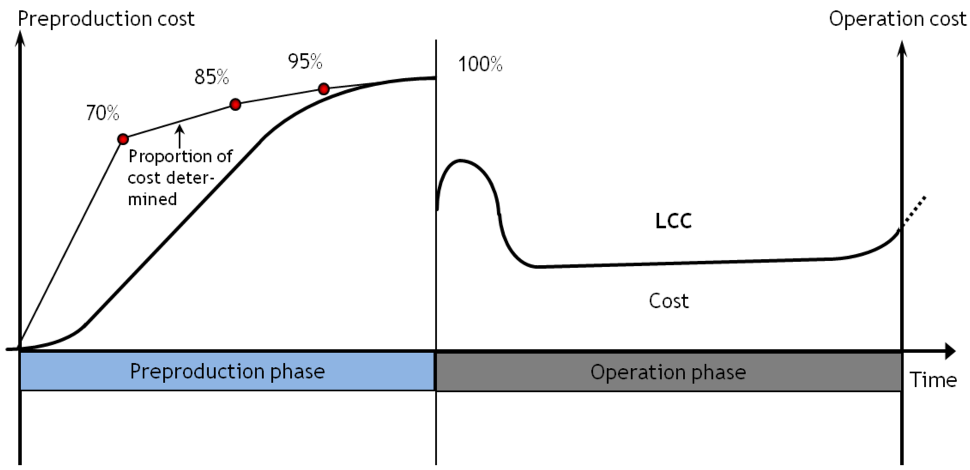

Figure 4.7 The LCC Concept (Adapted from Ahlman 2002)

4.8.2 Life Cycle Profit

Maintenance has traditionally been viewed upon with economic measures and managers have aimed at reducing cost. With the LCP concept this changes. The equipment is utilized with the objective of making money. In order to be successful in a competitive market one needs to focus on both revenue and cost. [70]

The formula for calculating LCP is merely the difference between the *life cycle revenue* (LCR) and the LCC for a piece of equipment according to Equation 4.6.

$$LCP = LCR - LCC$$

Equation 4.6

Both the revenue and cost elements needs to be discounted and LCP is thus the net present value of future profits/losses. The revenue side of LCP is very sensitive to disturbances in quality, on time delivery and production capacity. Figure 4.8 shows how the LCP for a piece of equipment typically varies with the aging of the equipment. [71]

[68] Barringer H.P., “A life cycle cost summary”, paper presented at the International Conference of Maintenance Societies (ICOMS® -2003), Perth, May 20-23, 2003

[69] Kawauchi Y. & M. Rausand, ”A new approach to production regularity assessment in oil and chemical industries”, Reliability Engineering & System Saftey, vol. 75, no. 3, 2002, pp. 379-388

[70] Ahlmann H., “Maintenance effectiveness and economic models in therotechnology concept”, Maintenance Management International, vol. 4, 1984, pp. 131-139

[71] Ahlmann (2002)

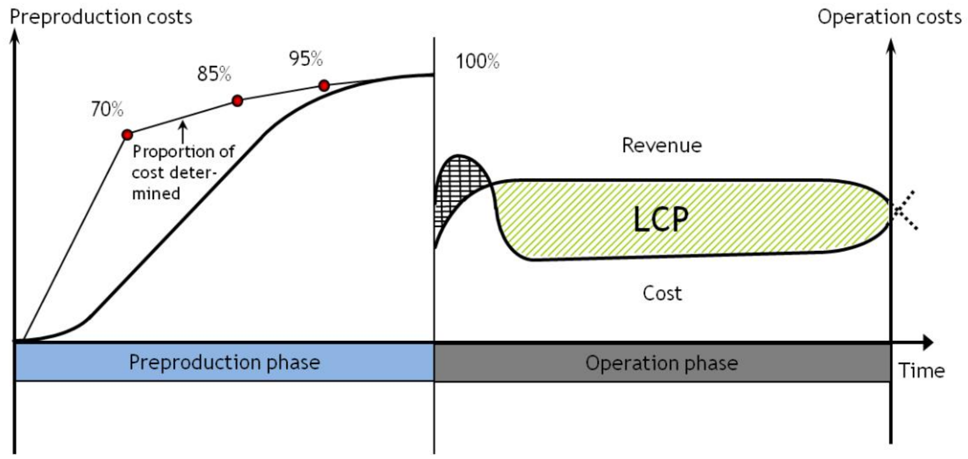

Figure 4.8 The LCP Concept (Ahlman 2002)

While LCC only focuses on the internal efficiency of the business LCP focuses on both the internal and external efficiency. In a dynamic and changing market the need for a model which takes external effectiveness into consideration becomes increasingly more important.

4.9 Effect of Maintenance Strategies

The maintenance strategies introduced in Section 4.9 affects the length of maintenance related downtime in different extent. Figure 4.9 illustrates how the total maintenance downtime could change depending on which strategy is chosen. The strategies can be divided into three different groups: *reactive*, *proactive*, and *aggressive* maintenance. [72]

Reactive maintenance is distinguished by running equipment until failure occurs, in other words the strategy related is CM, which is defined in Section 4.3. Although reactive maintenance give raise to minimal costs and manpower related to keeping equipment running, the overall maintenance costs to repair devastating failures increases. This is due to secondary failures, which would not have occurred if the primary failure could have been avoided. Besides the increase in overall maintenance cost, problems can occur due to unpredictability in production capacity and quality.

Proactive maintenance includes preventive and predictive maintenance, as defined in Section 4.2, corresponding to the strategies PM and CBM in Figure 4.9. Both these maintenance strategies reduce the probability of equipment breakdowns, avoiding to some extent CM. Furthermore, CBM offers additional benefits by advocating maintenance only when needed, limiting the need to interrupt production at scheduled intervals as the case is for PM.

[72] Swanson L., "Linking maintenance strategies to performance", International Journal of Production Economics, vol. 70, no. 3, 2001, pp. 237-245

The *aggressive maintenance* group of strategies has a more holistic view, compared to the other two groups. Maintenance takes an active role in improving the design of new and existing equipment in order to increase availability and efficiency as well as reducing maintenance costs and time. Consequently the strategies *maintenance and reliability at the design phase* (MRD) and *maintenance, reliability, and redundance at the design phase* (MRRD) in Figure 4.9 belongs to the aggressive maintenance group.

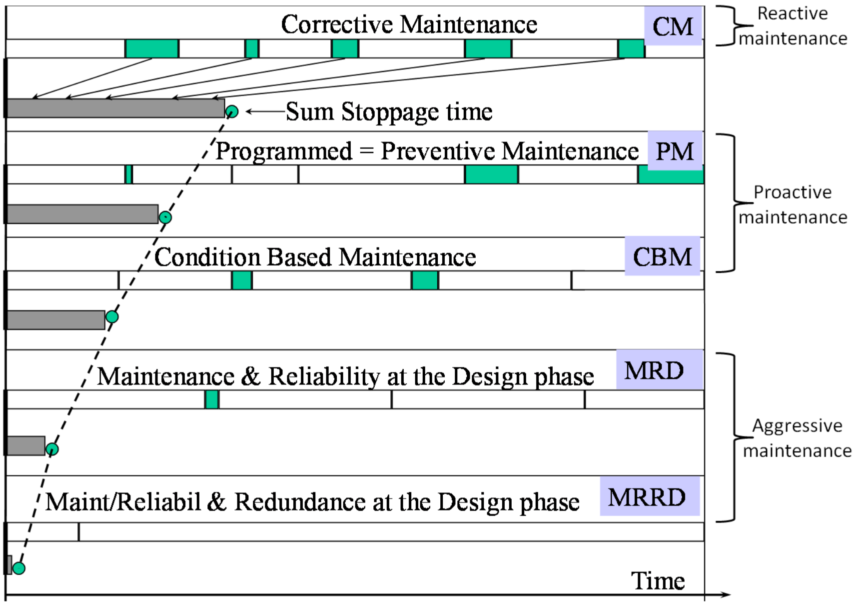

Figure 4.9 Effect of maintenance strategies (Ahlmann 2002)

5 The Hauler Industry

Chapter 5 has the objective of exploring the conditions under which hauler companies act. The core in developing an MPI system, with LCP as the main objective, lies in understanding what affects profitability most significantly. The ways in which MPI:s can be measured are affected by how maintenance solutions are provided to haulers, something which will also be explored in this chapter.

Chapter 5 is based on interviews with twelve service sales representatives working at Scania workshops from Piteå in the north of Sweden all the way to Malmö in the south. Five haulers, representing the segments: *forestry transports, tank and bulk transports, semi truck transports,* and refrigerated *full load haulage* have been interviewed as well. The hauler industry organization *Sveriges Åkeriföretag* and the Swedish association for maintenance technology, *Utek*, have been interviewed to give a holistic view of the hauler industry and maintenance. In addition to this 20 Scania CV employees working with maintenance related issues have been interviewed. Annual reports for hauler companies have been gathered from the database *"AffärsData"* to provide financial statistics.

5.1 Positioning in the Business System

A system break down is desired in order to clarify the positioning of the project in relation to the hauler. By mapping the interrelations in the hauler industry one can illustrate the services and demands affecting the hauler in his everyday business.

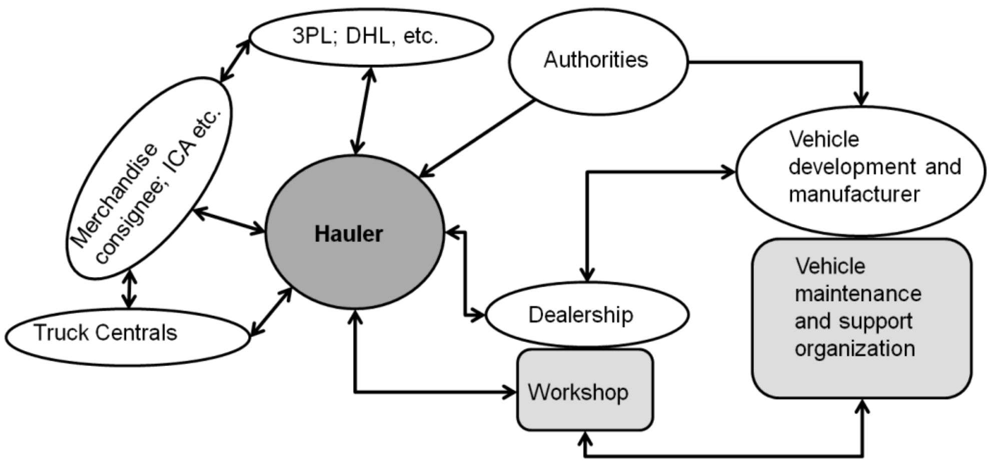

Figure 5.1 This project has direct influence only on the rectangle shaped factors in the system.

Starting with the hauler as the hub in the system, a principle sketch is presented in Figure 5.1. In general the hauler's customers can be identified as *third party logistics* (*3PL*) providers, *truck centrals* (*Lastbilscentraler*) and *merchandise consignee* (*ICA etc.*). There can also be several other constellations e.g. the consignee orders the delivery from a 3PL who outsources the actual transport assignment to a hauler. The communication is bi –or multilateral in most cases in the above mentioned relationships.

The authorities have a unilateral effect, with regulations and policies on the hauler. When it comes to regulations, the *vehicle development and manufacturer* is also affected but from a more technical perspective.

The relationship between the hauler and *dealership/workshop* is crucial for both parties and is built on trust. To have a good communication between the hauler and dealership/workshop is important to make sure the right maintenance activities are performed on the vehicle. A well maintained vehicle will have higher reliability and thus be more profitable. It is of great importance that the dealership/workshop understands the hauler's business in order to provide the right services.

Given the main objective and delimitations of this project, the interrelations which can and should be influenced are the ones between the hauler and workshop as well as the *vehicle maintenance and support organization*.

In reality there are close ties between the dealership and workshop as well as between the: *vehicle development and manufacturer* and *vehicle maintenance and support organization*. The projects system approach disregards from this fact due to the projects delimitations, i.e. the design and customer specification of the vehicle is given.

5.2 Maintenance Terminology

As seen in Figure 4.1, maintenance can be divided in several ways. Depending on the application, some sets of subgroups are more suited than others. In this project we divide maintenance into two different sets of subgroups which in turn give rise to three different kinds of maintenance activities which is the result from three kinds of events. Table 5.1 comprises the terminology used for the different sets.

Set 1	Preventive maintenance	Corrective maintenance	
Set 2	Planned		Unplanned
Maintenance activity	Service	Repair	Emergency repair
Event	Tear and wear	Minor fault	Breakdown

Table 5.1 Set of subgroups defining maintenance terminology in the hauler industry.

The initial set of subgroups, Set 1, divides maintenance into preventive and corrective maintenance. This set captures differences in maintenance activities based on whether a fault has occurred and needs to be corrected or if a fault was prevented from happening. The second set, Set 2, divides maintenance into planned and unplanned activities. The costs that occur when performing maintenance are strongly dependent on whether maintenance can be planned or not.

Service is what we call planned PM and it is the effect of tear and wear on a component or fluid. Repair is when a minor fault, which does not affect the functioning of the vehicle, has occurred and the CM can be planned for a suitable occasion. Emergency repairs are characterized by being corrective and unplanned and they are the effect of a breakdown and do not entail the hauler to continue on his current transportation assignment.

5.3 Differences to Manufacturing Industry

What has become evident to the project is that most research concerning maintenance and maintenance performance is focused on production equipment. To a large extent it is possible to apply theories based on production equipment on maintenance of vehicles, but there are however differences. There are also differences between different transport segments and these can be very significant and have large impact on how maintenance is best performed.

One of the most central differences lies in the fact that production equipment is located to a specific location or a specific factory and maintenance is thus performed where the equipment is used. Vehicles however are constantly moving and maintenance is conducted at workshops that the vehicle has to visit. Vehicles are also subject to various kinds of climate, road qualities, dust, topography etc. which affects the tear and wear as well as the failure frequencies of components. This makes maintenance of vehicles troublesome since vehicles with the same technical specification can be subject to very different tear and wear due to different conditions.

Transport assignment can be received with short or long notice. Some transport segments have contracts stretching over several years with fixed routes each day while others only have a few days or even a few hours notice on their assignments. Planning of maintenance activities thus becomes a challenge.

There are also differences between countries due to laws and regulations. In Sweden the gross weight of a truck rig must not exceed 60 metric tons while on the European continent the maximum gross weight allowed is usually 44 tons. The gross weight affects the tear and wear of the vehicle and the need for maintenance thus varies between countries.

5.4 Definitions within the Hauler Industry

The differences between production equipment and vehicles presented in Section 5.3 will impose changes to some of the definitions and terminology presented in Chapter 4. The concepts availability, uptime, downtime and LCP will be applied in a slightly different way to be more suited for maintenance of vehicles.

5.4.1 Availability

In Section 4.5 the parameters planned operating time, uptime and downtime are defined. These definitions still hold in principle but with a slight alteration to them. It has been found that the division of maintenance into planned and unplanned is highly relevant for the hauler industry. The cost and non-realized revenue that occurs during a maintenance activity is mainly dependent on if the activity is planned or not. It is thus suitable to divide maintenance into planned and unplanned. It has furthermore, during the interviews, been found that a planned maintenance activity often can be performed while the vehicle is not intended for use. During such circumstances the maintenance activity will not be considered as downtime. Figure 5.2 illustrates the new definition of planned operating time, uptime and downtime.

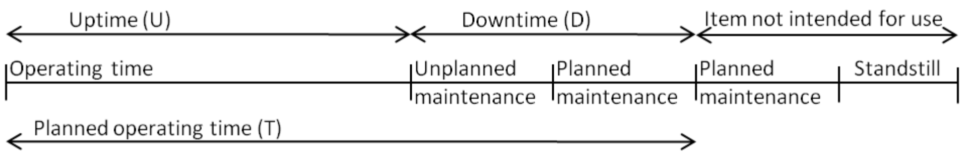

Figure 5.2 The relationship between uptime, downtime and planned operating time

Since the objective of this project is to measure the performance of maintenance, disturbances that are not related to maintenance are disregarded from. The category waste, which was included in Figure 4.2, has thus been included in operating time.

5.4.2 The Hauler´s LCP

Applying the LCP concept on the hauler industry involves finding the cost and value drivers associated with running a haulage business. LCP takes both cost and revenue into consideration but revenue is often represented in terms of non-realized revenue. In our case the non-realized revenue is the revenue a hauler is missing out on due to maintenance activities. By performing maintenance activities in a more efficient and effective way the profit of the hauler can be increased.

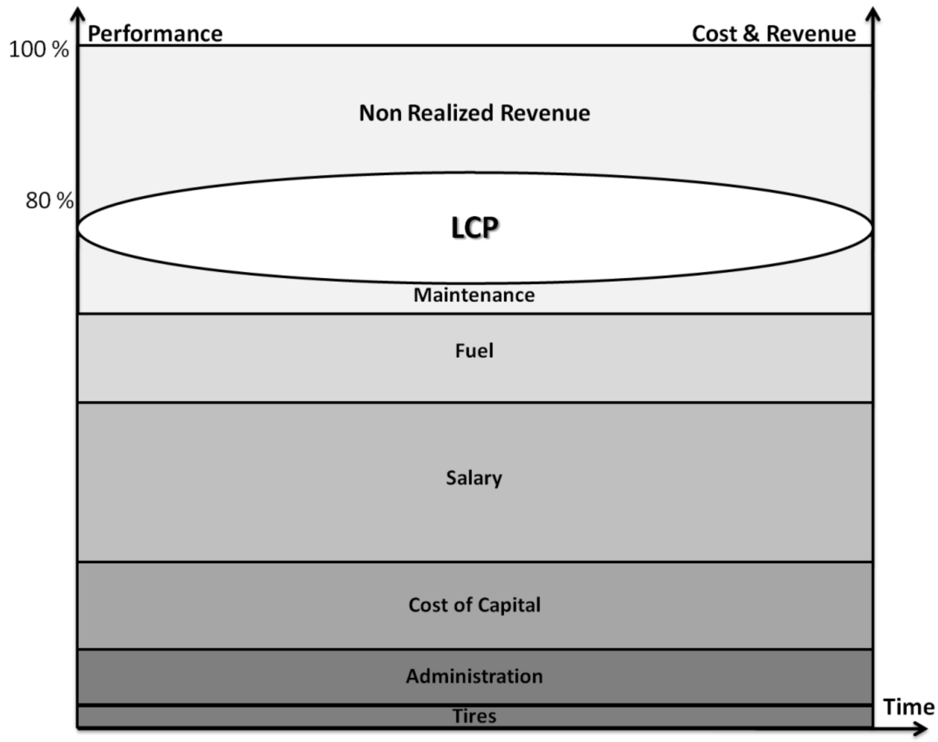

Figure 5.3 Illustrates the different elements which comprises the haulers (Adapted from Ahlmann 1984)

Figure 5.3 illustrates the principle cost and non-realized revenue elements which has a direct effect on profitability. The left vertical axis in Figure 5.3 represents the performance of a haulage company as a percentage. A value of 100 % means that there is no downtime at all and that the hauler can perform services during his entire uptime with a fill rate of 100 %. The right vertical axis represents cost and revenue where revenue will amount to the level indicated by the upper edge of the *"LCP-cigar"* and the costs to the lower level of the *"LCP-cigar"*. LCP will be the difference between revenue and cost. The horizontal axis represents time. The shape of the *"LCP-cigar"*, with a low profit both early and late in the lifespan of the vehicle, can be recognized from Figure 4.8.

To further clarify how Figure 5.3 should be interpreted an example will be presented. Consider a hauler with one vehicle that is transporting goods between Lund and Södertälje. The hauler has a desire to use his vehicle during all weekdays. However, once a month he has to visit a workshop to perform maintenance during a weekday. In addition to maintenance downtime the hauler can only fill his truck up to 80 % of its loading capacity. Assuming there are 20 working days each month the hauler will have a performance level of 76 % (80 % fill rate during 19/20 days). By performing maintenance during weekends, when the vehicle is not intended for use, the hauler can achieve a performance level of 80 % (80 % fill rate during 20/20 days). If the hauler in addition to better maintenance planning would get another customer to fill his truck up to 95 % his performance level would be 95 % (95 % fill rate during 20/20 days).

5.4.3 Cost and Non-realized Revenue Elements for a Haulage Company

A description of each cost and non-realized revenue element, shown in Figure 5.3, is presented to clarify what they compose.[73]

Tire Cost

Tire costs entail all costs associated with the purchase and changing of tires during the life cycle of the vehicle.

Administration Cost

Administration cost includes cost for management, route planning, sales, advertising and human resources staff.

Cost of Capital

Cost of capital comprises four different costs; interest, insurance, tax, and depreciation. Most vehicles are bought with borrowed money and the hauler thus has to pay interest. The interest depends on the credit worthiness of the hauler as well as the retail price of the vehicle. Insurance of the vehicle is regulated by law and the cost for insurance depends on several factors. In addition to insuring the vehicle other insurances for the cargo and driver are included. Taxes are regulated by law and depend on factors such as weight, fuel type, number of axels and type of coupling unit.

Depreciation is the value the vehicle looses when it is used and thus subjected to tear and wear. The total depreciation of the vehicle is given as the difference between the retail price and the residual value. From interviews with haulers as well as service sales representatives it has been found that a hauler keeps his/her vehicle for 4-6 years.

Driver Cost

Driver cost is the cost for having a driver in the vehicle during its life cycle. It includes salary, payroll tax (arbetsgivaravgift), pension contribution (pensionsavsättning) and work-wear.

Fuel Cost

This is the cost of fuel for the vehicle during its entire life cycle.

Maintenance Cost

Maintenance costs are directly related to maintenance and they comprise costs for labour, spare parts, consumables such as oil and filters, replacement vehicles as well as towing. It is not unusual that the hauler has outsourced the maintenance activities to a workshop. In that

[73] Sveriges Åkeriföretag, Åkerihandboken 2010, version 200912, Stockholm, 2009

case the invoice the hauler receives from the workshop or towing company is the maintenance cost.

Maintenance Downtime

The non-realized revenue due to maintenance downtime is divided into three categories: transport, waiting, and workshop activities. While the vehicle is en route to or from the workshop, waiting for maintenance to begin or while maintenance is being performed; it is unable to generate revenue. This leads to non-realized revenue. There is one exception, and that is when maintenance is being performed when the truck is not intended for use. Such time is not downtime, and thus no loss of revenue occurs.

Badwill

A vehicle suffering a breakdown that causes a delay can impose badwill for the hauler. Although hard to quantify, badwill often has an effect on market share and loss of customers i.e. customers chooses other haulage companies which will deliver on time. Since badwill affects revenue it is to be considered as non-realized revenue.

Fill Rate

The fill rate of the vehicle is understood as the percentage of loading capacity that is filled with goods. Loading capacity can be indicated both as weight and volume depending on the application.

The project will make the assumption that fill rate cannot be affected by maintenance. Therefore, effects of an increase in fill rate will from this point forward not be taken into consideration when making calculations of non-realized revenue.

5.5 Maintenance Scorecard for the Hauler Industry

The MSC presented as Figure 5.4 shows the interrelations between factors that influence the hauler's profit. It comprises the four perspectives; *Workshop Developing and Learning, Hauler's Process Perspective, Hauler's Customer Perspective and Hauler's Financial Perspective*. It is derived from the MSC shown in Figure 4.5 and the changes made are based on the interviews conducted within the project.

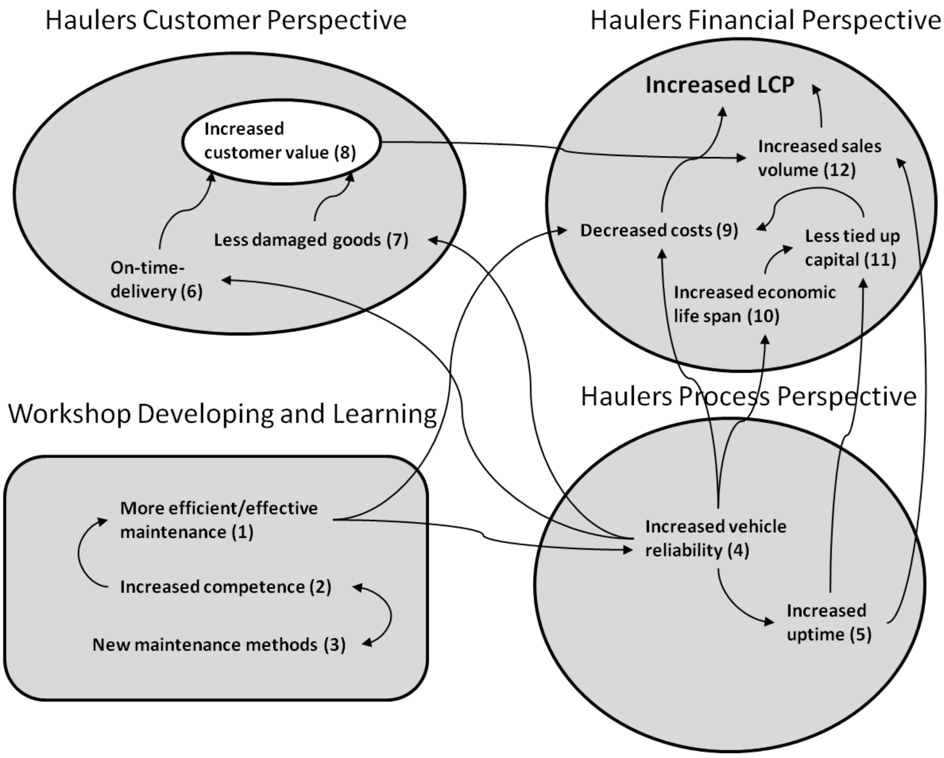

Figure 5.4 MSC for the hauler industry (Adapted from Ahlmann 2002)

The *Workshop Developing and Learning perspective* focuses on the future maintenance solutions. The dynamic setting in which the hauler conducts his/her business is dependent on constant development of maintenance solutions. As mentioned in Section 5.1 the relationship between the workshop and the hauler is of great importance and this becomes evident when studying the MSC in Figure 5.4. It is not unusual that the hauler company has outsourced its maintenance activities to a workshop. The MSC thus includes the activities of two companies rather than one, namely both the hauler and the workshop. As can be seen in Figure 5.4 *Workshop Developing and Learning* emphasizes efficiency and effectiveness of maintenance (1). With new maintenance methods (3) and increased competence (2), maintenance can be performed with a higher economic efficiency. Increased competence and new maintenance methods have a bi-lateral relationship. By increasing competence, new ideas will be born resulting in new maintenance methods. By implementing new methods staff will have more tools to work with and thus have an increased competence.

Hauler´s Process Perspective has the internal efficiency of the hauler in its focal point. The most essential factors are the reliability of the vehicle (4) as well as its uptime (5). This is intuitive, without a functioning vehicle the hauler will not generate any revenue and thus no profit. By being able to perform maintenance in a more efficient and effective way the reliability of the vehicle will increase. Components with a high failure frequency are inspected and maintenance is being performed when it is needed. The increase in reliability will offer the hauler more uptime as a result of less workshop visits.

Hauler´s Customer Perspective is the way the hauler is being perceived by his/her customers. The internal processes should support the demand the customer has on the hauler. The most significant aspects of a transport service is the ability to be on-time (6) and that goods are not damaged (7). Increased reliability supports both these aspects. To fulfil, and even exceed, customer expectations leads to an increase in customer value (8).

Finally, the *Hauler´s Financial Perspective* has to do with the hauler’s financials. All three previous perspectives have had the goal to increase profitability. There are direct links between *Workshop Developing and Learning* and costs. By more efficient maintenance solutions (1) cost efficiency is achieved by a decrease in costs (9). However, reducing direct costs of maintenance is not the only factor affecting the hauler’s profitability. The increased reliability of vehicles (4) makes breakdowns and minor faults less likely to occur, which in effect will decrease costs (9). Another aspect of increased reliability is the increased economic life span (10) of the vehicle. A well maintained vehicle will be able to operate over a longer period of time resulting in less tied up capital (11). The *Hauler´s Process Perspective* offers more to the *Hauler´s Financial Perspective* by means of offering uptime which enables the hauler to increase his sales volume (12). In addition to increased sales volume, increased uptime will further decrease tied up capital since each vehicle can perform more transport assignments.

Let us exemplify how an increase in uptime can lead to less tied up capital. Consider a hauler with a customer demand that requires him to have 100 vehicles operating every day. Due to maintenance downtime an average of three vehicles are in the workshop at any given time. The hauler thus needs a fleet of 103 vehicles to meet customer demand. By more effective maintenance, which increases reliability and thus uptime the hauler now only has two vehicles in the workshop at any given time. This has the effect that the hauler only needs 102 vehicles in his/her fleet to meet customer demand.

5.6 Cost Allocation in the Hauler Industry

The hauler industry can be very varying, both from a business premise and a technical perspective. This is due to the wide diversification of transport types in the business. Therefore cost allocations will be presented for ten different segments[74] as well as an average of all segments.

Segmentation of the different transport types is necessary in order to derive conclusions on a more detailed level. The segmentation can also provide a more reliable overview of the industry, illuminating common denominators and differences in the industry. The cost allocations for the different segments reflect the differences presented in Section 5.3.

Below are the different segments and cost allocations within the segments as well as an average of all segments. The segmentation is fine-meshed enough to capture most of the transport types in the industry and at the same time provides an adequate and manageable grouping of the industry as a whole. Figures 5.5-5.15 illustrates the common cost drivers in the industry, which are: s*alary, fuel, cost of capital, administration, maintenance,* and *tires*. Transport types with short distances stand out with high *salary* and *capital* costs. Naturally the cost allocation for long distance transport types is dominated by the variable costs, *salary* and *fuel*. For the average hauler: *salary, fuel,* and *cost of capital* are the largest cost elements.

Local Distribution

Transport assignments performed mainly in a city. Distinguishing for this segment is that a large share of the transport is dedicated for loading and unloading. The investment for the vehicle is relatively low and it most often operates one shift, during day time.

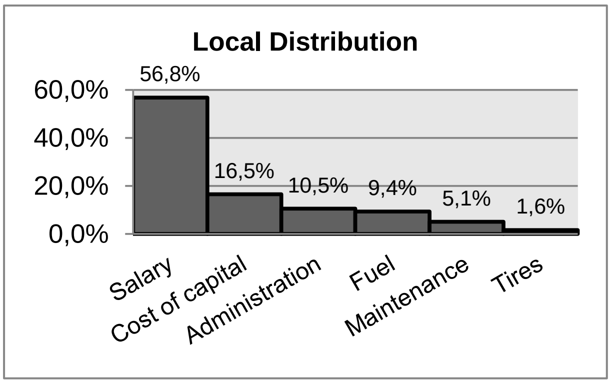

Figure 5.5 Characterized by salary being the largest cost.

[74] Sveriges Åkeriföretag (2009)

Regional Distribution

This segment comprises distribution without a trailer and with several stops for loading and unloading. It is similar to *local distribution*, but as the name indicates, has a larger geographical work area.

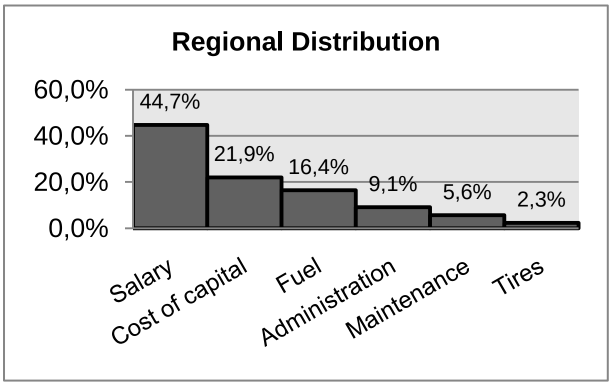

Figure 5.6 Works over a larger geographical area than local distribution.

Long Distance Distribution

This segment is a mix of the *full load haulage* and the *regional* distribution segments. It is distinguished by long distances with trailer and several stops for loading and unloading.

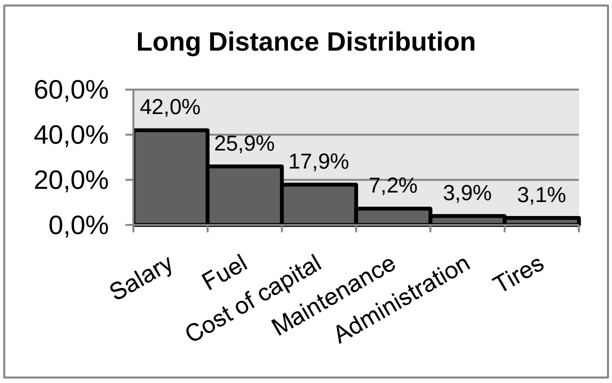

Figure 5.7 A mix of full load haulage and regional distribution.

Full Load Haulage Transport

Transport assignments featuring truck and trailer or similar configurations. The segment is characterized by a relatively short portion of time spent on loading and unloading, i.e. a majority of the operating time is spent on the road.

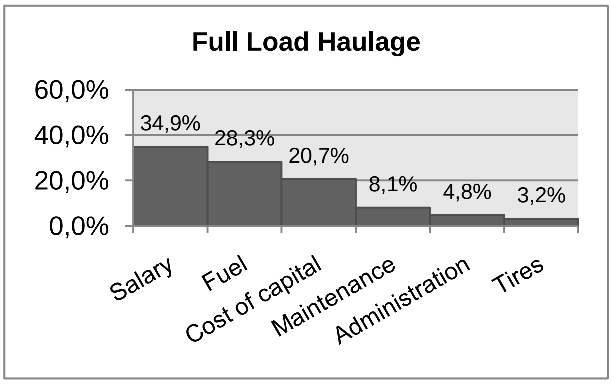

Figure 5.8 A large share of time spent on the road.

Semi Truck Transports

This segment features trucks (tractors) pulling semi trailers or containers. The distance driven in relation to operating time is relatively high.

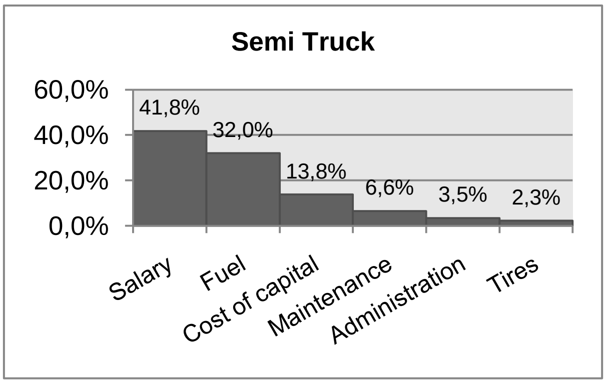

Figure 5.9 This segment is characterized by having the largest share of fuel cost amongst the segments.

Tank and Bulk Transport

Transport assignments, operating in shift, characterized by bulk or tank transports.

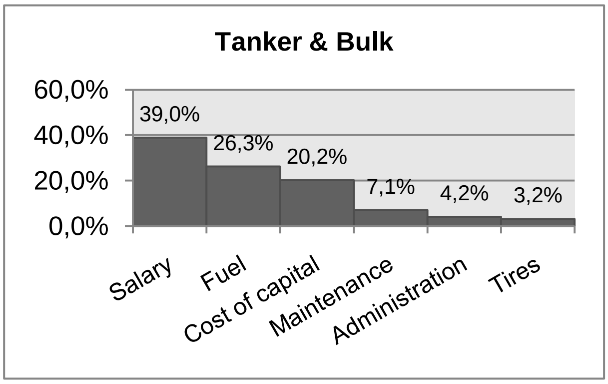

Figure 5.10 These transports are characterized by pulling heavy loads and operating many shifts.

Forestry Transports

Transportation of forest raw materials, e.g. round timber and wooden chips, distinguishes this segment. Usually operates in more than one shift.

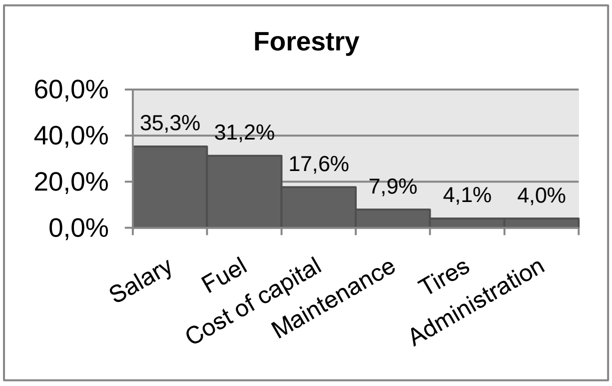

Figure 5.11 Operates more than one shift.

Construction over Short Distances

Trucks used in construction e.g. crane trucks, characterized by low mileage and lots of idling.

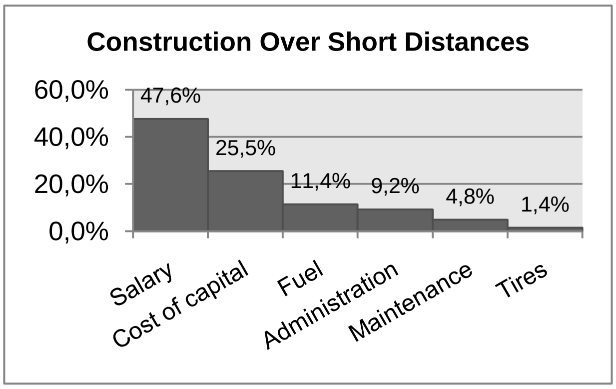

Figure 5.12 This type of truck is typically seen at a construction site.

Construction Transports without Trailer

The trucks in this segment perform more traditional transport assignments, without trailer, in a construction environment. Dumper trucks are common in this segment.

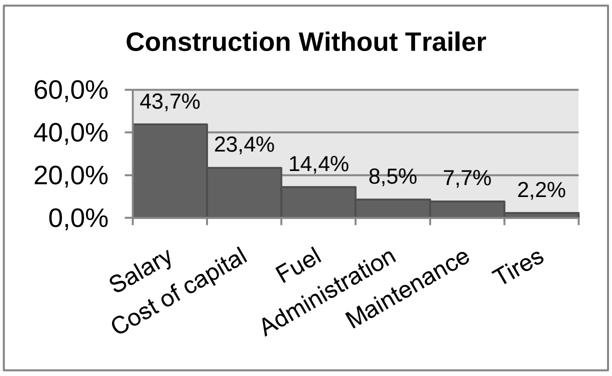

Figure 5.13 Dumper trucks are common in this segment.

Construction Transports with Trailer

Truck associated with construction. The vehicle has at least three axles and some type of trailer.

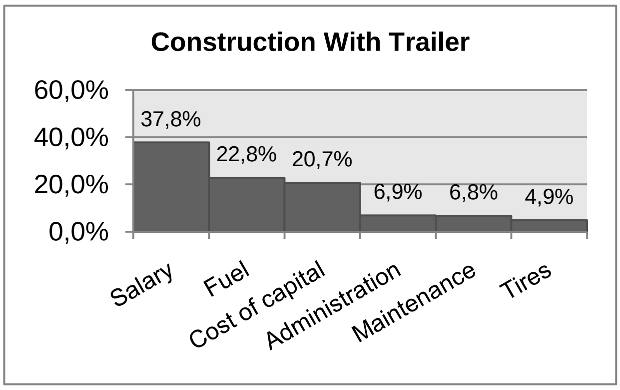

Figure 5.14 Typically travels longer distances than other construction segments.

Average Hauler

The average hauler has a cost allocation according to Figure 5.15. It is similar to many of the individual segments and the conclusion is that it is quite representative for many types of transports. The average is calculated as the arithmetic mean of the individual segments.

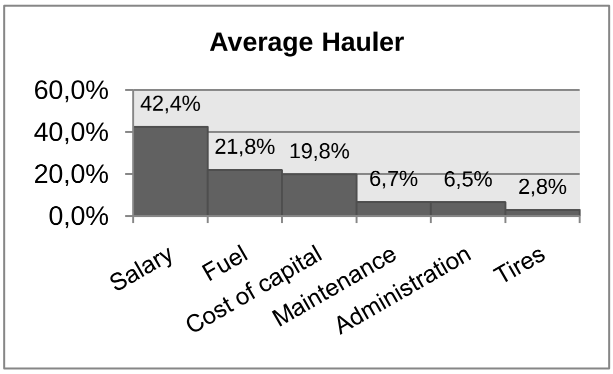

Figure 5.15 The figure shows the cost allocation for the average truck in Sweden.

Segment	Annual mileage	Common type of vehicle	Common road surface conditions	Number of shifts	Characteristics
Local Distribution	Low	Truck with two axles and no trailer	Good	1	Distribution in cities
Regional Distribution	Medium	Truck with three axles and no trailer	Good	1	Distribution between cities
Long Distance Distribution	High	Truck with three axles pulling a trailer	Excellent	≥ 1	Several loading and unloading occasions
Full Load Haulage Transport	High	Truck with three axles pulling a trailer	Excellent	≥ 1	Few loading and unloading occasions
Semi Truck Transports	High	Tractor pulling a semi-trailer	Excellent	≥ 1	Few loading and unloading occasions
Tank and Bulk Transport	High	Tanker trucks	Poor/Good/ Excellent	≥ 2	Heavy load and high utilization
Forestry Transports	High	Timber truck	Poor/Good	≥ 2	Heavy load and high utilization
Construction Over Short Distances	Low	Crane truck	Poor	1	Lots of idling
Construction Transports Without Trailer	Low	Dumper truck, hook lift truck, mining truck	Poor	≥ 1	Medium to heavy load and harsh operating conditions
Construction Transports With Trailer	Medium	Truck with at least three axles, pulling a trailer	Poor/Good	≥ 1	Heavy load

Table 5.2 Summary of the segments in the hauler industry (Based on Åkerihandboken 2010).

Table 5.2 summarizes the segments and provides additional information about what is significant to them. Many of the segments spread over quite a wide range and the table merely emphasizes what is most common.

5.6.1 Improvement Potentials

As seen in Figures 5.5-5.15 the common denominator for the hauler business is that the top three cost drivers are salary, fuel, and cost of capital. There is one exception, *Local distribution*, where administration is the largest cost. However, for all ten segments, *salary* is the top cost driver.

Out of the six cost drivers illustrated in Figures 5.5-5.15, the only one this project studies directly is *maintenance*, which is obviously not a major cost driver. However, maintenance has a significant impact on several of the cost elements. Figure 5.16 illustrates the indirect effects maintenance can have on costs. A mapping of the indirect impact of maintenance on the hauler company would highlight the full potential of the cost rationalization maintenance can offer.

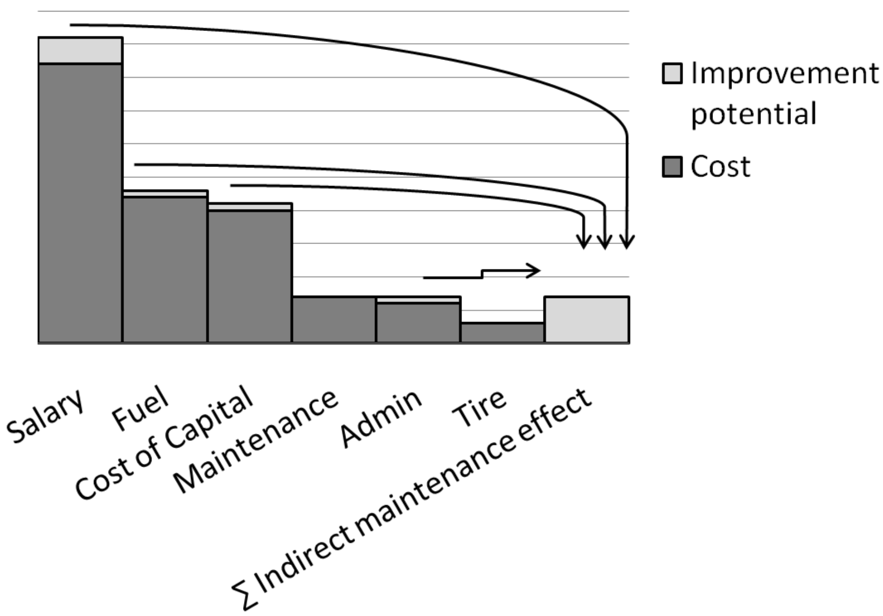

Figure 5.16 The sum of the *indirect maintenance effects* can be viewed as *waste* connected to maintenance. Consequently this *waste* can be minimized by efficient and effective maintenance routines/methods.

Let us study the effects of maintenance on the cost drivers in Figure 5.16. According to Section 4.7.3 and 4.9, more efficient and effective maintenance solutions can reduce direct costs of maintenance. This is a direct effect that maintenance has on the hauler's cost. Another scenario is that the direct maintenance costs are unchanged, and instead maintenance is improved. This can result in a reduction or total elimination of breakdowns, which in turn would lower total salary costs as well as cost of capital. The lowering of unproductive salary costs is one of the largest cost reductive effects of improved maintenance. Lower cost of capital is a consequence of higher availability and longer economic life cycle of the vehicle due to maintenance. Furthermore, less unplanned and planned maintenance could affect the costs for administration.

The above is an example of possible improvements. It is more or less an illustration of the possible indirect effects of maintenance in the hauler industry. In order to explore and quantify the full potentials of a more efficient and effective maintenance more detailed mapping is required. The economic impact of maintenance will be further studied in Section 6.1.

5.7 Economic Figures

A survey is conducted within the project to clarify the financial climate of the hauler industry. The bases for the survey are company financial reports.[75] The figures are extracted for the last four accounting periods and the data represents financial years from the beginning of 2004 to the middle of 2010. Due to technicalities in the data collection, statistics are presented in two year periods with each period overlapping one another. This has a moving average effect on the data and smoothes out large differences.

Companies included in the survey have fulfilled all of the below criteria:

- The company is an "*aktiebolag"* (limited company)
- Turnover per employee exceeds 0,5 MSEK
- Turnover per employee is below 3 MSEK
- Companies cannot be on their first financial year

The constraints are chosen since a lot of companies stating that they are performing transport services are not haulage companies. By only including companies with a turnover between 0,5-3 MSEK most companies that are not haulage companies are excluded. In addition to these constraints every company with a turnover exceeding 80 MSEK that is not a pure hauler company has been excluded. There is an average of 4 669 companies fulfilling the criteria above for each of the years.

[75] Affärsdata, retrived 26 November 2010, < http://www.ad.se/startpage.php>

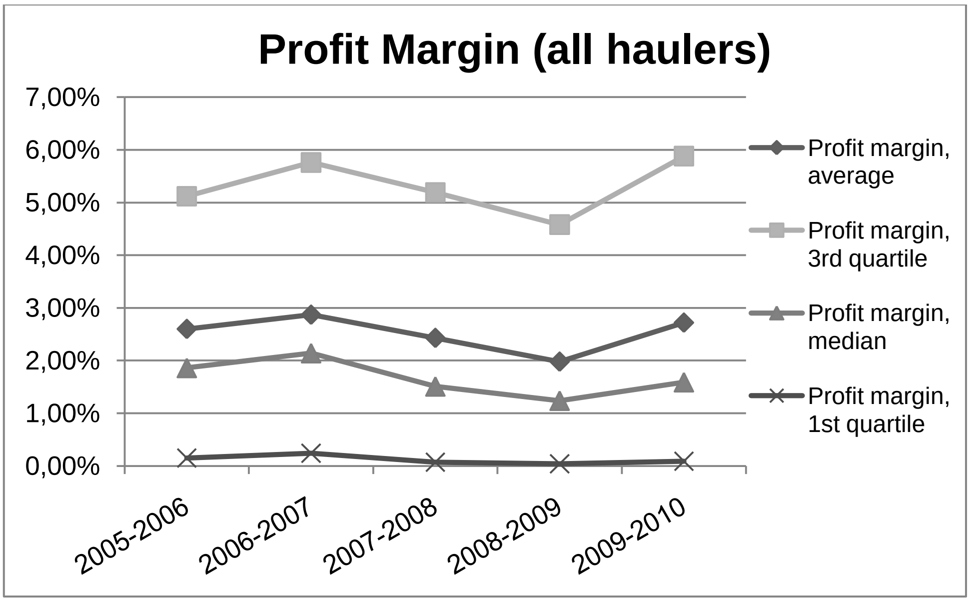

Figure 5.17 The figure illustrates the profit margin for the average hauler. The business cycle can be spotted clearly with boom during 2006-2007 and recession during 2008-2009.

Figure 5.17 shows average and quartile profit margins for all haulers over the years 2005-2010. The business cycle can clearly be spotted and it becomes evident that the hauler industry is sensitive to recessions. The moving average effect smoothes differences between boom and recession.

	All haulers	**Haulers with ≤ three employees**	**Haulers with > three employees**
Turnover, average	9,269 MSEK	2,228 MSEK	16,739 MSEK
Employees, average	7,86	1,77	14,31
Employees, median	3	2	8
Turnover per employee, average	1,179 MSEK	1,257 MSEK	1,169 MSEK
Profit margin, average	2,46 %	3,78 %	2,28 %
Profit margin, 3rd quartile*	5,18 %	6,59 %	4,02 %
Profit margin, median	1,67 %	2,16 %	1,32 %
Profit margin, 1st quartile	0,12 %	0,12 %	0,11 %

Table 5.3 The compilation of financial data is a weighted average over the years 2004-2010. The industry is mostly made up of smaller companies.

Approximately half of the Swedish haulers have three employees or less. Due to this fact a division of haulers into those with more than three employees and those with less than or equal to three has been made. Figures are presented in Table 5.3 for each of these groups as well as for all haulers. The data is a weighted average of all years from 2004-2010.

* The 3rd quartile represents the 75th percentile, meaning 75% of the data is below the 3rd quartile and 25% above. The 1st quartile works in the opposite way with 75% of the data above and 25% below.

The hauler trade is highly competitive and characterized by low profit margins. The 1st quartile is very close to zero and this tells us that roughly 25 % of haulers are losing money every year. As one can see in Table 5.3 the smaller companies have a higher profit margin than the larger ones. There is also a significant difference in turnover per employee between the two. The reasons for these differences are somewhat unclear and the project will not discuss this matter any further.

5.7.1 Working Hours per Year

During a year a truck driver will be working 1716 hours on average. The calculations below are based on the number of working days in Sweden during 2010, in addition to a series of assumptions that are compiled in Table 5.4.

Yearly working hours breakdown	
Number of weekdays	261
Vacation days	-25
Holidays occurring during weekdays	-7
Sick days	-9
Parental leave	-3
Education and leave	-2,5
Total working days	214,5
Total working hours(8 hours per day)	1716

Table 5.4 Compilation of the amount of working hours a hauler has each year.

The number of weekdays amount to 261 for the year of 2010. From those days 25 will be vacation and another 7 will be holidays occurring during weekdays. The project further assumes that the driver has 9 sick days and another 3 days for parental leave. Education and leave amount to another 2,5 days which makes the total number of working days 214,5. This amounts to 1716 work hours each year and this figure will be used as a template in calculations further on in the project. It should be noted that this calculation aims at presenting the number of hours that a driver works each year and not the amount of hours that he is paid for.

6 Development of the MPI System

A MPM system has the objective of measuring the efficiency and effectiveness of maintenance according to Section 4.6. It is furthermore of the utmost importance for the measures to be linked to the corporate strategy of the haulage company. The positioning of the project is to have the hauler in focus and it is also the hauler's LCP that has been chosen as the main target of the MPI:s. The reason for this is based on the strategy of Scania CV, to give the hauler the highest possible uptime and thereby means to become more profitable. One of Scania CV' core values are "Customer first" and it is the projects belief that by putting the hauler's LCP in focus the project is not only oriented towards the objective of the hauler industry but also towards Scania CV' core value.

6.1 Economic Impact

This section will show calculations on the impact of maintenance on the hauler's profitability.

Initially, general assumptions on costs and revenue will be made and formulas for calculating the impact of different maintenance activities will be shown. Secondly a series of examples will be presented to reflect the impact of different maintenance activities.

6.1.1 Impact of Planned Maintenance Activities

According to Table 5.1, PM and repairs are characterized by always being planned and the project will in Section 6.1 assume that no waiting time is imposed in connection to a planned maintenance occasion. The result of this assumption is that as soon as the vehicle is available to the workshop the maintenance occasion begins. During planned maintenance the driver could either be on or off duty, which will affect the driver cost. The hauler's profit will be influenced by two factors when a planned maintenance occasion occurs: increased costs and loss of revenue.

The largest costs associated with a planned maintenance occasion are the material and labour costs. These often come in the form of an invoice from the workshop. Some haulers utilize their vehicles during several shifts and for some the vehicles are always intended to be on the road. When these vehicles need to visit a workshop for service or repair there could be a need for a replacement vehicle. There are a number of different alternatives of how to replace a vehicle some of which include: rental vehicle, replacement vehicle from own fleet, replacement vehicle from a competitor etc. The common denominator for all replacement alternatives is that the cost for them is at least as big as for the hauler's own vehicle. The project will make the assumption that as soon as a replacement vehicle is needed the hourly cost is the same as for the hauler's own vehicle. In addition to the above mentioned costs there might be costs associated with transporting the driver to and from the workshop.

While the vehicle is at the workshop it is unable to generate revenue. This leads to non-realized revenue for the hauler. However, the hauler will not suffer the full effect of non-realized revenue since variable costs, such as fuel and tires, does not occur. Furthermore, whether the driver is on or off duty also has an impact on the effect of non-realized revenue. Instead of studying the non-realized revenue it becomes more interesting to look at the value that is lost, illustrated in Equation 6.1.

$$value\ of\ non\text{–}realized\ revenue = non\text{–}realized\ revenue - variable\ costs$$

Equation 6.1

Apart from profit impacts in the workshop the vehicle has to be transported to and from the workshop. While being en route to and from the workshop the costs are the same as if the driver was on a transport assignment. Thus the full effect of non-realized revenue comes into action when being en route to and from the workshop.

6.1.2 Impact of Unplanned Maintenance Activities

When an unplanned maintenance occasion occurs it is the effect of a breakdown. Scania CV has a vehicle assistance service called *Scania Assistance* which coordinates the emergency repairs, resulting from breakdowns. When a breakdown has occurred a mechanic is sent to the breakdown site. There are three major scenarios for how and where the vehicle will be subject to the emergency repair. The best case scenario is that the vehicle is able to get to the workshop by own means. The second alternative is that the vehicle can be repaired on the side of the road and the third that the vehicle has to be towed to the nearest workshop.

Depending on what kind of goods the vehicle is transporting there can be a need for a replacement vehicle. For certain types of transports such as flowers, food, transports going to industries with low inventory levels etc. the likelihood for a replacement vehicle is high. As for planned maintenance occasions, vehicles operating in several shifts are more likely to be replaced.

The total time required to get the vehicle back on road is made up of several activities such as waiting for assistance vehicle, fault diagnosis, waiting for tow truck, waiting for the workshop to be able to start the repair and the actual repair of the vehicle. The vehicle will not generate any revenue during any of these hours, meaning that non-realized revenue will be imposed during all hours. The project will further assume that the driver is on duty for the entire emergency repair occasion.

6.1.3 Maintenance Impact on Profitability

Section 5.6 has showed that the cost allocation is very different for each of the transport types. Most preferably an analysis for each transport type should be conducted. Apart from differences in cost allocation there are other factors such as demands of on-time-delivery, what goods that are being transported, number of shifts, quality of road, average speed etc. that affects each transport types sensitivity towards maintenance. It would be wrong to make the assumption that each of the transport type’s has the same average profit and turnover as the average of all transport types. The analysis will thus be conducted on the average hauler by using the average cost allocation as well as the average profit margin and turnover. The cost allocation presented below in Table 6.1 is thus the average of all transport types. The impact of maintenance on profit will be presented as cost per maintenance occasion and cost per maintenance hour. Tables 6.1 and 6.2 present financial data for the average employee, as well as the allocation of costs amongst the different cost elements.

	Per year	Per hour
Turnover per employee	1 179 000 SEK	687 SEK
Profit margin	2,46 %	
Profit per employee	29 003 SEK	17 SEK
Cost per employee	1 149 997	670 SEK

Table 6.1 The economic figures presented are based on annual reports and represents the average of all haulers over the years 2005-2010. Section 5.7 has a detailed description of the data gathering.

Cost allocation(average for all transport types)		Per year	Per working hour
Salary	42,4 %	487 139 SEK	284 SEK
Fuel	21,8 %	250 814 SEK	146 SEK
Tires	2,8 %	32 545 SEK	19 SEK
Administration	6,5 %	74 290 SEK	43 SEK
Cost of capital	19,8 %	227 929 SEK	133 SEK
Maintenance	6,7 %	76 935 SEK	45 SEK
Total	100 %	1 149 997 SEK	670 SEK

Table 6.2 The cost allocation is reached by multiplying the yearly cost with the percentage each cost element composes. By dividing the yearly cost for each cost element with the number of working hours the cost per working hour is reached.

Planned Maintenance Occasions

In this example it is assumed that it takes a total of one hour to drive to and from the workshop and that fuel and tire depletion during this hour is the same as when the vehicle is on a transport assignment. The costs and value of non-realized revenue should be interpreted as; what would the effect be if a vehicle was subject to one extra hour of maintenance or one extra maintenance occasion.

As a template for the material cost it will be assumed that each hour of maintenance gives rise to 530 SEK in material costs during service and 1300 SEK during repair and emergency repair. A description of the templates is found in Appendix 4.

	Service		**Repair**	
Fixed cost/maintenance occasion				
Non-realized revenue	687 SEK		687 SEK	
Total/occasion	**687 SEK**		**687 SEK**	
Percentage of profit	**2,4 %**		**2,4 %**	
Cost/maintenance hour	Driver	No driver	Driver	No driver
Hourly labour rate	600 SEK	600 SEK	700 SEK	700 SEK
Value of non-realized revenue	522 SEK	238 SEK	522 SEK	238 SEK
Material cost	530 SEK	530 SEK	1300 SEK	1300 SEK
Total/hour	**1652 SEK**	**1368 SEK**	**2522 SEK**	**2238 SEK**
Percentage of profit	**5,7 %**	**4,7 %**	**8,7 %**	**7,7 %**

Table 6.3 The value of non-realized revenue is calculated as; revenue-fuel-tires-(salary).

It has been assumed that the vehicle is unable to generate revenue during the entire maintenance occasion. However a maintenance occasion lasting for half a workday might cause the hauler to decline a transport assignment that would have lasted the entire day. In reality non-realized revenue is usually imposed during more hours than the duration of the maintenance occasion.

According to Table 6.3, a change in maintenance extent leads to a substantial impact on the hauler's profit. As an example the profit would increase by 19,5 % per employee (2,4 % +3 * 5,7 %), corresponding to 5 656 SEK, if a three hour service occasion was eliminated.

Unplanned Maintenance Occasions

Three scenarios will be presented for an emergency repair and they will be denoted breakdown 1-3. The scenarios are based on the three major scenarios from Section 6.1.2. Common to all three scenarios is that the driver is on duty during the entire emergency repair occasion and that the vehicle is unable to generate revenue.

Breakdown 1

The hauler has suffered a breakdown and has placed a call to *Scania Assistance*. The hauler has been told that he/she can continue on his/her own to the nearest workshop, however at low speed. The goods he/she is carrying are not sensitive and a replacement vehicle is not necessary.

Breakdown 2

A breakdown has occurred and this time the situation is more severe. The *Scania Assistance* service coordinator has told the hauler to sit tight and that an assistance vehicle is on its way. Once the technician arrives the vehicle can be repaired on the roadside. The transported goods are not very sensitive and a replacement vehicle is not necessary.

Breakdown 3

This time we have something of a worst case scenario and the vehicle needs to be towed to the nearest workshop. In addition the goods are of a sensitive nature and has to be delivered on-time, meaning a replacement vehicle is needed.

	Breakdown 1	**Breakdown 2**	**Breakdown 3**
Cost per occasion			
Assistance fee	0 SEK	700 SEK	700 SEK
Towing	0 SEK	0 SEK	5000 SEK
Total per occasion	**0 SEK**	**700 SEK**	**5700 SEK**
Percentage of profit	**0 %**	**2,4 %**	**19,7 %**
Cost per hour			
Hourly labour rate	800 SEK	800 SEK	800 SEK
Value of non-realized revenue	522 SEK	522 SEK	522 SEK
Material cost	1300 SEK	1300 SEK	1300 SEK
Replacement vehicle	0 SEK	0 SEK	670 SEK
Total per hour	**2622 SEK**	**2622 SEK**	**3292 SEK**
Percentage of profit	**9,0 %**	**9,0 %**	**11,4 %**

Table 6.4 The hourly cost for a replacement vehicle is assumed to be the same as the hourly cost for the hauler's own vehicle, 670 SEK/h.

In Table 6.4 it can be seen that the impact on profit per employee varies from 0 – 19,7 % for the different scenarios, concerning occasion based costs. Regarding the hour based costs variation is between 9,0 – 11,4 %. By simple mathematics it can soon be understood that it does not take many hours of breakdown before the entire years profit is eradicated.

It should be added that the analysis above does not include all costs that can occur in relation to a breakdown. Costs for transporting the driver to his home or paying for a night at a hotel are costs that are not unusual. There could also be penalty fees due to late deliveries. We choose not to include the above mentioned additional costs because the size and presence of them are very unclear. The calculations above should thus be considered as a lower limit to the cost of a breakdown.

6.2 The Set Takes Shape

In Figures 6.1-6.3 the set of MPI:s are presented in three tree structures. The MPI:s are grouped into economic measures, availability based measures, and customer satisfaction related measures. The MPI:s are derived based on the cost allocations presented in Section 5.6, the improvement potentials presented in Section 5.6.1 and the economic impacts presented in Section 6.1. The logic behind the MPI:s lies in finding those measures which most significantly affects profit.

The economic and availability based MPI:s has the purpose to measure the performance of the PM programme from the hauler's perspective. MPI:s in these trees have been chosen based on if what they are measuring will affect profitability. The customer satisfaction based MPI:s are on the other hand a validation of the external effectiveness of the PM programme i.e. how the hauler perceives the PM programme. It is important not only that the PM programme has the qualities to enable the hauler to be profitable but it is also important that these qualities can be communicated to the hauler.

Two MPI:s stands out as more significant in how they affect profitability. These MPI:s are found on the highest strategic level in the economic and availability based trees respectively. They are characterized by being dependent on several factors and they are intended to show the big picture. Figures 6.1-6.3 illustrates the three trees and the arrows found above each MPI represents whether a high, ↑, or low, ↓, value of the MPI is desired. In Appendix 3 each of the MPI trees can be found in an enlarged format.

6.3 Economic Tree

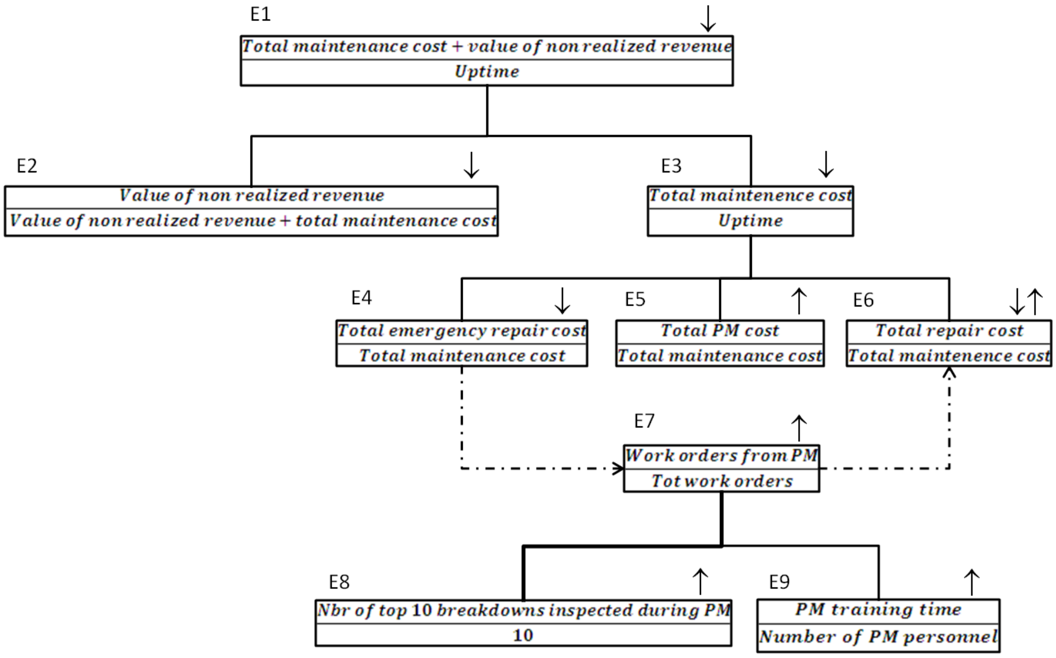

Figure 6.1 The arrows above each MPI represents whether a high or low value is desired for that MPI.

The first main MPI, E1 in Figure 6.1, measures the costs and value of non-realized revenue per unit of uptime. It displays the total economic impact maintenance has on profit per unit uptime. Apart from badwill this MPI captures the total economic impact of maintenance and is thus the most important measure since it is directly related to the objective of maximizing LCP.

E1 is affected by the cost efficiency of maintenance, how well the PM programme prevents breakdowns, the duration and number of maintenance occasions etc. Due to the many factors affecting E1 it is very blunt and to understand the value of this MPI it is important to break down these factors into more MPI:s. The economic tree, Figure 6.1, is designed to break down the factors that most significantly affect E1. MPI:s E2 and E3 acts as the first breakdown level of E1 and will in more detail describe what E1 depends on. The breakdown is structured to make a difference between maintenance cost and the value of non-realized revenue. It is desired for E2 to have a low value since non-realized revenue strikes against profit very hard. During times of recession haulers have less transport assignments and the value of non-realized revenue is likely to be smaller and have less significance. E2 should be interpreted as an indicator of how much maintenance that is scheduled when the vehicle is not intended for use. E3 on the other hand describes costs and since there is always an invoice or pay check associated with the measure it is much more tangible. E3 is further broken down into three MPI:s, E4-E6, which represents the different maintenance activities: emergency repair, repair, and PM. A well functioning PM programme should strive to eliminate all need for CM and it is thus very interesting to measure how costs are distributed between the three activities.

It is unrealistic to believe that PM can eliminate all need for repairs. Certain components have a life span which is shorter than the economic life span of the vehicle and these components will thus have to be either repaired or replaced. An important aspect of the PM programme is to detect tear and wear or minor faults and correct them before a breakdown occurs, MPI E7 measures this property by looking at how many work orders that comes from PM occasions. The dotted arrows in Figure 6.1 represent a shift of maintenance costs from emergency repairs towards repairs. This is the desired effect of a larger share of repair work orders stemming from the PM programme. E7 depend mainly on two factors; that the appropriate components are inspected regularly and that staff have the correct skills to detect faults. MPI:s E8 and E9 are designed to measure these two properties. E8 measures how many of the top ten breakdown causes that are inspected during PM. The drawback of E8 is that certain components are difficult to inspect and even though common breakdown causes are inspected it could have little or no effect on the breakdown frequency. A high value of E8 will give rise to an increase in E7.

6.3.1 Description of MPI:s in the Economic Tree

The following section will in detail describe each of the MPI:s in the economic tree. The description comprises what the MPI:s depend on, their strengths and their weaknesses.

E1) $$\frac{\textit{Total maintenance cost} + \textit{value of non realized revenue}}{\textit{Uptime}}$$

When measuring the economic impact of maintenance both costs and the value of non-realized revenue have to be taken into account. E1 measures the total value, per unit of uptime, which is lost due to maintenance. A small decreasing E1 has a positive effect on the hauler’s LCP.

Strengths: It gives the true cost of maintenance showing both direct and indirect maintenance cost as well as the value of non-realized revenue due to maintenance.

Weaknesses: E1 does not include badwill.

E2) $$\frac{\boldsymbol{Value\ of\ non\ realized\ revenue}}{\boldsymbol{Value\ of\ non\ realized\ revenue+total\ maintenance\ cost}}$$

E2 gives the value of non-realized revenue as a percentage of the total value that is lost due to maintenance. A small value of this MPI means that a large share of maintenance occasions occurs when the vehicle is not intended for use. Emergency repairs have a far greater effect on the value of non-realized revenue than planned maintenance occasions and consequently the MPI will be more sensitive to changes in the number of breakdowns. A small value for this measure is beneficial.

Strengths: The MPI takes the difference between planned and unplanned maintenance into consideration.

Weaknesses: The indicator cannot be measured and has to be approximated instead.

E3) $$\frac{\boldsymbol{Total\ maintenance\ cost}}{\boldsymbol{Uptime}}$$

E3 has the objective to show if maintenance is being performed in a cost efficient manner. It measures the total maintenance cost put in relation to the uptime of the vehicle. The indicator depends on both the effectiveness and efficiency of maintenance and should be as low as possible.

Strengths: E3 puts a price on uptime telling us how much maintenance has to be put in for each hour of uptime.

Weaknesses: No distinguish is made between the different type of maintenance.

E4) $$\frac{\boldsymbol{Total\ emergency\ repair\ cost}}{\boldsymbol{Total\ maintenance\ cost}}$$

E4 measures the emergency repair cost as a share of total maintenance cost. The effectiveness of the PM programme is reflected by this MPI, since one of PM main tasks is to avoid breakdowns and instead transform potential breakdown failures to planned repair opportunities. A low value of this indicator is desirable because it reflects that most of the maintenance is planned, that is the maintenance occasions are mainly PM or planned repairs.

Strengths: E4 illustrates the emergency repair cost in a more apprehensive context and highlights PM effectiveness.

Weaknesses: The MPI does not reflect the cause for the emergency repair.

E5) $\frac{Total\ PM\ cost}{Total\ maintenance\ cost}$

E5 measures the PM share of the total maintenance cost, reflecting the effectiveness of PM. Since PM is always regarded as a planned maintenance activity and planned maintenance is preferred over unplanned, this MPI should be as high as possible.

Strengths: Illustrates the PM cost in a more apprehensive context, highlighting PM effectiveness. By effective PM, potential failures that could lead to breakdowns are discovered, leading to planned repairs. These cost less than emergency repairs leading to lower total maintenance cost.

Weaknesses: Does not reflect the absolute value of the maintenance cost, which could be high.

E6) $\frac{Total\ repair\ cost}{Total\ maintenance\ cost}$

E6 gives the share of total maintenance cost that is made up of repairs. It depends on the costs for all three kinds of maintenance activities.

Strengths: Sheds light on the share of planned repairs out of total maintenance costs. E6 is a necessary MPI when fully evaluating the effects of PM.

Weaknesses: E6 can be hard to interpret since an increase of the measure, resulting from fewer breakdowns, is positive. On the other hand could a decrease of the measure be positive if it is a result of more effective PM. It is thus important to never draw any conclusions based solely on this MPI.

E7) $\frac{Work\ orders\ from\ PM}{Tot\ work\ orders}$

E7 shows the effectiveness of the PM programmes proactive performance. It indicates the amount of repair work the PM programme generates. Furthermore the MPI also illuminates if the workshop is effective in one of its main tasks, namely discovering potential failures before these result in breakdowns.

Strengths: E7 is handy in order to evaluate the effectiveness of a PM programme. The indicator should be high, reflecting that a majority of the work orders are found through the PM programme.

Weaknesses: Indication of poor performance can have ambiguous reasons. The lack of good inspection skills or poorly motivated inspectors would give the same indication as an inadequate PM programme. However, the former can be solved by continuous training and involvement of the inspector in the work process.

E8) $$\frac{Nbr\ of\ top\ 10\ breakdowns\ inspected\ during\ PM}{10}$$

E8 points at the effectiveness of the PM programme. It is a reasonable assumption to make that components that often fail should be inspected during PM occasions. By constantly updating PM inspection points to reflect those faults that are most common the PM programme will become dynamic and focus on the right things. This indicator should be high.

Strength: Inspection points are updated to reflect the most common faults.

Weakness: For some components tear and wear is difficult to detect meaning that inspecting them will not help in preventing failures.

E9) $$\frac{PM\ training\ time}{Number\ of\ PM\ personnel}$$

E9 shows the average time spent on training of PM personnel. Highly qualified personnel will have a positive effect on an efficient and effective implementation of PM processes.

Strengths: E9 brings out the importance of personnel training. With a higher level of complexity of maintenance objects, a higher level of training is required in order to perform the right actions in the right way.

Weaknesses: E9 does not take tacit knowledge exchange occurring between PM personnel into account. The motivation of the personnel is not caught by this MPI. Low motivated personnel, even though highly trained, can lead to ineffectiveness.

6.4 Availability Tree

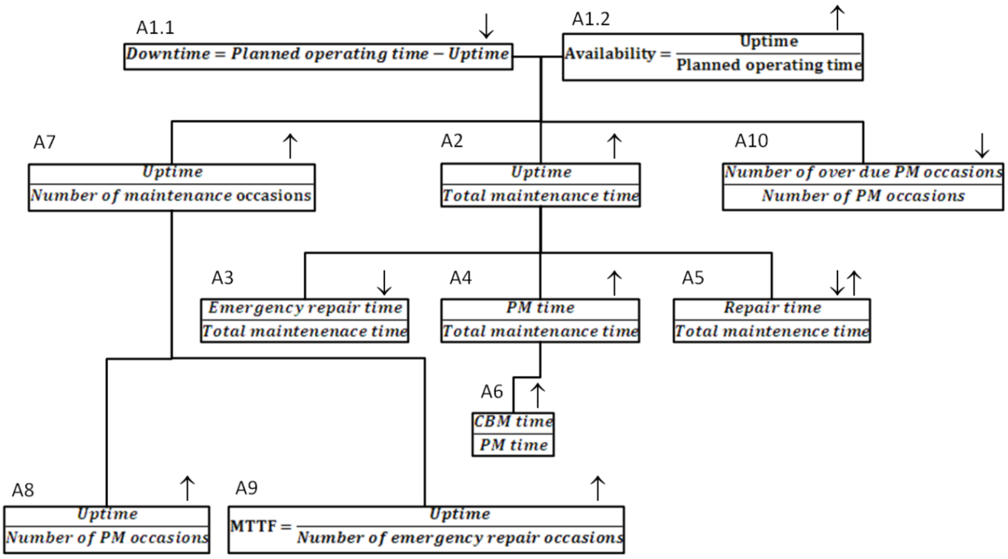

Figure 6.2 The arrows above each MPI represents whether a high or low value is desired for that MPI.

In the availability tree, illustrated in Figure 6.2, the most significant MPI:s are downtime, A1.1, and availability, A1.2. The measures each have a drawback making them hard to use in practice, but by combining them this drawback is eliminated. A1.1 and A1.2 will together serve as the main MPI in the availability tree. A discussion on why both measures are needed can be found in Section 6.4.1.

From Section 6.1 it can be seen that the value of non-realized revenue has a significant impact on profitability and it is during downtime that the hauler is unable to generate revenue. This makes A1.1 and A1.2 important, by keeping the amount of downtime to a minimum the value of non-realized revenue will also be at a minimum. It further has the quality of measuring the effectiveness of PM since a low value of downtime, or a high value of availability, will only be achieved if the amount of unplanned maintenance is low and planned maintenance is being performed when the vehicle is not intended for use. A1.1, A1.2 and E1 depend to an extent on the same factors however in a slightly different way. Section 7.4.3 will present an example which clarifies just how they differ.

The total time that a vehicle spends in the workshop highly affects availability. The PM programme shall strive to maximize A2 to ensure high availability and low downtime. An increase in A2 is an indication of maintenance being performed more efficiently resulting in less time in the workshop. An equally significant cause is the effectiveness of the PM programme, by doing the right things breakdowns can be avoided and thus resulting in less time in the workshop i.e. increased availability and decreased downtime. It should be noted that there is a significant difference between total maintenance time and downtime. According to Figure 5.2 downtime is induced when a maintenance activity occurs during planned operating time. Total maintenance time however is all time that is dedicated to maintenance activities. The effects of this difference will be discussed further in Section 6.6.

A2 can in turn be further broken down into the MPI:s A3-A5. These measures are similar to E4-E6 with the difference that they measure the time spent on different maintenance activities rather than cost. The distribution of cost and time are related since a large part of costs depends on time. However there are differences due to material costs. These differences will be examined more thoroughly in Section 7.4.3. PM can be further broken down into predetermined and condition based maintenance. According to Section 4.9 it is reasonable to believe that with more proactive maintenance strategies, such as CBM, the total time spent on maintenance will decrease. MPI A6 is thus motivated since it measures the share of PM that is performed as CBM.

Apart from the time a vehicle spends at the workshop the number of maintenance occasions are important. A large number of maintenance occasions can give rise to a lot of downtime even though the workshop hours themselves are not that many. For haulers with transport assignments stretching over long periods of time and for those with long distances to the workshop the more significant the number of occasions becomes. Each maintenance occasion comes with costs that are fixed and only depend on the number of occasions. A7 measures this property by showing the amount of uptime that is available between each maintenance occasion. As mentioned before there is a large difference between a planned and an unplanned maintenance activity, which is why A7 is divided in two. A8 measures the amount of uptime between each PM occasion and is thus the PM interval measured in uptime. A9 on the other hand measures the amount of uptime between each emergency repair and is usually referred to as MTTF.

The availability trees final branch deals with on-time-delivery in the workshop. It is of great importance that the PM occasions are performed on time. When the time scheduled for PM is up any extra workshop time will become unplanned time. This will affect the hauler in a similar way as a breakdown, without the cost for parts and towing of course. If A10 starts to deviate only slightly from its minimum of zero the workshop should investigate the reasons. It could depend on customers being late to their scheduled PM. Another possible cause could be that standard times are too tightly set. A third possibility could be that the workshop is not working efficiently due to staff lacking competence or motivation. Due to the many possible causes it is important to never take action based solely on A10.

6.4.1 Description of MPI:s in the Availability Tree

The following section will in detail describe each of the MPI:s in the availability tree. The description comprises what the MPI:s depend on, their strengths and their weaknesses.

A1.1) $$\boldsymbol{Downtime = Planned\ operating\ time - Uptime}$$

A1.2) $$\boldsymbol{Availability = \frac{Uptime}{Planned\ operating\ time}}$$

Downtime is an absolute measure and indicates the amount of downtime the vehicle is subject to. It has a major drawback that it is not related to how much the vehicle is used. This is where availability comes into play, being a relative measure it gives the amount of uptime in relation to the planned operating time. The problem with availability is that significant changes in uptime will result in minor changes in availability. The reason for this is that uptime constitutes a large share of planned operating time. If a vehicle has an availability of 98% and the amount of downtime is halved it will only give an increase in availability of 1%. By combining the two measures both absolute and relative changes can easily be detected.

Another approach, to more easily be able to detect changes in availability, is to look at the logarithm of availability. By taking the logarithm small changes will more easily be detected. What is lost with this approach is however the interpretation of the MPI. While availability is an intuitive measure the logarithm of availability will only be a number. The project thus choose to keep both A1.1 and A1.2 for the sake of interpretation.

The objective of the MPI:s is to measure the efficiency and effectiveness of the PM programme. Availability measures the percentage time the vehicle is available for the hauler and the MPI should be as high as possible. Downtime measures the absolute time the vehicle is not available to the hauler, and this indicator should be as low as possible. Both MPI:s depend on the amount of preventive and CM that is being performed during planned operating time.

Strengths: Changes in downtime are easy to detect. Availability relates uptime to how much the vehicle is intended to be used.

Weaknesses: Changes in availability are difficult to detect. Downtime is a relative measure and does not relate to how much the vehicle is used. A high value of availability or a low value of downtime could mean that all planned maintenance activities are performed when the vehicle is not intended for use. It is thus not necessarily a measure of how efficient the PM is performed. This is most evident when calculating the indicator for vehicles that only operate one shift per day.

A2) $\frac{Uptime}{Total\ maintenance\ time}$

The objective of A2 is to measure the efficiency and effectiveness of the PM programme. The MPI A2 measures how much uptime that is obtained from each hour spent on maintenance. With an effective PM programme the appropriate maintenance activities are focused on, which increases the reliability of the vehicle. While with an efficient PM programme maintenance activities are being done the right way, meaning less time in the workshop. Both these factors results in less total maintenance time as well as increased uptime. The effect of better planning shines through in the indicator as well, however not as strongly. A high value for this indicator is desirable.

Strengths: Opposed to availability, A1.2, this MPI can never give a false positive, meaning that the measure has improved but there has not been an actual improvement. An improvement must be the effect of either better planning, which affects uptime but not total maintenance time, or more efficient/effective PM, which improves both uptime and total maintenance time.

Weaknesses: Since the indicator depends on several factors it can be difficult to find out which of the factors that has imposed a change on the indicator.

A3) $\frac{Emergency\ repair\ time}{Total\ maintenance\ time}$

A3 gives the share of total maintenance time that is related to emergency repairs. The measure depends on the effectiveness of PM and the indicator should be as low as possible.

Strengths: A3 acts as feedback to the PM programme, since one of the main objectives for the PM programme is to prevent critical breakdowns.

Weaknesses: No indication on how many hours that are spent on emergency repairs is given. Even though the percentage is low it could still mean that far too many hours are spent on emergency repairs.

A4) $\frac{PM\ time}{Total\ maintenance\ time}$

A4 measures the effectiveness of the PM programme in the sense that if PM is a large percentage of the total maintenance time we have had very little CM. With little or no CM, PM has fulfilled its objective to prevent failures. This indicator should be high.

Strengths: Measures the effectiveness of PM.

Weaknesses: A4 gives a false positive if time spent on PM increases but the desired effect, decreased CM, does not occur. Another issue with the indicator is that it does not consider if PM is performed during planned operating time or when the vehicle is not intended for use.

A5) $\frac{Repair\ time}{Total\ maintenence\ time}$

A5 measures the share of total maintenance time that is related to repairs. The interpretation of this MPI can be troublesome, since it can be beneficial with both an increase and a decrease of the measure. An increase can be the effect of faults being detected before they cause breakdowns which results in more planned repairs which is positive. On the other hand a decrease in the MPI can be beneficial if it is the effect of more effective PM. It is thus important to study several MPI:s at the same time.

Strengths: Singles out repair time, a planned activity. If an activity is planned the negative impact on the hauler’s profitability is strongly limited. A5 measures the effectiveness of the PM programme.

Weaknesses: Difficult to interpret.

A6) $\frac{CBM\ time}{PM\ time}$

A6 emphasizes time spent on CBM in relation to time spent on PM. The MPI gives a measure of the share of PM that is dedicated to CBM. It is desired that A6 is high.

Strengths: Useful for following up the progresses made towards total CBM strategy.

Weaknesses: Difficulties in determining a suitable level for this MPI since some components could be unsuitable for CBM.

A7) $$\frac{\textit{Uptime}}{\textit{Number of maintenance occasions}}$$

The MPI, A7, shows how much uptime that is available between maintenance occasions on average. It gives the maintenance interval measured in uptime. It depends on the effectiveness of PM and should be as high as possible.

Strengths: The MPI gives a general view of how much uptime, on average, is obtained between maintenance occasions.

Weaknesses: No conclusions can be made about reliability since all kind of maintenance occasions are included. No information about the length of each maintenance occasion.

A8) $$\frac{\textit{Uptime}}{\textit{Number of PM occasions}}$$

The objective of A8 is to elucidate the amount of uptime between PM occasions and is thus the PM interval measured in uptime. It is desirable to have a large value of this MPI but it is more important to have a large value of A7.

Strengths: By measuring the average uptime between each PM occasion the efficiency of PM can be highlighted. Consolidation of PM occasions can lead to synergy effects especially if the fixed costs, linked to the occasions, are significant.

Weaknesses: Optimizing solely on this MPI could cause an increase in breakdowns, due to insufficient PM occasions. No information about the length of the PM occasions.

A9) $$\frac{\textit{Uptime}}{\textit{Number of emergency repair occasions}}$$

A9, known as MTTF, is a measure of the reliability of the vehicle and the greater the value the higher the reliability. The indicator gives the average uptime between two consecutive breakdowns. Since the PM programmes main focus is to ensure reliability of the vehicle this is a very useful way of measuring its effectiveness.

Strengths: Measures the likelihood of failures and gives a good measure of the vehicles' reliability.

Weaknesses: If the vehicle is not used during its uptime a high values of MTTF could be misleading.

A10) $$\frac{\text{Number of over due PM occasions}}{\text{Number of PM occasions}}$$

A10 measures if PM is performed as scheduled. The efficiency, motivation and skill set of PM staff, the ability to plan as well as the efficiency of the PM methods are measured. A low figure would represent that PM tasks are performed on time, reflecting that PM staff and methods are efficient.

Strengths: A good measure to follow up changes in PM efficiency, regarding e.g. PM staff training.

Weaknesses: Other factors like customer delays or cancelations can influence the indicator and result in false negative or positive signals. There are difficulties in exactly deriving changes, since these could depend on either staff or PM method. Rigorous methods and accuracy is required when measuring this MPI.

6.5 Customer Satisfaction Tree

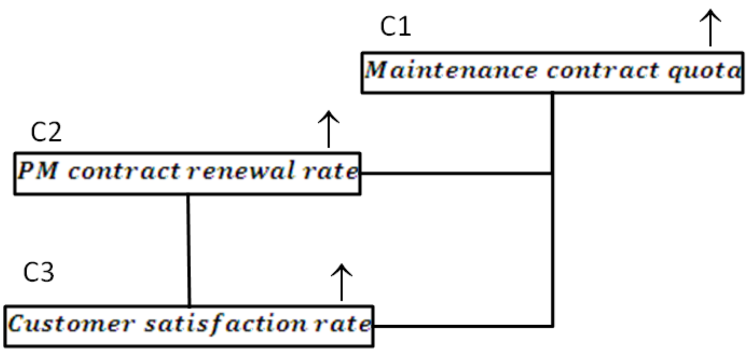

Figure 6.3 The arrows above each MPI represents whether a high or low value is desired for that MPI.

As mentioned previously, in Section 6.2, the customer satisfaction related MPI:s measure the external effectiveness of the workshop. It has the focus to validate whether the service products offered by the workshop are attractive to the hauler or not. C1, in Figure 6.3, measures the share of customers which has an active maintenance contract. If a large share of haulers chooses to sign a contract this is a validation that the offer is attractive to them. Many vehicles are sold with a PM contract and whether haulers renew their contracts or not is a good measure of the satisfaction with the contract. C2 captures this property. The final measure, C3, has customer satisfaction rate in mind. This MPI will be the result of a customer satisfaction survey and should ideally be designed to measure in detail what haulers are satisfied with and where improvements need to be made.

6.5.1 Description of MPI:s in the Customer Satisfaction Tree

The following section will in detail describe each of the MPI:s in the customer satisfaction tree. The description comprises what the MPI:s depend on, their strengths and their weaknesses.

C1) $\boldsymbol{Maintenance\ contract\ quota}$

C1 gives the share of vehicles with a maintenance contract. It measures the long term external effectiveness of the provided maintenance services. C1 reflects the hauler's satisfaction regarding maintenance.

Strengths: Measures the external effectiveness of the maintenance solution offered to haulers.

Weaknesses: The measure is blunt. It depends on both factors which the maintenance organization can influence and factors which generally cannot be influenced. Factors which can be influenced are e.g. the skill of sales representatives, flexibility regarding when the workshop is open for business and customized maintenance. Factors which generally cannot be influenced are e.g. distance to the workshop or if the haulers are fond of maintaining the vehicles themselves.

C2) $\boldsymbol{PM\ contract\ renewal\ rate}$

The share of renewed PM contracts is reflected by C2. The measure is intended to reflect the customer satisfaction for the maintenance services provided.

Strengths: Takes into consideration not only the competence of the workshop but also if the PM programme, as a whole, appeals to customers.

Weaknesses: Catches only the satisfaction of customers with a maintenance contract. Furthermore, the MPI is influenced, to some extent, by the skills of the service sales representatives. The effects of being good at selling a bad product will eventually catch up, especially since the MPI is focused on renewal. So the MPI will still reflect the need for improving the PM programme, but being bad at selling a good product can lead to wrongful conclusions about the performance of the PM programme.

C3) $\textit{Customer satisfaction rate}$

C3 highlights the general customer satisfaction, regarding maintenance services.

Strengths: Works as an organized feedback channel from customers. Has the ability to catch the demand and request from all customers.

Weaknesses: There lies a risk of a subjective perception instead of an objective evaluation. In other words, this measure can to some extent depend on the customer expectations and not the actual performance of the PM programme.

6.6 Sub Optimization and Interrelation

Figures 6.1-6.3 show the most fundamental relations between the MPI:s. However not all interrelations are shown in the figure, since almost all indicators have some kind of connection to each other. Each MPI is often dependent on several factors and it can thus be difficult to find the cause of a change in it. There is also a risk of sub optimization if only a few MPI:s are studied, as opposed to the entire set. By combining the information from several MPI:s sub optimization can be avoided and this section will discuss some of the pitfalls of sub optimization and also how the MPI:s interrelates.

The structure of the MPI trees has the logic that the higher in the tree the less detail in the indicators. The division of the MPI:s into three trees is not black and white and there are dependencies between the trees. Essentially those MPI:s dealing with time can easily be translated into costs and vice versa. The old saying *"time is money"* is very true in the hauler industry.

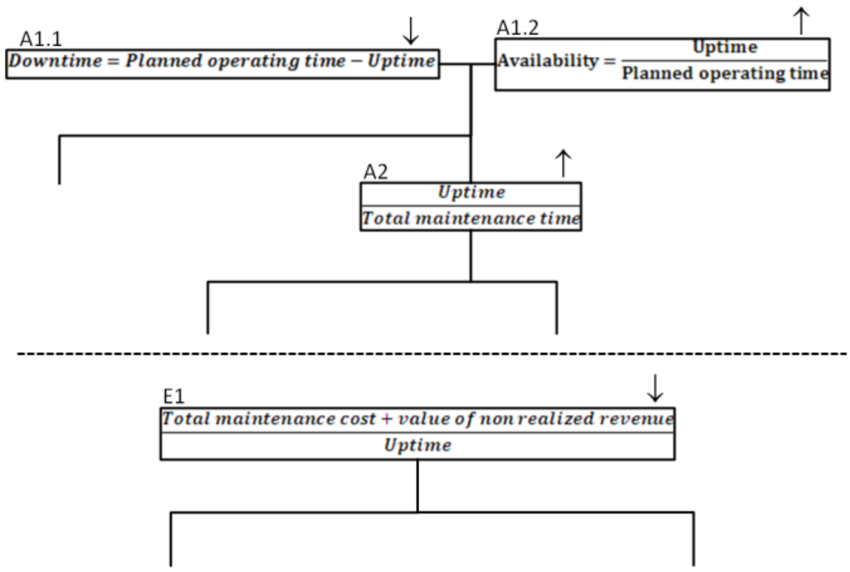

Figure 6.4 The top of the availability and economic trees.

Figure 6.4 shows the MPI:s found at the top of the economic and availability trees , E1, A1.1, A1.2, and A2. These MPI:s have many factors in common which is the case for many of the other MPI:s in the two trees. Usually they depend on the same factors but there are differences. By studying the difference between: A1.1, A1.2, and E1 conclusions on differences between other MPI:s in the two trees can be made. It is the structure of the MPI:s that enables these conclusions. Since all MPI:s are broken down from their main MPI, changes in the main MPI will present themselves in the lower hierarchy levels as well.

The main MPI:s depend on the efficiency and effectiveness of PM and they are affected by the total time spent on maintenance. Generally speaking an increase in A1.1, or a decrease in A1.2, is likely to induce a decrease in E1 and vice versa. However there are scenarios where changes appear as positive in one of the measures but a further study shows that there has in fact been a negative impact on profitability. Assume for instance that there has been a decrease in downtime, i.e. A1.1 has decreased. This is generally something good but there are scenarios that could induce a decrease in A1.1, which is not desired. It is possible to have the vehicle in the workshop hundreds of hours each year and at the same time have little or no downtime at all. If all maintenance activities are performed when the vehicle is not intended for use no downtime what so ever will be imposed. At the same time the invoices from the workshop will be very substantial and E1 is likely to be sky high. A decrease in A1.1, or an increase in A1.2, is thus only positive if it coincides with a decrease in E1.

A similar pitfall to the one just mentioned exists in the relationship between: A1.1, A1.2, and A2. The MPI:s A1.1 and A1.2 only takes those maintenance activities which occur during planned operating time into consideration while A2 disregards from when the maintenance activity takes place. If additional maintenance activities are introduced when the vehicle is not intended for use this will affect A2 negatively since the total time spent on maintenance will increase. At the same time A1.1 and A1.2 will remain unchanged since no additional downtime has been induced. Based on the two previous examples the conclusion becomes that A1.1 and A1.2 must never be interpreted on their own but should be combined with either E1 or A2.

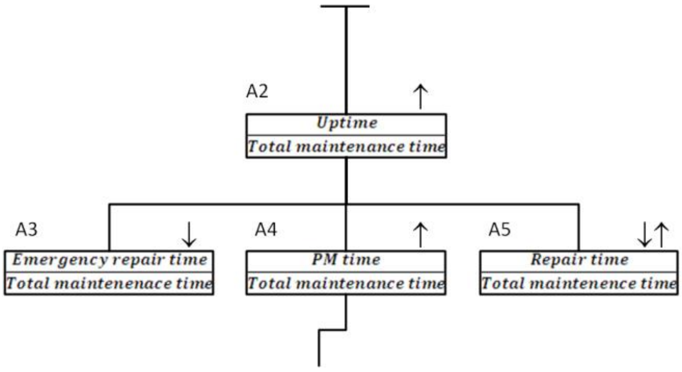

Figure 6.5 Breakdown of A2 into: emergency repair, PM, and repair.

Figure 6.5 shows MPI:s A2-A5 which gives a breakdown of the total time spent on emergency repairs, PM, and repairs. It is always desirable to have a large share of total workshop time made up of PM and a small share of emergency repairs. The share of time spent on repairs is however more difficult to interpret. If emergency repair hours are replaced with repair hours an increase in the share of repair hours, A5, is desired. If PM hours are replaced with repair hours it is highly undesired with an increase in A5. MPI A5 must therefore always be combined with A3 and A4 before making any conclusions. Jointly for indicators A3-A5 is the importance of looking at indicator A2. The uptime each workshop hour generates cannot become too small regardless of the distribution of workshop hours.

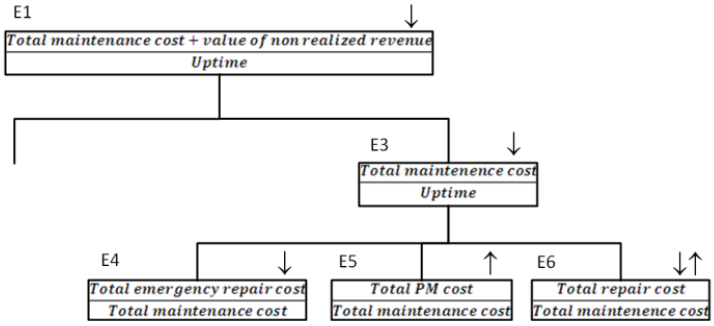

Figure 6.6 Selection of MPI:s from the economic tree.

A similar reasoning to the one above is valid when looking at E4-E6, shown in Figure 6.6. The share of costs associated with PM should be high while the share of costs associated with emergency repairs should be low. An increase in E6 is only good if it coincides with an unchanged or lower value of E1 and E3. As with the availability measures the most important thing is to make sure that E1 is as low as possible. Since not all costs depend on time it is not surprising to find differences in the distribution of time and the distribution of costs.

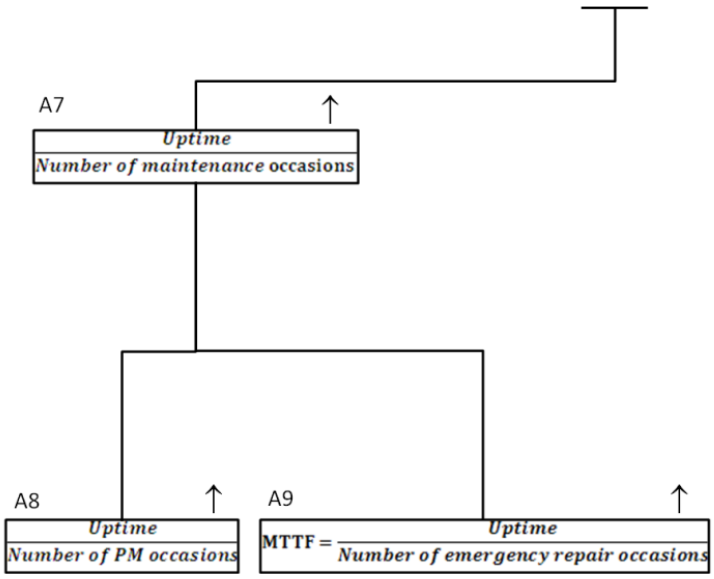

Figure 6.7 Occasion related MPI:s from the availability tree.

Figure 6.7 shows the MPI:s in the availability tree which deals with maintenance occasions. A7 indicates the average uptime between each maintenance occasion and this MPI should be as large as possible. However if the PM interval becomes too large there will be an increased probability of a breakdown occurring. The PM interval should therefore only be extended if A9 does not decrease. A7 functions as a balance between increasing A8 and the risk of a decrease in A9.

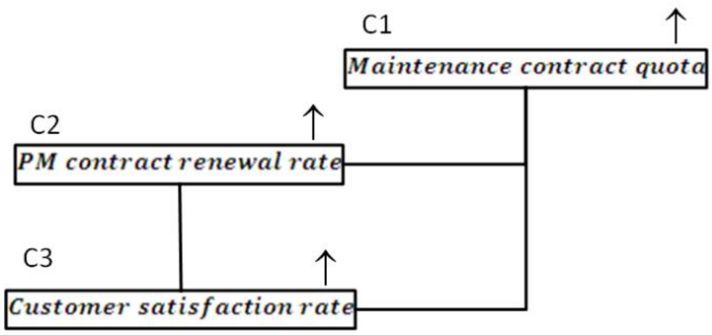

Figure 6.8 Customer satisfaction related MPI:s are highly dependent on each other.

Figure 6.8 shows those MPI:s which are related to customer satisfaction. The MPI:s related to customer satisfaction are highly dependent on each other. If the maintenance contract quota, C1, is high it is reasonable to believe that many customers are renewing their contracts when they expire, meaning that C2 should also be high. If a large share of customers are buying contracts and also renewing them, this should be an indication that they are satisfied with the product they are buying. However customer satisfaction is a highly relative measure and it depends on the expectations customer have on the products. A high value of C3 does not automatically mean that the PM programme is of high quality and neither does a low rating indicate that the PM programme is performing badly. The relative measure that C3 provides is still of great value since it indicates how good the workshops are at meeting customer expectations.

What the examples above have shown is that it is inappropriate to draw conclusions based on a single or even a few MPI:s. The trees presented in this project should be viewed as a measurement system and not as individual measures.

6.7 A Multi-Criteria Hierarchical Structure for Scania CV' MPI:s

While developing and identifying the MPI:s, a trade off between complexity and scope of the system has been a recurring issue. A high degree of complexity is followed by the risks of overburdening the users with information, thus making the system difficult to interpret and utilize. While an over simplified system, although being user friendly, may be unable to catch important aspects of what it is intended to measure. Although the tree structures in Figures 6.1-6.3 (also found in Appendix 3) facilitates the interpretation and interrelation of the MPI:s, there is a lack of overview of the system.

Section 4.7.5 introduces a multi-criteria hierarchical framework for MPM. The MPI:s developed can be organized in the framework, which provides a better overview of the MPI system. The ordering of the MPI:s, according to a multi-criteria hierarchical structure, will allow management at different levels to focus on MPI:s that concerns them directly. It reduces the risk of information overburdening management and at the same time an over simplification of the system is avoided. The different levels within the hierarchical structure should not be regarded as isolated silos. Besides making the system more user friendly, the structure aids the breakdown of strategic goals into objective targets for the maintenance managers. Figure 6.9 positions the MPI:s, presented in Sections 6.3-6.5, in a multi-criteria hierarchical structure (also found in Appendix 3).

Hierarchical level / Multi-criteria	Strategic level	Tactical level	Functional level
	Top management	Middle management	Operations / workshop
Economic related MPI:s	**E1, E3, E4**	**E1, E3, E4, E5, E6, E8**	**E7,E9**
Availability related MPI:s	**A1.1, A1.2, A2**	**A1.1, A1.2, A2, A3, A4, A5, A6, A7, A8, A9, A10**	**A10**
Customer satisfaction related MPI:s	**C1, C2, C3**	**C1, C2, C3**	**C1, C2, C3**

Figure 6.9 Multi-Criteria Hierarchical Structure for Scania CV' MPI:s. (Based on Parida 2007)

MPI:s positioned at the *strategic level* are of a comprehensive nature. They provide the *top management* with a holistic view of the performance of the PM programme. The MPI:s at the strategic level can also be used by top management for evaluating implemented maintenance strategies.

The *tactical level* refers to the *vehicle maintenance and support organization* within Scania CV. The *vehicle maintenance and support organization* is affected by MPI:s which are more detailed and deep going, but the more comprehensive MPI:s are also of interest. The extent of MPI:s designated for the *vehicle maintenance and support organization* is because of the decisive role the organization has regarding implementing and changing the PM programme.

The *functional level* is the workshop, i.e. where the actual maintenance takes place. The MPI:s, illustrated by Figure 6.9, positioned at the *functional* level are characterized by measuring local, i.e. on workshop or dealer company level, performance.

As seen in Figure 6.9 some of the MPI:s are positioned on several hierarchical levels. This is because these MPI:s are relevant for more than one hierarchical level and should therefore not be isolated to a single level. Especially customer satisfaction related MPI:s are equally important for all three hierarchical levels. The workshop in general, and the service sales representative in particular are affected directly by customer satisfaction related MPI:s, but more on a local customer level. The *tactical* and *strategic* levels are also affected by the customer satisfaction related MPI:s, but in their case it is on a regional level.

6.8 Measuring the MPI:s

When evaluating MPI:s, precision in the measures is of great importance. It is essential that the MPI:s shows what they are supposed to show and that they are not influenced by imprecise measures. This section will, as detailed as possible, set requirements on the measures that the MPI:s are built of to ensure that the correct information is going into the MPI:s. For some measures it will be extremely important to have exact figures while others will have more relaxed requirements.

Planned Operating Time

The measure *planned operating time* is used in MPI A1. Planned operating time represents the time that the hauler would like to use his vehicle. The problem with measuring this number lies in “would like”. Information about when the hauler wishes to use his vehicle is troublesome to attain with a high degree of accuracy. It is suggested that when customers sign maintenance contracts, information on when the vehicle is desired to be use is gathered. In addition, information about how many shifts the truck is intended to operate should be gathered. This information can be used not only with the purpose of measuring how the PM programme performs but also to assist the workshop in the planning of maintenance occasions.

Uptime and Downtime

The measure *uptime* is used in the following MPI:s: A1.2, A2, A7, A8, A9, E1, and E3 while the measure *downtime* is included in A1.1. Uptime and downtime are closely tied and both are of great importance. At the same time both measures are difficult to measure with high accuracy. It is important to capture even small changes to the measures since they can have a large impact on profitability. According to Section 4.5 uptime is defined according to Equation 6.2.

$$uptime = planned\ operating\ time - downtime$$

Equation 6.2

Every time a maintenance activity occurs during the planned operating time the vehicle will be subject to downtime. It is suggested that uptime and downtime shall be measured by registering which maintenance occasions that occur during planned operating time. The maintenance time for these occasions will then be total downtime. By subtracting downtime from planned operating time, uptime is finally obtained. Planned operating time shall be calculated as stated above.

Emergency Repair Time

The measure *emergency repair time* is used in MPI A3. Every minute after a breakdown occurs until the vehicle is back on road should be taken into consideration. Breakdowns due to traffic accidents should not be included in emergency repair time even though the assistance centre is involved in the situation. This delimitation is made since an accident does not in general depend on the PM programme.

Repair Time

The measure *repair time* is used in MPI A5. The repair time includes all time related to repair occasions, including time to and from the workshop as well as waiting time.

PM Time

The measure *PM time* is used in MPI A4. PM time consist of all time related to PM occasions, including the travel to and from the workshop as well as waiting time.

CBM Time

The measure *CBM time* is used in MPI A6. The CBM time is a subset of PM time. As the term indicates it is time used for CBM activities. It is suggested that activities in the workshop are classified based on if they are condition based or not.

Note: CBM time does not include waiting time and time spent travelling to and from the workshop. Total CBM strategy does not mean that A6 has a value of 1. Instead total CBM strategy is reached much sooner depending on the time spent on travelling to and from the workshop.

Total Maintenance Time

The measure *total maintenance time* is used in the following MPI:s A2-A5. In total maintenance time both planned and unplanned maintenance are included or alternatively expressed: emergency repair time, repair time, and PM time. The actual time associated with the maintenance activity, and not only the invoiced time from the workshop, should be considered as maintenance time. The term *actual time* includes every single minute dedicated to the maintenance occasions, regardless if it is the travelling time to and from the workshop or the total time for an on-call emergency action.

Number of Maintenance Occasions

The measure *number of maintenance occasions* is used in MPI A7. It is the total number of maintenance occasions during a specific period of time. It includes all maintenance activities that are performed in the workshop as well as those emergency repairs that are being performed on the road when a vehicle has suffered a breakdown. It does however not include the daily or weekly inspections that the driver performs on the vehicle.

When two maintenance occasions occur immediately after each other it should be regarded as one occasion. This is because the costs of getting to and from the workshop only occur once.

Number of PM Occasions

The measure *number of PM occasions* is used in MPI:s: A8 and A10. The number of PM occasions is straightforward to measure. It is all PM occasions during a specific period of time for a vehicle. It does not include daily or weekly inspections that are carried out by the driver. If a PM occasion is split in two it should be considered as two occasions.

Number of Emergency Repair Occasions

The measure *number of emergency repair occasions* is used in MPI A9. As with the number of PM occasions this measure is straightforward to measure. It entails all emergency repairs that are defined as an unplanned CM occasion. If several faults are corrected at one single occasion this shall be considered as one occasion.

Number of Overdue PM Occasions

The measure *number of overdue PM occasions* is used in MPI A10. As soon as a PM occasion is not finished within the scheduled time it will be considered to be an overdue PM occasion. If the PM occasion give rise to a CM occasion immediately after the PM occasion this shall not be considered as an overdue. It is suggested that the workshop keeps notes on overdue PM occasions.

Value of Non-realized Revenue

The measure *Value of non-realized revenue* is used in the following MPI:s: E1 and E2. There are challenges in how to measure the value of non-realized revenue. They mainly depend on the fact that non-realized revenue is an estimation of the value that is lost during downtime. Efforts have been made to generalize this measure in order to give an estimate of the true value. Equation 6.1 presents the theoretical formula for calculating the value of non-realized revenue and Equation 6.3 presents the approximation.

$$value\ of\ non\text{-}realized\ revenue = downtime * (revenue\ per\ hour - variable\ cost\ per\ hour)$$

Equation 6.3

The variable cost per hour can both include and exclude driver costs depending on the situation. It is suggested that the value of non-realized revenue should be estimated by calculating the average costs and revenue that a vehicle has per time unit. These values shall then be used to calculate the value of non-realized revenue according to Equation 6.3. Section 6.1.3 has a detailed description on how to calculate average costs and revenue.

Total PM Cost

The measure *total PM cost* is used in MPI E5. Total PM cost is comprised of the workshop invoices which can be derived to the PM occasion.

Note: There are additional costs, as stated in Section 6.1.1, which can be derived to PM occasions. Measuring these costs is extremely hard if not impossible, due to the wide range which these cost can occur in. Hence, they are not included in the MPI measure.

Total Repair Cost

The measure *total repair cost* is used in MPI E6. The measure consists of the workshop invoice associated with repair occasions.

Note: The additional cost, as mentioned in Section 6.1.1, which can be linked to repair occasions are not included. The same reasoning is applied as for total PM cost, measuring the additional costs are extremely hard if not impossible.

Total Emergency Repair Cost

The measure *total emergency repair cost* is used in MPI E4. In the same way as the two previously mentioned measures, total PM and repair cost, the total emergency repair cost consists of the workshop invoice. There are however dissimilarities regarding the additional costs. The charging of emergency assistance fee as well as potential costs for towing and for a replacement vehicle should be included in total emergency repair cost. The main reason for including these costs is the high likelihood that some of them occur and that they are possible to measure. They also comprise a considerable amount of the total cost and it would be misleading to exclude them.

Total Maintenance Cost

The measure *total maintenance cost* is used in MPI:s E2-E6. The cost measures described above, total PM cost, total repair cost and total emergency repair cost, are all subsets of total maintenance cost. Consequently total maintenance cost is the sum of these three costs.

Total Work Orders

The measure *total work orders* is used in MPI E7. All work orders that involve a CM activity shall be included in total work orders. Several work orders can be performed during the same maintenance occasion and it is of great importance that each job is included in the total number.

Work Orders From PM

The measure *work orders from PM* is used in MPI E7. Every time a PM occasion give rise to a CM work order this should be recorded. Faults that are detected during PM and does not give rise to a work order should not be included in the measure.

Number of Top Ten Breakdowns Inspected During PM

The measure *number of top Ten breakdowns inspected during PM* is used in MPI E8. Data should be gathered on which components fail most frequently. It should then be investigated which of these that are inspected during PM.

PM Training Time

The measure *PM training time* is used in MPI E9. The total amount of time dedicated for training and education of PM personnel is to be recorded and summed up.

Maintenance Contract Quota

The measure *maintenance contract quota* is used in MPI C1. It should measure the share of vehicle stock with an active maintenance contract. There should be a limit for the age of the stock. A proposed limit is to measure the five year vehicle stock; this proposal is a result from interviews with service sales representatives.

PM Contract Renewal Rate

The measure *PM contract renewal rate* is used in MPI C2. The measure entails all vehicles with contracts that are signed when the vehicle is new and that expire before the vehicle is five years old. The renewal rate is then defined as the share of customers that chooses to renew their contracts when they expire.

Customer Satisfaction Rate

The measure *customer satisfaction rate* is used in MPI C3. The basis for the customer satisfaction rate should be designed to consider multiple aspects of the maintenance services offered. Questions relevant for improving the performance of PM and maintenance as a whole should be included e.g. workshop opening hours and technical aspects of the PM programme.

7 How the MPI system is used

The MPI system can be utilized in several different ways some of which include evaluation of a PM programme and development of it. In Chapter 7 examples are illustrating how the MPI system can be used to develop and evaluate Scania CV' PM programme.

7.1 Time Frame and Scope

When using the MPI system it is of great importance to be consistent with the choice of time frame and the set of vehicles or companies. The time frame can be chosen to be anything from a month to several years, as long as all data going in to the MPI:s cover the same period of time. The vehicles or companies that are studied can also be chosen freely as long as all MPI:s are based on the same data.

It should be stressed once more that the level of detail and accuracy in the data going in to the MPI system is of the utmost importance. The level of detail will be decisive for whether changes to the MPI:s are the result from actual changes to the PM programme or just variances in the data going in to the MPI:s.

7.2 Evaluation

Evaluation of the present PM programme is one important field of use for the MPI system. One evaluation method is to measure the past performance of the PM programme, for instance last year's performance. The objective is to evaluate whether the performance has been satisfactory or not.

The method of evaluating past performance starts with defining the time frame and scope which is of interest to study. The next step is to define how each MPI should be measured. Section 6.8 contains recommendations on how to measure each of the measures used in the MPI:s. Some measures are necessary to approximate since their nature does not allow for them to be measured, value of non-realized revenue is an example of such an MPI. After the measures are defined, data collection is performed. It is important to make sure that what is intended to be measured is actually measured. Once data has been collected it has to be processed and subsequently MPI:s are calculated.

To interpret results it is recommended to recurrently evaluate the PM programme based on the same vehicles or companies. Since there are great differences in maintenance needs among vehicles, it is of great importance that the choice of vehicles or companies remains consistent from evaluation to evaluation. A comparison between the segments *full load haulage* and *construction over short distances* would present large differences in all MPI:s. Not because the PM programme has changed but since the maintenance need is vastly different between the two segments. The choice of vehicles could for instance be to choose all vehicles that are used for long distance haulage in Sweden. Even though the vehicles are not the same from year to year it is reasonable to believe that they are representative for the segment.

7.3 Development

The MPI system can also be used to develop the PM programme and to see if proposed changes will have the desired effect on the hauler's profitability. Since development concerns suggested changes there is no data available. Assumptions are thus necessary to make in order to be able to calculate the MPI:s. These assumptions vary depending on what changes are being proposed. In Sections 7.5.1-7.5.2 two changes are proposed and assumptions on their effects are made. A suggested mode of procedure is to start with an evaluation of the present PM programme to get a baseline for the development. Assumptions on what effects the proposed changes will have on the MPI:s will then have to be made. Depending on the changes proposed the assumptions will be more or less troublesome to make.

Another approach is to base changes in the PM programme on an evaluation from the MPI system. Those MPI:s that has stood out as weak points in the evaluation are suggested to focus on. The findings from the MPI system cannot be used to say anything about what should be done in order to make improvements. However, by studying the MPI:s in the lower hierarchy levels the problem can be sufficiently narrowed down.

7.4 Application of the MPI system

Below follows an evaluation and a couple of examples that will clarify how changes to the PM programme affects the different MPI:s. The examples are designed to show both the interrelation between MPI:s as well as to give a picture of how to use the MPI system to evaluate and develop the PM programme.

7.4.1 Vehicle specification

The data that forms the basis for the evaluation is gathered from Scania CV' maintenance database. The vehicles chosen are commonly used in the segment *Full load haulage* and the evaluation is thus illustrative for this segment. Figure 7.1 shows a picture of the specified truck which usually pulls a trailer. The selection of vehicles is based on the following requirements:

- Truck used for long haulage transport assignments
- Yearly distance covered 100 000-300 000 km
- Truck with three axles, where one is a driving axle (6x2)

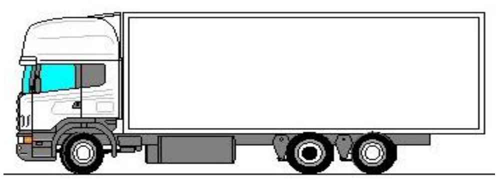

Figure 7.1 This type of truck usually pulls a trailer and the maximum gross weight of the truck rig is 60 tons.

- Truck delivered to customer during 2004
- Truck with a *Green card contract*
- Truck sold in Sweden

There are a total of 15 vehicles which fulfil the requirements above, and the data used in the evaluation will be averages of the data collected from these vehicles. The data is collected for the first four years of operation and the data used is an average over those years.

7.4.2 Calculations

Section 6.8 describes how each of the measures used in the MPI:s should be measured or approximated. Some of the measures required are not measured by Scania CV today, in these cases assumptions and approximations are used to calculate the MPI:s. Those approximations will be presented and described in this section. For all other measures the description in Section 6.8 are valid.

In the collected data, costs are classified as being related either to PM or CM. There are however discrepancies in the collected data, on several occasions costs that are obviously not PM related, such as towing, assistance fees etc., are classified as PM costs. This discrepancy has been corrected to give a correct picture of the distribution of costs.

Changes to the Availability Tree

The measures *PM time*, *Repair time*, *Emergency repair time* and *Total maintenance time* are not measured today. However, the invoiced workshop labour cost is measured and by using the known hourly workshop labour rate the number of invoiced workshop hours can be calculated. The number of invoiced hours will serve as an approximation for the different maintenance activities. The effect of this approximation is that possible waiting time for performing maintenance is not included, as well as the time it takes to transport the vehicle to and from the workshop. This issue will be addressed by adding an extra hour for each maintenance occasion.

The workshop labour cost is not divided into emergency repair and repair and it is thus not possible to calculate them separately. In the examples below, MPI:s A3 and A5 will be replaced by

$$\boldsymbol{A35} = \frac{\boldsymbol{CM\ time}}{\boldsymbol{Total\ maintenance\ time}}.$$

The measure *Number of emergency repair occasions* is replaced by *Number of CM occasions*. MPI A9.1 will in the evaluation be defined as

$$\boldsymbol{A9.1} = \frac{\boldsymbol{Uptime}}{\boldsymbol{Number\ of\ CM\ occasions}}.$$

The measure *Planned operating time* is not measured today and in the examples the approximation from Section 5.7.1 will be used. It will be assumed that each shift the truck operates has a planned operating time of 1716 hours. The average amount of shifts each truck operates has to be approximated. The yearly distance the studied vehicles are covering each year is 177 820 km. It is assumed that a driver operating a long haulage vehicle has an average speed of 70 km/h which enables the driver to cover 120 000 km each year. The conclusion is that the vehicles studied are operating 1,5 (177 820/120 000 = 1,5) shifts on average, which translates to 2574 hours of planned operating time per vehicle and year.

It is further assumed that 75 % of all maintenance activities have occurred during the planned operating time and the measure *Downtime* will thus be 75 % of *Total maintenance time*. *Uptime* can now easily be obtained by subtracting *Downtime* from *Planned operating time*.

Changes to the Economic Tree

The measures *Emergency repair cost* and *Repair cost* are not measured separately by Scania CV and MPI:s E4 and E6 are thus replaced by

$$\boldsymbol{E46 = \frac{CM\ cost}{Total\ maintenance\ cost}}.$$

The measures *Work orders from PM* and *Number of PM personnel* are not measured today, and an adequate way to approximate these measures has not been found. MPI:s E7 and E9 will thus not be included in the evaluation and examples in Section 7.5.

Changes to the Customer Satisfaction Tree

None of the measures in the customer satisfaction tree are adequately measured today, and thus the MPI:s in the Customer satisfaction tree are not included in the example and evaluation in Section 7.5.

7.5 Evaluation of Scania CV' PM Programme

The evaluation of Scania CV' present PM programme is based on the vehicles presented in Section 7.4.1. Sections 6.8 and 7.4.2 describe how the measures have been calculated. Since not all MPI:s can be calculated, and the number of vehicles is small, from a statistical stand point, the evaluation should not be considered to be representative for Scania CV' PM programme. Sections 7.5.1 and 7.5.2 will illustrate how two different changes in the PM programme impacts the system of MPI:s.

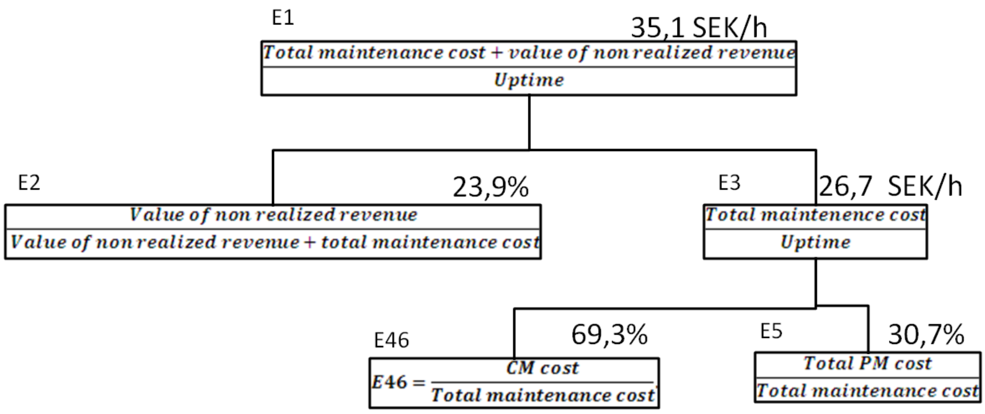

Figure 7.2 Evaluation of MPI:s in the economic tree.

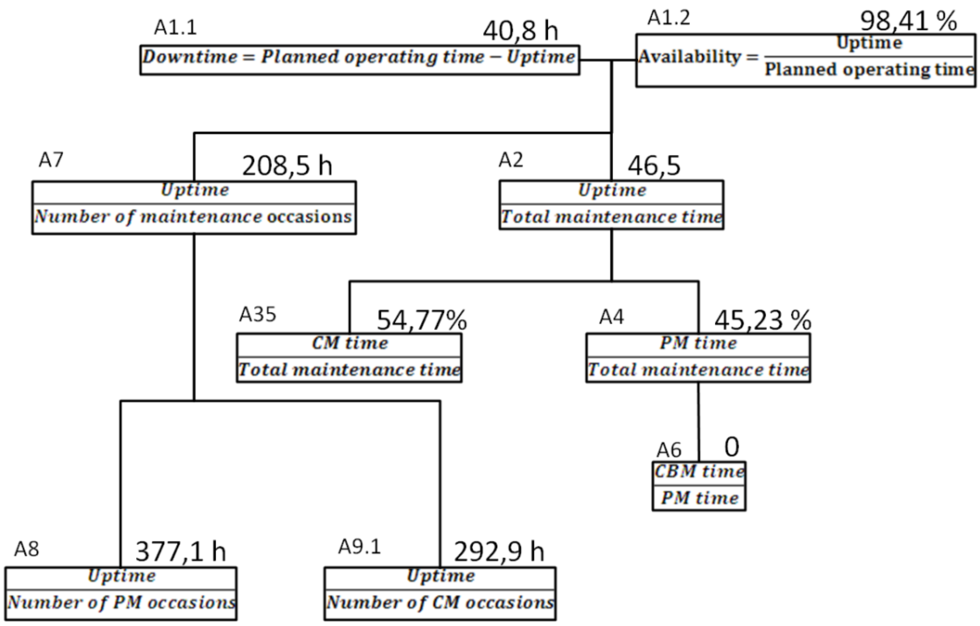

Figure 7.3 Evaluation of MPI:s in the availability tree.

Figures 7.2 and 7.3 represent the present performance of the PM programme. Since no evaluation of this kind has been made previously it is difficult to say if the performance is good or bad. There is however certain remarks that can be made based on the MPI:s in Figures 7.2 and 7.3.

It is striking that the share of CM time is larger than the share of PM time. A well functioning PM programme has the objective of reducing the need for CM and Scania CV' current PM programme does not reach a desired distribution of time. The share of cost related to CM is larger than the share of time related to CM which leads to the conclusion that each hour of CM is more expensive than each hour of PM. The difference lies both in the hourly rate but also in the material cost. Other costs, such as towing, are also present in connection to CM.

The value of non-realized revenue constitutes 29,6 % of the total value that is lost due to maintenance, MPI E2. This number should be considered with caution since it depends to a large extent on the share of maintenance occasions that occur when the vehicle is not intended for use. In the evaluation it has been assumed that 25 % of maintenance occasions take place when the vehicle is not intended for use and the value of E2 is a result of this.

Between each workshop visit there are 208,5 hours of uptime available, indicated by MPI A7. This means that there are roughly five full work weeks between each workshop visit. If MPI:s A8 and A9.1 are studied it can be seen that CM occasions are more frequent than PM occasions. There is an average of 377,1 hours between each PM occasion and only 292,9 hours between each CM occasion, indicated by MPI:s .

The selection of vehicles which have had a contract for five years is too small to include in this evaluation. But, it should be noted that the fifth year of operation is likely to show a substantial increase in CM cost.

7.5.1 Adding an Extra PM Occasion

We will now study the effect of a set of changes in the PM programme. An extra PM occasion is added to the PM programme. It is assumed that the occasion takes place when the vehicle is not intended for use, thus no additional downtime or non-realized revenue is imposed. Furthermore, it is assumed that the duration of the extra occasion is three hours, plus one extra hour to transport the vehicle to and from the workshop. The total material and hourly costs for the PM occasion is assumed to be 5000 SEK. The objective of the extra PM occasion is to reduce the amount of CM, but it is assumed that the objective is not achieved, i.e. there is no reduction in CM. Figures 7.4 and 7.5 show the new MPI trees after the extra occasion has been added. Those MPI:s that have changed due to the extra PM occasion are indicated with ↑ if they have increased and with ↓ if they have decreased.

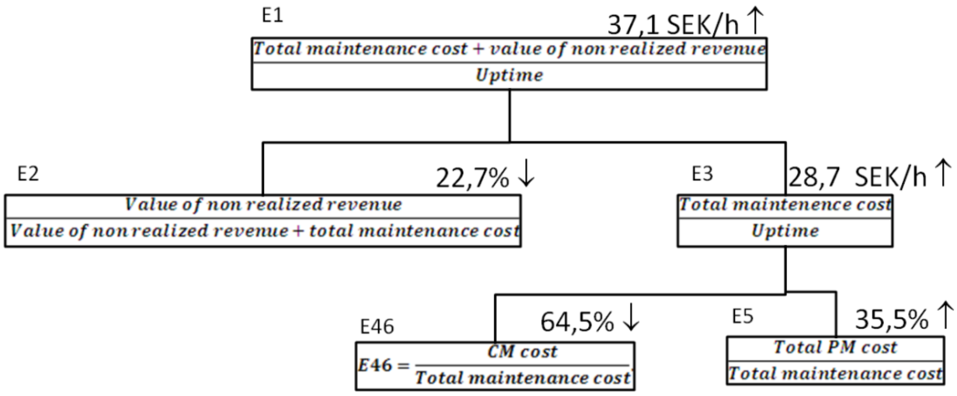

Figure 7.4 Economic tree after an extra PM occasion has been added.

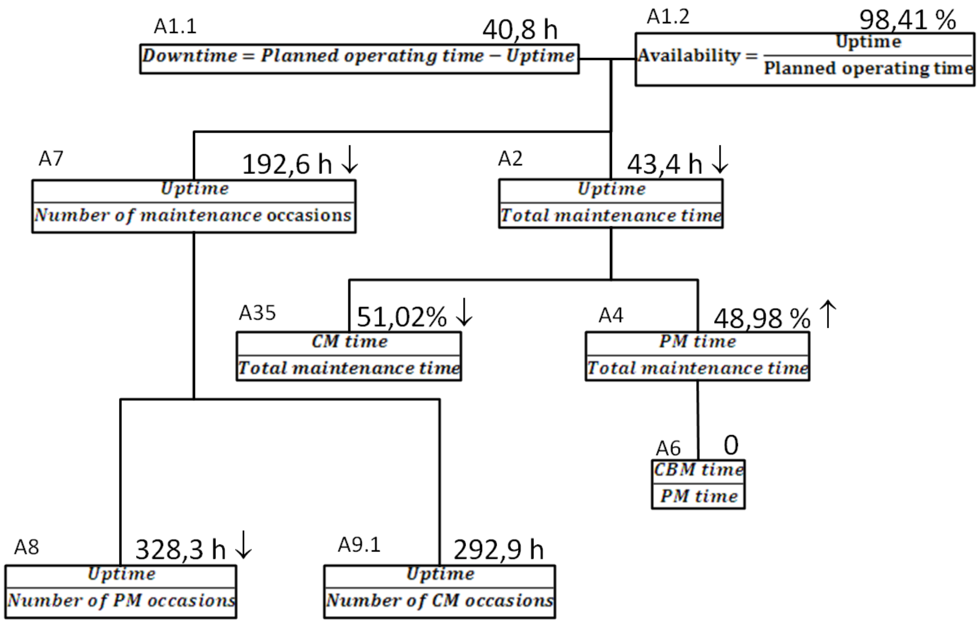

Figure 7.5 Availability tree after an extra PM occasion has been added.

It can be seen that both *Downtime*, A1.1, and *Availability*, A1.2, are unchanged. At the same time there has been an increase in E1 and a decrease in A2 which are both undesired effects. If the MPI:s A35, and E46 are studied it can be seen that the share of time and cost related to CM has decreased. This is usually something good but in this particular case it is the result of a PM programme that performs worse. Looking at MPI:s A7 and A8 it can be seen that they have both decreased. This is due to the extra PM occasion which makes the average uptime between maintenance occasions shorter.

By adding an extra PM occasion, which does not improve the reliability of the vehicle, several of the pitfalls presented in Section 6.6 are illustrated. Even though some MPI:s has shown improvements (A35, A4, and E2), the overall performance of the PM programme has decreased making the hauler company worse off. The conclusion is the same as in Section 6.6, that A1.1 and A1.2 should never be interpreted without looking at E2 or A2. Changes in the distribution of time and cost should never be interpreted without studying A2 and E2 respectively.

When adding extra PM occasions, or extra inspection points, it is important that they actually increase the reliability of the vehicle. If the characteristics of a component does not easily allow for detection of tear and wear it might not be suitable to inspect that component. On the other hand, components where tear and wear can be detected with ease are more suited to inspect during PM.

7.5.2 Impact of More Effective PM

In the following section a scenario is presented where the effectiveness of the PM programme has been increased. The amount of PM occasions is the same, but it is assumed that the increased effectiveness of the PM programme results in a decrease in the duration and number of CM occasions. Moreover, it is assumed that the number CM occasions has decreased by one occasion and the total time spent on CM has decreased with four hours, all this as a result of more effective PM. The four hours CM were previously conducted during planned operating time, thus downtime decreases by four hours in the scenario. Furthermore, it is assumed that the reduction in CM results in a decreased CM cost by 10 000 SEK. As a consequence of eliminating four hours downtime the value of non-realized revenue decreases with 2088 SEK. The arrows in Figures 7.6 and 7.7 illustrate the changes that have occurred relative to Figures 7.2 and 7.3.

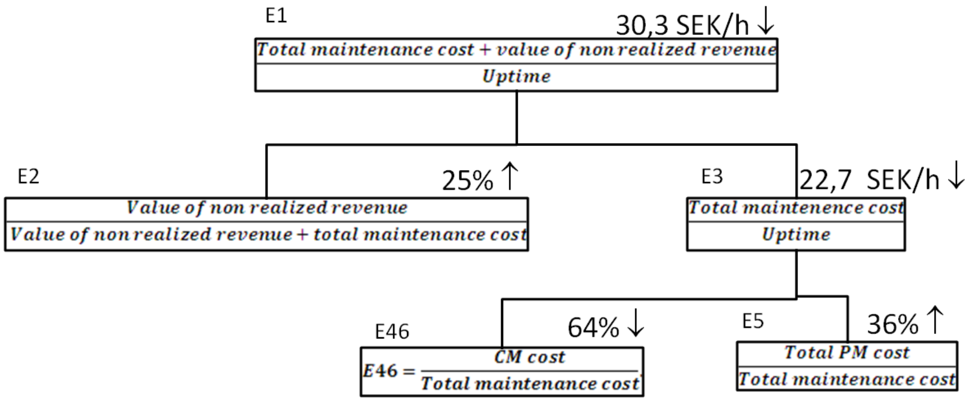

Figure 7.6 Economic tree after an increased PM effectiveness.

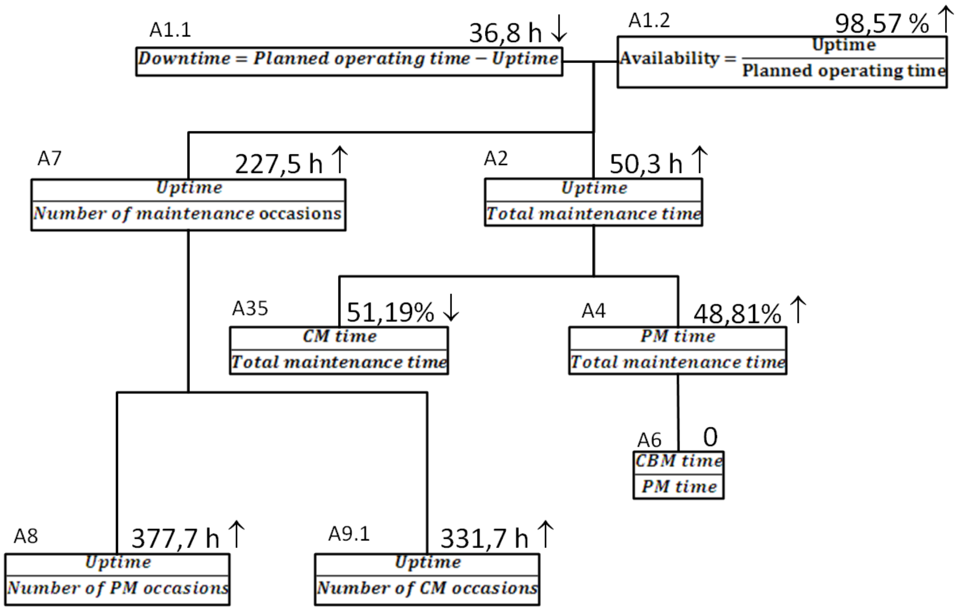

Figure 7.7 Availability tree after an increased PM effectiveness.

MPI:s A1.1 and A1.2 have both improved and there is now more availability and consequently less downtime. The change in availability is 0,16 percentage points, corresponding to a four hour decrease in downtime. This demonstrates what has been brought to light in Section 6.4.1, that small changes in availability correspond to significant changes in downtime.

A2 has also shown improvement and there is now more uptime available for each hour of maintenance performed. The share of cost and time related to CM has decreased as a result of less CM, due to more effective PM. Looking at A35 and A4 it can be seen that the total maintenance time is almost evenly distributed between CM and PM. However, the distribution of cost still has a large weight towards CM.

The value lost due to maintenance, E1, has decreased from 35,1 SEK/h to 30,3 SEK/h which is a substantial improvement. E3 has shown similar improvements and has decreased from 26,7 SEK/h to 22,7 SEK/h. MPI E2 has increased slightly from 23,9 % to 25 % and the value of non-realized revenue now comprises a larger share of E1 than before. An increase in E2 is generally something undesired but in this case it has not signified any loss. The percentage decrease in CM cost was larger than that of value of non-realized revenue and E2 has thus increased.

Finally MPI:s A7-A9.1 have all improved and there is now more uptime available between each workshop visit. There is a slight improvement of A8, even though there have not been any changes to the number of PM occasions, due to the increase in uptime.

8 Conclusions

The purpose of this Chapter is to summarize the findings based on the analysis in Chapter 6. The critical findings which give answer to the overall purpose of the project are highlighted and based on these findings further recommendation are presented. The chapter is finalized by the identification of interesting fields for further research.

8.1 Purpose

As a reminder of the projects purpose a brief summary is presented below.

The overall purpose of the project is to find an answer to the question: *How does one measure the performance of preventive maintenance for heavy trucks?*, i.e. the project was initiated in order to develop tools for measuring the performance of PM. Crystallizing the goals of the project results in the following points:

- Develop a set of MPI:s, which forms a system that measures the performance of PM, from a LCP perspective
- Inference on how to measure the set of MPI:s
- Evaluate Scania CV' present PM programme according to the developed measurement system

8.2 Findings

In the development of the MPI system the project has found three main MPI criteria: *economic, availability* and *customer satisfaction* related MPI:s. Furthermore the project has come to the conclusion that scrutinizing the MPI:s separately can result in sub-optimization or wrongful conclusions of the PM programmes performance. A comprehensive view is required when regarding the system. The *economic* and *availability* based MPI:s measure the performance of the PM programme from the hauler's perspective. The *economic* and *availability* MPI:s have been chosen based on if what they are measuring will affect the hauler's profitability. The LCP perspective is a suitable foundation for measuring the performance of a PM programme, since a hauler procures a truck in order to generate profit for his or her business. Consequently the LCP perspective is one of the cornerstones when measuring the effects on the hauler's profitability. Besides the costs which can be directly referred to maintenance the LCP perspective also takes the *value* of non-realized revenue, occurring due to maintenance, into consideration. The *customer satisfaction* based MPI:s are on the other hand a validation of the external effectiveness of the PM programme i.e. how the hauler perceives the PM programme. Moreover the MPI system has been ordered according to a multi-criteria hierarchical structure. This structuring provides a better overview of the MPI:s, allowing management at different levels to focus on MPI:s which concern them directly, thus reducing the risk of information overburdening.

When developing the MPI system the authors strived to have an unbiased approach. In the initial stage of the MPI system development the authors disregarded if the measures used in the MPI:s seamed difficult to measure, as long as they were not impossible to measure. The unbiased approach allowed the project to fully focus on the objective of the MPI system, developing a system that measures the performance of PM. The difficulties of measuring certain measures did not disappear just because the project disregarded from them. There are crucial measures which will always have difficulties regarding their measuring process, irrespectively of resources or efforts invested in the measuring process. An example of measures being difficult to measure is *uptime* and *downtime,* which are closely tied and both of great importance to the MPI system. The accuracy issues with *uptime* and *downtime* can be derived to the measure: *planned operating time*, of which *uptime* and *downtime* depend on, as seen in Section 6.4.1. The problem with *planned operating time* is that the measure is of a very subjective character. Primary data about when the hauler *wishes* to use his or her vehicle is troublesome to attain with a high degree of accuracy.

The projects evaluation of Scania CV' present PM programme is not fully adequate, although the evaluation points out certain tendencies of the PM programmes performance.

The inadequacy is due to several factors:

I. Some of the measure used by the MPI system are not recorded by Scania CV and as a consequence it is not possible to acquire a comprehensive view of the MPI system

II. The project found discrepancy, as explained in Section 7.4.2, in some of the data which were recorded

III. The data, which the evaluation is based on, comprise of too few trucks, which raises questions about the statistical significance of the evaluation

If the factors I-III was addressed both the reliability and validity, of the evaluation of Scania CV' present PM programme, would increase. However some issues would still remain. Firstly, when using the MPI system it is important that the data sample is consistent with the samples used in previous evaluations, regarding truck segment mix and various other factors. Secondly, as far as the project knows, there have not been any previous evaluations of this kind, regarding Scania CV' PM programme. Despite the pitfalls mentioned in Sections 6.6 and 7.4.3, the MPI system does what it is supposed to, *measure the performance of preventive maintenance for heavy trucks*, but there is nothing to compare or benchmark the results against.

8.3 Recommendations

In order to manage maintenance it is of importance to measure maintenance. Therefore the project has a number of recommendations for Scania CV, regarding further proceedings in measuring the performance of PM for heavy trucks.

I. Scania CV should start collecting data of the measures, identified in Section 6.8

II. The data discrepancies mentioned in Section 7.4.2 should be eliminated

III. In order to track the progress of PM performance, routines should be implemented for reoccurring evaluation of the PM programme

IV. The possibilities for benchmarking, based on the MPI system, against one or several competitors should be investigated and performed if possible. Collaboration with the competitor subject for benchmarking increases the feasibility of this recommendation, due to the sensitive nature of the data required by the MPI system

8.4 For Further Research

The scope of the project was limited to the Swedish heavy truck market, with a focus on Scania truck owners. Therefore it would be of interest to study if the MPI system could be applicable on other markets than the Swedish and if the MPI system could be valid for other truck brands.

Besides manufacturing heavy trucks, Scania CV also manufactures buses and engines for industrial and marine use. Consequently it is of interest to conduct similar projects, i.e. projects that study how to measure the performance of PM, regarding buses and engines for industrial and marine use.

Further studies about alternative ways to define and measure *planned operating time* would be of interest.

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Interview subjects

All interview subjects are presented in the list below.

Service sales representatives

Andersson, Anders, *Service sales representative*, Scania-Bilar Sverige AB, 2010-10-27

Andersson, Lennart, *Service sales representative*, Motor AB Halland, 2010-10-27

Blom, Mikael, *Service sales representative*, Skellefteå Tunga Fordon AB, 2010-10-22

Eldholm, Jörgen, *Service sales representative*, Scania-Bilar Sverige AB, 2010-10-26

Johansson, Jesper, *Service sales representative*, Berner&Co Tunga Fordon AB, 2010-10-19

Lövgren, Kjell, *Service sales representative*, Scania-Bilar Sverige AB, 2010-10-25

Nyholm, Tom, *Service sales representative*, Scania-Bilar Sverige AB, 2010-10-27

Olsson, Magnus, *Service sales representative*, Visby Tunga Fordon AB, 2010-11-01

Persson, Jörgen, *Service sales representative*, Müllers Lastbilar AB, 2010-10-20

Raba, Raoul, *Service sales representative*, Atteviks Lastvagnar AB, 2010-10-26

Sundström, Roland, *Service sales representative*, Bilmetro Lastbilar AB, 2010-10-25

Wahlbäck, Mikael, *Service sales representative*, Bilmetro Lastbilar AB, 2010-10-12

Haulers

Andersson, Holger, *Chairman of the Board*, H & J Anderssons Transport AB, 2010-12-08

Bogeling, Jeff, *CEO*, Länna Internationella Transporter AB, 2010-11-24

Condrup, Christer, *Operations Manager*, Bring Frigo AB, 2011-01-10

Larsson, Björn, *Owner*, Göte Larsson Transport HB, 2010-12-13

Others

Almér, Thomas, *Technical Manager – R&M and Uptime*, Scania CV AB, 2010-09-07

Andersson, Björn, *Head of Quality Information*, Scania CV AB, 2010-10-15

Björklund, Jan, *Project Director*, Scania CV AB, 2010-09-08

Egerhag, Sven, *Senior Engineer Maintenance Programme*, Scania CV AB, several occasions

Eriksson, Anders, *Regional Manager*, DynaMate Industrial Services AB, 2010-11-03

Eriksson, Joakim, *Product Manager, Forestry*, Scania CV AB, 2010-10-21

Eriksson, Markus, Function Specialist, Scania CV AB, 2010-09-23

Frånlund, Jan, *President*, Föreningen underhållsteknik, Utek, 2010-12-02

Grimpe, Sandro, *Servicemarket Manager*, Scania-Bilar Sverige, 2010-11-23

Grufman, Lars, *Commercial Manager Scania Assistance*, Scania CV AB, 2010-11-05

Gustavsson, Anders, *Managing Director*, Scania Transportlaboratorium AB, 2010-09-09

Johansson, Göran, *Senior Technical Advisor*, Scania CV AB, 2010-12-16

Johansson, Mårten, *Technical Manager*, Sveriges Åkeriföretag, 2010-11-08

Johansson, Per-Erik, *Senior Consultant*, DynaMate Industrial Services AB, 2010-11-03

Lindqvist, Ann, *Senior Engineer*, Scania CV AB, 2010-09-28

Olofsson, Klas, *Development Engineer*, Scania CV AB, 2010-09-10

Orre, Sigvard, *Strategic Marketing Director*, Scania CV AB, 2010-10-21

Pernestål, Anna, *Project Manager*, Scania CV AB, several occasions

Raab-Åhl, Susanne, *Business Concept Manager*, Scania CV AB, 2010-09-08

Smitt, Sofia, *Product Manager*, Scania CV AB, 2010-10-01

Sörensen, Sten, *Business Concept Manager*, Scania CV AB, 2010-09-08

Appendix 1 – Interview Questions for Service Sales Representatives

All of the interviews were conducted in Swedish which is why the questions are presented in Swedish. A total of twelve interviews were conducted with service sales representatives. All interview subjects received the interview questions before hand and all twelve interviews were recorded with the consent of the subjects. Out of the twelve interviews, eleven were conducted face to face and one over the phone. Some of the questions have little or no relevance to this project due to the co-operation with another masters student.

Intervjufrågor Servicesäljare

Intervjun är en del i det empiriska underlaget för två examensarbeten som avser Scanias tillsynsprogram för tung lastbil. Intervjutiden beräknas till cirka 1,5 timme.

1. Inledning

1.1 Hur gammal är du?
1.2 Vilken yrkesbakgrund har du?
1.3 Hur länge har du arbetat som servicesäljare?
  a. På Scania?
  b. Andra märken/branscher?
1.4 Hur många verkstäder representerar du?
  a. Vilka?

2. Återförsäljare/verkstad

2.1 Vilka typer av tilläggstjänster erbjuder verkstaden? T.ex. lånebil, hämt-lämn-service, besiktning…
2.2 Hur många anställda finns på verkstaden?
2.3 Hur ser omsättningsfördelningen ut mellan tillsyn och reparation?
2.4 Är det samma personal som jobbar med reparation och tillsyn?
2.5 Vilka är öppettiderna för tillsynsarbeten/reparation?
2.6 Vem är det som står för försäljningen av tillsynsavtal?
  a. Fordonssäljaren?
  b. Servicesäljaren?
  c. Kundmottagare?
  d. Annan, vem?

3. Kunden

3.1 Hur ser din typiska kund ut?
   a. Hur många fordon har kunden totalt, Scania och andra märken?
   b. Vilken typ av drift kör kunden?
   c. Hur många år använder kunden fordonet?
   d. Hur mycket använder kunden fordonet? (Tid och sträcka)

Följande frågor syftar till att utreda skillnader och likheter som finns mellan olika drifter samt storlek på kund. Vi delar in kunderna i storleksordning enligt nedan.

Egen åkare med ett fordon
Egen åkare med 2-5 fordon
Flotta med 5-20 fordon
Flotta med mer än 20 fordon

4. Kundens perspektiv

4.1 Vilken typ av avtal säljer du mest och hur är dessa utformade?
4.2 Vad ser kunden som den största fördelen med att köpa ett tillsynsavtal? Den största nackdelen?
4.3 Hur upplevs prisnivån på tillsynsavtalen?
4.4 Hur avgörande är priset för om en kund väljer att köpa ett tillsynsavtal?
   a. Hur vanligt är det att en kund avstår att köpa ett tillsynsavtal på grund av priset?
4.5 Hur gör kunderna sina beläggnings och körplaner?
   a. Tillgängliga bilar och förare
   b. Långtidskontrakt med inbokade körningar
   c. Kontrakt med flytande planer
   d. Uppdykande och brådskande ad hoc uppdrag etc.
4.6 Hur upplever kunderna tillsynsintervallen?
4.7 Hur upplever kunderna längden av tillsynstillfällena?
4.8 Vad tror du påverkar kunderna mest, tillsynsintervallen eller längden av tillsynstillfällena?
4.9 Hur viktigt är det för kunden att ha sitt fordon tillgängligt?
   a. Upplever du att kunder har svårt att få in tillsynstillfällen i sitt schema?
4.10 Vad är kundens uppfattning om tillsynens påverkan på restvärdet?
   a. Vilken är din uppfattning?
4.11 Vilka tjänster tror du kunden uppskattar/skulle uppskatta mest?
   a. Andra öppettider (vilka?)
   b. Hjälp att hämta/lämna fordonet…

5. Försäljning

5.1 Vad baserar du valet av tillsynsintervall på när du gör kontrakt för olika kunder?
5.2 Vilken är den avgörande faktorn när kunden tar beslut om att köpa ett tillsynsavtal?
5.3 Förändras tillsynsavtalet om kunden ändrar årlig körsträcka/drifttyp under avtalsperioden?
   a. Hur ställer sig kunden till en förändring i avtalet?
5.4 Täcker Scanias nuvarande serviceutbud in de behov som kunden har? (kontraktslängd, tilläggstjänster, intervall, tillsyn av påbyggnader mm.)
   a. Ställer kunderna krav som inte kan tillgodoses av det nuvarande utbudet?
5.5 Vilket är det bästa säljargumentet?
5.6 Vilka delar av tillsynsprogrammet är kunderna mest tveksamma/positiva till?
   a. Använder kunden argument med utgångspunkt från vad konkurrenterna erbjuder?

6. Behovsanpassat underhåll

6.1 Har olika kunder olika underhållsbehov/olika inställning till underhåll?
   a. Var finns i så fall de stora skillnaderna/likheterna?
6.2 Kunden ställs vid ett tillsynstillfälle inför frågan att byta en komponent som är sliten men fullt funktionsduglig. Hur reagerar/agerar kunden?
   a. Hur villig är kunden att byta komponenter i förtid?
6.3 Vad skulle det innebära för kunden om det gick att utforma underhållsplanen utifrån följande parametrar?
   a. Användande av fordon – verkstaden säger till när det är dags för tillsyn
   b. Kundens prioriteringar
   c. Säsongsvariationer
   d. Möjlighet att dela upp underhållsarbete mellan verkstad och kund
   e. Miljöaspekter
6.4 Vad finns/krävs för tekniska hjälpmedel för att kunna behovsanpassa tillsynen?

7. Tillsynens inverkan på lönsamheten

7.1 Hur påverkar tillsynsprogrammet kundens lönsamhet?
   a. Finns det en medvetenhet hos kunden om hur tillsynen påverkar deras lönsamhet?

7.2 Vilken är den mest avgörande faktorn för kundens förmåga till lönsamhet?

7.3 Finns det en skillnad mellan ett planerat tillsynstillfälle och en reparation vad gäller påverkan på kundens lönsamhet?
   a. Hur ser kunder på oplanerade verkstadsbesök?

7.4 Finns det någon skillnad mellan en planerad och en oplanerad reparation vad gäller påverkan på kundens lönsamhet? (Planerad; rep kan vänta tills lämpligt tillfälle finns. Oplanerad; Rep måste utföras vid väg alt. direkt efter avslutat uppdrag.)

Appendix 2 – Interview Questions for Haulers

All of the interviews were conducted in Swedish which is why the questions are presented in Swedish. A total of four interviews were conducted with haulers. The haulers did not receive the questions before hand and all interviews were recorded with the consent of the haulers. Out of the four interviews, three were conducted over the phone and one face to face. Some of the questions have little or no relevance to this project due to the co-operation with another master's student.

Intervjufrågor åkare

- Hur många fordon/förare har du?
- Hur länge har ni fordonen? Behåller ni bilen efter att den är avskriven? Hur lång avskrivning brukar ni ha?
- Vilka typer/märken av bilar har du? (Fjärr, distribution etc., specifikation 4x2 etc.)
- Varför har du valt att köpa Scania? (Vad var det som var viktigt, vad avgjorde valet)
- Känslighet för oplanerat driftstopp? Vad är ni mest känsliga för?
- Vad händer vid ett oplanerat driftstopp? Rutiner, hur går det till?
- Vilka kostnader är sammankopplade med ett oplanerat driftstopp? Generellt? Värsta/bästa möjliga scenario?
- Har ni extra kapacitet, om ja varför?

- Vilka typer av tilläggstjänster vill du ha från verkstaden? T.ex. lånebil, hämt-lämn-service, besiktning…
- Vilka öppettider skulle du vilja ha för tillsynsarbeten/reparation? Är du beredd att betala mer för detta?
- Täcker Scanias nuvarande serviceutbud in de behov som du har? (kontraktslängd, tilläggstjänster, intervall, tillsyn av påbyggnader mm.)
    - Ställer du krav som inte kan tillgodoses av det nuvarande utbudet?
    - Hur fungerar Fleet Management systemet?
- Vilka delar av tillsynsprogrammet är du mest tveksam/positiv till?

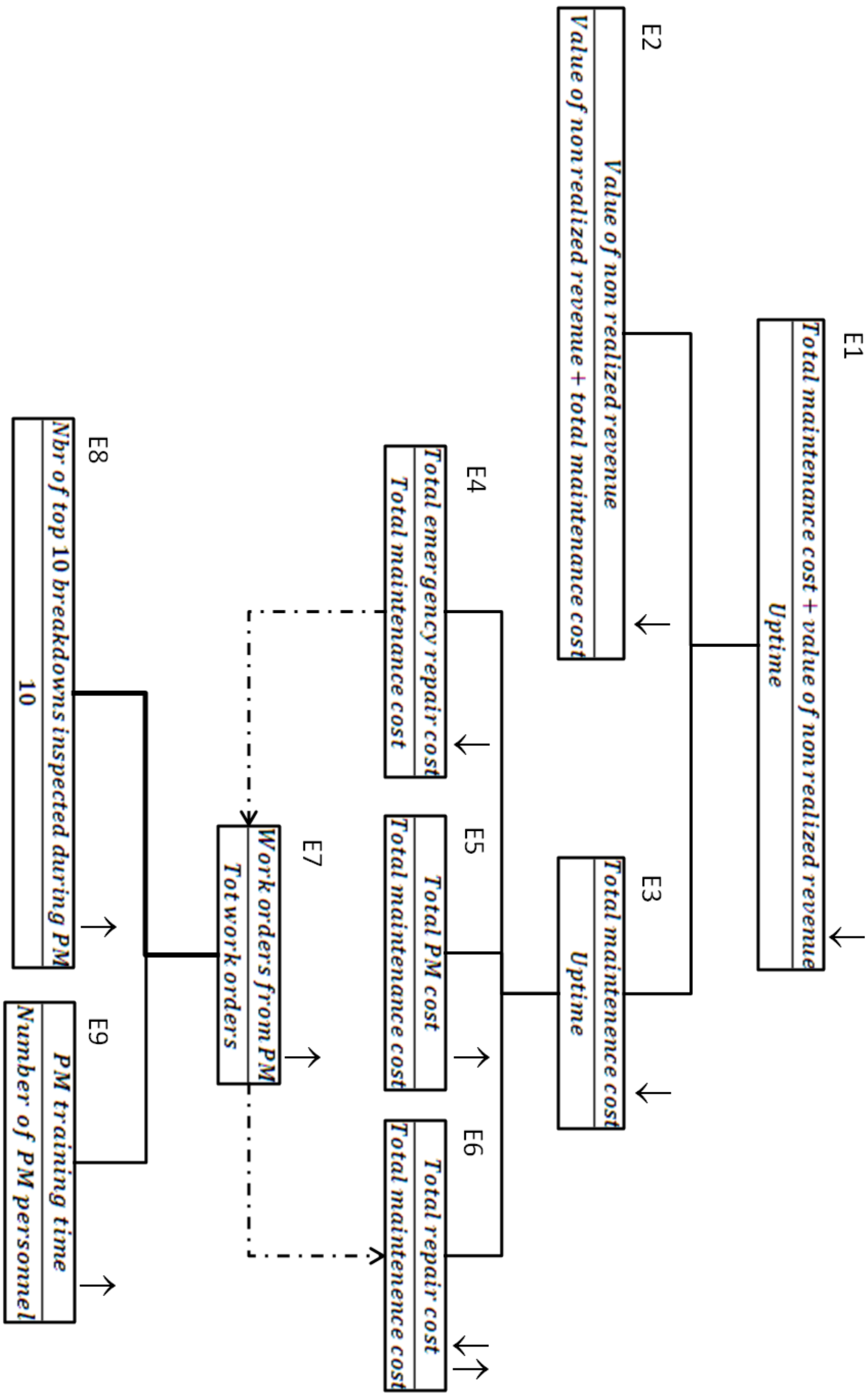
- Vilken typ av avtal har du och hur är dessa utformade?
- Vilken är den avgörande faktorn när du tar beslut om att köpa ett tillsynsavtal?
- Vad ser du som den största fördelen med att köpa ett tillsynsavtal? Den största nackdelen?
- Hur upplever du prisnivån på tillsynsavtalen? Hur avgörande är priset för dig om du väljer att köpa ett tillsynsavtal?
- Hur gör du dina beläggnings och körplaner?
    - Tillgängliga bilar och förare
    - Långtidskontrakt med inbokade körningar
    - Kontrakt med flytande planer

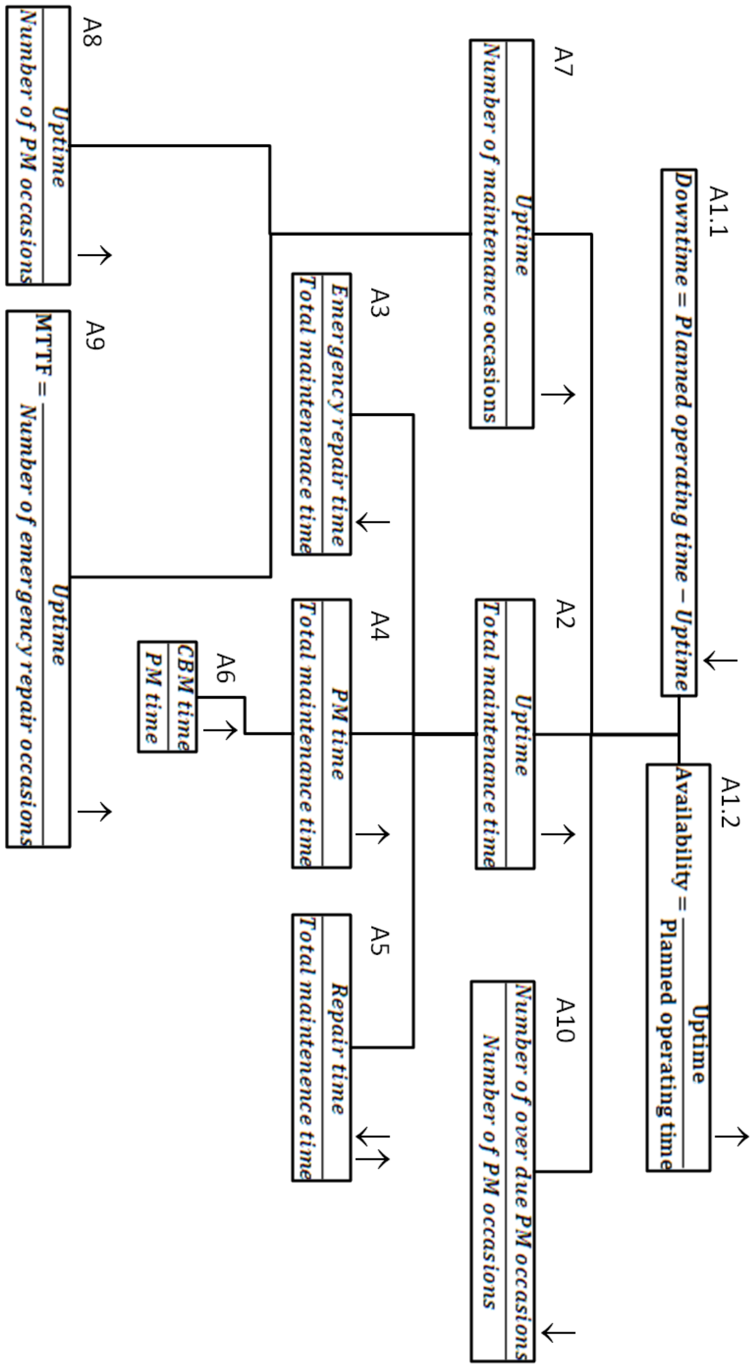
  - Uppdykande och brådskande ad hoc uppdrag etc.
- Hur upplever du tillsynsintervallen?
- Vad har mest betydelse för din verksamhet, tillsynsintervallen eller längden av tillsynstillfällena?
- Hur viktigt är det för dej att ha ditt fordon tillgängligt?
  - Upplever du att det är svårt att få in tillsynstillfällen i ditt schema?
  - Hur långt i förväg vill du veta att en bil ska in på tillsyn?
- Vad är din uppfattning om tillsynens påverkan på restvärdet?

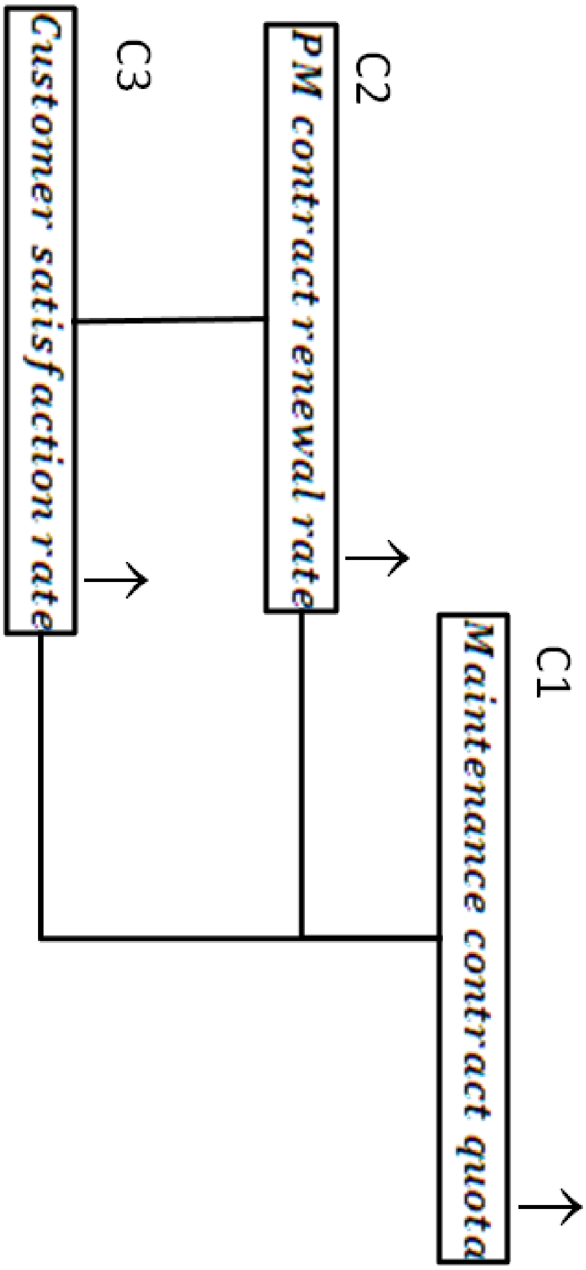
- Hur villig är du att byta komponenter i förtid?
- Vad skulle det innebära för dig om det gick att utforma underhållsplanen utifrån följande parametrar?
  - Användande av och slitage på fordon – verkstaden säger till när det är dags för tillsyn
  - Kundens prioriteringar
  - Säsongsvariationer
  - Möjlighet att dela upp underhållsarbete mellan verkstad och kund
  - Miljöaspekter

- Hur påverkar tillsynsprogrammet din lönsamhet?
- Vilken är den mest avgörande faktorn för din förmåga till lönsamhet?
- Finns det en skillnad mellan ett planerat tillsynstillfälle och en reparation vad gäller påverkan på din lönsamhet?
  - Hur ser du på oplanerade verkstadsbesök?
- Finns det någon skillnad mellan en planerad och en oplanerad reparation vad gäller påverkan på din lönsamhet? (Planerad; rep kan vänta tills lämpligt tillfälle finns. Oplanerad; Rep måste utföras vid väg alt. direkt efter avslutat uppdrag.)

Appendix 3 – MPI tree structures




A1.1
Downtime = Planned operating time − Uptime
A1.2
Availability = Uptime / Planned operating time
A2
Uptime / Total maintenance time
A3
Emergency repair time / Total maintenenace time
A4
PM time / Total maintenance time
A5
Repair time / Total maintenence time
A6
CBM time / PM time
A7
Uptime / Number of maintenance occasions
A8
Uptime / Number of PM occasions
A9
MTTF = Uptime / Number of emergency repair occasions
A10
Number of over due PM occasions / Number of PM occasions


C3
Customer satisfaction rate
C2
PM contract renewal rate
C1
Maintenance contract quota

Hierarchical level / Multi-criteria	Strategic level	Tactical level	Functional level
	Top management	Middle management	Operations / workshop
Economic related MPI:s	**E1, E3, E4**	**E1, E3, E4, E5, E6, E8**	**E7,E9**
Availability related MPI:s	**A1.1, A1.2, A2**	**A1.1, A1.2, A2, A3, A4, A5, A6, A7, A8, A9, A10**	**A10**
Customer satisfaction related MPI:s	**C1, C2, C3**	**C1, C2, C3**	**C1, C2, C3**

Appendix 4 – Maintenance Material Cost

PM material cost per hour (SEK/h)	530
CM material cost per hour (SEK/h)	1300

Table 1 Material cost per hour of maintenance.

Table 1 presents the material cost per hour of PM and CM respectively. The material cost per hour is calculated by dividing material cost by invoiced maintenance time.