2007:54

DOCTORAL THESIS

Maintenance Strategy for a Railway Infrastructure in a Regulated Environment

Ulla Espling

Luleå University of Technology
Division of Operation and Maintenance Engineering
Luleå Railway Research Center

2007:54 | ISSN: 1402-1544 | ISRN: LTU-DT -- 07/54 -- SE

Doctoral Thesis

Division of Operation and Maintenance Engineering

MAINTENANCE STRATEGY FOR A RAILWAY INFRASTRUCTURE IN A REGULATED ENVIRONMENT

ULLA ESPLING

Luleå Railway Research Center
Division of Operation and Maintenance Engineering
Luleå University of Technology

PREFACE

The research work presented in this thesis has been carried out at the Luleå Railway research Center (JVTC) and Division of operation and Maintenance Engineering.

First of all, I would like to express deep gratitude and thanks to my supervisor Professor Uday Kumar, who persuaded me to accept the challenge of going in for the PhD program, also thanks to my co-supervisor Adjunct Professor Ulf Olsson for his kind support. A special thank to Jan Hertting at Banverket who made it possible for me to proceed with the research study.

I would also like to express my gratitude to all my colleagues and friends at the Division of Operations and Maintenance Engineering, especially Aditya Parida, who helped me through the final phase of my thesis giving support and valuable advice, thanks also to Thomas Åhrén for all good advice and for being a skilled co-writer.

Furthermore, I would like to acknowledge the financial support given by the Swedish Rail Administration (Banverket) and Luleå Railway Research Center (JVTC).

I would also say thanks to my near and dear friends and family, who not only supported me, but also suffered from my absence.

Ulla Espling

Luleå, November 2007

ABSTRACT

The operation and maintenance of railway infrastructure is complex, strictly regulated by government legislation, and must be working in close cooperation with all the stakeholders including customers involved, in order to avoid sub optimization.

The business configuration of the Swedish Railway system makes it very difficult to optimize the entire railway operation, as many times its stakeholders have conflicting demands. Furthermore, the issues are made more complex by mixed traffic with varying speed and axle load. Thus, developing an integrated and holistic operational and maintenance policy is complex considering multiple stakeholders with varying and conflicting interest and business demand.

In Sweden, the railway sector is divided into various business areas owned and operated by independent organizations or companies. Banverket is a government authority responsible for the Swedish railway infrastructure administration and also responsible for research and development work in the railway sector. In 1998, Banverket was reorganized into a client/contractor organization in order to increase the effectiveness and efficiency of the railway infrastructure.

This research describes and analyzes, how Banverket administrates the government owned infrastructure according to the stakeholders' including government, and customers' demands. Based on this, literature/case studies, interviews and real life experiences, a conceptual framework has been developed that describes all the factors that the infrastructure manager has to consider. The purpose of the framework is to help the infrastructure manager to make decisions with a more proactive maintenance approach that will improve the whole railway transport system and satisfy its customers. The factors are classified as how important they are for the maintenance strategy, i.e. how large their impact is on the capacity and transport quality, and how flexible they are, i.e. can the infrastructure manager influence them with available resources.

The framework also describes whether the factors are strategic, tactical or operative, and how they are related to each other and how it will affect the railway system, if one of them is changed. The framework considers the parliamentary transport policy goals, laws and regulations, demands on health, safety and environment, interaction between vehicle and track, as well as between infrastructure manager and maintenance contractor.

Problems associated for managing infrastructure maintenance strategy, some of the factors like, partnering and outsourcing, benchmarking and risk management are also studied, analyzed and discussed. The work has been conducted in close cooperation with Banverket and other partners associated with railway. Banverket has used this framework, while formulating their internal strategy, to achieve effective and efficient operation and maintenance.

Key Words: Framework, outsourcing, partnering, benchmarking, risk analysis, railway, regulated environment.

SUMMARY IN SWEDISH

Drift och underhåll av järnvägsinfrastruktur är komplex, strikt reglerad av lagar och regelverk och måste ske i nära samarbete med alla järnvägens intressenter för att undvika suboptimering.

Den rådande affärsstrukturen för den svenska järnvägen, med alla dess aktörer, som ibland har motstridiga krav och önskemål, gör det svårt att optimera för drift och underhåll. Situationen försvåras ytterligare av att banorna trafikera av blandad trafik, dvs. av gods- och passagerartåg med varierande hastighet och axellast. Att utveckla och integrera en holistisk underhållsstrategi som beaktar alla intressenters krav för att öka hela järnvägssystemets effektivitet kräver någon form av beslutsstöd.

Den svenska järnvägen är uppdelad i flera olika affärsområden som ägs och drivs av nya oberoende organisationer och företag. Banverket är den myndighet som ansvarar för järnvägsinfrastrukturen. I egenskap av myndighet har Banverket sektoransvaret för forskning och utveckling inom järnvägssektorn. Ökade krav på effektivisering medförde att Banverket 1998 delades upp i en beställar- och utförarorganisation.

I det här forskningsarbetet beskrivs och analysera hur Banverket förvaltar statens spåranläggningar enligt statens och intressenternas krav. Baserat på detta har ett begreppsmässigt ramverk utvecklats som beskriver de faktorer som förvaltaren av järnväg måste ta hänsyn till. Syftet är att ramverket skall hjälpa förvaltaren att fatta beslut som medför ett mer proaktivt underhållsarbete kan genomföras, som främjar hela transportsystemet och dess intressenter. Faktorerna i ramverket klassas i hur viktiga de är för underhållsstrategin dvs. hur stor deras inverkan är på kapacitet och transportkvalitet, hur flexibla de är och om förvaltaren kan påverka dessa med tillgängliga resurser.

Ramverket beskriver också om faktorerna har strategisk, taktisk eller operativ inverkan samt hur de är relaterade till varandra och hur systemet påverkas om en av faktorerna förändras. Ramverket tar hänsyn till de övergripande transportpolitiska målen, lagar och regelverk, krav på hälsa, säkerhet och miljö, samspelet mellan fordon och bana respektive mellan förvaltare och underhållsentreprenör. Emedan ramverket speglas mot en beställar- och utförarorganisation har även outsourcing, partnering, benchmarking och riskanalys beaktats.

Arbetet har utfört i nära samarbete med Banverket och andra järnvägsintressenter.
Banverket har tillämpat ramverket för att ta fram underhållsstrategier för att göra drift- och underhållsverksamheten mer effektiv.

Nyckel ord: Ramverk, outsourcing, partnering, benchmarking, riskanalys, järnväg, regelstyrt.

LIST OF APPENDED PAPERS

Paper I: Olsson, U. and Espling, U. (2004). Part I. A framework for partnering for infrastructure maintenance. *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 4, pp 234-247.

Ulf Olsson helped defining the basic concept and Ulla Espling performed the analysis.

Paper II: Espling, U. and Olsson, U. (2004). Part II. Partnering in a railway infrastructure maintenance contract – a case study. *Journal of Quality in Maintenance Engineering,* Vol. 10, No. 4, pp 248-253.

Ulla Espling did the case study and Ulf Olsson provided supporting discussion.

Paper III: Espling, U. and Kumar, U. (2004). Development of a proactive maintenance strategy for railway infrastructure; a case study. In: *Workshop Proceedings of the International Maintenance Congress Euromaintenance 2004,* Barcelona May 11-13, pp 31-38.

Ulla Espling conducted the case study and Uday Kumar provided the feed back.

Paper IV: Akersten, P.A. and Espling, U. (2005). Postponed replacement – a risk analysis case study, *Proceedings of 9th International Conference of Maintenance,* Hobart Australia 31 May 2005 ICOMS 2005.

Per Anders Akersten described the basic construction and Ulla Espling provided worked out information from the railway context.

Paper V: Espling, U. and Kumar, U. (2007). Chapter 23 - Benchmarking of the Maintenance Process at Banverket (the Swedish National for Rail Administration, in *Handbook on "Maintenance of Complex System"* Springers, UK (Under publication).

Ulla Espling conducted the case study and Uday Kumar provided the feed back.

Paper VI: Espling, U. and Åhrén, T. (2007). Outsourcing as a strategic tool to fulfil maintenance objectives - a case study for Railway. Submitted for publication in a Journal.

The major portion of work was performed by Ulla Espling. Thomas Åhrén provided the feedback.

Paper VII: Espling, U. (2007). Development of a conceptual framework for managing maintenance strategy for a client/contractor organisation in a regulated environment. Submitted for publication in a Journal.

LIST OF RELATED PAPERS AND REPORTS NOT APPENDED

Espling, U. (2004). *Ramverk för en drift- och underhållsstrategi ur ett regelstyrt infrastrukturperspektiv*. Licentiatuppsats, 2004:45, Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2004A). *Benchmarking av basentreprenad år 2002 för drift och underhåll av Järnväg*. Luleå University of Technology, Luleå, (in Swedish).

Espling, U. (2005). *Arbetsgrupp TURSAM, Årsrapport 2004*, 2005:28, Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2006). *Arbetsgrupp TURSAM, Årsrapport 2005*, 2006:17. Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2006). *Stratoforce Strain to Force Wayside Detector, ett delprojekt i projektet "Ett entreprenöriellt universitet"*, (2006:11). Luleå University of Technology (in Swedish).

Espling, U., Gustavsson L. and Larsson D. (2002). *RLP Rødlys-prosjektet*. Technical Report 2002:18, Luleå University of Technology, Luleå (in Swedish).

Espling U., Nissen, A. and Larsson, D. (2007). *Strategi och metodutveckling av underhållsgränser för fordons- och banunderhåll, sett ur ett ekonomiskt perspektiv*., 2007:07. Luleå University of Technology, Luleå (in Swedish).

Espling, U. and Olsson, U. (2003). Partnering for Railway Network Efficiency. *Conference Proceedings IHHA International Heavy Haul Association Congress*, Dallas, USA, 5th - 7th May, pp 4.55-4.58.

Kumar, S., Espling U. and Kumar, U. (2007). A Holistic Approach towards Rail Maintenance – An Overview of Swedish Iron Ore Line. Submitted for publication in a Journal.

Larsson, D., Espling, U. and Nissen, A. (2007). Vehicle classification Based on Wayside Monitor Data – A Case Study. *Conference Proceeding IHHA International Heavy Haul Association Congress*, Kiruna 11 - 13 June, 2007, pp 471-477.

Nissen, A., Larsson, D., Espling, U. and Lagnebäck, R. (2007). Mowing from Safety Limits towards Maintenance Limits. *Conference Proceeding IHHA International Heavy Haul Association Congress*, Kiruna 11 - 13 June, 2007, pp 349-358.

Olsson, U. and Espling, U. (2004). A framework of Partnering for Infrastructure Maintenance. *Conference Proceedings, Euromaintenance 2004, Barcelona May 11-13 2004, pp. 79-87.*

Patra, A., Espling, U. And Kumar, U. (2007). Life Cycle Cost of Railway Track - An Overview, *20th International Congress & Exhibition on Condition monitoring and Diagnostic Engineering Management*, 2007, June 13-15, Faro, Portugal.

Åhrén, T., Espling, U. and Kumar, U. (2005). Benchmarking of Maintenance process; two case study from Banverket, Sweden. *Conference proceedings Railway Engineering,* London July.

Åhrén, T. and Espling U. (2003). *Samordnet/Felles drift av järnvägen Kiruna – Narvik,* 2003:08. Luleå University of Technology, Luleå (in Swedish).

TABLE OF CONTENTS

1. Introduction

A brief introduction to the problem is given in this chapter. It covers the underlying background and problem areas of the research study. It also discusses the research question's limitations and finally the structure of the thesis is discussed.

1.1 Background

The railway infrastructure asset needs an innovative, integrated and proactive solution for its interoperability requirements for the improvements in safety and security, reliability and maintainability. High operative and maintenance costs are barrier for improved financial performance of railway operation (ERRAC, 2007). Therefore, solutions for finding improved efficiency through optimizing the infrastructure and rolling stock cost of investment and maintenance are becoming important (ERRAC, 2007). Therefore, infrastructure managers need to meet the market demands of passenger and freight operators and provide a safe and secure infrastructure at a price that will make the rail transport attractive and competitive.

In Europe, the railway system is usually government owned and operated in order to provide the society and industry with a reliable mode of transport. This means that the strategic objectives of the railway system in Europe are often based on political decisions. In Sweden, the railway sector is divided into various business areas owned and operated by independent organizations or companies. Banverket is a government authority responsible for the Swedish railway infrastructure administration and also responsible for research and development work in the railway sector (Banverket, 2007). In 1998, Banverket was reorganized into a client/contractor organization in order to increase the effectiveness and efficiency of the railway infrastructure. These organizational changes had no significant improvement effect on train delays or functional failures, leading to the assumption that there is a need for changing the organizational culture within operation and maintenance, while changing from a reactive to a proactive approach (Banverket, 2000; Banverket 2001; Banverket, 2002; Banverket 2003; Banverket 2004; Banverket 2005; Banverket 2006).

The railway system is a complex one, having varying demands to meet the customer's requirements. It is divided into infrastructure and rolling stock (for passenger and freight). The infrastructure system is usually divided by different technical branches i.e. track, electrical system, signalling system, and telecom system. All these branches varying functional needs put challenging demands on the railway management (Lichtberger, 2005).

The regulated environment considers the law and high safety demand, besides the European Commission's (EC) White paper on the railway sector, which sets objectives for railway operation with reference to year 2000, in terms of (European Commission, 2001; ERRAC, 2007):

- Doubling the passenger traffic and tripling freight traffic by 2020.
- Improving travel time by 25-50%.
- Reducing the life cycle cost of infrastructure by 30%.
- Reducing noise levels to 69 dB for freight and 83 dB for high speed trains.
- Increasing safety and reducing fatalities by 75 %.

These objectives have put additional demands on the railway infrastructure, which leads to the operational and maintenance requirements (ERRAC, 2007; Zoeteman and Swier, 2005):

- increase of speed and acceleration,
- increase of axle loads and traction power, and
- more rigid vehicles with greater stiffness.

These are the future demands for the European Railways, and the message to the infrastructure manager is that these should be done without more funding for the operation and maintenance of infrastructures.

Managing the railway infrastructure is a complicated and complex task, as it has to take into consideration the requirements of both external and internal stakeholders (Espling, 2004). Banverket's activities are steered by Parliamentary transport policy goals (see Figure 1), in which the objectives, the economic agreements, planning criteria and how the various operational and maintenance responsibilities are divided amongst Banverket's units are laid down (SIKA, 2003). The goals are there after broken down into yearly governmental approval letters by the Ministry of Enterprise, Energy and Communications (SIKA, 2007). In this letter, Banverket's tasks for the fiscal year are given. The letter starts with the overall goal, which provides a system of transport for the citizens and the business sector all over the country that is economically effective and sustainable in the long term. Six sub-goals which support the overall goal are (Banverket, 2007):

1. an accessible transport system,
2. a high standard of transport quality,
3. safe traffic,
4. a good environment,
5. positive regional development, and
6. a transport system offering equal opportunities.

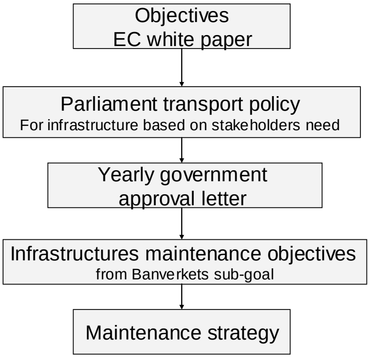


Figure 1. Railway infrastructure management

The objectives are then translated into the infrastructure management task. The maintenance strategy is formulated by considering the following (Espling, 2004; Espling and Åhrén, 2007; Banverket, 2000A):

- Yearly funding according to governmental approval letter.
- A client/contractor organization, where the in-house contractor has to compete with external contractors.
- Contract duration time which is longer than one year.
- Different kinds of contracts with different duration time, scope, payment forms.
- Short-sighted traffic operation agreements with the traffic companies, putting the focus on effectiveness and efficiency at the expense of long-sighted administration and development work.
- Internal and external regulations.
- Safety demands.
- Demands in increased punctuality in combination with competition of time on track between traffic operation and maintenance activities.
- Asset with different complexity, age and standard.
- Limited access to the track for maintenance work.
- Time scheduling process, not aligned with budget process and planning process.
- Life Cycle Cost (LCC) and total asset cost management.
- Public Procurement Act.

The strategy also aims to enhance the organization's culture for continuous improvement from an integrated and holistic railway perspective, taking into account the customers' demands (Banverket, 2007D; Coetzee, 1999).

In order to increase the competitiveness of railway transport, the infrastructure management must be effective and efficient. The infrastructure manager also has to consider all the parties involved; maintenance contractors, traffic companies etc. Due to involvement of the different organizations and their complex needs, there will always be gaps in their perception, understanding, making the system difficult to be holistic and integrated (Espling, 2004; Zoeteman, 2001).

The business configuration of the Swedish Railway system makes it very difficult to optimize the entire railway operation. Furthermore, the issues are made more complex by mixed traffic with varying speed and axle load (Larsson et al., 2007; Nissen et al., 2007). Thus, developing an integrated and holistic operational and maintenance policy is complex considering multiple stakeholders with varying and conflicting interest and business demand.

1.2 Research Problem

In order to increase the effectiveness, efficiency and competitiveness of railway transport, there is a need for effective management of the infrastructure. Setting objectives, making strategies and managing the system need to be carried out in close cooperation with all parties involved, in order to avoid sub optimization. A holistic and integrated approach is needed to consider demands of all stakeholders (Parida and Chattopadhyay, 2007; Coetzee, 1999) and to avoid sub-optimization. The complexity and the regulated environment compels the infrastructure manager to consider all related factors and obstacles and be prepared to deal with all the issues and challenges to act in a proactive manner (Espling and Kumar, 2004).

One of the approaches adopted to make maintenance process more effective and efficient is by implementing outsourcing and partnering, which leads to more focus on core activities, introduces effective and efficient work processes and also stimulates open market competitiveness (Kakabadse and Kakabadse, 2000; Tsang, 2002). This necessitates a need for a framework to deal with issues and challenges arising due to implementation of outsourcing and partnering in a new business environment, where client and contractor are interacting to enhance the effectiveness of maintenance process, eventually leading to a win-win situation for clients and maintenance contractors. To achieve world class or best in the branch performances, many companies are performing benchmarking exercises, but still it is rare in railway sector even though some studies are performed from research point of view (Stalder et al., 2002). However, these studies are at theoretical level and these are not based on normalised statistics leading to difficulties in understanding result from a practical perspective. The concept of benchmarking may be applied to initiate a process of achieving continuous improvement (Espling and Kumar, 2007, Wireman, 2004).

It will be immense use, if benchmarking which is an established method to compare and enhance the performance of organisation can be implemented in Swedish railway sector, so that, Swedish railway sector will gradually achieve world class performance. There are some studies available from other railway and industrial sector, which are considered during this study (Zoeteman and Swier, 2005; Espling and Kumar, 2007; Stalder et al., 2002).

By benchmarking the contracts, best practice can be found and gaps between expected performance and delivered performance can be identified, see Figure 2. This necessitates a framework for a decision support system for the maintenance managers to assist them in making correct decisions, so that they can manage the infrastructure more effectively and efficiently. A literature search shows that, in the past, no such framework has been developed to assist the infrastructure managers in their day to day operations (Espling 2004, Espling and Kumar 2007; Zoeteman and Swier, 2005: Ashraf et al., 1998). Such a framework needs to consider all the critical factors influencing the reliability and availability of the infrastructures, facilitating achievement of the goal set by the government (Espling, 2007).

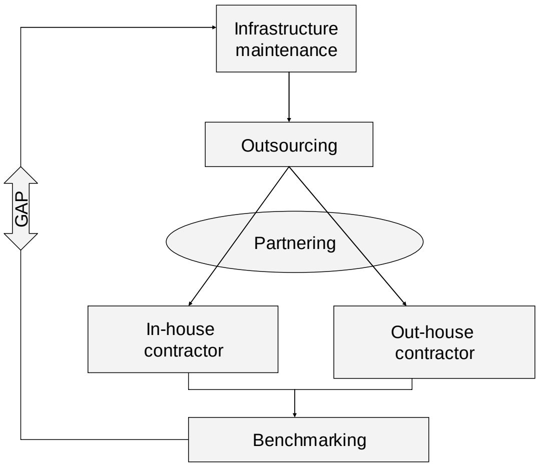


Figure 2. Infrastructure maintenance in a client/contractor organisation.

The infrastructure maintenance strategy essentially involves all the parties that will be co-operating through e.g., partnering, besides outsourcing the maintenance to the in-house and out-house contractor, as given in Figure 2 (Barlow et al., 1997; Espling and Olsson, 2004; Kemi, 2001; Larsson, 1999). The performances of the associated parties are needed to be benchmarked with the industry standard, so as to achieve the agreed goals. The gap, if any while reviewing the outcomes and comparing with the achieved goals to the agreed one will require modification in the maintenance strategy adopted.

1.3 Research Questions

Based on the above mentioned research problem, the following research questions are formulated:

- How to develop a framework that supports a proactive infrastructure maintenance strategy?
- What factors are required to be considered to develop a framework that supports a proactive maintenance strategy?
- What are the problems associated for managing some of the factors like; outsourcing and partnering, and risk management in Swedish railway sector?
- Can benchmarking process be used for Swedish Railway sector to enhance the performance of maintenance process.

1.4 Purpose of the Research Study

The purpose of the this research is to identify and describe factors influencing development of a proactive strategy for operation and maintenance of infrastructure, fulfilling overall business goals and objectives of the railway sector, taking into account the flexibility of these influencing factors and/or their potential for changing the reactive approach into a proactive strategy.

While formulating a conceptual maintenance framework, to provide support for infrastructure manager, which will be proactive and benefit the entire railway transport system, a facilitating decision support system is needed. Besides, factors like; outsourcing and partnering, benchmarking and risk management are also to be studied, discussed and implemented, wherever possible.

1.5 Scope and Delimitations

The study considers only the railway infrastructure issues for a Swedish railway sector for effective and efficient management of the maintenance process.

While considering the conceptual maintenance framework, the existing sub-goals of the Banverket have been taken into consideration, also, the internal regulations are considered as applicable.

The study is limited to the routine management of the maintenance process for the infrastructure of Banverket, and considers all related issues and questions. However, maintenance activities due to modification, renewal and new investment are not considered. Also, associated factors other than outsourcing and partnering, benchmarking and risk management are not considered.

2. Research approach and methodology

This chapter provides a brief introduction to the research approach and the research methods.

2.1 Introduction

The aim for every researcher is to be able to present her/his way of investigating and verifying the research question leading to the results, whether it provides the desired answer or not. The researcher should be able to define her/his way of making the journey from question to result, thereby making it possible for other researchers to follow all steps taken. Subsequent researchers may have different opinions, but as long as the first researcher defines her/his opinion and choice of route, it will be possible to broaden out the research results for those who follow. It is therefore, essential for every researcher to be able to define the research process and their chosen methodology in a way that can be easily followed by other researchers (Backman, 1998; Gummeson, 2000).

2.2 Research Purpose

What is the purpose for research? Taflinger (1996) mentions that it is to learn something, or to gather evidence you do not already know. It can thereby be put in different perspectives, such as if the research is exploratory or descriptive (Neuman, 2003).

In this research, the purpose is both to learn from the present situation and gather evidence in order to draw conclusions, although it should be open to the researcher to draw her/his conclusions from learning from the present situation and gathering evidence and present it's perspectives both in an exploratory and descriptive way.

2.3 Research Approach

The research approach in this study is applied, with the limitation not to be too exploratory, leaving the interpretation to the professional managers. The approach has been a mix of induction, deduction and abduction (Molander, 1998; Alvesson and Sköldberg, 1994).

2.4 Research Methodology

The research methodology in this project can be described as an iterative process presented in Figure 3 (Wigblad, 1997), starting with identifying the problem or phenomenon needed to be investigated. The problem thereafter has been approached in a scientific way by surveys and literature search and study, which have been viewed from a scientific perspective. The study has then come up with a research perspective; an approach, how to solve the problem has been set up including existing theories, the aim, the objectives and the research questions. The methodology chosen in these study theories have been tested and verified by different case studies, interviews, experiments, action research and questionnaires. Both exploratory and descriptive single and multiple cases studies have been used (Yin, 2003). The purpose of action research is to assist people in extending their understanding of their situation and thus resolve problems that confront them (McNiff and Whitehead, 1998; McNiff et al, 1996; Ottosson, 1996; Stringer, 1996). In order to focus on the research questions, it is necessary to delimitate boundary context in order to get research that can be conducted under controlled circumstances.

A conceptual framework of maintenance management can facilitate effective and efficient decision making in maintenance of railway and will act as an essential component of a decision support system. A conceptual framework explains either graphically or in narrative form, the main issues to be studied, the key factors, variables and the presumed relationship amongst them. The methodology used is to set out bins, naming them, and getting clearer about their interrelationship. It is vital to be selective and to decide which variables are most important, which relationships are likely to be most meaningful, and as a consequence, what information should be collected and analyzed (Miles and Huberman, 1994). The methodology for building up a conceptual frame work has been combined with a reduced multi criteria decision analysis (MCDA (Dogson et al., 2000, 2002). MCDA is a methodology for evaluating options on individual, often conflicting criteria, and combining the separate evaluations into one overall evaluation. MCDA consist of seven stages: 1. Consider context, 2. Identify options, 3. Establish objectives and criteria, 4. Score option on the criteria, 5. Assign importance weights to the criteria, 5. Assign important weights to criteria, 6. Calculate overall scores and 7. Examine results, sensitivity analyses and sorts. This study includes stage 1 to 3 and gives an approach for how to use stage 4 and 5.

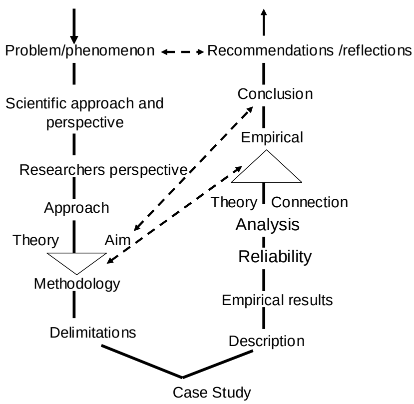


Figure 3. The iterative step wise testing approach, adapted by Wigblad (1997).

Theories and hypotheses have been studied in various case studies, amongst them the partnering project, benchmarking project, TURSAM (Applied Maintenance in

Cooperation) process, with an action research approach. From the case studies' description conclusions on empirical results have been evaluated concerning their reliability (Espling, 2005; Espling 2006). Analysis has been conducted in order to verify theories/hypotheses and connections. The result of the empirical data leads to conclusions and recommendations. During the process of analysis and discussion, the research question and objectives are checked against conclusions, with an aim to double-check that the researcher does not lose the real thread in her/his research. Both qualitative and quantitative methods have been used. Also the methodology chosen must align with the empirical data. Finally, at the end of the research, it is revealed, if the problem/phenomenon has been solved, and if the solution is as expected, or not.

2.5 Data collection

This research project has been fully supported with total insight and access into all Banverket's (Infrastructure Management) systems. Also, the researcher had the opportunity to be a part of the TURSAM process, which has continuously been running since 2002, (Espling, 2005; Espling, 2006), in which almost all involved parties in the operation of the Iron Ore Line in Sweden have been participating.

Data has been collected from Banverket's internal intranet, Banverket's Infrastructure system for assets BIS, failure system Ofelia, Inspection System Bessy, track quality measuring data, way side monitoring systems for wheel flats and hot bearings (Nissen, et al, 2007; Espling et al, 2007; Espling, 2004A). Also, data from LKAB and MTAB has been collected and fully utilised. Data has also been collected during the case studies, from questionnaires, interviews, and from available systems for literature research (Yin, 2003).

2.6 Structure of the research

The structure of the thesis can be described as based on an iterative process, starting with Papers I and II, in which the research problem was identified. There was an adverse relation between the client and contractor, a need for common objectives and a need for closer cooperation between all railway actors was there. Paper III, describes the current situation within Banverket; affecting factors were identified and approaches are worked out in a general framework. One important task for the maintenance manager is to be aware of the consequence and risks connected with maintenance decision makings. In Paper IV tools and models for analysis of risk are discussed and a risk model suggested. Paper V and Paper VI; gather more research data and information about the owner organization and its ability to execute maintenance management by using benchmarking and outsourcing. The output from Papers I -VI is then used as input for Paper VII, where a conceptual framework is developed for application by Banverket.

3. Summary of appended papers

In this chapter important results from seven different papers contributing to the research results are summarized.

In Paper I: A framework for Partnering within Infrastructure Maintenance is developed. Partnering is a managerial approach used by two or more organizations to achieve specific business objectives by maximizing the effectiveness of each participant's resources. It is used in complex projects, where activities are critical to a client's business. The approach for partnering is based on mutual objectives, an agreed method of problem resolution and active search for continuous measurable improvements. The partnering concept focuses on teaming, trust building and openness between the partnering parties. The benefits from partnering are; cost reduction between 5 and 30 %, time savings between 10 and 40 %; and improved project quality. A successful partnering project needs six elements, 1) trust, 2) the "right" personalities, 3) openness in communication, 4) organizational culture and organizational learning, 5) teambuilding, and 6) the role of management (CEO).

It is essential to have a functioning structure for following up performance. Both objective and subjective goals must be followed up and performance issues dealt with by the partnering group as a whole. Also, CEOs or top management need to be committed and involved in the implementation. A facilitator is required to co-ordinate, facilitate and develop a charter which is commonly agreed upon and with ranked objectives.

In Paper II: The partnering concept is tested for operation and maintenance contracts in a case study. The partnering process was implemented in contract negotiation, execution and methods for evaluating and developing the outcomes. Six common objectives were agreed on in a special process led by a neutral facilitator. The client decided to use the payment form; target price combined with an incentive clause. This would ensure an additional amount as a bonus for the contractor if work was executed at a cost lower than the target cost. It was also agreed that the client's gain on the incentive was to be used for additional orders to the contractor. The contractor was paid according to actual costs.

The results were verified within a year as all objectives were met or exceeded. The objectives and the results are summarized below:

- Reduction in train delays, target - 5%, result - 19 %.
- Reduction in costs, target - 6 %, result - 13 %.
- Reduction in break down repairs, target - 5 %, result – 14 %.
- Reduction in inspection remarks, target ± 0 %, result - 11 %.
- Quality track index – target, not specified, in other terms better than the previous years for almost all of the nine railway lines. Result better on all lines except one, due to measurement undertaken before maintenance.
- Relations client/contractor, target - better, results - better.

All targets were achieved due to the positive spiral effects triggered by achievement of a sub-goal. The sub-goal was to smooth and eliminate the variations in resource requirements by the contractor when utilizing personnel from the snow removal operation. This led to increased reliability of the infrastructure as a result of less failure thereby unplanned (corrective) maintenance calls. This in turn, resulted in surplus resources (in terms of money) which made it possible to increase the number of preventive maintenance actions. This resulted in fewer defects reported during the infrastructure assessments' inspection which led to more funds available for preventive maintenance activities, which then led to decreased costs and increased train punctuality.

Further, it is concluded that CEOs and top management must be committed to the partnering process and also be involved in the implementation of the process in the organization to make certain that staff at all levels support partnering.

In Paper III: Based on experience from the operation and maintenance process, the current status (as of 2003) of maintenance practice at Banverket is discussed and presented in a framework. The framework takes into account business objectives, regulations, health safety and environment demands, interaction between traffic companies, the infrastructure manager and contractors. The high amount (~ 35 %) of corrective maintenance indicates that there is a need for a more proactive management of the maintenance strategy that should lead to minimum traffic hindrances and provide traffic capacity on demand. In 2003, 18 % of all train delay was caused by malfunctioning of the infrastructure. To be more proactive more predictive, and preventive maintenance are needed. Preventive maintenance is more cost-effective, at least three times cheaper than corrective maintenance, gives higher quality and is more dependable than corrective maintenance. While forming the maintenance strategy for railway infrastructure, the manager must consider the interacting parts in the maintenance system between the infrastructure and the traffic companies' vehicles. The manager has also to consider whether the methodology or strategy chosen will put demands on the contractor to enhance his competence or invest in new maintenance equipment. The funding for maintenance is given for one year, the duration of the maintenance contract is three to five years, the maintenance planning for the track is usually 1,5 years, so as to include it in the time table for running the trains. The IM has to negotiate with the traffic companies for putting in time for maintenance, rebuilding and renewal work. Only corrective maintenance and snow removal can be done without planning in advance. The IM has also to be prepared for sudden unexpected decreases/increases in the funding due to political decisions. Therefore, the strategy for budget, maintenance planning and procurement/contracting processes must be closely linked. To achieve the set objectives, one has to have a need-based-budgeting system that allocates funds as per the requirements and infuses long-term thinking in the management of the infrastructure. Figure 4 presents an approach or framework that guards itself from variation in budgetary allocation for the maintenance of the infrastructures by executing a maintenance strategy which facilitates the expenditure level maintained at an average level, see dotted line EF. The line CD presents funding blocked for payments for the maintenance contracts, here presented for a service level contract, including corrective maintenance, snow removal and maintenance stipulated by internal regulations, i.e. predetermined maintenance and inspections for safety. The line AB marks the level for corrective maintenance for which a proactive strategy sets the objective to decrease by starting a continuous improvement process. There is also a need to have a strategy for prepared activities to be done when sudden increases/decreases in the funding appears.

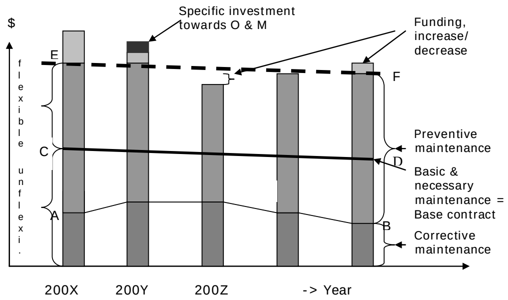


Figure 4. Maintenance budget system aligned with procurement/contracting process and maintenance strategy.

The desired need for planned infrastructure maintenance must consider how the infrastructure is used (traffic volume and type), the actual standard of the infrastructure and the climate and the total amount of assets and geographical location. The planned maintenance must then be classified in “must be done”, “must be done but can be reduced” and “can be postponed” though it is often difficult to get full funding for the whole maintenance plan.

In Paper IV: The paper deals with the risk based decision criteria for maintenance if to defer or postpone maintenance work is taken under uncertainty. The case reported here is the risk analysis performed to aid in the decision whether to undertake renewal work on a track section within a few years, or to postpone the renewal for a further ten to fifteen years. The risk analysis has been performed, making use of several methodologies or tools: preliminary hazard analysis (PHA), a requirements oriented failure mode and effects analysis (FMEA), event tree analysis (ETA) and probability estimation by Delphi technique.

The risk analysis work has resulted in the pinpointing of a few failure mechanisms to be studied in depth. It also resulted in a comprehensive description of the various routine preventive maintenance actions used and their capacity for identifying faults caused by the various failure mechanisms.

The risk analysis performed was seen as a pre-study. It has clearly pointed out the need for more detailed descriptions of the main failure mechanisms. This also necessitates the development of analytical models for studying the rail/track deterioration characteristics.

In Paper V: This paper discusses how to improve by learning from best practice and through benchmarking of maintenance for railway infrastructure". Benchmarking is a tool for continuous improvement that helps develop realistic objectives, strategic targets and facilitates the achievements of excellence in maintenance. The company needs to have a deep understanding and good knowledge regarding their own organisation's processes before benchmarking itself with external companies, i.e. having their own core business under control before learning from others. Benchmarking has been conducted for three different cases; 1) benchmarking of the maintenance process for cross-border operations, 2) study of the effectiveness of the outsourcing of the maintenance process by different track regions in Sweden, and 3) study of the level of transparency among the European railway administrations. In these case studies; the focus is on railway infrastructure, excluding the rolling stock. The benchmark between the different track regions exposes a very well defined structure for the accounting system, for the purchasing and contract document and for the maintenance plan. Unfortunately this structure is not followed by all the track regions, making it difficult to compare maintenance activities. Some of the results from the benchmarking points out obstacles for effective benchmarking, though data cannot be collected. The results are:

- Overhead cost for the contractor is not available due to the competition between the different contractors.
- If the contract is a total commitment contract bought with lump sum, the maintenance costs are given in an aggregated form on a very high level.
- The competition between the traffic companies has led to poor traffic statistic, i.e. the infrastructure manager does not know how much traffic is running on the track, nor what kind of traffic, types of vehicles, axle load and speed.
- Asset age is not always reported in the asset system, which makes it difficult to establish an opinion of the current condition based on how much traffic it has been exposed to.
- Maintenance man hours, material cost (spare parts) and maintenance vehicle/equipment cost is not reported back to the IM's accounting system, because of the difficulties of getting this data back from, e.g. lump sum contracts.
- There is a lack of maintenance history data. Maintenance history data can be found in the asset system for preventive component exchange, tamping and grinding, but not for corrective exchange, tamping and grinding.

The benchmark process also revealed cost drivers for the infrastructure which were failures or defects in rail, sleepers, rail joints, turnouts, level crossings, and catenaries (overhead wire).

The choice of contract form, payment forms and cooperation shows a better result if:

- target price with incentives are used as payment form,
- a scorecard perspective is used to set the objectives within the contract and these are followed up in quality meetings,
- there are frequent meetings, where top managers from the local areas participate,
- there are forms for cooperation and an open and clear dialogue, for example partnering,

- there is a focus on increased preventive maintenance of assets with frequent functional failures and a high maintenance cost which will provide results, e.g. turnouts, and
- root cause analysis is used.

And finally, there is a need to develop better indicators or measurements for benchmarking; these should be aligned with the measurement for following up the maintenance strategy. Today the comparable indicators are:

- corrective maintenance cost/total maintenance cost including renewal,
- total maintenance cost/turnover,
- maintenance and renewal cost/cost for asset replacement and
- maintenance cost/track meter.

Finally benchmarking is a tool that should be used more within the railway. “Gives gains with relatively little effort” is a truth that needs some modification. Benchmarking cannot be used if its results are not implemented. The benefits from benchmarking do not occur until the findings from the benchmarking project are implemented and systematically followed up and analyzed against the set targets and goals.

In Paper VI: In the paper the pro and cons for outsourcing maintenance are discussed and a basic requirement for outsourcing maintenance is proposed containing 9 steps:
1. establish objectives,
2. decide what to outsource,
3. establish measures to follow up the objectives,
4. plan how to achieve the objectives,
5. form an organisation responsible for the outsourcing process,
6. choose scope and contract,
7. choose forms for cooperation,
8. identify the supplier market, and
9. choose forms for ending the contract.

Different maintenance contracts have been studied within the Swedish Railway Administration (Banverket) concerning scope, objectives, contract forms etc. and outcome. A gap analysis is conducted between the basic requirements and the practice in the outsourced contracts in order to find risk and improvement areas. The result points out that Banverket is very skilled in purchasing and running the contracts while the improvement areas are setting objectives that are more strategic and measurements that capture the economical, quality, reliability, availability and assessment of condition degradation rates. There is also a need for risk analysis concerning issues as safety and outsourcing core activities and core competence.

Some general findings are that Banverket has chosen to outsource all maintenance, including so called core maintenance, in order to create a supplier market and at the same time it has taken the decision to outsource despite the situation of more than 20 % corrective maintenance, indicating a low level of control. Also the performance contract and the change in the regulations have reduced the possibilities for the infrastructure manager to get information from the inspection remark system concerning the assets' degradation.

Risk of losing control over maintenance costs; the difficulties in following up the maintenance costs are due to:

- buying the contract on a lump sum resulting in putting the economical result back to the accounting system in a very rough presentation of costs
- deviations between the contracts concerning the use of the accounting structure,
- difficulties in deducing the cost from the original maintenance contract and other maintenance activities bought outside the contract.

Paper VII: In order to design for an efficient and effective decision support system for the Swedish railway system, involving all parties, a conceptual framework is considered. A conceptual framework explains either graphically or in narrative form, the main issues to be studied, the key factors, variables and the presumed relationship amongst them. The methodology used is to set out bins, naming them, and getting clearer about their interrelationship. It is vital to be selective and to decide which variables are most important, which relationships are likely to be most meaningful, and as a consequence, what information should be collected and analyzed. The methodology for building up a conceptual frame work has been combined with a reduced multi criteria decision analysis (MCDA). MCDA is a methodology for evaluating options on individual, often conflicting criteria, and combining the separate evaluations into one overall evaluation. The conceptual framework is developed for handling a maintenance strategy in a government regulated environment for the railway sector. To achieve maintenance excellence, the manager needs to have a basic capability and to set three objectives; in the strategic level, to be sustainable and create a view for maintaining excellence in the future, in the tactical level, to create a plan for preventive and predictive maintenance and in the operational level, i.e. in daily work management, to create a continuous improvement process. The trade-off will be quality, return on investment, secured health, safety and environment for a minimal cost, minimal time and minimal risk. In a complex environment, a large number of factors have to be considered. This is the daily situation for the railway infrastructure manager, who buys all maintenance from an in-house contractor or from an external contractor. He has to consider the political decisions, yearly funding, high safety demands etc. He is also, struggling with a high amount of corrective maintenance that inflicts a reactive approach on the management. A decision support tool can facilitate the management, and as a first step, a conceptual framework can be used. The first step is to identify the important factors and group them according to the maintenance process, see Table 1 column 1 and 2. Next question asked is, how important this factor i.e. what significance it will have to affect a proactive maintenances process, see column "Significance". The conceptual framework has been developed by getting answers to the following four questions;

1. Is it possible for the manager to affect the factors on a high, medium or low level?
2. Is it possible to affect the factors from a strategic perspective, a tactical perspective, or an operative perspective?

3. What are he inter-relationship between the factors?
4. What are the failure and risk consequences concerning quality (Q), cost, return on investment (ROI), health (H), safety (S) or environment (E)?

The first question helps the manager to focus on areas that can be affected. The first level is the CEO's possibilities to influence the infrastructure management by e.g. discussions with the stakeholders or funding allocation. The CEO might have a high to medium influence on the overall objectives, but have a high influence of forming the maintenance objectives e.g. strategically increase punctuality by 25 %, tactically by focusing on solving e.g. the problems causing most train delays, operational mean time to repair less than 2 hours. CEO has also to consider the risks associated with these objectives and how this strategy may affect another factor in the framework.

In the following levels, the framework application cascades down through the hierarchy and on each level, the responsible manager answer the same question, see column Local IM Influence.

The second question is to lift the focus from the yearly funding approach to a more proactive based on need (see column "strategic", "tactic" and "operative") e.g. a high transport quality needs to be placed strategically by increasing the punctuality with 25 %, tactically by finding the asset which causes the highest amount of delays; and find proactive solutions to decrease these delays and operationally, to have a high service level. The third question is a reminder (see column "related to)" e.g. if more funding is received for maintenance activities, time on track for conducting them must be negotiated with the customers, i.e. train operating companies. The fourth question is what the consequences are of doing or not doing maintenance. These are also used to motivate the different decisions to be taken.

By using the methodology and answering the question, the local IM is presented with those factors that he has the ability to influence in a proactive direction. The local manager can affect the objectives, the maintenance program and plan by setting strategic and tactical objectives on how to reduce corrective maintenance, mainly by implementing the continuous improvement programs. This conceptual framework can also be used on an overall strategic level by focusing on those factors answered, having high significance for the maintenance process and possible to be influenced on a CEO level.

Table 1. Conceptual framework

Key Issues / Flow	Factors	Significance	CEO IM influence	Local IM Influence	Objectives: Strategic	Objectives: Tactic	Objectives: Operative	Risk of affecting (Ranking x Rating): Q	ROI	H	S	E	Related to
Objectives (O)	an accessible transport system	High	Medium	Low			Keep the level						F
	a high standard of transport quality	High	High	Medium	x	x	x	x	x				F, ES, CI
	safe traffic	High	High	High	x	x	x			x	x	x	TS, ES
	a good environment,	High	High	High	x	x	x					x	TS, ES
	positive regional development and	High	Low										
	a transport system offering equal opportunities.	High	Low										
Demands (D)	Laws	High	Low	Low									
	Internal regulations	High	High	Low									
	Governmental approval letter	High	Low +	Low									
	Customers demand	High	High	Low									MP (time)
	Technical demands	High	High	Low	New innovations?								
Funding (F)	Snow removal	High	Medium			Historical							
	Predetermined maintenance	High	High	High			Funding reserved				x		D
	Corrective maintenance	High	Medium		x	x							CI
	Condition based inspections	High	High	High			Funding reserved				x		D
	Condition based maintenance	High	Medium										
Maintenance program (MP) and Maintenance plan	Snow clearence	High	Medium	Medium				x					CI
	Predetermined maintenance	High	High	Low			Follow regulations						D
	Condition based inspections	High	High	Low			Follow regulations						D
	Condition based maintenance	High	High	High	x	x	x	x	x				CI, F
	Corrective maintenance	High	High	High	x	x	x	x	x				CI
Execution, Sourcing process (ES)	LOU	High	Low	Low									D
	Scope	High	High	High	x	x	x		x				O, MP, TS
	Contract form	High	High	High	x	x	x		x				O, MP, TS
	Payment form	High	High	High	x	x	x		x				O, MP, TS
	Cooperation form	High	High	High	x	x	x	x	x				O, MP, TS
	Mateial resource requiernmet	High	High	Medium									D, MP
	Maintenance equipment resource requireme	High	High	Low									
	Skilled personnel resource requirement	High	High	High		x	x						D, MP, TS
Technical system (TS)	Standard/condtions	High	Medium	Low									
	Used capacity	High	Medium	Low									
	Degradation speed	High	Medium	Medium									
	Interaction track/vehicle	High	Low	Low									
	Un expected input	High	Medium	Medium									
	Un expected output	High	Medium	Medium									
	Design	High	High	Low									
Continuous improvement (CI)	Reporting (feedback data)	High	High	High	x	x	x	x	x				O, MP, ES
	Analysis	High	High	High	x	x	x	x	x				O, MP, ES
	Improvement activities	High	High	High	x	x	x	x	x				O, MP, ES

Note: CEO=Chief Executive Officer, Q=Quality, ROI=Return on Investment, H=Health, S=Safety, E=Environment

4. Discussion and conclusions

This chapter discusses and presents the findings of the present research, which was conducted to answer the stated research problem and questions. Furthermore, the main research results and the contribution of the thesis are presented. Finally, scopes for further research are also suggested.

4.1 Discussion

The main objective of this research is to identify and describe factors of forming an infrastructure framework for the maintenance strategy of Banverket in a regulated environment. The railway infrastructures under a regulated environment have high demands due to varying and complex requirements from both internal and external stakeholders, combined with changing political decisions (Espling, 2004A). These demands make the infrastructure managers' decision making process to manage the maintenance of the railway infrastructure more difficult and complex. Further, higher corrective maintenance with higher cost (Hägerby and Johansson, 2002; Kunttu et al., 2007) rather than a balanced corrective and predictive maintenance places the infrastructure manager in a loose-loose situation (Espling, 2004; Zoeteman. 2006). These situations enhance a culture focusing on solving the daily difficulties and developing operational objectives, seldom having time for reflection of the future i.e. a reactive behaviour. To overcome this situation, and to support the infrastructure manager, the decision support conceptual framework for the infrastructure is considered, discussed and suggested. In paper VII, table 2 and Figure 5, the possible phases of activities, like; objectives, demands, funding, maintenance program and maintenance plan, and execution of sourcing process, technical system and continuous improvement; of an maintenance process are given. These phases can be influenced through a proactive approach at both strategic, i.e. setting objective under a dynamic situation; and tactical level through execution, measurement and feedback for a continuous improvement cycle (Deming, 1994). In this research, the associated issues, like; outsourcing and partnering, benchmarking and risk management have been studied in detailed and results are reported in the papers published and appended to the Thesis (see Figure 5).

The development of the concept for the infrastructure framework for maintenance of the railway infrastructure strategy is given at Figure 5. The complexities of the regulated environment with various stakeholders demands are considered in this research as illustrated in Figure. In order to manage various complexities, there is a need to change the reactive management attitude towards a proactive one (Zoeteman, 2006). In a complex situation like this, one therefore have to focus on those variables, that can be affected and promote a value-added output (Liyanage and Kumar, 2003). A decision support tool can facilitates the management and also work for continuous improvement, and as a first step a conceptual framework can be used (see Paper VII*)*. The strategy for the conceptual framework, essentially involves all the parties, which will be co-operating through e.g., partnering, besides outsourcing the maintenance to the in-house and out-house contractors. In order to benchmark the performances of the associated parties, the industry standards are to be compared with, for achieving the desired organizational goals. Further, every decision making process need to consider; the risk consequences, methods and tools to minimize the risk, which also has been discussed and included in paper IV. A number of maintenance tools and methods are being used by different industries to support the decision making, while considering risk consequences. Two such methodologies are; Reliability Centered Maintenance (RCM) (Nowland and Heap, 1978; Moubray, 1997) and Total Productive Maintenance, (TPM) (Nakajima, 1988). Though, not in true form, Banverket is using part of these methodologies in their organizations in some way or other. Since, these methodologies are not considered and applied by Banverket from the strategic point of view, a holistic approach including the risk aspect was considered in this research.

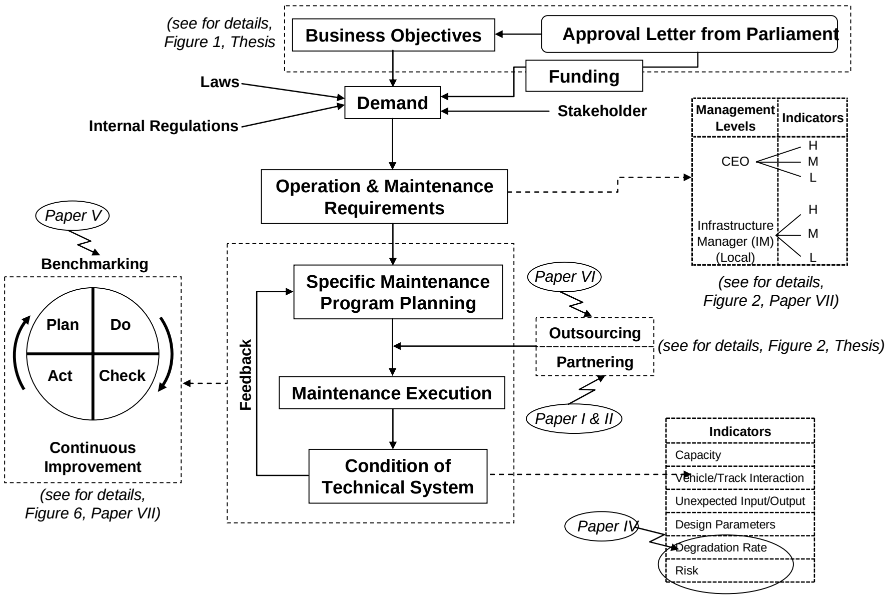


Figure 5: Concept for infrastructure framework for Maintenance strategy

While considering the conceptual framework, the factors were identified and grouped by their belongingingness to the maintenance process. The conceptual framework was developed by getting answers to the questions like; is it possible for the manager to manage and affect the factors, is it possible to affect the factors from a strategic perspective, a tactical perspective, or an operative perspective, what are the inter-relationship between the factors and parties involved, and what are the failure and risk consequences.

In this research, reactive and day-to-day management of infrastructure maintenance process, i.e. the ability to describe the operative maintenance process in the execution and continuous improvement phase for pinpointing the improvement areas are considered and discussed (Paper VII). Also, three domains for creating a continuous improvement process, namely; the strategically domain; including methodologies and tools, the execution domain; including operational and maintenance system and the evaluation domain; which includes performance evaluations tools are considered (Ahlmann 2002; Beck, 2003; paper VI and Paper VII). These areas are pin pointed by the conceptual framework that has been examined in paper VII. The key issues like; "Stakeholders demand, laws and internal regulations", "maintenance program "and "maintenance plan;" are difficult to influence, though these are stipulated by the governmental demands, laws or internal regulation. Therefore, it is important to discuss the contribution of a decision support system. The framework (Paper III and Paper VII), discussed and focused on the improvement and risk areas, as identified in the strategic domain, concerning how to influence the objectives; in the execution domain, concerning conducting different scope and contract forms (see paper VI) and in the evaluation domain, tools for evaluation and continuous improvements (see paper V).

By comparing the costs of corrective and preventive maintenance, one is able to get information on the profitability of the preventive work carried out as planned. A cost-effective analysis conducted by Kunttu et al (2007), shows that corrective maintenance is three times more expensive than preventive maintenance due to loss of production and higher labor cost. The potential for transferring corrective maintenance costs to preventive maintenance cost is therefore high (see Paper II). A reactive management approach is identified in Paper III, paper IV, and paper V, showing a high amount of corrective maintenance. Beck (2003), states that a reactive approach is promoted by a culture focused on the "problem-of-to-day". Such a culture in combination with too little funding for maintenance, with too much corrective maintenance, and unspecified objectives (Banverket, 2007), eats away all the available resources, placing the infrastructure managers in a 'loosing spiral'. Therefore, it is desired that the infrastructure mangers should focus on a balanced combination of predictive and corrective maintenance strategy, to convert the loosing spiral to a winning one (Paper II). It is also, important that the maintenance objectives should be more specified to achieve the overall objectives of the organization. Karlsson (2005) confirm that only the first four of the six sub-goals are supported by the prevailing maintenance strategy. In paper VI, it has been mentioned that, the last two sub-goals are difficult to achieve directly by the application of maintenance strategy.

Outsourcing of maintenance is not an easy task; as there are many aspects that need to be considered. A basic requirement for outsourcing of maintenance has been proposed and tested, in paper VI. A gap analysis has been conducted between the basic requirements and practice in the outsourced contracts. By this methodology, it has been possible to identify improvement areas. Also, in paper VI, a risk for the client for losing the control of cost and asset condition, because of the general objectives and insufficient condition reports, are discussed. Although, there is a well defined structure for controlling the maintenance, negotiation, budget and accounting, all activities are not fully utilized. One of the factors, which can be influenced by the local manager, is to formulate the correct objectives towards the scope in the contract and continuous improvement. When the objective is formulated, the manager has to consider, if this objective is on a strategic level, tactical or operational level (Tsang et al, 1999, Parida and Kumar, 2006).

It is also, necessary for the client to be involved in the execution of the contract for creating a culture of innovation, development and excellence, for example, by means of partnering. Partnering is used in complex projects in order to enhance the cooperation between the client and a contractor. A framework for partnering and target driven contracts, has been suggested and tested by a case study (Paper I and II). It can be seen that, commonly developed objectives combined with target price and incentives can trigger a process for continuous improvement. The approach for partnering is based on mutual objectives, an agreed method of problem resolution and active search for continuous measurable improvements. The partnering concept focuses on teaming, trust building and openness between the partnering parties. CEOs or top management must be committed and involved in the implementation process of the partnering.

A model for risk analysis is considered and discussed (Paper IV). All the maintenance associated risks must be studied, analyzed and identified, so that preventive actions to reduce the consequences and replacement decision can be planned (Jardine, 1973). Also, operational effectiveness and efficiency, besides, performance measurement for risk analysis, and enhanced knowledge, competence and skill, describing the risk for loss of ROI, quality, health, safety and environment needs to be developed.

Benchmarking can be used as a tool for continuous improvement within Banverket, to enhance the performance of maintenance process (Paper V). The result from the benchmarking, points out the gap between expected and achieved performance, thereby identifying the improvement areas through the application of performance measurement and lead indicators (Paper V; Parida and Chattopadhyay, 2007). There is a need to develop better indicators or measurements for benchmarking and these should be aligned with the measurement for the follow up of the selected maintenance strategy. Today the comparable indicators are:

- corrective maintenance cost/total maintenance cost including renewal,
- total maintenance cost/turnover,
- maintenance and renewal cost/cost for asset replacement and
- maintenance cost/track meter.

Also, benchmarking is a tool that should be used more within Banverket (Paper V). Benchmarking cannot be of value, if its results are not implemented. Benchmarking also facilitates a culture of continuous improvement in the organisation as it makes performance visible and also presents a platform for comparison with others. The continuous improvement process is triggered by the questions like; is it possible to find a better way of working? Since, the starting situation must be defined, prior to the improvement process, benchmarking should be used as a tool to define the starting point, by identifying those measures that can describe the current situation (Paper V). The benchmarking methodology has also been tested for its ability to provide input into the continuous improvement process (Åhrén et al, 2005; Åhrén and Espling, 2003).

The framework shows that Banverket is putting adequate efforts in driving for its goal achievement, while a lot needs to be done to draw the roadmap for the long term perspectives. Also, this conceptual framework indicates the areas, which can be effected by its application, even in a regulated environment. The conceptual framework developed by this research study can be adopted and used by other industries and organization as well, with suitable modifications.

4.2 Research Contribution

The developed conceptual framework has been applied in Banverket, the methodology of which can also be used for other branches by identifying their unique factors. It is also possible to move between different hierarchical levels in the organisation, though the framework is task orientated. This research, describes how Banverket manages the administration of the state owned railway infrastructure under a client/contractor organization. Based on this a conceptual framework has been developed.

Outsourcing of maintenance is not an easy task; there are many aspects that need to be considered. A basic requirement for outsourcing maintenance has been proposed and tested. A gap analysis has been conducted between the basic requirements and practice in the outsourced contracts. By this methodology, it has been possible to identify the improvement areas. Partnering is used in complex projects in order to enhance the cooperation between the client and a contractor. A framework for partnering has been suggested and tested by a case study.

Benchmarking can be a tool for continuous improvement. The result from the benchmarking study, points out the gap between expected and received performance. Improvement areas have been identified
The main contributions of this research are:

- A framework to support a proactive infrastructure maintenance strategy was developed and suggested (Paper III and Paper VII).
- The associated factors and key issues required to be considered for developing the framework are identified and applied (Paper III and Paper VII).
- The problems associated with implementation of outsourcing and partnering practices, and risk management; have been investigated and remedial measures are presented (Paper I, Paper II, Paper IV, and Paper VI).
- The benchmarking process as used in the Swedish railway sector to enhance the performance of the maintenance process to achieve a continuous improvement have been studied and discussed (Paper V)

4.3 Scope for further research

There is always a scope for undertaking further research, as no research is absolutely conclusive. The scopes for undertaking further research in this area are;

- Further verifying the framework's approach for consequences like; risk and safety, as also to apply the framework for other industries.
- Application of this framework as an input for developing an integrated decision support system for any organization with suitable modification.
- Formulating the objectives for the railway maintenance process in terms of reliability, availability, maintainability and safety.
- Developing methods for risk analysis and enhanced knowledge for describing risk in loss of ROI, quality, health, safety and environment for the railway sector.

REFERENCES

Ahlmann H. (2002). From traditional practice of the new understanding; the significance of life cycle profit concept in the management of industrial enterprise, *IFRIMmmm Conference* ,Växjö Sweden, 6-7 May 2002.

Alvesson, M. and Sköldberg, K. (1994). *Interpretation and reflection: philosophy of science and qualitative method.* (in Swedish), Lund, Studentlitteratur.

Ashraf, W.L., O'Connor R.F and Williams, G.B. (1998). An effective maintenance system using the analytical hierarchy process, *Integrated Manufacturing Systems* 9/2.pp 87-98.

Backman, J. (1998). *Rapporter och uppsatser.* Lund, studentlittertur.

Banverket (2000). Banverkets Årsredovisning (Annual Report) 2000.

Banverket (2000A). BVF 900.3 Säkerhetsordning; Trafiksäkerhetsinstruktion (SÄO). Borlänge, Banverkets Bibliotek.

Banverket (2001). Banverkets Årsredovisning (Annual Report) 2001.

Banverket (2002). Banverkets Årsredovisning (Annual Report) 2002.

Banverket (2003). Banverkets Årsredovisning (Annual Report) 2003.

Banverket (2004). Banverkets Årsredovisning (Annual Report) 2004.

Banverket (2005). Banverkets Årsredovisning (Annual Report) 2005.

Banverket (2006). Banverkets Årsredovisning (Annual Report) 2006.

Banverket (2007). Goals. http://www.banverket.se/en-gb/Amnen/About-Banverket/Duties-and-organisation/Goals.aspx, 2007-11-03

Banverket (2007D). BVH 800 Vägledning till Banverkets underhållstrategi, HK 06-4446/OR20.

Barlow, J., Cohen, M., Jashapara, M. and Simpson, Y. (1997). "*Towards Positive Partnering*", The Policy Press Bristol, U.K.

Beck, R. (2003). Achieve Best-in-Class Reliability. *Conference proceedings AIChE Spring National Meeting*, March 30-April 3, New Orleans. LA

Coetzee, J.L. (1999). A holistic approach to the maintenance problem (1999), *Journal of Quality in Maintenance and Engineering*, Vol 5 no 3 pp276-280.

Deming, W., E. (1994). *The new economics for industry, government education.* Massachusetts, Institute of Technology, Center for Advanced Engineering Study Cambridge.

Dodgson, J., Spackman, M., Pearman, A. and Phillips, L. (2000) Multi-Criteria Analysis: A Manual. Department of the Environment, Transport and the Regions, London, http://www.communities.gov.uk/archived/publications/corporate/multicriteriaanalysismanual, (2007-11-07).

ERRAC (2007), Strategic Rail research Agenda 2020, Publishes by European Rail Research Advisory Council (ERRAC), Secretariat, www.errac.org

Espling, U. (2004). *Ramverk för en drift- och underhållsstrategi ur ett regelstyrt infrastrukturperspektiv*. Licentiatuppsats, 2004:45, Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2004A). *Benchmarking av basentreprenad år 2002 för drift och underhåll av Järnväg*. Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2005). *Arbetsgrupp TURSAM, Årsrapport 2004.* Luleå University of Technology, Luleå (in Swedish).

Espling, U. (2006). *Arbetsgrupp TURSAM, Årsrapport 2005*. Luleå University of Technology, Luleå (in Swedish)

Espling, U. (2007). Development of a conceptual framework for managing maintenance strategy for a client/contractor organisations in a regulated environment, Submitted for publication in a Journal.

Espling, U. and Kumar, U. (2004). Development of a proactive maintenance strategy for railway infrastructure; a case study. *Workshop Proceedings of the International Maintenance Congress Euromaintenace 2004*, Barcelona May 11-13, pp.31-38.

Espling, U. and Kumar, U. (2007). Benchmarking of the Maintenance for Railway Infrastructure. *Maintenance Handbook* , Chapter 23 Springer Publication.

Espling U., Nissen, A. and Larsson, D. (2007). *Strategi och metodutveckling av underhållsgränser för fordons- och banunderhåll, sett ur ett ekonomiskt perspektiv.* Luleå University of Technology, Luleå (in Swedish).

Espling, U and Olsson, U. (2004). Part II. Partnering in a Railway Infrastructure Maintenance Contract – A Case Study. *Journal of Quality in Maintenance Engineering,* Vol 10, No 4. pp 248-253.

Espling, U. and Åhrén, T. (2007). Outsourcing as a tool to fulfil maintenance objectives, a case study for Railway. Submitted for publication in a paper.

European Commission (2001). DG VII, A strategy for revitalising the Community's Railways, Brussels, (White paper)

Gummesson, E. (2000). *Qualitative Methods in Management Research.* California, Thousand Oaks, Calif.: Sage.

Hägerby, M., and Johansson, M. (2002). *Maintenance performance assessment: strategies and indicators*. Master Thesis, Linköpings tekniska högskola, Linköping.

Jardine, A.K.S. (1973). *Maintenance, Replacement and Reliability.* Pitman Publishing.

Kakabadse, N. and Kakabadse, A. (2000) Critical review – Outsourcing: a paradigm shift. *Journal of Management Development,* Vol. 19 No 8, pp. 670-728.

Karlsson, V. (2005) An overall view of maintenance. *European Railway Review,* 11**,** pp 11-17.

Kemi, L. (2001) *Funktionskrav och partnering för drift och underhåll av järnvägar,* Licentiate thesis. Luleå, Luleå University of Technology, Luleå. (in Swedish).

Kunttu, S., Ahonen, T., Reunanen, M. and Anttonen, J. (2007). Maintenance Development based on the cost-effectiveness analysis of tasks. *Maintenance & asset management,* Vol. 22, No 1, pp 20-25.

Larsson. L. (1999). Partnering inom Banverkets drift- och underhållsverksamhet, Luleå University of Technology, Master Thesis (in Swedish).

Larsson, D., Espling, U. and Nissen, A. (2007) Vehicle classification Based on Wayside Monitor Data – A Case Study. *Conference Proceeding IHHA International Heavy Haul Association Congress,* Kiruna 11 - 13 June, 2007, pp 471-477.

Liyanage, J., P. och Kumar, U. (2003). Towards a value-based view on operational and maintenance performance management. *Journal of Quality in Maintenance Engineering,* Vol. 9, No 4, pp. 333-350.

Lichtberger, B. (2005) Track Compendium; Formation, Permanent Way, Maintenance, Economics. Eurailpress, Hamburg.

McNiff, J., Whitehead, J. (1998) *Action Research: Principles and Practice.* Macmillan Education Ltd.

McNiff, J., Lomax, P. and Whitehead, J. (1996). *You and Your Action Research Project*. Hyde Publications, London.

Miles, M., B., Huberman, A., M. (1994). *An Expanded Sourcebook; Quality Data Analysis; Second Edition.* California, SAGE Publications, Thousand Oaks.

Molander, B. (1988). *Vetenskapsfilosofi: en bok om vetenskap och den vetenskapande människan.* Second edition. Thales, Stockholm (in Swedish).

Moubray, J. (1997). *Reliability-centred maintenance.* Oxford : Butterworth Heinemann.

Nakajima, S. (1988). *Introduction to TPM; Total productive maintenance*. Productivity Press, Cambridge.

Neuman, W.L. (2003). *Social research methods*, 5 Edition , USA

Nissen, A., Larsson, D., Espling, U. and Lagnebäck, R. (2007). Mowing from Safety Limits towards Maintenance Limits. *Conference Proceeding IHHA International Heavy Haul Association Congress*, Kiruna 11 - 13 June, 2007, pp 349-358.

Nowland, F.S. and Heap, H.F. (1978). *Reliability-centered maintenance*. US Department of commerce, Virginia.

Ottosson, S. (1996) Dynamic product Development: Findings from participating action research in a fast new product development process. *Journal of Engineering Design*, June 1996, Vol . 7. Issue 2, p151-170.

Parida, A. and Chattopadhyay, G. (2007). Development of Multi-Criteria Hierarchical framework for Maintenance Performance Measurement (MPM). *Journal of Quality in Maintenance Engineering*, Volume 13, Number 4.

Parida, A. and Kumar, U. (2006). Maintenance Performance Measurement (MPM): Issues and Challenges. *Journal of Quality in Maintenance Engineering*, Volume 12, Number 3, pp. 239-251.

SIKA (2003). *Statens Institut för kommunikationsanalys. Uppföljning av de transportpolitiska målen*, Bulls Tryckeribolag, Halmstad

SIKA (2007). *Statens Institut för kommunikationsanalys. Uppföljning av de transportpolitiska målet och dess delmål.* SIKA Rapport 2007:3

Stalder, O., Bente. H. and Lüking, J. (2002). The Cost of Railway Infrastructure. *Prom@in, Progress in Maintenance Management of Railway Infrastructur*e, 2. pp 32-37.

Stringer, E.T. (1996). *Action Research: A Handbook for Practitioners*. Sage Publication, Inc

Taflinger, R.F.; (1996). Introduction to Research. http://www.wsu.edu.8080/~taflinge/research.html 2007-10-01

Tsang, A.H.C. (2002). Strategic dimension of maintenance management. *Journal of Maintenance Management*, Vol. 8 No. 1, pp 7-39.

Tsang, A.H.C. and Jardine, A.K.S. and Kolodny, H. (1999). "Measuring maintenance performance: a holistic approach". *International Journal of Operation & Production Management*, Vol. 19 No. 7, pp 691-715.

Wigblad, R. (1997). *Karta over vetenskapliga samband; orientering i den samhällsvetenskapliga metodljungeln*, Studentlitteratur, Lund

Wireman, T. (2004). *Benchmarking BEST Practice in Maintenance Management.* New York, Industrial Press Inc, New York.

Yin, R.K (2003). *Applications of Case Study Research, Second Edition*. Sage Publication, London.

Zoeteman A. and Swier J. (2005). Judging the Merits of Life Cycle Cost Benchmarking. *Conference Proceedings, IHHA International Heavy Haul Association*, Rio de Janeiro, June 14-16.

Zoeteman, A. (2001). Life cost analysis for managing rail infrastructure, Concept of a decision support system for railway design and maintenance, *European Journal of Transport and Infrastructure Research*, Vol. 1, No. 4, pp. 391-413.

Zoeteman, A. (2006). Asset maintenance management: state of the art in the European Railways. *International Journal of Critical Infrastructures*, Vol.2, Nos. 2/3 pp 186

Åhrén, T., Espling, U. and Kumar, U. (2005). Benchmarking of Maintenance process; two case study from Banverket, Sweden. *Conference proceedings Railway Engineering, London July 2005*.

Åhrén, T. and Espling U. (2003). *Samordnet/Felles drift av järnvägen Kiruna – Narvik*, Luleå university of Technology, Luleå(in Swedish).

PAPER I

Part I. A framework for partnering for infrastructure maintenance

Olsson, U. and Espling. U. (2004). Part I. A framework for partnering for infrastructure maintenance. *Journal of Quality in Maintenance Engineering,* Vol 10, No 4. pp 234-247.

Part I. A framework of partnering for infrastructure maintenance

Ulf Olsson and
Ulla Espling

The authors

Ulf Olsson is based at Consulting Division, Swedish Rail Administration, Luleå, Sweden and also at Division of Operation and Maintenance Engineering, Luleå Railway Research Centre, Luleå University of Technology, Luleå, Sweden.
Ulla Espling is based at Division of Operation and Maintenance Engineering, Luleå Railway Research Centre, Luleå University of Technology, Luleå, Sweden.

Keywords

Partnership, Maintenance, Supplier relations

Abstract

The nature of maintenance is complex and greatly influenced by relationship among various actors involved in execution of maintenance tasks. The relationship factor becomes more critical when outsourcing maintenance tasks. The most important success factor is creating mutual "goodwill trust" between partners. Another important factor is the use of economic incentives for both parties. A formal partnering process, top management support and relevant outcome measures are also important for a partnership to be positive. Partnering is a potential "tool" to create success. Based on a review of the partnering literature and experiences from Swedish railway sector, a partnering framework for maintenance contracts has been developed. The partnering framework considers four main factors, namely requirements and potential for partnering, the partnering process, success elements and measures on partnering success.

Electronic access

The Emerald Research Register for this journal is available at
www.emeraldinsight.com/researchregister

The current issue and full text archive of this journal is available at
www.emeraldinsight.com/1355-2511.htm

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · pp. 234–247
© Emerald Group Publishing Limited · ISSN 1355-2511
DOI 10.1108/13552510410564855

Practical implementation

This paper presents a framework for partnering for infrastructure maintenance. The proposed framework will be useful for infrastructure managers practising partnering approach in negotiation and execution of a contract for maintenance. The framework takes into account various influencing factors and examines their interrelationship and provides a road map for conflict resolution. The paper also describes the critical success factors for partnering and provides guidelines for building up mutual trust amongst all partners involved in maintenance tasks execution.

Introduction and background

Over the past decade there has been an increasing focus on organizational efficiency. Maintenance activity is an area where organisations have often sought to introduce greater efficiency. Restructuring a maintenance department has become a common strategy when an organisation makes change in several of its units.

Contracting out infrastructure maintenance (for example, roads, streets and railways) has become a popular strategy in several European countries over the last ten years. This type of change has taken place in countries such as Great Britain, Holland, Denmark and Sweden.

A contract approach which spells out each party's duties, unforeseen events are settled by resorting to legal rules and communication has been used in Sweden since 1992 for contracting out public road and street maintenance. There have been substantial price reductions ranging from 10 to 20 per cent in bidding (Olsson and Johansson, 1999). The hard price competition has led to some disadvantages. No margin is allowed for developing production processes plus many contractors have tested how much they can reduce the level of service provided (Danielsson, 1998). The flexibility for coping with unforeseen events during contract periods is low and expensive (for the client). These disadvantages have in some cases led to adverse relationships between the two parties. This rigid and uncommunicative approach to maintenance contracting used in Sweden is similar to and "borrowed" from the construction

The authors are thankful to Dr. Uday Kumar, Professor of Operation and Maintenance Engineering and Director Luleå Railway Research Centre for discussions and his suggestions to improve the manuscript. The authors are also thankful to Swedish Rail Administration for its permission to publish this paper.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

industry. One possible reason for the problems that have arisen is that the contracts were developed for construction and not maintenance with its greater need for flexibility. Also, the contracts typically fail to provide for asset preservation and to recognize working conditions such as inconvenient traffic patterns in areas being maintained.

Similar adverse relationship problems between clients and contractors are common in the construction industry in Sweden and elsewhere. According to Barlow *et al.* (1997), the British construction industry has experienced problems in the areas of "low productivity, a litigious and adversarial environment, and a limited take up of technological and business process innovations". Partnering is now being used widely in the British construction and in maintenance industries. There is hope and interest that this strategy will improve relations between clients and contractors plus integrate competencies that will lead to increase in productivity and quality of delivery.

To avoid adverse situations in maintenance contracts, the Swedish National Road Administration (Vägverket) has introduced project partnering in two contracts. A target price per year along with contractor incentives and penalties is being used. The Administration and the contractors (including any major subcontractors) agree on mutual targets for the contract. All parties are expected to do more than what the contract spells out. All measures needed to meet the targets are discussed and mutually agreed upon. The idea is to use an integrated competence that draws upon the skills of all to solve important matters during the contract period. The level of communication and flexibility is much better than in traditional contracts (Hörnfeldt, 2003). It has also been observed that the partnering approach has created a quality of communication between the administration and contractors that benefits overall road network operations. It is said that contractors "have the ability to shift their operations to meet the expressed needs of the Road Administration".

The Swedish National Rail Administration (Banverket) has started to gradually contract out maintenance and renewal activities. Out of eight contracts awarded so far two include partnering as an important contract feature. Introducing more collaborative contract approaches combined with target price and incentives is definitely a trend in Sweden for the maintenance and renewal of the state owned infrastructure.

This paper presents a framework for project partnering that may be used in infrastructure maintenance and renewal contracts. The framework is based on a review of partnering literature and assessments of similar contracting in other countries.

What is partnering?

The term "partnering" has a number of definitions; some not necessarily agreeing with others. Neither the construction industry nor the academic community has commonly agreed upon definitions.

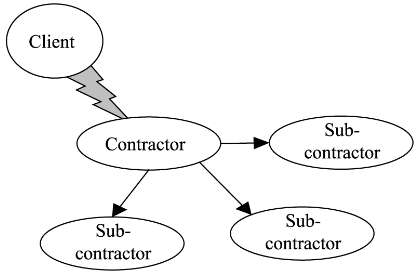
More positively, many definitions overlap. The definition used by the Reading Construction Forum contains many of the most important elements (Bennet and Jayes, 1995). It defines "Partnering is a managerial approach used by two or more organisations to achieve specific business objectives by maximizing the effectiveness of each participant's resources. The approach is based on mutual objectives, an agreed method of problem resolution and active search for continuous measurable improvements".

More concisely, Barlow *et al.* (1997) describes partnering "as a set of processes to aid inter organizational collaboration and improve performance". He adds that this form of collaboration is consciously enforced in order to build a high degree of mutual trust. Figure 1, shows a traditional project contracting configuration and Figure 2, shows a partnering configuration.

The partnering concept focuses on:
- teaming together key personnel from the client, contractor and important subcontractors;
- trust building; and
- openness between the parties (transparency amongst the partners).

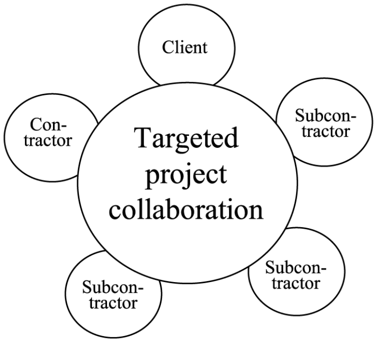
The partnering process is intended to create a win-win situation where increased efficiencies mean contractor's operating costs are lowered and savings can be passed on to the customer.

Figure 1 Traditional project contracting – the distance between each party represents limited, communication



Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

Figure 2 Partnering contracting – the absence of any distance between parties represents communication which is open, continuous and not limited to contract specifications



Source: Olsson and Espling (2003)

Literature on strategic partnering and project partnering separates the two. Strategic, or long term partnering, has a duration of several projects or contracts while project partnering is used to describe partnering for single projects or contracts.

Later, at the end of the 1980s the US Army Corps of Engineers developed (Kadefors, 2002) partnering as a way to avoid litigation, lower costs and keep projects within planned time frames. Partnering as a way of working spread rapidly during the 1990s and is today commonly used in the construction industry in English speaking countries. In Great Britain, the Latham (1994) report contributed to the establishment of partnering by focusing on a strong demand for better cooperation between the parties involved in construction contracts.

Advantages and disadvantages

The Reading Construction Forum has carried out several studies on partnering in Great Britain concerning construction projects. One study (Barlow *et al.*, 1997) showed that using project partnering contributed to a cost reduction between 5 and 30 per cent and time savings between 10 and 40 per cent.

Also found was that projects which used the principal of strategic partnering with all key actors being involved in daily operations showed cost reductions up to 40 per cent and timesaving up to 50 per cent.

The Texas Department of Transportation investigated the effects of partnering in over 200 construction projects and compared outcomes with non-partnered projects. The positive effect of (Kadefors, 2002) partnering on costs, time and logistics were over $10 million, saved for the largest projects

According to Barlow *et al.* (1997), the mutual benefits of partnering are:

- *Improved project quality*. Better solutions are said to emerge when there is the early involvement of key parties.
- *Reduced claims and litigation*. Partnering represents a proactive approach to problem avoidance. The Texas Department of Transport reports a reduction in dispute claims from 28 to 2 per annum.
- *Improvements in costs, scheduling and profitability*. The potential for participants to influence costs and time frames is greatest in the early phases of a project. The competence and experience of all the key players are used in a proactive manner.
- *Better working environment*. Attitudes and communication is a typical result of partnering.

The benefits of partnering in maintenance contracts can, according to Hörnfeldt (2003), include:

- increased flexibility in meeting road user needs;
- the length of time road networks are closed or restricted due to construction is lessened; and
- maintenance costs are lower and functionality of all systems is greater.

Similar results have been reported by Kemi (2001), for partnering used in railway maintenance contracts in Sweden.

Potential disadvantages for both parties when using partnering are:

- Partnering requires more management involvement, especially when introducing and starting up the partnering process, as well as during project duration.
- "An over dependency on the partnership and maintaining the value received: entering a partnering relationship does not mean firms abandon competition, merely that competition is more focused on whatever costs or performances are more critical to the client" (Barlow *et al.*, 1997).
- The client may be tempted to transfer benefits that are uncalled for, to partners.
- For government operated or controlled contracting, a partnering relationship could place non-partnered contractors at a disadvantage during bidding on subsequent contracts (e.g. the contractor with partner status may have access to restricted information). This may reduce competitiveness, which is contrary to expected governmental practices.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

From partnering project studies some recommended guidelines have been developed. These are best used as an initial framework during the development of a partnering relationship. Bresnen and Marshall (2000a) maintain that "there is still a need for more systematic and in-depth research which examines the nature, efficacy and feasibility of a partnering approach" i.e. there is still work left to do.

Framework for partnering

Frameworks used for construction projects

A framework described by Barlow et al. (1997)
In their work, Towards Positive Partnering, Barlow and his associates describe a framework upon which a construction industry partnering relationship can be established. Their descriptions are detailed, based on a number of case studies within the British construction industry and summarise prevailing partnering trends in that country's construction industry. In the following parts of this section, many of their most important points are summarised. While the framework cannot be directly applied to maintenance activities, it serves as a reference point for the development of the strategy of partnering as it can be applied to maintenance activities.

Contextual dimensions

According to Barlow *et al.* (1997), partnering can be seen as a set of processes, which facilitates inter organizational collaboration and improves performance. It is stressed that the partnering relationship must emphasise equality where all partners are able to improve performance because of support from all other partners. A way to measure results to make certain that benefits are equal is essential. Although the relationship is a client-contractor relationship it is also critical that there be a degree of equality; a relationship where all partners have approximately the same status and ability to communicate openly. Barlow *et al.* go on to describe partnering as a relationship where each side is highly dependent on other partners. An equal power balance, where each partner strives to improve his own performance in an environment where improvements supported by other partners, is seen as a key element in successful partnering relationships. Barlow *et al.* (1997) emphasise that it is critical for all partners to understand that "contextual dimensions" are present and that decision makers among all partners need to understand the importance of a power balance between all partners.

Barlow *et al.* (1997) describe different stages of partnering. It is emphasised that the needs and circumstances of a client may vary and thus dictate the form of partnering used. Where basic construction work is to be performed and contractors are easily replaced then more traditional client-contractor relationships may be most appropriate. Where work to be performed will be more long-term the different stages of partnering are more appropriate. Relationships that use incentive contracts where a contractor is obligated to seek improvements independently and the client is not similarly obligated may be most appropriate. This form of partnering still encourages communication but does not require the client change nor invest to resources in building a long-term relationship.

The authors also describe partnering relationships where there is a high degree of interdependence and a balance of power between partners. The closest form partnering relationship is seen as appropriate for joint ventures where there is an equality of risk. For example, where there are a limited number suppliers then partnering may be an ideal strategy. This stage of closeness might occur where construction work is complex or critical for a client's operations. In this case, collaborative partnering to achieve performance improvements among all parties is the optimal strategy.

For successful partnering the following six elements are needed Barlow *et al.* (1997):

- the need for trust;
- the "right" personalities;
- openness in communication;
- organizational culture and organizational learning;
- teambuilding; and
- the role of management.

The need for trust
Partnering relationships will not emerge without a high degree of trust. Building trust may be the hardest part of creating a partnership. Trust can emerge from an accumulation of shared experiences and from a gradual deepening of mutual understanding.

The interdependence of the partners has to be recognised by all. Short-term gains that benefit only one partner must be outweighed by the benefits of overall performance relative to the overall partnering targets.

The "right" personalities
It is necessary to overcome destructive competitive relationships in which people are possessive and defensive. Instead, all participants should be encouraged to openly express their views more. Having the right people on a team is therefore essential. However, not everyone is fit for partnering and it happens sometimes that this

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

becomes evident after a project has started. It might be necessary to replace individual project members so as to be able to go on with a partnering process.

Openness in communication
A basis for the emergence of trust is the establishment of high levels of communication between organisations, partnering-teams and individuals. Close and effective communication prevents problems from becoming disputes and aids in problem solving. Communication at all levels is important in order to encourage people to give early, informal warnings about potential problems. Exchange of information through regular face-to-face meetings is important.

Organizational culture and organizational learning
A primary goal of partnering is to learn new strategies and introduce efficiencies. This can mean that traditional activities or relationships within a partnering organisation will be altered or eliminated. The change may be perceived as threatening to individuals or groups within a partner's organisation and they may attempt to resist change. Recognition that attitudes based on an organisation's culture (e.g. this is the way we do things around here) is present and must be addressed is critical. With effective management of employee attitudes it is possible to make organizational culture a positive force that contributes to the learning of new ideas.

Teambuilding
Teambuilding is seen as an important part in the process of building trust and aligning different perspectives of people from culturally diverse organisations. One objective of teambuilding workshops is the drafting of a "partnering charter". The underlying assumption is that people are more likely to support what they actively created.

Studies by Bresnen and Marshall (2000a) found that teambuilding efforts helped groups through the formative early stages of partnering. Group identity was encouraged and individuals developed feelings of ownership in partnering projects. Learning was then facilitated as individuals had positive attitudes towards new ideas.

The role of management
The level of commitment by upper management in each organisation is fundamentally important. There is a need to ensure that client management agrees with the goals of a relationship rather than their believing that it is being imposed from above.

Barlow *et al.* (1997) emphasise the important influence the upper management can have on the success of a partnering relationship by arguing that the extent to which partnering arrangements foster improvement is critical. Defining and implementing action is typically the responsibility of upper management. Thus, for partnering, the participation of both client and contractor management is necessary for true collaboration and mutual performance enhancement.

Furthermore, it is management's responsibility to allow partnering to work over organizational boundaries, yet within the corporate framework of each organisation involved.

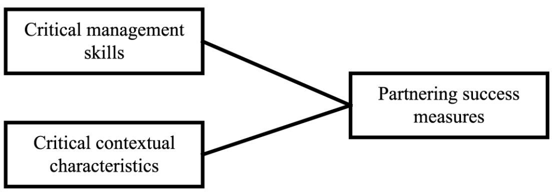
While this subsection emphasises the work of Barlow *et al.* (1997), it is also important to comment that they are describing concepts that are commonly used by those writing about partnering.

Framework according to Cheng et al. (2000)
E. Cheng and various co-authors in a series of paper present another description of partnering frameworks used in the construction industry. The framework presented by Cheng, while similar to that developed by Barlow *et al.* groups partnering concepts into fewer categories. Also, data collected by Cheng comes from all over the world and thus attempts to describe the worldwide state of partnering. Generally, the primary categories are managerial involvement, initial planning and operations. Figure 3 shows the framework described by Cheng *et al.*, 2000, in an earlier paper in a series of articles on partnering.

Contextual dimension

Cheng and his various co-authors in their different papers emphasised that one critical characteristic of successful partnering is that before entering a partnering arrangement an organisation must be clear about why it is doing so. An important step is therefore to examine how partnering relates to its overall corporate strategy. In addition, an organisation must identify with whom it is willing to form partnering relationships. The key point being made by Cheng is that it is essential to understand the aspirations and culture of potential partners in order to be able to develop a successful partnering arrangement.

Figure 3 Framework of partnering – leadership and performance measurement are emphasised



Source: Cheng *et al*. (2000)

Critical success factors, according to Cheng *et al.* (2000) are:

- mutual trust (the need for trust);
- management support (the role of management);
- adequate resources;
- co-ordination;
- creativity; and
- long term commitment.

Among management skills, effective communications and conflict resolution skills are mentioned as important.

Measures of the critical factors have been divided into objective and subjective measures. Key objective measures are cost variations, profit variation, rejection of work, schedule variation, change in scope of work, safety measures, rework, litigation and tender efficiency. The most important subjective measure is perceived satisfaction of partner's expectations

The conceptual framework of project partnering relations

This section discusses elements seen as important for a conceptual framework for project partnering. The more traditional approach to contracting, often referred to as "arm's-length" contracting, is contrasted to the closer contractual relationship of partnering (the idiom, "arm's-length", is used here to describe relationships where each party is independent of the other; this is the opposite of partnering).

Arm's-length contractual relations (ACR) and project partnering relations (PPR)

According to Sako (1992), an arm's-length contractual relationship involves a specific discrete economic transaction. Before a relationship begins a detailed contract is written that describes each party's responsibilities in every conceivable situation. If some unforeseen problem arises it is settled using a previously agreed upon arbitration process or the legal system where business is being conducted. All dealings are at "arm's-length" so that the freedom to make decisions and operate independently of any other party to the contract is preserved. This can be referred to as "arm's-length contractual relations" or "ACR".

Project partnering relations (PPR), used by clients in the public sector also involves an economic contract. In this type of arrangement, partnering can be described as a set of processes designed to facilitate inter organizational collaboration and improve performance. Here, collaboration is consciously enforced in order to build a high degree of mutual trust among all partners. The contractual relationship is deliberately structured so that all parties must work closely together in a cooperative partnership.

ACR is characterised by a low degree of actual and perceived interdependence while PPR is characterised by mutual dependence with respect to all important project matters.

The basic features of the ACR and PPR used in contracts in the public sector as they manifest themselves in practice are summarised in the Table I.

There are three dimensions that capture the essential differences between ACR and PPR. The first is the degree of openness between the parties, the second is the attitudes towards shortcomings in any enquiry documents, and the third is the attitude towards unforeseen events.

In PPR contracts, openness is necessary but not sufficient to build mutual trust. In ACR contracts too much openness can become a liability during negotiations. Shortcomings in a contract's specifications or unforeseen events in an ACR contract, be used by a contractor as an opportunity to add charges. For the client, deficiencies in specifications or unforeseen events become a risk that may cause budget overruns. In a PPR project, the contractor and client work to solve issues, case by case and by applying a fairness code.

For a publicly own client, it is of great importance not to favour any contractor or supplier unfairly during contract competition or during a contract period. It is easy to remain impartial with an ACR contract because of the formal and the independent way it is carried out. One important feature of an ACR relationship is that every conceivable eventuality is spelled out in a contract. Differing opinions by parties are therefore solved by interpreting a contract. Case by case solutions in a PPR contract can lead to unfair advantages for some contractors if not handled in a business like manner by a client. Most important for governmentally owned or controlled clients is that all monetary transactions be handled with great care and to have benchmarks for comparison against ACR contracts with similar projects.

Trust between contract parties

In writing about relations between companies, Sako (1992) says that, "Trust is a state of mind, an expectation held by one trading partner about another, that the other behaves or responds in a predictable and mutually acceptable manner". She goes on to explain that trust between trading parties has a role in increasing the predictability of mutual behaviour.

Sako (1992) describes three types of trust that exist between trading parties:

(1) contractual trust;
(2) competence trust; and
(3) goodwill trust.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

Table I Features of ACR and PPR (ACR features follow Sako,1992 and have been adjusted to public sector contracts more accurately describe)

Item	Arm's-length contractual relations (ACR)	Project partnering relations (PPR)
A	*Transactional dependence*	
	Buyer seeks to maintain low dependence by trading with a large number of competing suppliers. Supplier seeks to maintain low dependence by trading with a large number of customers	For a publicly own buyer it is important to maintain transactional independence between individual projects. Within a PPR-project mutual dependence to create mutual trust is desirable. For a supplier to the public sector avoidance of dependence is not a high priority
B	*Contract bidding process*	
	Bidding takes place under the procurement laws. Prices are agreed on before order is commenced	Same procedure as for ACR contracts with one exception; bidders are asked to respond to the PPR concept. Response is evaluated when comparing bids
C	*Project length*	
	For the duration of a contract. Short-term commitment for both parties	Same as for ACR but sometimes with extensions if the initial contract is successful
D	*Project targets or goals*	
	Are set by the client. Only "hard targets".	Mutual project targets/goals are set by all parties in collaboration. Both hard and soft (relation-based) targets/goals may be developed
E	*Project organisation*	
	Traditional "counterpart" organisations.	Partnering groups are founded consisting of key persons representing all parties to a contract
F	*Project decisions*	
	Each party decides on matters independently.	All decisions of importance for a project are decided in collaboration
G	*Unforeseen events*	
	Settled by legal or normative rules chosen by the client.	Settled "case by case" aiming for a fair deal for both parties in order to build mutual trust. Conflict resolution models are often included in the contract (e.g. time limits for different organisation levels)
H	*Type of contract/payment*	
	Fixed price or bill of quantities	Target price combined with incentive/penalty rules. Payment according to actual costs
I	*Knowledge transfer between contract participants*	
	Low degree of transfer. A tendency to withhold relevant information to be tactically used in future negotiations	A high degree of transfer. Incentives are built in to stimulate "best practices".
J	*Communication channels*	
	A narrow and formal channel between client and contractor. Frequency kept to a minimum necessary to do business	Extensive communication at all levels. Frequent contacts.
K	*Risk sharing*	
	Little sharing of risks. Risk responsibility is spelt out in explicit prior agreements. Each party manages its own risks	Sharing of project risks. Unforeseen loss or gain is decided case by case using some fairness principle. The parties carry out joint risk management actions
L	*Trust (see descriptions on trust that follow)*	
	Negotiated, contractual and competence trust	Contractual, competence and goodwill trust

Contractual trust means that each party keeps promises (written and oral agreements). Any business transaction relies on "contractual trust" for its successful execution. More contractual trust is usually needed when using oral agreements. The expectations concerning a trading partner's technical and managerial competence constitute competence trust. An effective quality assurance program operated by a supplier also means that, in turn, a customer is expected to extend a higher level of "competence trust". The third type, "goodwill trust" refers to the mutual expectations of open commitment to each other, which is defined as a willingness to do more than formally expected.

According to Sako (1992), the key to goodwill trust is that there are neither explicit promises as in contractual trust nor professional standards as in the case of competence trust. What distinguishes goodwill trust from contractual trust is the expectation that the contract parties are committed to take initiatives (or to exercise discretion) to exploit new opportunities over and above what was explicitly promised. Such "partial gift exchanges" are necessary to maintain goodwill trust while fulfilment of explicit promises is enough to sustain contractual trust.

While discussing goodwill trust, practices unique to Japanese business were used to amplify points made about the value of goodwill trust. In particular, Sako describes a Japanese business practice obligational contractual relation (OCR) [1]. According to Sako, the central difference between ACR and OCR is in goodwill trust, which exists only in OCR contracts. Sako also points out two dimensions that capture the essence of ACR and OCR relationships: the degree of interdependence and the time span for reciprocity.

ACR contracts are having a low degree of interdependence while OCR relationships are characterised by heavy interdependence. In ACR, short-term commitments are common while OCR means mutual long-term commitments.

PPR projects in public infrastructure construction are not allowed by most public procurement laws to have contractual long-term commitments. The only exceptions are very big and ongoing infrastructure projects (for example, new railway lines). For maintenance contracts however, long-term contracts (five to seven years combined with options for two to three more years) are common today. So, in maintenance contracts the same time dimension as in OCR relationships is present. This may make it possible to create OCR-like conditions between PPR maintenance contract parties. In PPR contacts there will be a higher degree of mutual interdependence as compared to ACR relationships. This is true for PPR construction projects and much more so for PPR maintenance contracts.

The potential to achieve OCR-like conditions are therefore much better in public PPR maintenance contracts than in PPR construction contracts.

ACR and PPR contracts both rely on contractual and competence trust for an acceptable outcome. Barlow *et al.* (1997), Cheng *et al.* (2000) and Kadefors (2002) all mention the importance of mutual trust in PPR contracts. It seems that some degree of what Sako (1992) defines as goodwill trust must be present for there to be a successful PPR contract.

How is trust created and sustained?
Contractual trust rests on moral norms and honesty. In short, it means keeping promises. This is the minimal amount of trust embodied in most ethical codes.

Competence trust may be attained by purchasing existing competence in the market place. Clients in the public sector usually assure themselves of the bidder's competence by using "soft parameters" during the procurement phase. Competence can also be attained by investing in creating competences. It can mean the client transferring some part of its in-house knowledge to a contractor as people or technology. It could also mean that the client and contractor jointly develop new technology.

Can goodwill trust in business be created by intent or not?
As mentioned earlier goodwill trust is to be found in Japan between OCR contract participants. Is it possible to create a similar goodwill trust in new business relations and, in particular, use PPR in public construction and maintenance contracting? Sako (1992) refers to one case studied by Lorenz (1988), where subcontractors created trusting relations through the practice of partnership. Frequent personal contact between partners, much exchange of information and mutual assurances took place. No partner was expected to give blind loyalty to another.

In PPR contracts a process is being used in order to develop mutual trust. A partnering group is formed consisting of key personal from a client, contractor and important subcontractors. This group develops its own charter for a project. Open and frequent communication is stimulated which addresses all types of issues. All parties are expected to continually work towards successful project outcome and to look for performance enhancing measures. Adverse situations will occur in most projects. A morale commitment by the parties not to take advantage of another party is an important PPR dimension. Case studies (Rhodin, 2002) in Sweden indicate that relationships with and empathy for partners was significantly enhanced when an effort was made to build trust.

Benefits from trust
According to Sako (1992), "transactional[2] efficiency is enhanced whenever conditions exist which promote information flows, increase effort exertion, and reduce the need to incur transaction costs associated with curbing opportunistic behaviour". Contractual and competence trust are necessary for there to be trustworthy and effective information exchanges. Goodwill trust normally means that there will be a sincere effort to act dynamically in response to new situations not covered in contract documents. "Trust is also a necessary but not sufficient factor in achieving total organizational efficiency".

The beneficial effect of trust in creating constant and reliable expectations, a necessary basis for flexible responses, has great potential with respect to PPR public sector maintenance contracts. The need for flexible responses is much higher in maintenance and renewal contracts than in construction projects.

Factors influencing the outcome of PPR

According to Cheng *et al.* (2000), it is important for an organisation to examine why it is entering a partnering arrangement, i.e. which conditions will support successful partnering relationships.

The development process should be an important part of any partnering framework. A formal development process is important yet, it is not enough without good relations (Kadefors, 2002).

Success factors and pre-defined measurements of accomplishments are described by both Barlow and Cheng as main characteristics of a framework for partnering.

A general schema for partnering should contain the elements shown in Figure 4. Partnering is shown as a process which aims for continuous improvement and where feedback is essential.

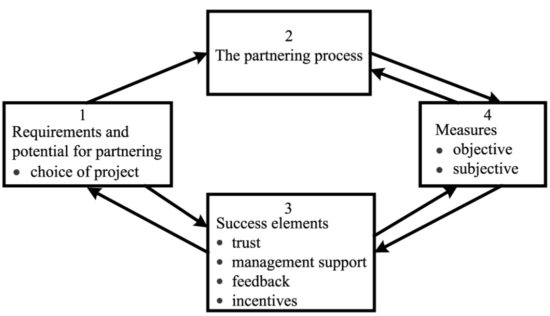
Requirements for partnering

According to Cheng *et al.* (2000), it is important for an organisation to examine why it is entering a partnering arrangement and how partnering relates to its strategy. In addition, an organisation must identify with whom it would form a partnering relationship. A critical feature in an effective relationship is the willingness of both parties to seek to improve their performance.

It is also essential to identify project types and activities with good potential for partnering. These are

- complex projects;
- activities that are critical to a client's business; and
- projects in markets where the number of contractors are limited.

Figure 4 Schema of factors influencing the PPR outcome



It is important to monitor ongoing partnering projects. Assessment of performance can help to evaluate the potential for partnering in future contracts.

The partnering process

Rhodin (2002) identified the processes and structures essential to partnering in the construction industry. Table II summarises her findings.

Five of the process elements in Rhodin's framework are common to what is found in the partnering literature. Element numbers three and six are not so common. Integrating design and construction gives great potential for finding good technical solutions for a project. The purchasing/procurement process is essential in order to stress the importance of a healthy ongoing competition and to establish effective rules for a partnering process and its structure.

A more complete process should include the elements shown in Table III.

Table II Structural elements per Rhodin, 2002

S. No.	Process	Structural element
1	Common goals	Partnering charter (goals, norms)
2	Conflict resolution	An established structure for conflict resolution
3	Design construction integration	An established structure for design integration
4	Evaluation and continued improvements	An established structure
5	Teambuilding	Organisation (roles, relations, leadership, power)
6	Purchasing	Contract conditions
7	Relations and trust	Expectations (norms, roles, relations)

Table III Suggested partnering process elements

S. No.	Process
1	An equal flow of information to all partners
2	Using a partnering facilitator
3	Descriptions of the expected partnering in proposed contract specifications
4	Dividing the risk so that all partners believe there is risk equity
5	Economic incentives
6	Purchasing/procurement
7	Formation of a steering group
8	Formation of a cooperation group
9	Teambuilding
10	Agreeing on common goals
11	Formation of an operative group that will meet every week.
12	Continuous Relationship and trust building/monitoring
13	Conflict resolution
14	Joint Risk Management
15	Evaluations and continuous improvements

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

It is important before implementing a partnering relationship to clarify how much, when and how risks should be shared. According to Rahman and Kumaraswamy (2002), joint risk management is seen as a useful tool in cooperative relationships such as partnering.

Following up on outcomes (interim and final) and getting hold of why a process is not functioning as planned is essential for having a successful outcome. This task can be performed by a skilled facilitator.

Success factors

Barlow *et al.* (1997) and Cheng *et al.* (2000), both describe the following success elements:

- the need for trust;
- management support;
- open and effective communication; and
- conflict resolution structure and skills.

In addition, Cheng and his co-authors mention creativity while Barlow *et al.* discusses the importance of organizational culture and learning. Barlow *et al.* also stresses critical value of having the right people on a team. Incentives are often being used as an important factor in partnering contracts. A lot of partnering contracts include some form of incentive/penalty formula based upon a target cost. The client and contractor are always included and, in some cases, any designer.

Bresnen and Marshall (2000b) discussed the possible impact of incentives on collaboration, commitment and trust in partnering contracts. They studied nine partnering contracts and found that incentive/penalty provisions in contracts helped to encourage cooperation and collaboration as both parties could increase savings or increase earnings. But according to the authors, there are important limitations in the use of incentives as a means of reinforcing collaboration, commitment and trust.

- The basic principles of behaviour modification theory are not being taken into account in the incentive systems.
- Understanding participant evaluation of rewards is important and should be understood.
- There are different levels of motivation commitment – what might be good for an organisation is not necessarily good for individual members.

The implication is that when developing an incentive system that could reinforce motivation, commitment and trust there is a need for the system to be carefully designed and well placed within a total partnering package.

Measures

"Measures allow participants to assess the current status of a partnering arrangement and identify strengths and weaknesses. Measurements must reflect parameters that are indicative of goal achievement. Because monitoring requires resources, it is best to strategically select a system that measures only those aspects of a partnering relationship most critical to success (Crane and Felder, 1999).

In order to identify potential benefits and problems as early as possible, it is essential to have a functioning structure for following up performance. Both objective and subjective goals must be followed up and performance issue dealt with by the partnering group as a whole.

Causes of successes and failures need to be followed up in order to create an environment where improvement is encouraged and project members are encouraged to move in positive directions.

A partnering framework for infrastructure maintenance

Key characteristics of maintenance (a comparison with construction)

The primary goal of any maintenance activity is to support the core functions of any organisation so that the organisation is able to continue carrying out those functions without interruption.
A successful maintenance operation must consider business objectives, operational demands as well as health, safety and environment concerns. Maintenance operations have a number of properties that are both similar and different from typical construction operations. With respect to similarities, both involve using materials for work on various kinds of structures and use similar equipment. Differences between the two are described in Table IV. Apparent from Table IV is that there are major differences between construction and maintenance activities. Despite these differences, there remain enough similarities to justify applying many partnering practices used in construction to the field of maintenance.

One of the most important differences between construction and maintenance is that construction operations have a relatively easy to identify starting point whereas maintenance operations are ongoing. For maintenance operations, the more uncertain status of asset conditions, varying workload priorities and whether conditions warrant maintenance activities cause it to be difficult, if not impossible, to foresee and write detailed and accurate contract conditions for infrastructure maintenance and renewal.
Maintenance contracts are best left incomplete due to the limited ability to predict events during a contract period (which is often five to seven years

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

Table IV Key characteristics of maintenance

Construction	Maintenance
A. Time perspective	
Construction work can be described as a project, with a start and an ending	Maintenance is an ongoing process.(which should be conducted under continuous improvement)
Short contract periods of one to three years	Long contract periods of five to seven years
B. Asset conditions	
Construction works are carried out in a relatively short time period and with new materials	Asset conditions will change with the time due to age, use, wear and any other influence
The condition of assets will not change much during project duration	Requirements change making it difficult to describe need for action taken
C. Specifications	
Detailed standards and specifications	Difficult to exactly assess asset condition before, during and after a contract period
D. Dependence	
Contracts are designed to minimise dependence between client and contractor.	Major dependence between client/contractor. Contractor's engagement, knowledge and flexibility is essential and critical. Contractor has invested in personnel competence, machines and equipment for contract
E. Competence	
Work is carried out by employees with all levels of education and skill.	Low education levels. Competence developed on the job. Successful outcome is dependent undocumented or recognised skills
F. Knowledge	
Extensive documented knowledge required (handbooks, research reports, papers). Traditional university programs, courses apprenticeship programs. Frequent meetings and conferences	Maintenance is a new formal discipline. Methods and tools are sometime unknown to maintenance management and personnel. Formal training not widely available. Few meetings and conferences for learning
G. Finance	
Clear budget boundaries. Change costs must be negotiated.	The budget fluctuations are common. Maintenance activities postponed or cancelled when funds unavailable
H. Working conditions	
Construction is normally sole activity in area of operations	Work performed on existing structures while they are being used
Work performed within planned time frames	Time allocated for maintenance work is limited. Demands for rapid response in event of failure. Must plan for preventive and predictive maintenance

for public maintenance contracts). A contractor-client relationship where there is strong trust is an ideal condition for maintenance operations as trust and a willingness to work together cooperatively can be the best strategy for cost reduction and development of innovative work strategies.

It is important to keep in mind that maintenance is an important activity for the preservation of capital investment. When outsourcing maintenance, a client must know what goods and services are being ordered in contracts. Yet, maintenance is done to fulfil a demand function and it is often difficult to describe the needed actions and at the same time take in account factors such as climate, changes in traffic, wear and degradation that can influence the timely completion of requested work. Buying a function through a contract rather than depending on in-house resources is a new approach to operations and maintenances. There are few, if any, frameworks or guidelines to guide planning and management. Furthermore the complexity and the risks in the procurement of services are high leading to misjudgements in planning. A good relationship developed through project partnering is expected to reduce the business risk. The trust and cooperation in a partnering relationship can cause misjudgements and unanticipated needs to be more economically and efficiently managed in a way that all parties can benefit. The client can save on costs and reduce time needed for maintenance while the contractor can better plan work so that the use of personnel and resources is optimised.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

Framework for partnering in maintenance

The framework for partnering in maintenance contracts can be built up by combining the features of PPR in Table I with the factors shown in Figure 3 with special attention to the key characteristics discussed in Table III.

The elements of PPR shown in Table I are essential but not enough for successful partnering in a maintenance contract.

The elements outlined in Table I can be related to the key characteristics of Table V as follows:

The key factors to consider are as for project partnering in general:

- the requirements for partnering;
- the partnering process;
- success elements; and
- measurements.

Requirements and potential for partnering

According to Barlow *et al.* (1997), the potential for partnering is great for:

- complex projects;
- activities that are critical to a client's business; and
- markets where the number of contractors are limited.

Good maintenance strategies are difficult to develop because level of use can be unpredictable (deterioration and wear due to traffic loads), structure ageing and weather conditions. The amount of reconstruction work to be performed is often decided only a year in advance of actual work. As a contract will last for a number of years, maintenance planning and operations are best regarded as complex and changing.

Some maintenance activities are critical for the successful operation of a business. When maintenance is ineffective the business may be unable to operate and end up failing. In the case of public transport operations the impact of ineffective maintenance operations can have even a wide negative impact. When public transport preventive maintenance is ineffective then passenger transport and goods shipment are delayed. These delays can have a negative impact upon a wider economy, as passengers, finished goods and raw materials do not arrive within planned time limits.

Table V Connection between features of PPR and characteristics of maintenance

Features of PPR	Key characteristics of maintenance
A Transactional dependence	g.,
C Project length	a.,
G Unforeseen events	f., c.,
L Trust	d., e.,

For train systems, punctuality is an issue closely followed by the media (newspapers, radio and television).

For Sweden, the status of contracted maintenance for the rail network is serious as there are not many contractors willing and able to perform railway maintenance activities. Today, maintenance is conducted in-house (short duration work) or has been competitively purchased for a relatively long duration (three to seven year). This offers opportunities to pursue partnering in the same time perspective as is done in strategic partnering.

This analysis suggests that the potential for partnering is very high for rail maintenance activities. Cost reductions of up till 30 per cent in combination with high availability performance is possible.

Partnering can be used in the following situations:

- With existing contracts when in-house resources are inadequate for needed maintenance and
- Purchasing of new maintenance contracts.

With both existing and new contractors a partnering relationship can lead to the creation of a "learning organisation" where new efficiencies and strategies that benefit all parties can develop (De Vilbiss and Leornard, 2000).

The partnering process

The construction partnering process elements listed in Table II can be equally applied to maintenance partnership contact in the rail industry.

Some additional important factors in a rail maintenance contract are:

- Accurate descriptions of asset conditions in measurable terms to serve as a base for planning work and the formulation of common objectives.
- Clear descriptions of client/contractor primary objectives, specifications and prognoses on how assets will be utilised during contract duration
- Shaping of a common action plan for reaching planned objectives.

Success elements

In principal, the same success elements for partnering in construction activities can be used for maintenance operations as discussed in section "A framework described by Barlow *et al.* (1997)".

It is recommended that economic incentives should be combined with these success elements to achieve the business goal. A simple model for planning, follow up and assessing outcome is also needed.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

Another key factor is to the efficient use of the silent or tacit knowledge possessed by a rail network's maintenance personnel. Howells (1996) describes how employee knowledge enhances organizational efficiency when it is incorporated into planning and operations. In the case of rail maintenance, the knowledge of network conditions and maintenance techniques possessed by in-house maintenance personnel can be used during partnering with contractors. As members of the teams working with contractors it will be possible for in-house maintenance personnel to share their knowledge and contribute to problem avoidance and the development of appropriate skills among contractor employees.

Measurements

Key functions must be measured both to know system states and to assess contractor performance. This can be done with so-called key performance indicators. For railways it is, for example, the number of delay minutes due to maintenance and traffic safety incidents.

Other important targets in the partnering charter must be measured for example:

- production costs;
- time spent on asset maintenance activities;
- the number of functional failures; and
- effects on the environment.

For maintenance, trend analysis is of special interest because work is being performed on assets that are growing older and are being used for longer periods of time between maintenance operations. Systems for early warning of functional failures are of great interest so as to steer maintenance processes in the right directions.

The demand for following trends and doing prognosis analyses on technical conditions of assets is an important aspect that differentiates maintenance from construction projects.

Conclusion and recommendations

A framework of partnering in infrastructure maintenance

A general framework of partnering in maintenance contracts should lean on three cornerstones:

- features of PPR according to Table I;
- factors described in Figure 4; and
- key characteristics of maintenance described in Table IV.

The potential for partnering is, in general, significant for maintenance contracts. Long contract periods, complexity, the need for flexibility and client/contractor need for a strong dependency to achieve success are all prerequisites that support the use of partnering for rail network maintenance operations.

The partnering process is, in principle, analogous to partnering in construction projects. The adjustments recommended in this paper consider differences and recommend modifications when applicable.

Necessary success factors for maintenance partnering are to first create an atmosphere of mutual trust, second to provide economical incentives for improvement and third that contractor and client so-called tacit or silent knowledge is effectively integrated into planning and operations.

Measurements of client/contractor satisfaction before, during and after a contract are essential as positive attitudes toward partnering can be a significant indicator of success. Technical and functional assessment of asset conditions can serve to as a second measure of performance outcome.

Recommendations for partnering in infrastructure maintenance contracts

Recommendations for successful partnering in infrastructure maintenance contracts in the public sector:

- A gain-sharing mechanism, financial incentives for partners to reduce project costs and improve the performance be formulated and included in any contract.
- Rules for circumstances for the justification of changes in target cost.
- CEO or top management must be committed to the partnering process and also be involved in the implementation of organizational processes uses to implement a partnering arrangement.
- Require the presence of a facilitator to co-ordinate and facilitate implementation.
- Teambuilding. It is important to create a project-partnering team comprised of key personnel from the client, contractor and any important sub-contractors.
- Continuous communication between all parties that helps to reinforce a message of honesty and openness and which eliminates barriers caused by differences in organizational cultures.
- Developing a charter with commonly agreed upon and ranked objectives.
- Developing an agreed strategy for meeting partnering objectives.

These recommendations are similar to those in general for project partnering. In addition, maintenance partnering projects should include:

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 234–247

- Clearly stated goals in connection to the end users;
- An agreed strategy for developing the maintenance process; and
- A strategy for involving all personal in the partnering process especially those "on the floor".

Notes

1 The Obligational Contractual Relation (OCR) is an approach used in Japan. OCR involves an economic contract and one vital part is that the trading partners entertain a sense of mutual trust and interdependence. The time span is often much longer than in ACR contracts.

2 Transactional costs includes costs of drafting and negotiating agreements, managing the product flow, on-going trading, adjustment associated with changing business (renegotiating prices and contractual terms) or technological conditions.

References

Barlow, J., Cohen, M., Jashapara, M. and Simpson, Y. (1997), *Towards Positive Partnering*, The Policy Press, Bristol.

Bennet, J. and Jayes, S. (1995), "Trusting the team: the best practice guide to partnering in construction", *University of Reading*, Centre for Strategic Studies in Construction.

Bresnen, M. and Marshall, N. (2000a), "Partnering in construction: a critical review of issues, problems and dilemmas", *Construction Management and Economics*, Vol. 18 No. 2, pp. 229-37.

Bresnen, M. and Marshall, N. (2000b), "Motivation, commitment and the use of incentives in partnerships and alliances", *Journal of Construction Management and Economics*, Vol. 18 No. 5, pp. 587-98.

Cheng, E., Li, H. and Love, P. (2000), "Establishment of critical success factors for construction partnering", *Journal of Management in Engineering*, Vol. 16 No. 2, pp. 84-92.

Crane, T. and Felder, J. (1999), "Partnering measures", *Journal of Management in Engineering*, Vol. 15 No. 2, pp. 37-42.

Danielsson, U. (1998), "Outsourcing road maintenance, a step forward or just a trend?" (in Swedish) paper presented at the Nordic Conference in Road Maintenance, The National Road Administration, Borlänge.

De Vilbiss, C. and Leornard, P. (2000), "Partnering is the foundation of a learning organization", *Journal of Management in Engineering*, Vol. 16 No. 4, pp. 47-57.

Hörnfeldt, R. (2003), *Partnering for Road Maintenance in the Norsjö District* (in Swedish), Luleå University of Technology, Luleå.

Howells, J. (1996), "Tacit knowledge, innovation and technology transfer", *Technology Analysis & Strategic Management*, Vol. 8 No. 2, pp. 91-106.

Kadefors, A. (2002), *Trust and Collaboration in the Construction Industry* (in Swedish), *Chalmers University of Technology*, Gothenburg.

Kemi, L. (2001), "Performance Contracts and Partnering for Railway Maintenance", (in Swedish), Licentiate thesis, *Luleå University of Technology*, Luleå, p. 39.

Latham, M. Sir (1994), *Constructing the Team: Joint Rewiew of Procurement and Contactual Arrangements in the United Kingdom Constuction Industry*, HMSO, London.

Lorenz, E.H. (1988), "Neither friends nor strangers: informal networks of subcontracting in French industry", in Gambetta, D. (Ed.), *Trust: Making and Breaking Co-operative Relations*, Blackwell, New York, NY, pp. 194-210.

Olsson, U. and Espling, U. (2003), *Partnering for Railway Network Efficiency*, paper presented in International Heavy Haul Conference, May, Dallas, TX.

Olsson, U. and Johansson, P. (1999), *Outsourcing Street Maintenance* (in Swedish), Kommentus förlag, Stockholm.

Rahman, M. and Kumaraswamy, M. (2002), "Joint risk management through transactionally efficient relational contracting", *Journal of Construction Management and Economics*, Vol. 20 No. 1, pp. 155-63.

Rhodin, A. (2002) "Interaktionsprocesser i byggprojekt: en studie i partnering som kraft för förändring", Interaction Processes in Construction Projects] (English summary), Licentiate thesis, Department of civil and mining engineering Thesis, Luleå University of Technology, Luleå, pp. 53.

Sako, M. (1992), *Prices, Quality and Trust: Inter-firm Relations in Britain & Japan*, Cambridge University Press, Cambridge.

PAPER II

Part II. Partnering in a railway infrastructure maintenance contract: a case study

Espling, U. and Olsson, U. (2004). Part II. Partnering in a railway infrastructure maintenance contract: a case study. *Journal of Quality in Maintenance Engineering,* Vol 10, No 4. pp 248-253.

Part II. Partnering in a railway infrastructure maintenance contract: a case study

Ulla Espling and
Ulf Olsson

The authors

Ulla Espling is based at the Luleå University of Technology, Luleå, Sweden.
Ulf Olsson is based at the Luleå University of Technology, Luleå, Sweden and also in the Consulting Division, Swedish Rail Administration, Luleå, Sweden.

Keywords

Partnership, Procurement, Maintenance

Abstract

In 2000, the concept of partnering was introduced as a pilot project in an in-house contract for operation and maintenance of railway infrastructure. A facilitator introduced the client, the Swedish National Rail Administration (Banverket), and the in-house contractor, Banverket Produktion in partnering procedures before a contract was finalised. A contract with a target cost combined with incentives was negotiated. The partnering process was started by forming a team consisting of key personnel from the client and contractor. A charter containing mutual objectives was developed. Expected targets from the partnering process were achieved during 2001 and Banverket has decided to continue with the partnering process during the current year 2002 and expects to improve upon results to date. This paper presents the experiences from the implementation of partnering process to enhance the effectiveness of maintenance processes in order to enhance railway network efficiency in Sweden.

Electronic access

The Emerald Research Register for this journal is available at
www.emeraldinsight.com/researchregister

The current issue and full text archive of this journal is available at
www.emeraldinsight.com/1355-2511.htm

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · pp. 248–253
© Emerald Group Publishing Limited · ISSN 1355-2511
DOI 10.1108/13552510410564864

1. Practical implications

The case study presented in the is paper discusses the implementation of partnering approach in a contract negotiation and execution for operation and maintenance of railway assets in Northern Sweden. A positive spiral effect triggered by the implementation of partnering approach in maintenance contract execution is discussed and demonstrated on the basis of a pilot study conducted in the Northern Sector of the Swedish Rail Road Administration. This case study will be useful for both the infrastructure manager and maintenance contractors during negotiation and execution of a maintenance contract. It also describes methods that can be used by managers to evaluate the outcomes of the maintenance contract using partnering approach.

2. Introduction and background

Banverket, the Swedish National Rail Administration was reorganised in 1998 into an infrastructure administration and result units to seek greater efficiencies in the organisation. As a result, responsibility for all maintenance, rebuilding and new construction activities were made the responsibility of the independent Banverket Produktion organisation, hereafter called BVP or contractor. The infrastructure administration (the client) is represented by a head office and five railway Track Regions. Each railway region is subdivided into three geographical infrastructure-managing units called Track Areas.

The result units are now independent from the infrastructure administration. Today construction and design activities are 100 per cent open to the competitive market and maintenance will be gradually opened to competition and will be a fully open market in 2006. During the first year after reorganisation, a loose form of agreement governed the maintenance contract. Eventually this (this form of agreement) led to conflict during the negotiation of a new contract. Administration and maintenance management interpreted contract provisions differently and contract cost projections made by maintenance were deemed excessive by administration. The relations between key personnel in the Track Region and BVP became worse because of difficulties in

The authors would like to thank Swedish National Rail Administration for permission to publish this paper. They are also thankful to Professor Uday Kumar, Director Luleå Railway Research Center for his comments and suggestions to improve the manuscript.

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 248–253

understanding client requirements, uncertainty about final responsibility, risks and other areas poorly defined during reorganisation. This resulted in high costs, work that was not finished in time and of poor quality.

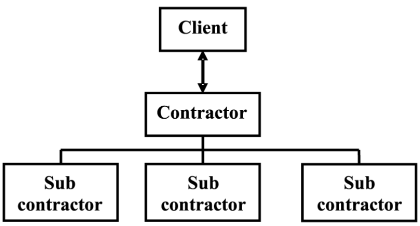
The conflict situation did not contribute to higher efficiency for the client or contractor. The client's close co-operation and communication with Luleå University of Technology (LTU) in other research areas resulted in the Regional Director of the Track Region being introduced to partnering concept while in contact with the LTU. The regional director saw the opportunities offered through partnering that to smoothen up the conflict situation and suggested the contractor to use partnering as a way of solving problems with the contracts. He summed up the problems and possibilities with the comment, "It takes two to dance a tango". After further discussion, the client and the contractor agreed to try partnering in a research and pilot project, which also involved the LTU.

The project sought to create a solid platform for collaboration between the client and contractor. In addition, the expectation to achieve a higher value for the investment made in maintenance resources was created.

3. Partnering as a method

Bresnen and Marshall (2000) describe how the British construction industry has traditionally treated procurement and contracting as an adversarial process. Barlow *et al.* (1997) echo this observation and go on to comment that the consequence has been low productivity, litigation, an adversarial environment, and a reduced ability to absorb technological and business process innovations. The conflict situation and the concurrent lack of cooperation are shown in Figure 1 (for more details, see Olsson and Espling, 2004). After signing a contract, the client and contractor meet only to discuss changes or activities to fulfil their contract. This type of relationship has often been called "arm's length" contracting and implies that each party is free to act independently of the other.

Figure 1 The traditional way of contracting out a project



This adversarial relationship has changed in recent years towards a "relationship that moves away from 'arm's-length' contracting and towards relationships based more upon co-operation and trust" (Bresnen and Marshall, 2000). Such relationships have been called partnering or alliances. Partnering can be a way of solving problems that arise when a traditional approach to contracting out projects has been unsuccessful.

The Reading Construction Forum has described partnering as: "Partnering is a managerial approach used by two or more organisations to achieve specific business objectives by maximising the effectiveness of each participant's resources. The approach is based on mutual objectives, an agreed method of problem resolution and active search for continuous measurable improvements (Bennet and Jayes, 1995)." According to Larsson (1999) the partnering method as a form of co-operation where all parties involved are sitting around the same table while solving all the problems that arise during contract execution as shown in Figure 2.

Partnering is now being used extensively in the construction industry and has stimulated considerable interest in it as a method to create better working environments. Partnering is also said to:

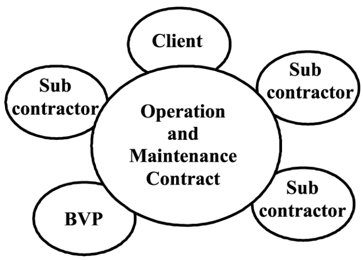
- improve project quality;
- reduce claims and litigation;
- reduce cost up to 30 per cent; and
- cause projects to finish on time.

Partnering centres on:

- teaming up of key personnel from the client, contractor and important subcontractors;
- trust building; and
- openness between the parties (transparency amongst the partners)

The partnering process is intended to create a win-win situation where each partner gains more than they would have, through a non-partnering relationship.

Figure 2 The partnering way of contracting out a project



Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 248–253

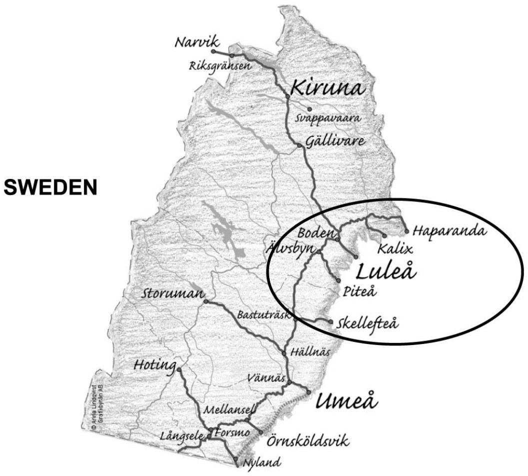
4. The pilot project

It was decided to start the pilot project in the Luleå Track Area due to its proximity to the LTU. Project members were sceptical about the usefulness of the project. Personnel in the Luleå Track Area thought that the project is unnecessary as there was good cooperation at the local level. The contractor employees feared that the partnering process could jeopardize the vision of BVP to develop itself into a competitive player in the open market. Many felt that partnering would end up being an excuse to fall back into old ways of working. Owing to this concern, neither the head of the Track Area nor the contractor's general manger wanted to be the project leader. The other two Track Areas in the region, Kiruna and Umeå, became the reference objects.

The planned partnering arrangement was presented to key client and contractor personnel. Several alternatives were discussed before it was decided to use partnering in the Luleå Track Area. Figure 3 shows the location of the Luleå Track Area inside the circle.

The area is used by both passenger traffic (speeds up to 140 km/h) and freight traffic (speeds from 50 to 100 km/h). The axle loads vary from 22.5 to 30 tons. All tracks, approximately some 600 km in length are single tracks. There are 250 turnouts, both electrified and non-electrified lines, signalling systems for automatic train control plus radio and telecom systems.

Figure 3 The northern track region is divided in three track areas, Kiruna, Luleå and Umeå



Note: The Luleå Track Area is located within the circle

4.1 The contract

The contract was negotiated and finalised in-house and the contractor, BVP, participated in the planning for partnering in this contract. As noted earlier, the contractor and client had been belonging to the same unit of Swedish National Rail Administration. They were split into separate, fiscally independent units as a strategy to introduce greater efficiencies into the Swedish rail system. This reorganisation had the provision that BVP, while acting as an independent contractor, was also to be the rail system's sole contractor for the first year after reorganisation. It was felt that a transition period was needed to give the newly independent units, the opportunity to develop internally before having to compete with other contractors. The opportunity was created for all parties to acquire experience in partnering contracts without having the additional demand of competitive contracting. For the purposes of this study, it meant that the variable of competition was controlled and focus could be placed on assessing the development of a partnering relationship.

The contract includes:

- snow clearance and ice removal;
- inspection connected to condition-based maintenance concerning overall system safety and maintenance;
- maintenance activity after inspection and all maintenance that might affect ore hauling was to be carried out within one week of identification;
- corrective maintenance of any other needs identified as acute; and
- predetermined maintenance.

A target cost (about 55 MSEK or €6.1 M) for the project was agreed between the partners. The "agreed project cost" was combined with an incentive clause, which ensured an additional amount as a bonus for the contractor if work was executed at a cost lower than the target cost. The bonus was to be in the amount of 30 per cent of savings made during the project's life. The remainder of the amount saved was to go back to client. In the event of a cost overrun, the contractor would pay a penalty of 30 per cent of the extra cost (when compared to the target cost of the project).

It was also agreed that the client's gain on the incentive was to be used for additional orders to the contractor. The contractor was paid according to actual costs.

The duration of the project was one year, between 2 May 2000 and 1 May 2001.

It is important to note that Swedish law pertaining to procurement in the public sector makes it possible to specify that a contract will include the partnering process and successful

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 248–253

bidders must agree that they will participate in partnering; as is done for all other proposed contract provisions. Details of the partnering relationship are then finalised after a contract has been signed. Private sector contracts may be tendered differently and in that private organisations may finalise all partnering details before a contract is signed.

4.2 The partnering process

Partnering was conducted in five steps.

The first step was to familiarise a broad group of personnel from the client's and contractor's organisations with the partnering concept. This group included all managers and engineers working in the Luleå Track Area and BVP.

Once the goal of the first step was accomplished, as a second step, a group consisting of chief executive officers (CEO-group) of the interested parties was formed to provide general guidelines as to how to go about the partnering process.

The third step was to form an operational partnering group. Key persons from the client and contractor who possessed the competencies mentioned in Table I were included in this group. The group included key personnel needed to carry out the contract. The client's representative consisted of the head of the track area and three district inspectors and the contractor's representatives consisted of the general manager and two chief foremen.

A key member of the partnering group was the facilitator, or pusher, whose role was to facilitate and make successful the partnering relationship. He also acted as a neutral facilitator during any planning or discussion so that any disagreements or misunderstandings were quickly resolved. In this pilot study, the facilitator was an employee of Banverket Consulting, an organisation that was also spun-off from the former rail system. The facilitator, in the role of consultant, had recommended trying partnering as a way to help resolve the contractual conflicts described in the introduction section.

As the partnering was also a research project, the partnering group included a PhD student whose task was to observe what happened and to write a summary report (Kemi, 2001).

Representatives of the train-operating department, the machine pool and others such as the track operations management were called in whenever needed.

All parties agreed that all employees participating in the partnering contract must accept and effectively participate in the project. It was planned that anyone having difficulty with the project would be replaced. Fortunately, all those in the project had some difficulty in participating and no one needed to be replaced.

Table II shows the most important and critical objectives selected through the partnering process out of the 15 originally listed in the partnering charter. As seen in the Table II, the partnering group established optimistic and pessimistic targets for each of the objectives.

In step five, a measurement and evaluation system was developed and, most importantly, an implementation program for correcting undesirable job trends that threatened achievement of the objectives was established.

A follow-up meeting was held every month for the specific purpose of assessing how the objectives were being met. This special partnering meeting was combined with ordinary contract meetings.

Kemi (2001) assessed whether the objectives had been met after one year. The findings are shown in Table III. For all objectives, the target was met or exceeded. For most of the objectives, the optimistic target was exceeded. Reductions in costs, times or quantities for "hard" targets were between 11 and 19 per cent.

All targets were reached due to the positive spiral effects triggered by achievement of a sub-goal. The sub-goal was to smoothen and eliminate the variation in resource requirement by BVP when utilising personnel from its snow removal operation. This led to increased reliability of the infrastructure as a result of

Table I The partnering group

Position	Client	Contractor	Neutral
Head of track area	X		
District inspector (Haparanda)	X		
District inspector (Luleå)	X		
District inspector (Alvsbyn)	X		
General manager		X	
Chief foreman (Boden)		X	
Chief foreman (Alvsbyn)		X	
Facilitator/pusher			X

Table II The partnering chart

Objective	Target, pessimistic	Target, optimistic
Reduction in train delays	5 per cent	− 5 per cent
Reduction in costs	6 per cent	− 6 per cent
Reduction in the number of breakdown repairs	5 per cent	− 5 per cent
Reduction in the number of defects noted during inspections	As the year before	− 15 per cent
Track quality index as good as the year before	Worse	Better
Better relations between client and contractor	As the year before	Better

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 248–253

Table III Results after one year

Objective	Achievement
Reduction in train delays	−19 per cent
Reduction in costs	−13 per cent
Reduction in the number of breakdown repairs	−14 per cent
Reduction in the number of defects noted during inspections	−11 per cent
Track quality index as good as the year before	Better
Better relations between client and contractor	Better

fewer failures and thereby fewer unplanned maintenance calls. This, in turn, resulted in surplus resources (in terms of money), which made it possible to increase the number of preventive maintenance actions. This resulted in there being fewer defects reported during infrastructure inspection. This then led to more funds available for preventive maintenance activities, which then lead to decreased costs and increased train punctuality. Figure 4 shows this upward spiral of positive achievement.

The client's and contractor's scepticism faded out when the positive outcomes from the pilot project and partnering process became evident. The main goal was achieved without affecting the quality of other processes.

In comparison with reference objects, the Kiruna and Umeå Track Areas, the results show that partnering returned to railway, more in cost and timesaving than was invested in the project. Table IV shows savings.

The positive outcome of this pilot project resulted in a decision by the client to adopt partnering to the whole of northern region that covers 1,680 km of track and 960 turnouts.

Figure 4 The positive partnering spiral

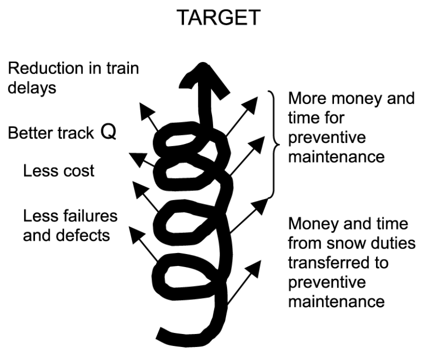


Table IV Results compared with the reference objects

Objective	Kiruna (per cent)	Umeå (per cent)	Luleå (per cent)
Reduction in train delays	−2	−23	−19
Reduction in costs	+8	+18	−13
Reduction in the number of breakdown repairs	−17	+4	−14

Luleå University of Technology was retained to evaluate the outcome of the project and a PhD student was assigned this task on a full-time basis.

5. Conclusions from the case study

The results from the pilot project indicates that partnering contracts have an excellent potential to better relations between parties, increase productivity and better preservation assets.

One important driving force in the success was the economic incentive. The fact that the client's gain was included in the contract in order to speed up the results was proved to be very effective.

6. Conclusions and recommendations

Recommendations for successful partnering in railway maintenance contracts are as follows.

- A gain-sharing mechanism, financial incentives for partners to reduce project costs and improve performance be formulated and included in a contract.
- CEOs and top management must be committed to the partnering process and also be involved in the implementation of the process in the organisation to make certain that staff at all levels support partnering.
- The presence of a facilitator is essential to co-ordinate and move actions in the right direction.
- *Teambuilding:* it is important to build a project-partnering team with key personnel from the client, contractor and important sub-contractors.
- An open and honest communication between all parties is required, it must be continuous and reinforce the message of greater openness plus seek ways to overcome any adverse organizational culture barriers.
- Develop a charter with commonly agreed and ranked objectives.
- Develop a commonly agreed upon strategy for meeting partnering objectives.

According to Barlow *et al.* (1997) partnering has the greatest potential for work that is complex or

Journal of Quality in Maintenance Engineering
Volume 10 · Number 4 · 2004 · 248–253

critical for a client's business. This is true for railway infrastructure maintenance.

7. Future research

Staff from Luleå University of Technology will be working with Banverket in assessing the expansion of the partnering concept into other regions of the rail system. It is planned for university staff to observe and, provide information on findings to the facilitator whenever appropriate. It will be of particular interest to assess how competitive bidding for contracts will influence the partnering process. Maintenance will be opened for competitive bidding in future years. Sweden's rail system already has companies from outside of Sweden operating passenger trains in some areas. Whether there will be similar competition for maintenance contracts and how it will develop remains to be seen.

References

Barlow, J., Cohen, M., Jashapara, M. and Simpson, Y. (1997), *Towards Positive Partnering*, Policy Press, Bristol.

Bennet, J. and Jayes, S. (1995), "Trusting the Team: the Best Practice Guide to Partnering in Construction", Centre for Strategic Studies in Construction, University of Reading, Reading.

Bresnen, M. and Marshall, N. (2000), "Building partnerships: case studies of client-contractor collaboration in the UK constructions industry", *Construction Management and Economics*, Vol. 18 No. 7, pp. 819-32.

Kemi, L. (2001), "Funktionskrav och partnering för drift och underhåll av järnvägar [performance requirements and partnering for railroad maintenance]", Licentiate thesis (in Swedish), Luleå University of Technology, Luleå.

Larsson, L. (1999), "Partnering inom Banverkets drift- och underhållsverksamhet [partnering in Banverket operation and maintenance activities]", Master thesis (in Swedish), Luleå University of Technology, Luleå.

Olsson, U. and Espling, U. (2004), "A framework of partnering for infrastructure maintenance. Part-I", *Journal of Quality in Maintenance Engineering* (in press).

PAPER III

Development of a proactive maintenance strategy for railway infrastructure; a case study.

Espling, U. and Kumar, U. (2004). Development of a proactive maintenance strategy for railway infrastructure; a case study. In: *Workshop Proceedings of the International Maintenance Congress Euromaintenance*, Barcelona May 11-13, pp.31-38.

The 17th European Maintenance Congress
EUROMAINTENACE 2004
11-13 May, 2004, Barcelona

DEVELOPMENT OF PROACTIVE MAINTENANCE STRATEGY FOR RAILWAY INFRASTRUCTURE A CASE STUDY

Ulla Espling and Uday Kumar
Department of Operation and Maintenance Engineering and Luleå Railway Research Center, Luleå University of Technology, SE- 971 87 Luleå, Sweden

Keywords: Maintenance strategy, framework, railway infrastructure.

Abstract: *The nature of infrastructure maintenance is complex and close to the customer, which increases the demands of a successful co-operation between all parties involved when making the railroad transportation business competitive.*

In this paper we discuss the current status of maintenance practices at Banverket –the Swedish National Rail Administration. Based on experience from our own operation and maintenance processes at the Swedish National Rail Administration and an extensive review of the maintenance literature from a world wide railway sector an approach (framework) for the operation and maintenance strategy has been developed, in order to make the operation and maintenance of infrastructure more cost effective through a more proactive approach.

The framework regards business objectives, regulations, health, safety and environment demands, interaction between railroad actors i.e. traffic companies, infrastructure owners and contractors.

1. Introduction

The environment created by the changing railway policy in Sweden led to restructuring of Swedish Railway authority to enhanced its competitiveness and make travel and goods transport cheap and economically viable. The restructuring program divided the Swedish Railway authority into two broad categories, namely organisation being responsible for management of infrastructures and companies with responsibilities for train operation. The organisation Banverket which was entrusted with management of infrastructures became responsible for design construction, maintenance, renewal and modification of tracks and related infrastructures with focus on track capacity and quality of permanent way .Banverket is divided into five administrative regions. Banverket was further divided into two major groups, namely infrastructure management group and contractors.

The group responsible for infrastructure management was made responsible for the day to day operation and maintenance of the infrastructure together with long term development of the assets. The other group called in-house contractors were treated as result units. In other words, they have to finance their activities through tasks and contracts obtained from the infrastructure managers. The infrastructure managers operated and acted within the framework of budgetary control and other directives from the government.

Despite high demands made on track, it must be laid and maintained at low costs to safe guard its competitiveness as compared to other mode of transport.

In the middle of the 90´s Banverket did change their maintenance strategy from predetermined maintenance towards condition based in order to do more cost effective maintenance but still guaranty the safety. Maintenance tasks are successively being subjected to open tender, with full competition planned 2006. Many regions with great success are practising the concept of partnering. By an incentive in the contract you can try to decrease the level of corrective maintenance which both part will benefit on. It is planned that the area of maintenance, which was in-house business, will be fully opened to market forces so as to introduce competition and thereby enhanced the effectiveness and efficiency of infrastructure maintenance However a recent study about the status of maintenance in Banverket's shows that corrective maintenance is growing at the cost of proactive maintenance program and strategy as shown in Figure 1 (Andersson, 2002).

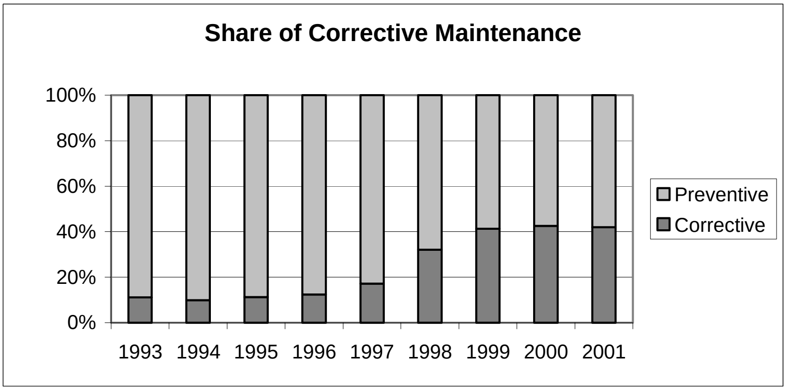


Figure 1. Share of Corrective Maintenance 1993-2001

Regardless of track design, provision must be made for necessary maintenance. Production windows for maintenance of various components of infrastructures should be effectively planned so that the railway transport is always competitive compared to other mode of transport. (Wently and Becker, 2002). Maintenance strategy should led to a minimum of traffic hindrances and should be able to provide "traffic capacity" on demand. From analysis of train delay information in Sweden, it is found that the contribution of infrastructure failure (Banverket) comes to 18% as show in Figure 2.

To deal with train delays mainly due to infrastructure failures a project called TURSAM "Tillämpat UndeRhåll i SAMverkan" (Applied maintenance in co-operation) was initiated by the Banverket in close co-operation with Luleå Railway Research Center (LRRC), Ore Transport Company (MTAB) and Norwegian State Railway(NSB) to develop proactive maintenance strategy so as:

- to increase the punctuality with 5 % per year
- to optimise the capacity for train traffic
- to reduce the corrective maintenance by 10 % by the year 2006

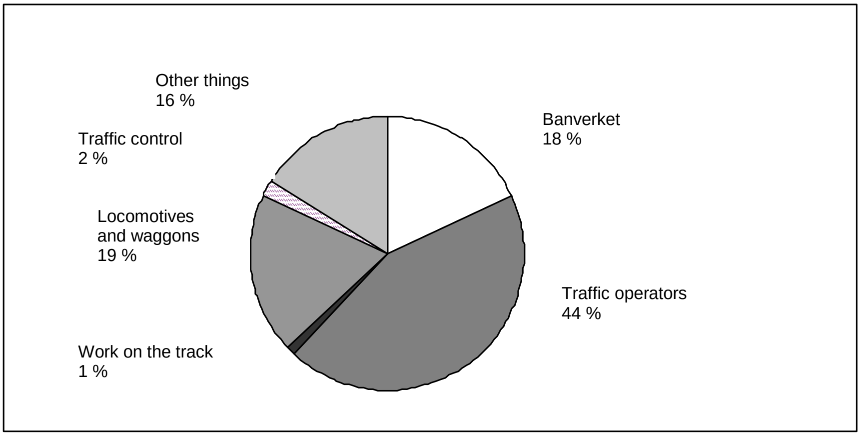


Figure 2. The distribution of the train delay.

The challenge for the group is to find ways of achieving all these goals at the same time meeting all the stakeholders' requirements without breaking the internal regulations within the allocated budgets. The group is partially financed by Banverket and is led jointly by LRRC and a senior manager from Banverket consulting Div. The working philosophy of the TURSAM group is that preventive maintenance in most cases (except in some cases it is more cost-effective to run to failure) is more cost-effective, gives higher quality and is more dependably then corrective maintenance (Ahlmann 1995, Wireman, 1998). Another rule of thumb is that corrective maintenance is up to three times more expensive then preventive maintenance. The One thing tested is a early warning system for turnouts and bulbs in signalling systems

In this paper we attempt to develop an approach or a framework for a maintenance strategy that support a change form an reactive approach toward a proactive regarding a holistic view and how to implement it.

2. Theory of maintenance and its management

The purpose of maintenance is to reduce the business risks. The business risk for the infrastructures mangers comes into picture due to non-availability of track or poor track performance. This can ultimately led to customers (passengers and goods) changing to other mode of transport or loss of revenue due to non-availability of track for transport. Therefore infrastructure manager must have a sound maintenance policy to ensure high availability of track and related infrastructure. To achieve this one has to understand the maintenance process and its various sub processes.

The output from a maintenance process will considerably be influenced by the input to the process. If the undesirable inputs such as wrong information, bad weather condition it may lead to undesirable outputs such as delays, reduced safety level, etc (see Figure 2). To achieve best results one needs a careful planning of all maintenance activities. The various elements of maintenance process are depicted in Figure 3.

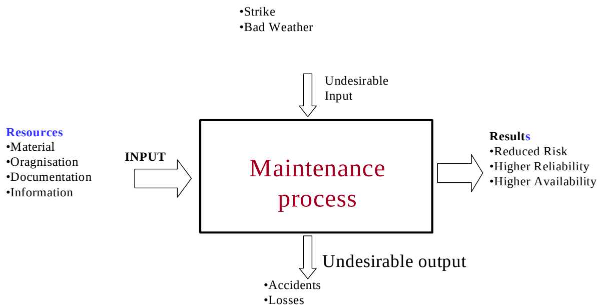


Figure 3. The maintenance process

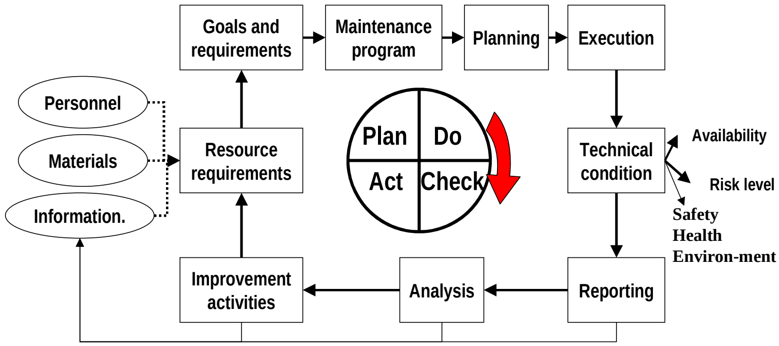


Figure 4. Elements of maintenance process

In fact to achieve the best maintenance results, one needs to have a sound maintenance strategy in line with corporate objectives and strategy. Since there are many groups and work units in a company, it's essential to develop a framework for strategy so that all the units/groups can develop their strategy to achieve their own unit /group targets. Often framework provides a broader view and approaches about the issues at hand. In this we will be developing /looking into a conceptual framework that describes and outlines the maintenance strategy for the Swedish Rail administration (Banverket).

3. Complexity of the railway infrastructure

As discussed in the introduction the complexity demands an holistic approach to both internal and external factors and processes that have direct or indirect influence on the operation and maintenance of railway infrastructure. While forming the maintenance strategy for railway infrastructure the manager most take in consideration the interacting parts in the maintenance system between wheel and rail and between pantograph and catenary, because of possible non-desired effects on the wheels and pantograph. The manager also have to consider if the methodology or strategy he chooses will put demands on the contractor to enhances his competence or invest in new machines or instruments. When the infrastructure manager enters into a operation and maintenance contract, he commits funds for three to five years for payment to contractor against executed work as agreed in contract. In the mean infrastructure manager (IM) must also have a flexibility to cut down on the maintenance activities because sudden unexpected decreases in the government grant owing to political resolutions. While the IM is responsible for the asset, Banverket Traffic sells time on track (track capacity) to the train operators. Before writing a contract, Banverket Traffic has to negotiate with the train operator for putting in time for maintenance, rebuilding and renewal work that he and the infrastructure manager have put together in a plan called BAP – plan for all activities on track. The plan includes all activities except snow clearance and running or urgent repairs tasks. On the other hand, the infrastructure manager have to put this plan BAP into his maintenance contract document so that the contractor can get an estimate of maintenance time available for each maintenance activity. Therefore the strategy for budget, maintenance and procurement must be closely linked (And also linked to "selling" strategy).

The group responsible for infrastructure in Banverket has chosen a strategy for condition-based maintenance in combination with predetermined maintenance. The structure for the control system is based on the European standard EN 133306:2001. But as shown in the figure 1 and 2, the strategy has not yet been successful, caused by lack of a functioning control system, need to get hold of the assets condition and where it is on the degradation curve.

The infrastructure manager is now working hard to start an organisation for continuous improvement and increase the activities for elimination of failures especially those causing train delays. One forum for decreasing train delays is the PULS-working group. As which are groups with key personnel from the traffic operators, infrastructure manager, contractor and traffic control, that comes together in monthly meeting at the offices for the traffic districts to discuss and solves problems that causes train delays.

During the first year after reorganisation, a loose contract was used for maintenance operations. The infrastructure manager and contractor only meet to discuss changes or activities that must be addressed in order to fulfil their contract. This type of relationship has often been called "arm's length" contracting and implies that each party is free to act independent of each other. But problems and a conflict situation soon arose and the infrastructure manager and the contractor realised that this traditional approach did not work in a complex operation and maintenance contract. This problem has also been studied for outsourcing maintenance in the municipalities (Mattisson, 2000). It was found that the prices of maintenance tasks performed went down, the quality was the same or a little less decreased, but the development work slowed down considerably unless the client did take a more active part in the contract.

Since 1998 several types of contacts has been tested, for example buying with fixed prices and specifying every work, buying a function. Partnering, a new way of collaboration in a maintenance contract was tested within the framework of a research and development project in 2000. The partnering method was combined with commonly agreed objectives for reducing the cost, train delays and combined with an incentive clause. A target cost for the project was agreed between the partners. The incentive clause ensured an additional amount as a bonus for the contractor if work was executed at a cost lower than the target cost. The result was very good and also led to a process of continuous improvement. Other ways have been to add special demands for increasing the quality and reliability combined with an incentive and/or on option of prolonging the duration with two years if the demands where full filled. The demands in the contract are strongly linked towards the maintenance objectives in the maintenance strategy.

4. Framework

As said before Banverket is financed through public exchequer and at the beginning of the every fiscal year gets funds for operation and maintenance of infrastructures, and naturally it is influenced and controlled by the political resolutions and decisions taken by the Swedish parliament. Traditionally, yearly budget variations are minor and amount to ± 5-10 % of the previous years budget. Besides, the normal budget allocation, government allocates funds to meet special requirement by the railway sector. In general, this approach to management of infrastructures by budgetary control leads to the short-term thinking" We have to operate within the budget directives and not as per the requirements of the infrastructures need" on year-to-year basis. To achieve the set results from the infrastructures one has to have needed based budgeting system that allocates funds as per the requirements and infuses long-term thinking in the management of infrastructures. Figure 5 presents an approach or framework there one guards itself from variations in budgetary allocation for the maintenance of infrastructures by executing a maintenance plan which facilitates the expenditures level maintained at an average level as demonstrated by the dotted line EF(see Figure 5). Furthermore, we have to reserve resources/fund to take care of basic and necessary maintenance activities by considering it as a fixed costs as demonstrated by the continuous line CD. Line AB in the figure depicts the current level of corrective maintenance

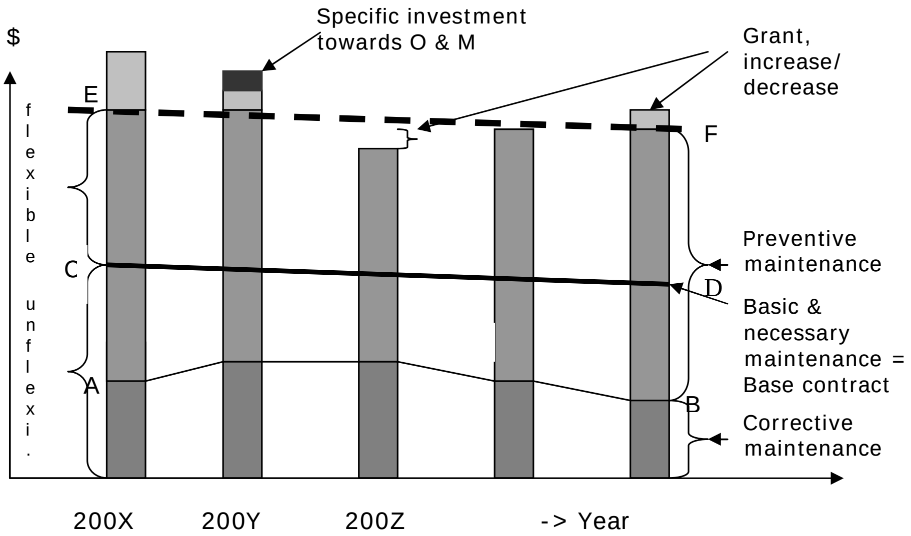


Figure 5. Prevalent maintenance budget system at Banverket

Figure 6 shows the budgeting principles, in the middle is operation and maintenance activities that must be performed in order to give the customer what he is asking for, outside there is the rest of the normal maintenance that you want to do but not always have money to do, and outside that there are the specific investment to be carried out in order to extend the life span of the infrastructure and meet other stakeholders requirement such as environmental control measures etc.

Basic and necessary operation and maintenance is the same as the basic contract, incorporating the five items, namely inspections in order to identify activities to perform condition based maintenance, snow clearance, repair of critical failures and inspection remarks to be dealt with immediately or within a week. Of these items one can influence snow clearance and corrective maintenance by negotiating the maintenance contract (see Figure 7).

The goal is to decrease the volume of the basic and necessary maintenance at the same time maintaining the standard track quality. The strategy is to buy maintenance function combined with incentives that identifies cost drivers, failure drivers, and incorporates seasonal adjustments and decrease the amount of maintenance tasks continuously.

An incentive for the contractor performing the task is that his contract can be extended for the next period if he achieves the goal set by the infrastructure managers. Based on the analysis and experiences a conceptual framework is suggested for Banverket maintenance strategy as illustrated in Figure 8. For details see Espling and Kumar (2004).

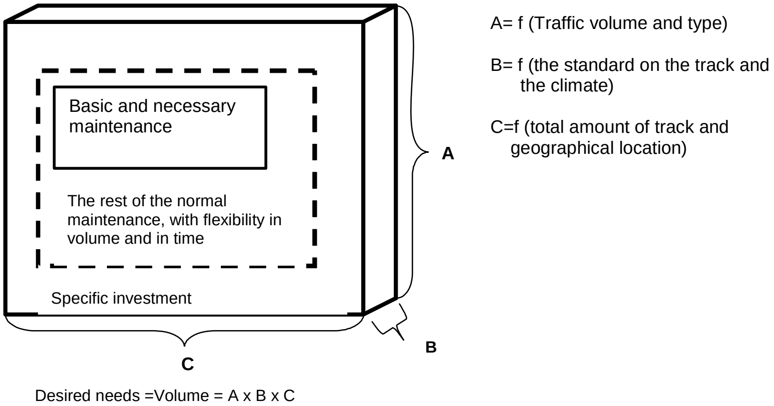


Figure 6. Strategy for budget

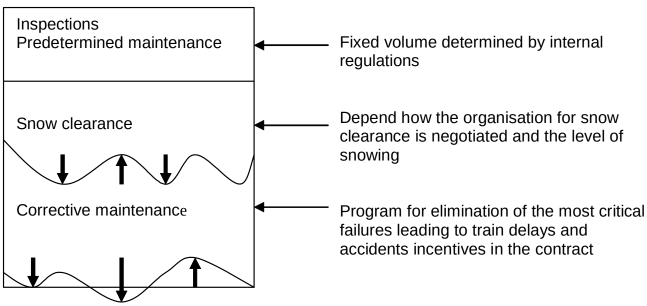


Figure 7. Strategy for contract negotiation

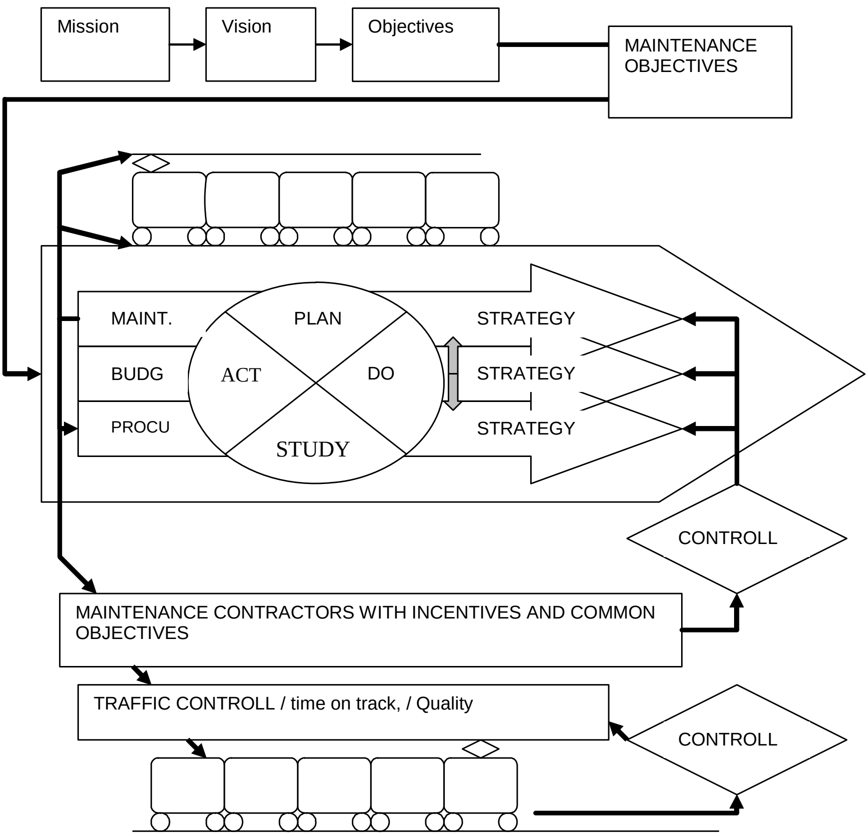


Figure 8. A conceptual framework for maintenance

5. Problem to implement the framework

One problem is lack of understanding the value of maintenance and what part it plays in the business activities. Although there is a well defined structure for controlling the maintenance, negotiation and budget and accounting, it is not fully used.

6. Concluding remarks

In general, it is noted that the poor management of asset by infrastructure managers incorporating maintenance organisation with no strategy often fails to fulfil the requirement of train operators and other stakeholders ultimately leading to many fold increased in total LCC for the infrastructure. It is meaningless to spend a large amount of energy each year on reviewing and cutting the maintenance budget to make the infrastructures economically viable. It is more effective to have a sound and proactive maintenance strategy to deal with the critical area of infrastructure operation and maintenance.

References:

1. Andersson M. “Strategic Railway Track Maintenance Planning – State of the Art, Swedish National Road and Transportation Research Institute (2002).
2. Ahlmann ”UTC Svenskt Underhållstekniskt Centrum, Sammanfattande resultat av ett 6-årigt forsknings- och utvecklingsprojekt inom området driftsäkerhet och underhåll” 1995
3. Wireman T. ”Developing Performance Indicators for Managing Maintenance” (1998).
4. Espling U and Olsson U. “Partnering in a Railway Infrastructure Maintenance Contract: a Case Study”, International Heavy Haul Association Conference Dallas May 2003
5. Espling U and Kumar U “Maintenance strategy for railway infrastructure: A case study (under preparation), 2004
6. Mattisson O. “Kommunala huvudmannastrategier för kostnadspress och utveckling: en studie av kommunal teknik”, Lund Business Press, 2000 (Only in Swedish).
7. Wently, R. and Becker, R “New developments for track machines. In innovations for cost effective railway track http://promain.server.de pp 38-43

Author (s):
Ulla Espling, Master of Science in Mechanical Engineering
Uday Kumar, Ph.D. Professor of Mechanical Engineering
Luleå Railway Research Centre, Luleå University of Technology, SE-971 87 Luleå, Sweden.
tel: ++ 46 920 49 19 91 and ++ 46 920 49 28 26
fax: ++ 46 920 29 19 35
e-mail: ulla.espling@ce.luth.se
uday.kumar@ce.luth.se

PAPER IV

Postponed replacement – a risk analysis case study

Akersten, P.A. and Espling, U. (2007). Postponed replacement – a risk analysis case study. *Proceedings of 9th International Conference of Maintenance*, Hobarts Australia 31 May 2005 ICOMS 2005.

POSTPONED REPLACEMENT – A RISK ANALYSIS CASE STUDY

Per Anders Akersten and Ulla Espling
Luleå University of Technology, Sweden

SUMMARY: In order to meet budgetary constraints regarding renewal and replacement work, the possibilities of deferring corrective maintenance and postponing preventive maintenance are often considered. It is a fact that the condition of the track changes over time when maintenance is deferred. This decision to defer or postpone maintenance work is taken under uncertainty, which calls for a risk analysis.
The case reported here is the risk analysis performed to aid in the decision whether to undertake renewal work on a track section within a few years, or to postpone the renewal a further ten to fifteen years. The risk analysis has been performed, making use of several methodologies or tools: preliminary hazard analysis (PHA), a requirements oriented failure mode and effects analysis (FMEA), event tree analysis (ETA) and probability estimation by Delphi technique.

The risk analysis work has resulted in the pinpointing of a few failure mechanisms to be studied in depth. It also resulted in a comprehensive description of the various routine preventive maintenance actions used and their capacity of identifying faults caused by the various failure mechanisms.

The risk analysis performed should be seen as a pre-study. It has clearly pointed out the need for more detailed descriptions of the main failure mechanisms. This also necessitates the development of analytical models for studying the rail/track deterioration characteristics.

Keywords: risk analysis; preventive maintenance; postponed maintenance; renewal; event tree analysis; failure mode and effect analysis; preliminary hazard analysis;

1 INTRODUCTION

In order to meet budgetary constraints regarding renewal and replacement work the possibilities of deferring corrective maintenance and postponing preventive maintenance are often considered. It is a fact that the condition of a railway track changes over time, and thus the decision to defer or postpone maintenance work is taken under uncertainty. This calls for a risk analysis. In this paper is described some experiences from such an analysis.

The case studied is a risk analysis, performed on the track segment between Långsele and Mellansel in northern Sweden. This is a 90 km track segment with several steep climbs and a number of rather narrow curves. The analysis was motivated by indications of a possible postponing of the renewal of the track segment under study. Beside the analysis of the risks related to the postponing of renewal, the project aimed at establishing a methodology to be used in subsequent risk analyses.

The analysis was initiated by the Swedish Rail Track Administration (Banverket) and the work was performed by a project team consisting of representatives of the Luleå Railway Research Center (JvtC) at Luleå University of Technology, SWECO Energuide, a consultancy company, and the Northern Region of Banverket. The risk analysis was to be performed for the track segment states at the years 2004, 2010 and 2020.

The risk analysis has it focus on maintenance aspects. The most severe consequence considered is derailment, but the possible effects of a derailment have not been included in the present study.

The analyses were further restricted to the permanent way, excluding turnouts and sub grade ballast, as these two categories are excluded from the possibly postponed track renewal project.

From a theoretical point of view, the project gives an illustration of the two most used repair models: maximal repair, i.e. restoration to good- as-new condition, and minimal repair, i.e. restoration to bad-as-old condition.

2 METHODOLOGIES

For the performance of the risk analysis we make use of the appropriate parts of the risk management process according to (1), schematically described in Fig.1.

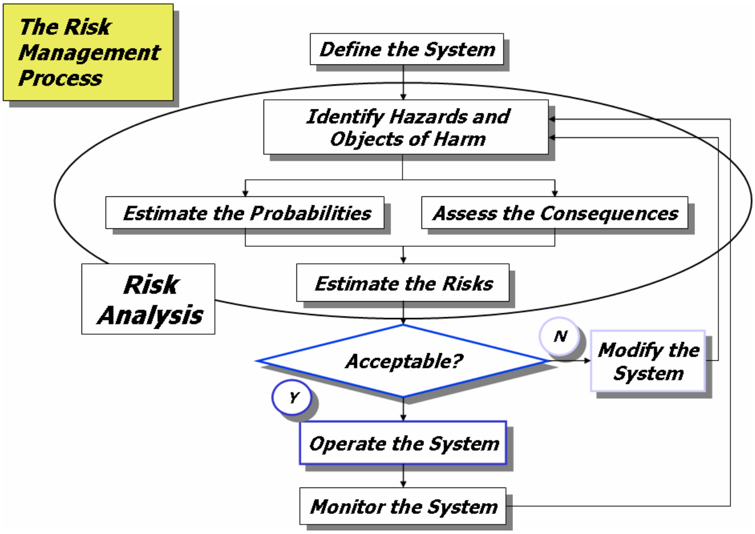


Fig.1 The risk management process

The two main parts of the risk analysis process are the risk identification part, and the risk assessment part, respectively. For the risk identification part we have made use of the following methodologies: *Preliminary Hazard Analysis (PHA)* and *Failure Mode and Effect Analysis (FMEA).* Both methods are well known, see e.g. (1), and they are easy to apply under the guidance of an experienced facilitator.

PHA is a method for hazard idenfication. It is used as a first step to an understanding of the risks presents and the need for risk control. The PHA makes use of the experience and imagination of the participants. This will often limit the spectrum of identified hazards only to what has been observed earlier. Several other possibilities may be overlooked.

FMEA – or FMECA, with C for ”criticality” - is more systematic than the PHA. The starting point is the set of requirements on the system under study, and its subsystems/components, often formulated as the functions they should perform. This implies, however, that non-functional requirements will be left out of the analysis.

For each requirement, or function, the possible failure or fault modes are identified and their consequences are analyzed. Existing means of reducing the probability of a failure/fault mode or mitigating the consequences are described, and an assessment of the criticality is made, based on the frequence of occurrence and the severity of the consequences. The analysis should result in a decision, and in principle there are only three decision alternatives: *Do something – Now!*, *Find more information*, and *Accept the present state*. Regrettably, some FMEA analysts will give themselves up to a numbers game, playing around with so-called RPNs (Risk Priority Numbers), making this the most time-consuming part of the analysis. A serious critique of this approach is given, e.g. in (2). However, the qualitative part of the FMEA is very useful and will result in a comprehensive list of existing hazards.

The methodologies used produce lists of existing hazards and their possible consequences for different objects of harm. For both methodologies there are different views on which consequences to focus upon. Some users advocate a focus on the most probable consequence, and some advocate a focus on the most severe consequence, the worst case. This has to be taken care of in the risk assessment part of the risk analysis.

The risk estimation part consists of the assessment of consequences and of estimation of frequencies or probabilities. Very much information may be lost if the aim of the risk estimation is to produce a single figure representing the risk. In almoste every case there is a spectrum of possible consequences and corresponding different event or decision chains. This can be taken into account, using Event Tree Analysis (ETA) for the description of the chains leading to different consequences. The assessment of frequencies or probabilities is more cumbersome. In general the historical facts available are either very scarce or not representative. The assessments have to be based on a combination of historical evidence and available experts' experience. The use of expert judgments is more accepted today, and there are several systematic approaches that enhance the credibility of the resulting judgments. One of the earliest and simplest approaches is the use of the Delphi technique in combination with absolute probability judgments.

Event Tree Analysis (ETA), see e.g. (1), is a methodology, used to identify the possible consequences of a specified initiating event. It is very useful to describe measures taken to mitigate accidents and to describe the sequences of events, decisions and other actions, leading to different end states. For the different events or actions in the event tree, conditional probabilities along each branch may be estimated and eventually combined into conditional probabilities of the end states, given the inititating event. The methodology is a useful companion to the hazard identification methodologies, providing a more detailed view of the possible consequences.

A widely used method for the elicitation of expert judgments, e.g. regarding rates of occurrences of failures or faults, is the Delphi technique. It makes use of the views of a panel of experts and represents a communication device, facilitating the formation of group judgments. The experts' knowledge is collected, using questionnaires and controlled opinion feedback. The questionnaires are sent to a group of experts and they have to provide individual opinions about the problems under study. After that, the experts' judgments are put together and feedback is given to the experts', allowing them to refine their views, ending up close to consensus. The main point behind this technique is that the problems experienced in conventional committee meetings should be avoided. One main reference is (3).

In the pre-study involving the case described in Section 1 this combination has been applied, due to its simplicity. There are several other approaches available, e.g. involving the use of the Analytic Hierarchy Process, see e.g. (4), for comparative judgments, but they have not been used in the current project.

In the present project, the risk identification was initially performed using a PHA. This was followed by a structuring of the failure modes and fault modes and their consequnces along the lines of a FMEA. For the assessment of consequences, a scenario based FMEA approach (2) was used. For the scenario description, Event Trees were used for the assessment of different possible consequences, resulting from a failure mode and fault mode.

This qualitative analysis part was followed by a quantitative estimate of rates of occurrence of failures or faults, combined with estimation of conditional probabilities in the event tree and, in some cases, assessment of costs related to various end states in the event trees.

3 RESULTS

3.1 Identification of failure and fault modes

In the PHA and FMEA analyses a number of major failure mechanisms were identified. For all of these failure mechanisms, derailment was identified as the worst case consequence. The different failure mechanisms considered in the risk assessment part were the following:

- Bad fastening between rail and pads
- Bad fastening between pads and sleepers
- Head-checks
- Horizontal cracks
- Table wear
- Plastic deformation of insulated rail joint
- Crack propagation (or initiation) in screw hole in rail waist (web)
- Short circuit in insulated rail joint
- Corrosion in level crossing
- Rots and cracks in sleepers
- Shelling
- Side wear
- Height track irregularities
- Side track irregularities
- Transverse crack
- Vertical crack (difference is made between lots manufactured in 1974 and other lots)
- Corrugation (short or long)

For each of these failure mechanisms an event tree has been constructed, taking the different routine preventive maintenance actions and inspections into account. One example is given in Figure 2 below, in which fictive figures of the various conditional probabilities are given.

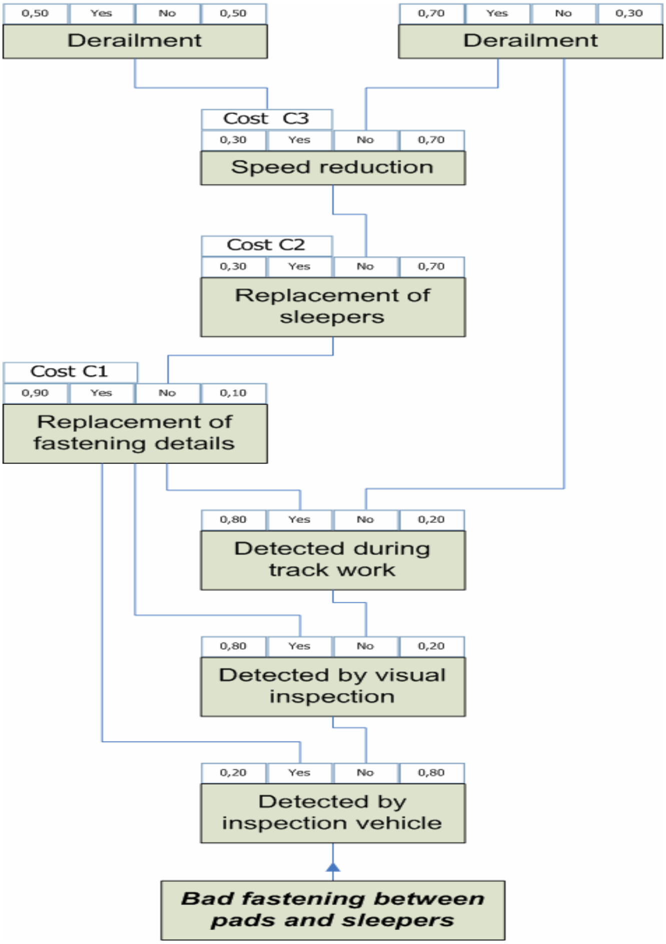


Figure 2. Event tree for the failure mechanism "Bad fastening between pads and sleepers".

Qualitative results

One of the main results of the present risk analysis was the systematic consideration of the various routine preventive maintenance actions, e.g. different types of inspection included in the condition based maintenance. The failure detection capacities have been thoroughly discussed within the project group, in most cases resulting in consensus. Also the introductory brainstorming sessions for the identifiction of requirements, functions, and hazards were very informative. The approach, combining systematic hazard identification methodologies and event tree analysis, showed to be very useful. It was accepted by all the members of the working group.

Quantitative results

We have to admit, that the quantitative analysis is a preliminary one. An important result is the proof of the fact that the estimation of rates of occurrences, of conditional probabilities in an event tree, and of costs (or other severity measures) of end states in an event tree, requires extensive training and experience.

The estimation of the risk of derailment related to the different failure mechanisms has given the following results, using relative figures:

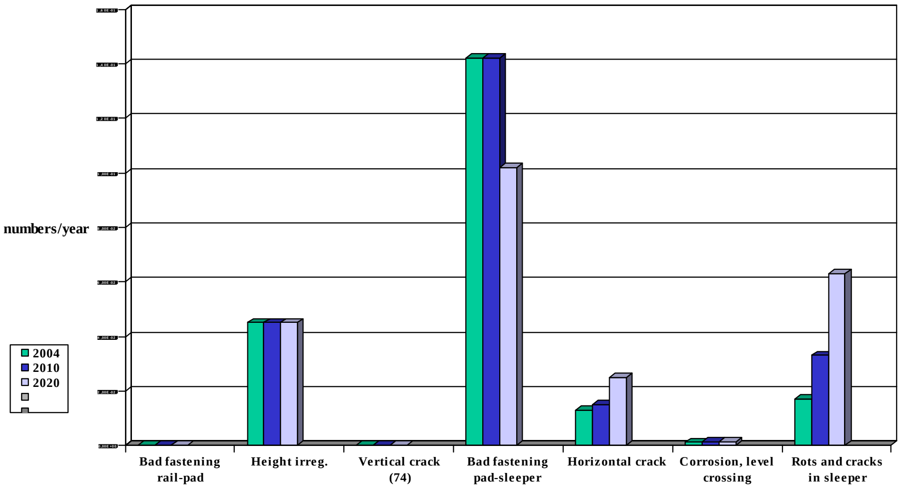


Figure 3. A comparison of derailment risks, resulting from a sample of failure mechanisms

For the comparisons between the different years under study, 2005, 2010 and 2020, rough estimates of routine replacements have been made by the experts in the working group. The result is presented in Figure 4, together with a derailment risk overview. The list is restricted to those failure mechanisms either having high derailment risks or showing some interesting trend.

Failure mechanisms	Increasd derailment risk	Derailment risk, trend 2004-2010-2020	Change in maintenance cost
Bad fastening pad-sleeper	✓	→ → ↘	✓(+)
Head-checks			✓(+)
Horizontal crack	✓	↗ ↗ ↗	✓(+)
Crack propagation, screw hole			✓(+)
Rots and cracks in sleepers	✓	↗ ↗ ↗	✓(+)
Height track irregularities	✓	→ → →	
Vertical crack (manufacturing year 1974)			✓(-)

Figure 4. Anticipated trends

4 CONCLUSIONS AND FURTHER WORK

From the pre-study performed, the following conclusions and recommendations for further work can be made.

- The proposed methodology is adequate for its purpose, and it has been readily accepted by the participants of the working group, also by those without any previos risk analysis experience.
- The procedure for the elicitation of rates of occurrences and probabilities has to be clearly described and the experts participating in the elicitation must be given appropriate training.
- A number of failure mechanisms need more thorough investigations, regarding the rate of occurrence of initiating events as well as the effects of routine inspections and replacement work.
- The consequences of derailments should be analyzed in more detail.
- The methodology needs to be developed by feedback of experience from further practical applications, led by a facilitator.

5 ACKNOWLEDGEMENTS

We should like to acknowledge the valuable contributions from the members of the project group.

6 REFERENCES

(1) IEC 60300-3-9 (1995) “International Standard IEC 60300-3-9. Dependability management - Part 3: Application guide - Section 9: Risk analysis of technological systems”, IEC, Geneve.

(2) Kmenta, S., and Ishii, K. (2000). "Scenario-based FMEA. A life cycle cost perspective" Proceedings of DETC 2000,

2000 ASME Design Engineering Technical Conferences, September 10 - 14, 2000, Baltimore, Maryland.

(3) Helmer, O.H. (1966). “The Delphi Method for Systematizing Judgments about the Future”, Institute of Government and Public Affairs, University of California.

(4) Saaty, T.L., and Vargas, L.G. (2001). “Models, Methods, Concepts and Applications of the Analytic Hierarchy Process”, Kluwer, London.

PAPER V

Benchmarking of the Maintenance Process at Banverket (the Swedish National Rail Administration)

Espling, U. and Kumar, U. (2007). Chapter 23 - Benchmarking of the Maintenance Process at Banverket (the Swedish NationalRail Administration, in *Handbook on "Maintenance of Complex System"* Springers, UK (Under publication).

Chapter 23

Benchmarking of the Maintenance Process at Banverket (the Swedish National Rail Administration)

Ulla Espling and Uday Kumar

23.1 Introduction

To sustain a competitive edge in business, railway companies all over the world are looking for ways and means to improve their maintenance performance. Benchmarking is a very effective tool that can assist the management in their pursuits of continuous improvement of their operations. The benefits are many, as benchmarking helps developing realistic goals, strategic targets and facilitate the achievement of excellence in operation and maintenance (Almdal, 1994).

In this chapter three different benchmarking studies are presented, these are; 1) benchmarking of the maintenance process for cross-border operations, 2) study of the effectiveness of outsourcing of maintenance process by different track regions in Sweden, and 3) study of the level of transparency among the European railway administrations. In these case studies the focus is on railway infrastructure excluding the rolling stock. The outline of the chapter is as follows. An overview of Swedish railway operation is presented in section 23.2. The definition and methodology in general is discussed in section 23.3. The special demands for benchmarking of maintenance is described in section 23.4 and in section 23.5, the special considerations caused by the railway context is overviewed generally for the railways and in more detailed from the Swedish context. The case studies are discussed in section 6 to 8. The discussions and conclusions are presented in section 23.9 and 23.10 respectively.

All the data pertinent to benchmarking of railway operation and maintenance were retrieved, classified and analyzed in close cooperation with operation and maintenance personnel from both infrastructure owners and maintenance contractors. The chapter discusses the pros and cons, the areas for improvement and the need for the development of a framework and metrics for benchmarking. The focus of this chapter is to visualize best practices in maintenance and also on proposing means for improvement in railway sector with special reference to railway infrastructure.

23.2 Swedish Railway Operations

The railway industry is presently in a state of transition, with new stakeholders emerging and old ones trying to adjust to the new operating environment. In each country of Europe, the railway administration was vertically integrated, i.e. to comprise all in "one body", almost until the end of the 1980's, when a new railway era started. The vertically integrated railway organisations were and still are partly government-funded and regulated by parliament through government directives. Figure 22.1 illustrates the organisational changes in Sweden from "single entity", SJ (the Swedish State Railways), to a number of business units, each functioning indepen dently to achieve their business goals. During 1988, SJ as a state authority was restructured to enhance its competitiveness and make railway travel and transportation economically viable. The restructuring programme divided SJ up into two major groups, namely train operating companies (TOCs) and infrastructure owners. The TOCs were expected to take the responsibility for transportation of goods and passengers in close cooperation with infrastructure managers. Today there are about twenty train operating companies (TOCs) functioning in Sweden. The railway infrastructure is managed by 'Banverket' (the Swedish National Rail Administration), which is a government body. In 1998, Banverket was reorganised into two distinct categories, purchasers or 'service buyers' and contractors, or 'service providers'. For administrative purposes, Banverket is divided into five regions, each of which is responsible for maintenance planning and purchasing, and following up the execution of the maintenance contract. In recent years, maintenance contracts have increasingly been awarded through open tender, thus being subjected to market competition.

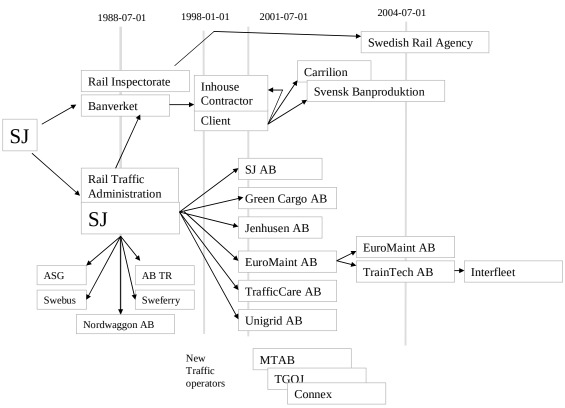


Fig. 23.1. Organisational changes within the Swedish railway system.

23.2.1 Maintenance

Railway infrastructure is a complex system. Usually such infrastructure is technically divided into substructures, namely bridges, tunnels, permanent way, turnouts, sleepers, electrical assets (both low and high voltage), signalling systems including systems for traffic control, telecom systems such as systems for radio communication, telecommunications and detectors, etc. Maintenance of all these subsystems is a complex issue which makes it difficult to plan and execute the maintenance task. Factors such as geographical and geological features, topography, climatic conditions need to be considered when planning for maintenance. Furthermore, the availability of track for maintenance is also an important issue to be considered when planning the maintenance tasks to be executed. Previously, maintenance management was based on technical system characteristics instead of asset delivery functions. Maintenance is critical for ensuring safety, train punctuality, overall capacity utilization and lower costs for modern railways.

The deregulation, privatization and outsourcing processes have created new situations, new organizations and new structures for collecting appropriate data from the field operations and extracting relevant information so as to make correct decision.

23.2.2 Need for benchmarking in maintenance

Many of the European railways have followed a similar evolution. Although many of the countries of Europe are now members of the European Union, questions are being raised concerning the transparency of the state-controlled railway sector in order to make comparisons possible and to find the best practices followed within the railway business. The European railway sector has gradually started to use benchmarking so that the different actors may be able to learn from each other.

23.3 Benchmarking: an Overview

Benchmarking has its root in fundamental business exercise and began to shape in the beginning of 1980. It was introduced as a tool for business development and is supposed to offer a key to large-scale improvements, as it provides a basis for learning from the best practices, providing a road map for copying the work process of the best in the class, i.e. it provides gains with relatively little effort (Dunn, 2003). In general the magnitude of the improvement is around 10 –15% (Varcoe, 1996) and in some cases it can be as high as 35% (Burke, 2004).

There are different benchmarking approaches ranging from the purely quantitative to the highly qualitative (Oliverson, 2000). Quantitative benchmarking will benchmark, for example, the percentage of emergency work orders, the number of skilled workmen per first line supervisor or the percentage of overtime. Moulin (2004) discusses benchmarking of the public sector, in which some aspects of performance measurement must be considered, and states that, since organisations in this sector often perform non-profitable administrative work, they should be viewed from a Balanced Scorecard perspective (see Kaplan and Norton, 1992) . Such organizational measures are useful to service users and provide a clear system for translating feedback from the analysis into strategy for corrective actions.

23.3.1 The Benchmarking Methodology

Successful benchmarking starts with a deep understanding and good knowledge regarding one's own organisation's processes; i.e. learning about one's own performance and bringing one's own core business under control before learning from others (Wireman, 2004).

The most common approach to benchmarking is to compare one's own performance indicators with those of competitors or other companies in the same area, which can be accomplished using simple questionnaires completed by personnel involved in maintenance activities, with little or no expert help to conduct comprehensive studies, or with help from outside firms providing expertise in the planning, execution and implementation of such processes. Based on what is to be compared, benchmarking can be classified as performance, process or strategic benchmarking (Campbell, 1995). Similarly, based on whom one should make a comparison with, benchmarking can be classified as internal, competitive, functional or generic benchmarking (Zairi and Leonard, 1994).

The results obtained from benchmarking identify the gap between one's own organisation's performance and the one following the best practices. These results are then used to improve and develop core competencies and core businesses, leading to lower costs, increased profit, better service towards the customers, increased quality, and continuous improvements. In order to gain benefits, an organisation has to mature in its own core competencies, and to ensure success, the ROI (return on investment) should be calculated for each benchmarking exercise (Wireman, 2004, Wireman, 1998).

A broad survey of the literature shows that, even though all the suggested methodologies for benchmarking are similar in their approach, they vary from a general two-step process to a more detailed 10-step process (Varcoe, 1996, Ramabadron *et.al.*, 1997, Wireman, 2004). All these steps can be related to Deming's famous PDCA cycle. Malano (2000) goes a little further and describes Deming's cycle as a "circular process" which includes the following phases; Planning, Analysis, Integration, Action and Review. The operational form of these 4 steps for the purpose of benchmarking may look like the following:

1. Detailed planning of the benchmarking operation is to keep the goal of benchmarking in focus (for example cost reduction, productivity, etc.) and identify suitable partners for benchmarking. This step essentially encompasses an internal audit to learn about the organisation's business indicators etc.
2. Identifying which business to visits and appropriate data collection
3. Analysis of the data and information collected to identify gaps and the sharing of information; and
4. Implementation and continuous improvement.

Most of the literature points out the fact that successful benchmarking needs a good plan specifying what to benchmark, whom to visit (to study the best practice), when to visit, and what types of resources are required for analysis and implementation. Often simple studies are completed at little cost and generally have no follow-up. Good benchmarking, on the other hand, is time- and resource-consuming and has well-structured follow-up plans etc. The selection of the type and scope of the benchmarking process should be made on the basis of the impact of the outcome on the critical success factors for the process (Mishra et.al., 1998).

A benchmarking exercise is of no value, if the findings are not implemented. In fact, without implementation it would be a waste of resources. The benefits of benchmarking do not occur until the findings from the benchmarking project are realized, and therefore performance improvement through benchmarking needs to be a continuous process.

23.3.2 Metrics

Metrics for benchmarking can be indicatores or KPIs as disuccesd in Chapter 19. In order to make the benchmarking process a successful exercise, it is important that the areas, the process enablers and the critical success factors required for a good performance can be identified, so that the common denominator or any common structure that is important to compare can be described by indicators or other types of measurements, often presented as percent (%) (Wireman, 2004). These performance drivers can be characterized as lead and lag indicators, lead indicators being performance drivers and lag indicators being outcome measures (Åhrén et.al., 2005).

23.4 Benchmarking of Maintenance

Maintenance is treated as an enabler of improved asset or equipment performance (see Figure 23.2) which creates additional value for the business process (Liyanage and Kumar, 2003). Its performance can be monitored by performance measures like availability, quality, value (cost) etc. (Mishra et.al.,1998)

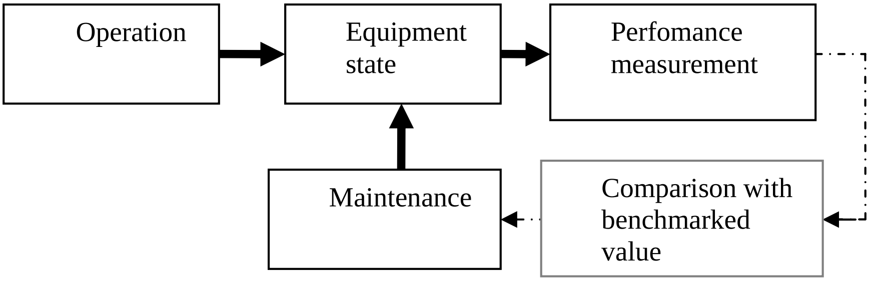


Fig. 23.2 Maintenance’s link with benchmarked value.

Since maintenance is a process of continuous improvement of the delivered performance, benchmarking can be used to improve efficiency in maintenance and offer solutions for improvement in maintenance performance. One definition of benchmarking maintenance used in practice is “the process of comparing performance with other organisations, identifying comparatively high performance organisations, and learning what they do that allows them to achieve that high level of performance” (Dunn, 2003).

Relevant data can contain the following; 1) the man hours, 2) the material costs, 3) the cost of preventive maintenance, 4) the cost of predictive maintenance and 5) the cost of maintenance contracting. In Europe the European Federation of National Maintenance Societies (EFNMS, 2006) has agreed upon 13 different maintenance indices to be used for presenting the results from benchmarking maintenance organisations.these are:

1. Maintenance costs as a percentage of plant replacement value.
2. Store investment as a percentage of plant replcement value.
3. Contract cost as a percentage of maintenance cost.
4. Preventive maintenance costs as a percentage of maintenance costs.
5. Peventive maintenance man hours as a percentage of maintenance man hours.
6. Maintenance cost as a percentage of turnover.
7. Training man hours as a percentage of maintenance hours.
8. Immidiate corrective maintenance man hours as a percentage of maintenance hours.
9. Planned and scheduled man hours as a percetnage of mainenance man hours.
10. Required operating time as a percentage of total available time.
11. Actual operating time as a percentage of required operation time.
12. Actual operating time divided by the number of immidiate corrective maintenance events.
13. Immidiate corrective maintenance time divide by the number of immidate corrective maintenance events.

Wireman (2004) states that the maintenance management impact on the return on fixed assets (ROFA) can be measured by two indicators, namely:

- maintenance cost as a percentage of the total process, production, or manufacturing cost.
- maintenance cost per square foot maintained.

23.4.1 Decision criteria from benchmarking exercise

Results as experienced from different benchmarking projects in the US have identified some rules of thumb that can be used to evaluate the results as well as make suggestions for future actions. One rule of thumb concerns the ratio of the corrective maintenance volume to the total maintenance volume. A level higher than 20% indicates a reactive situation where the future focus will be to bring the core business under control, since planned work versus unplanned work may have a cost ratio as high as 1:5. Another rule of thumb concerns a high level of overtime, which indicates reactive situations in the maintenance process. Since labour is a large cost driver for maintenance, the amount of overtime can have a large impact on maintenance costs. Another large cost driver is spare parts (Wireman, 2004, Hägerby 2002).

23.4.2 Railway Context

Benchmarking approaches used by industries to improve their performance through comparison with the best in the class, can be equally used for benchmarking of the railway operations. But unlike industrial sector, railway infrastructure consists of a larger number of individual assets, including substructure, permanent way, signalling, electrical and telecom assets that extend over zero or even hundreds of kilometres. Furthermore, there are large differences between the structures of the different railway organisations. At present, many organisations are characterised by comprising one entitiy, whereas some are divided up into traffic companies and infrastructure owners, with an in-house or outsourced maintenance function. The different types of traffic on the railway tracks have different degradation characteristics, and, therefore, it is difficult to compare passenger-intensive lines, with heavy haul lines or lines with mixed traffic. Furthermore, the data collected from the different partners selected for benchmarking is not always possible to compare without normalisation. It is also important to validate and audit the collected data to find outliers (Oliverson, 2000). Some examples of the normalisation required within railway benchmarking are presented in the following.

In a benchmarking project called “InfraCost”, data has been collected over a number of years to compare the asset life cycle costs of different railways. A complex normalisation process has been used to bring all the information, for example maintenance costs, renewal costs, local labour costs, intensity and speed of trains from different countries in Europe to a same base for comparison (see http://promain.server.de, Zoeteman and Swier, 2005).

Another way to normalize data is to identify the cost drivers and try to establish a link between performance and cost, on the one hand, and performance and the age of the assets, on the other hand. In order to compare the assets, compensation factors were established on the basis of the network complexity, measured in terms of (Staleder et al., 2002):

- the density of turnouts,
- the length of lines on bridges and in tunnels,
- the degree of electrification,
- the usage according to average frequencies of train per year and
- the average gross tonnage per year (freight and passenger).

In the project the costs drivers have been established, but the implementation of Life Cycle Cost (LCC) strategies for avoiding the difficulties of separating the maintenance cost from the renewal expenditures has not yet been fully realized (Stalder et.al., 2002).

When the International Union of Railways (UIC) in their benchmarking projects between the years 1996 and 2002 compared costs between Europe, USA and Asia, they found big differences in the costs. In an attempt to understand the differences, Zoeteman and Sweir (2005) developed a model that converted the benchmarked results into life cycle cost per km of track, including the maintenance cost, renewal cost and overhead cost both for the organization and the contractors. The major differences were in purchasing power, wages, turnout density, and degree of electrification, the proportion of single track and intensity of use.

Benchmarking is not yet common practice within the railway sector, and there is a need to build up a framework and metrics in order to compare and find out the best practices.

The aim of using benchmarking as a tool to improve prevalent maintenance practices within the railway sector is to demonstrate and measures that make it possible to compare the result from one operation to another regarding the railway administrations under different circumstances and conditions, and to identify the best practices in the area. Therefore, the benchmarking process has to be evaluated and normalised to fit the railway maintenance process. Accordingly, it is also essential to decide what kind of KPIs (Key Performance Indicators) need to be implemented for improvement.

23.5 Benchmarking in the Swedish railway sector

Benchmarking within the railway sector is characterized by state ownership and monopoly. One of the first benchmarking projects, “InfraCost” (http://promain.server.de, Zoeteman and Swier, 2005) showed big differences in maintenance costs among European, Asian and American Railway Administrations. The result from this benchmarking shows the need for establishing a common framework and common metrics for benchmarking. Initially benchmarking within Sweden was motivated using other reasons than finding the best practice. These were:

- checking, if it is possible to perform benchmarking and studying benchmarking methods,
- finding those key areas that are critical success factors or
- finding answers to questions like ‘Why is it less expensive to run railways in neighbouring countries?’.

The case studies presented in section 6 to 8 have used three different approaches concerning methodologies for data collection and classification, normalization and analysis of results. The case studies are:

1. Two neighbouring local track areas sharing a line for railway traffic on each side of the border. The aim was to compare the maintenance cost, identify differences and find areas to improve.
2. Internal benchmarking for maintenance contracts in order to find the best practice and to improve the maintenance contracts.

3. To determine what (maintenance) performance measures were in use within the railway sector in Europe. The aim was to scan the possibility of finding areas to compare, just by looking into those official documents that some of the railways have presented.

The common denominator between these case studies is used for benchmarking methodologies in order to find out if it is useful within the railway sector. The differences between these case studies are the main objectives of the benchmarking.

23.6 Case study – 1: Benchmarking across the border

A case study benchmarking a cross-border operation and maintenance process was initiated by Track Area A for the rail administration in Country A. Track Area A provides railway infrastructure in the western part in Country B, between City B in Country B and City A in their own country (Country A). The aim was to study and understand why the operation and maintenance cost are different on the other side of the border. They also needed to find out if those costs were comparable with the costs in country B and if it was possible to coordinate parts of the maintenance work between these two countries in order to decrease the cost (Åhrén and Espling, 2003).

The benchmarking process was conducted by Luleå Railway Research Center, a neutral party to both the organizations. During the preparatory stage of the benchmarking process, a total transparency between the infrastructure owners representing these two countries was agreed upon. It was also decided (by the sponsor of the study) not to make the result of the study public and to keep it confidential for 5 years.

Both track areas were organised more or less identically for the purpose of maintenance, and the maintenance activities were planned and executed in a similar way. It was therefore not necessary to examine and normalise the overhead costs of both the railway administrations.

23.6.1 Metrics and Data

The metrics and data collected were the cost for the operationa and maintenance and outcome of performance losses. The data were collected for one calendar year, from the systems for accounting, planning system, failure reporting and inspection and contained:

- budget versus performed outcome for maintenance costs,
- overhead costs for the local administrations,
- maintenance planning,
- failure statistics and
- the inspection remarks.

However, the following information and data relevant to the study could not be collected:

- overhead cost for the contractor (not available due to the competition between the different contractors),
- man hours (not available, not collected in the client system from the invoice),
- traffic volume,
- asset age, which were approximately the same (not necessary to collect, since the traffic mix and volume were the same),
- spare part costs (not available).

Normalisation
Since the organisation and accounting structure were almost the same, it was assumed that the missing data could be disregarded. The amount of normalisation was restricted to adjusting the currency.

23.6.2 Results and Interpretations

The available data and information were then sorted as shown in Table 23.1. The maintenance costs were grouped into the categories: snow removal, corrective maintenance and preventive maintenance, see Table 23.2.

Table 23.1. Comparing cost per metre of track

Object	**Track Area A**	**Track Area B**
Total cost	795	290
Maintenance cost	285	280
Track Area Administration cost (overhead)	220	8
Other external costs, e.g. consultancy	90	2
Charges fpr electric power	200	0

Table 23.2 Difference in percentage in maintenance costs between Track Areas A and B

Maintenance activities	**Difference in percentage from Track Area B**
Snow removal	+ 10%
Corrective maintenance, including organisation for preparedness (emergency service)	+ 32%
Preventive maintenance, including inspection	- 62%

The benchmarking result showed that the maintenance cost was approximately the same as the total cost per track meter. One of the findings was that the amount of corrective maintenance was very high in both track areas. A closer investigation showed that Track Area A had a larger amount of corrective maintenance and therefore less money for preventive maintenance.

Furthermore the overhead cost and other external costs such as travel costs, costs for consultancy etc. in Track Area A were much higher compared to Track Area B. One of the explanations was the geographical isolation of Track Area A from its own administration, resulting in higher traveling costs and the necessity of buying consultancy for some services that Track Area B could obtain from its nearby regional office. Another explanation was that Track Area A had to finance all its buildings, the electrical power and the cost for the traffic control centre, while this was taken care of by a separate organization for Track Area B.

It was also possible to find those areas of work that could be mutually coordinated, for example snow removal. However, this was something that needed to be negotiated and was therefore considered a political matter.

The implementation phase was the responsibility of the national railway administrations. The results were mainly used as arguments clarifying why the costs were so much higher for the railway line in Country A compared with those of other national lines.

23.7 Case study- 2. Internal Benchmarking for Maintenance contracts

All the maintenance work within Banverket is purchased either from the in-house contractor or from an external contractor. This necessitates legal operations, and maintenance business contracts are prepared and written for every maintenance commission, containing details of the work to be provided, with targets and agreed performance measures (for example; minimum of track down time in order to increase the train punctuality) to control the quality of the maintenance work to be performed.

Purchasing infrastructure maintenance is a complex issue due to the engineering complexities of railway assets, safety assurance, the usage type, the climate and the traffic mix. In particular, it is very difficult to define the task to be performed (procured) and the desired final outcome from the contract. Many different procurement models have been tested with varying degrees of success (Larsson, 2002).

This benchmarking project was launched at the request of one of the 16 local regional track area managers (clients) responsible for procuring the maintenance contracts. The manager had observed that their contracts with, in this case, the in-house contractor had resulted in an increase in the cost limits, while the performance and the quality had started to decrease.

The process started with an internal survey of an ongoing contract. The contract included snow removal and maintenance activities such as corrective maintenance (failure repair and repair due to inspection remarks classifying faults as requiring immediate action), inspections for safety and inspections for maintenance (classified as condition-based maintenance) and predetermined maintenance pin-pointed by the internal regulations. Repair work due to faults not classified in inspections as requiring immediate action was to be bought separately. The survey showed problems such as a high amount of corrective maintenance, increasing costs for failure repair, an increasing amount of backlogs and a long response time for failure calls. The aim was to find ways to improve the procurement and the next maintenance contract by learning from the experience and knowledge of other regional track areas in this respect.

The benchmarking process followed the standard procedure recommended for benchmarking as stated in an earlier section (Section 23.3). The study covered nine local track areas named as Track Areas A to I, and 6 of these were selected for the study and follow-up of qualitative interviews (D-I).

23.7.1 Metrics and data

Before starting the collection of data and other relevant information, the existing indicators and indices used by maintenance professionals available in the literature and through professional bodies, for example the EFNMS indices (2006), were examined for their suitability for the purpose of benchmarking maintenance practices in different track regions at Banverket. Most of these metrics were not found suitable for the purpose of this study and therefore actions were initiated to establish indicators that would facilitate this benchmarking process. Furthermore, information and data which were planned to be included in the study, namely details of maintenance-related measures such as maintenance costs, maintenance hours, material, maintenance vehicle costs, overhead costs etc., were missing or only available in the aggregate form, due to the competitive situation.

As the deregulation of the railway transport system in Sweden has led to competition among the traffic companies, it was not possible to get hold of traffic data, i.e. how the track was used, because this information is being treated as a business secret by the train operators.

Data from 2002 was collected from the systems for accounting, the failure reports, the inspection remarks, and the asset information and from the train delay reports. The following data were collected:

- Asset data from BIS: total length of track, total length of operated track, total amount of turnouts, total amount of operated turnouts, length of electrification, number of protected level crossings. An attempt was also made to define their standard by the assets' age and what type of traffic they had been exposed to – this had to be skipped as it was not possible to obtain complete data for all the assets and different track lines. The purpose was to know the intensity of track utilization.
- From the accounting system AGRESSO: Snow removal and maintenance costs for one year, defined per maintenance activity corresponding to the maintenance contract (corrective, predetermined, condition-based etc.) and cost per asset type (rail, sleeper, turnout etc.).
- From BESSY (Inspection remark system): The number of inspection remarks, classified as remarks requiring immediate attention or deployment of corrective measures or remarks requiring attention or correction in the near future (deferred inspections remarks).

- From OFELIA (Failure report system): Failure reports (including asset type and type of failure, time to fault localization and time to repair, symptoms and causes, place, date and time). Time to establish on the fault place.
- From TFÖR (Train delay system): Train delay statistics corresponding to infrastructure failures. TFÖR registers all the train delays and records them together with the respective reported infrastructure failure.
- Contracts and procurement documents.

23.7.2 Data collection

The data collected from the accounting system needed normalisation in particular, due to difficulties in separating normal track maintenance activities from track renewal activities, as these two concepts were frequently being mixed in the database. There were also some difficulties in using the prescribed terminology, because of misunderstandings in the maintenance context which resulted in the common structure for reporting cost back into the system not being used, and data had to be sorted afterwards into the "right boxes". Some track areas were using maintenance definitions and concepts from other branches representing the building and construction industry. Some "outliers" were also eliminated from the data, especially those representing some special or just-one-time investments made to increase train punctuality or reduce winter problems.

Cost drivers leading to non-availability of infrastructure for train operation or affecting safety were identified. The respective train delay hours were also retrieved. The cost drivers for the infrastructure were failure or defects in rail, sleepers, rail joints, turnouts, level crossings, and catenaries (overhead wire). On further investigation it was found that the cost related to sleepers could be classified as outliers, because a large amount of the sleepers replaced in the 1990's were delivered with inbuilt defects. These sleepers are being dealt with in a replacement phase within the framework of a large project.

In order to find the best internal practice within the organization, two parameters, the "amount of corrective maintenance" and the management indicator "return on fixed asset" (ROFA), were used.

22.7.3 Results and Interpretation

Track Areas A to I are the nine track areas, D-I are those selected by the infrastructure manager for qualitative interviews and track Areas A-C are references.

The data pertaining to various costs, corrective maintenance, condition based maintenance and failure and delay statistics from track area A to I for the year 2002 are given under table A.1 – A.7 of Appedix A to this chapter.

When using the parameter ROFA and the rule of thumb concerning the lowest amount of corrective maintenance, Track Areas B, G, C and H were the best performers see Figure 23.3, and the ROFA measurement showed a tendency of "more money per track metre, less corrective maintenance", see Figure 23.4.

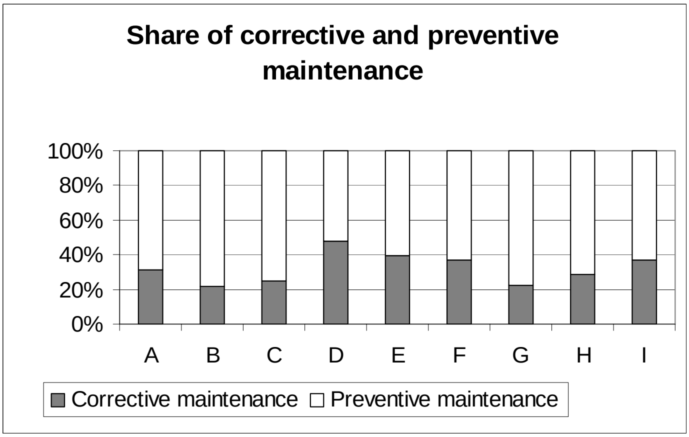


Fig. 23.3. Share of corrective maintenance and preventive maintenance for the nine track areas studied (Espling, 2004).

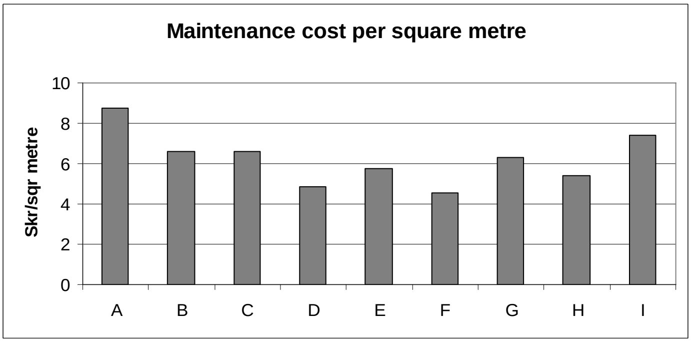


Fig. 23.4. Maintenance cost per square metre of track area (Espling, 2004)

Another comparison was made concerning the maintenance cost per meter within the framework of the maintenance contract for each track region under study. Track Areas H, C and G showed the best practice followed, see Figure 23.5. It was noted that the maintenance cost varies greatly per asset or per track meter unit among the compared track areas due to the asset standard, type of wear, climate and type of traffic.

To compare the performance, the amount of functional failures and train delay hours were listed as failure or delay hours per meter or per cost driving asset, see Figure 23.6. Even here the best performance was shown by Track Areas G and H.

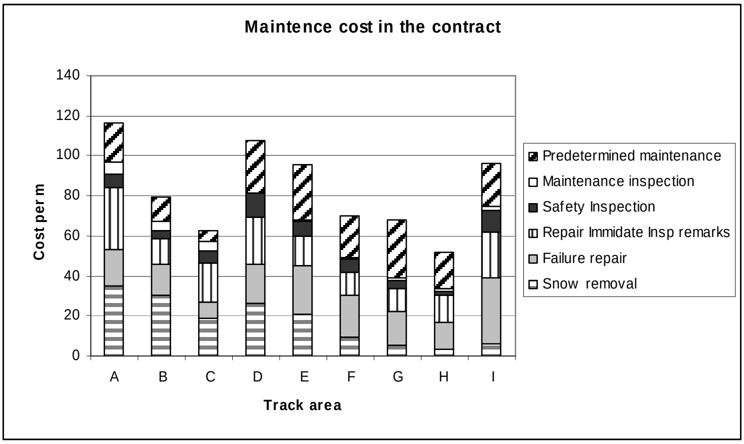


Fig. 23.5. Maintenance cost in the maintenance contract.

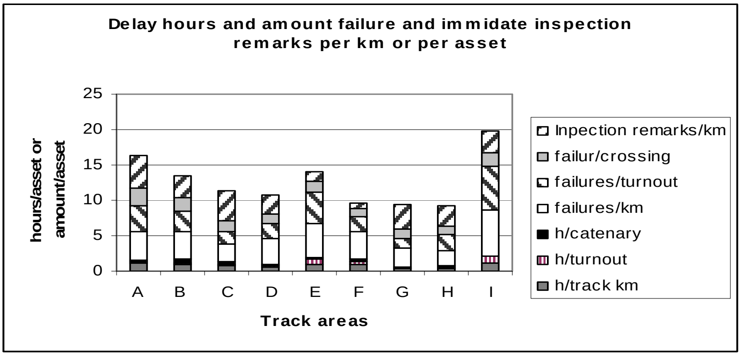


Fig. 23.6. A comparison of the performance of the different track regions

All these results obtained from the comparison of different track regions, in combination with the content of the maintenance contract defining work specifications within the maintenance contracts, were used for the gap analysis. The gap analysis was conducted with the help of interviews with the track area managers for Track Areas D-I. The best practice criteria were identified with the help of interviews and survey questionnaires. The best practices were:

- goal-oriented maintenance contracts combined with incentives,
- scorecard perspectives, quality meetings and feedback facilitate management by objectives,
- frequent meetings where top managers from the local areas participate,
- forms for cooperation and an open and clear dialogue, for example partnering,
- focus on increased preventive maintenance of assets with frequent functional failures and a high maintenance cost will give results, e.g. turnouts, and
- the use of Root Cause analysis.

The best practices identified from the benchmarking study were immediately implemented in the new purchasing procedures and documents. These were used for floating tenders and for new contracts by the infrastructure manager for the local tack area initiating this benchmark, and resulted in maintenance contracts at a much lower price with better control of quality and performance. The benchmarking study also identified the best practice for gaining control over backlogs by using SMS and other internet-based tools. Besides these, the maintenance contract was also provided with information about goals, objectives and expected incentives related to the execution of the maintenance contracts.

23.8 Case Study- 3: Tranparancy among the European Railway Administrations

In an attempt to find ways of benchmarking Railway Infrastructure Administrations as an "external observer" and to give an answer to the question "Is there any transparency in the railway systems of Europe?" five railway administrations were selected, see Table 23.3.

Table 23.3. Infrastructure managers (A-E) and important organisational differences

Infrastructure manager	**Outsourced maintenance**	**Traffic operation**	**Traffic operators**
A	Both external and internal	Free service	Many
B	Internal outsourcing	Free service	Few
C	Internal outsourcing	Included	Few
D	Both external and internal	Free service	Many
E	Both external and internal	Is bought	Few

23.8.1 Metrics

In this study, many official documents, such as annual reports and regulation letters and documents, were studied in detail in order to gain insight into the types of measures, key performance indicators and indices used by the railway administrations investigated (Åhrén et.al.,2005). The collected measures were then compared with those recommended by EFNMS in order to see if these could be used in future benchmarking exercises. Rather soon it was found that the EFNMS indices were developed for factories and plants and were not suitable for studying or benchmarking the performance of infrastructures, as they did not consider the type of asset, the age of the asset, the asset condition or the practice of outsourcing maintenance work in an open market.

Normalisation
Since data were qualitative in nature, no normalisation was carried out for the purpose of this study.

23.8.3 Results and Interpretation

The next step was to group the measurements according to the unit which they measured, for example cost went into the economy group.

The parameters collected and reported by the infrastructure managers were then classified into different categories of common denominators. These categories comprised the following: strong denominators (Sods) collected by everyone, medium denominators (Sims) collected by more than 50%, and weak denominators (Sews) collected by less than50%, and finally some indicators (I) also identified as Sods presented as a percentage value, see Figure 23.7. The results show that economic values, safety, and traffic are strong denominators, followed by quality, assets, and labour. It is important to note that “traffic” is the total traffic volume on a national level. These parameters could later on be used to develop new benchmark measures, e.g. maintenance costs per staff and amount of accidents per traffic volume.

Today the comparable indicators are:

- corrective maintenance cost / total maintenance cost including renewal,
- total maintenance cost / turnover,
- maintenance and renewal costs / cost for asset replacement and
- maintenance cost / track metre.

When comparing the outcomes of the findings only highly aggregated measures were used for the purpose of analysis, in terms of:

- economy,
- punctuality,
- safety,
- the number of staff employed,
- track quality, and
- total traffic volume divided up into passenger and freight kilometres

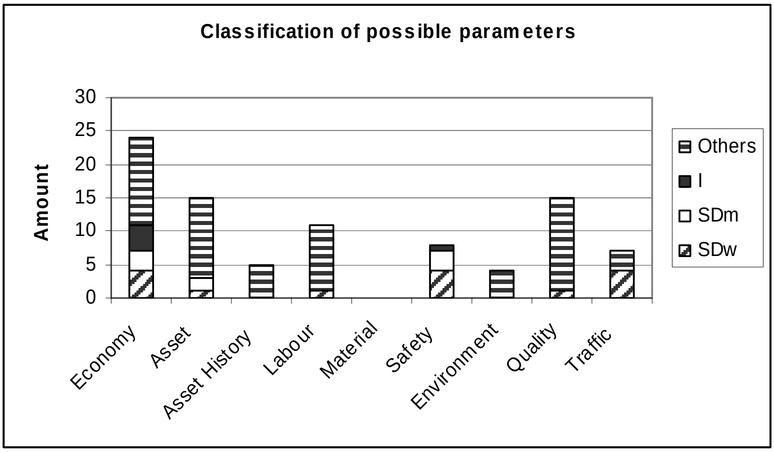


Fig. 23.7. Classification of possible comparable parameters

They can be used as benchmarking measures, the lag indicators showing past performance. This indicates that these areas of interest are important for every studied railway administration. It is also important to note that the identified measures can be defined as outcome measures from the railway maintenance process. It has not been possible to find any measures reflecting the actual maintenance performance. This can probably be explained by the fact that the maintenance activities are carried out by either in-house or external maintenance contractors (Åhrén et.al., 2005).

Some of the maintenance performance indicators are used by various organizations and provide railways with an opportunity to benchmark their operations internationally to improve their performance. One of the findings in the studies is that there are parameters missing regarding the traffic volume, infrastructure age, and history of the performed maintenance.

23.9 Discussion

The reason why most plants do not enjoy best practices in maintenance is that they do not picture how to structure a sustainable improvement process (Oliverson, 2000). Benchmarking can then be a tool for waking up organisations and their management in order to find improvement areas that create more value from the business process. However, on the way there are many pitfalls to be aware of, such as starting the process without knowing the starting point and the destination (Oliverson, 2000, Wireman, 2004). Other pitfalls are:

- Just doing quantitative benchmarking. Quantitative numbers just tell parts of the story, and the difficulty is to start the sustainable improvement process, by focusing on qualitative benchmarking (Oliverson, 2000). If the organisation does not have maturity or self-knowledge, it just glances at the figures and continues to do as it always has done before.

- Rejection of the results. Managers often overestimate their performance and react with disbelief to feedback that tells them that their plants are merely mediocre (Wiarda and Luria, 1998).
- Not being aware of the need for normalisation of data, including the problem of outliers or comparing “apples with bananas”
- Not finding the enablers (Wireman, 2004)
- Using benchmarking data as a performance goal.
- Believing that it is as easy as just copying the best practice into one’s own organisation, rather than learning.
- Unethical benchmarking.

The methodologies for performing benchmarking for plants are rather well developed, but need to be adapted for infrastructure. Today it is difficult to establish what is included in maintenance, renewal and new investment. Other difficulties are how the infrastructure administrations are organized, for example if the client/contractor is the organization, if the maintenance is outsourced, and how it is outsourced; outsourcing makes it difficult to collect costs for overheads, maintenance, man hours, spare parts, backlog’s etc.

Today there are a number of performance indicators in use connected to maintenance, covering for example the areas of safety, track quality and asset reliability. Maintenance performance and cost control are the so-called lag indicators.

23.10 Conclusion

Stating that the “benchmarking of maintenance provides gains with relatively little effort” is a truth that needs some modification. First of all, the theory of maintenance is a rather young science, which has resulted in a lack of common nomenclature and understanding of maintenance through value. This is one of the reasons why it is difficult to define what is included in maintenance and where to put the boundaries for renewal. There can also be different structures in use to describe what operation is and what maintenance is, and also for grouping maintenance into preventive and corrective maintenance. Outsourcing maintenance has become popular in recent years, and this makes it difficult to obtain all the necessary measurements, especially if the outsourcing is carried out in a performance contract (lump sum, fixed price). The assets’ complexity and condition are also difficult to compare and measure.

The multitude of entities involved in the railway systems after their restructuring has made it considerably difficult to locate the organization responsible for the problems encountered and to ascertain the course of action to be taken to rectify them.

Benchmarking cannot be used if its results are not implemented. The benefits from benchmarking do not occur until the findings from the benchmarking project are implemented and systematically followed up and analyzed against the set targets and goals.

The results from the three benchmarking studies presented show that benchmarking is a powerful tool and its methodology can be used by other industries. Since the focus of these case studies is the benchmarking process and not the continuous improvement process, it is important to point out the need for empowered enablers, who will be responsible for identifying the problem, finding a solution to the problem and implementing the solution and the continuous improvement processes. The case studies also show that there is some more improvement to be made in order to start the whole process of benchmarking including the implementation in an integrated manner.

23.11 Future research

Further research could be conducted to identify those parameters that are essential for developing lead indicators (Kaplan and Norton, 1992) for effective planning and execution of railway infrastructure maintenance tasks, by developing methods to select, evaluate and implement these indicators in open market competition.

More metrics, i.e. indicators and a measurement framework, should be developed and reconfigured for maintenance, making comparisons possible, for example from the Life Cycle Cost perspective vis-à-vis the business perspective. In railway administrations, one critical improvement area is enhancement of the quality of the incoming data. This can be achieved:

- by giving details of the status of the assets (age and degree of wear), the total traffic volume per year and the available time on track for infrastructure maintenance. This information should be incorporated as a correction factor in the analysis,
- by well-structured economic feedback reports on maintenance activities. This should be implemented so that it is possible to differentiate resources which are consuming corrective maintenance activities and those consuming preventive maintenance activities. The structure of the economic feedback reports on maintenance should be designed so that it may be possible to differentiate operation and corrective and preventive maintenance.
- by separating the specially targeted maintenance investment from normal “maintenance activities”; efforts to enhance punctuality in special campaign form are an example of the former.

23.12 Acknowledgements

The authors are thankful to Banverket (the Swedish Rail Administration) for sponsoring this research work and providing information and statistics through free access to their database.

22.13 References

Almdal, W. (1994), "Continuous improvement with the use of benchmarking", *CIM Bulletin*, Vol. 87 No.983, pp.21-6

Burke, C. J. 2004. 10 steps to Best–Practices Benchmarking. http://www.qualitydigest.com/feb/bench.html

Campbell, J. D. (1995). *Uptime: Strategies for Excellence in Maintenance Management*, Productivity Press, Portland, US

Dunn, S. (2003), Benchmarking as a Maintenance Performance Measurement and Improvement Technique. Assetivity Pty Ltd, http://www.plant-maintenance.com/maintenance_articles-Performance.shhtml

EFNMS (2006), http://www.efnms.org/efnms/publications/13defined101.doc

Espling, U. (2004), Benchmarking av Basentreprenad år 2002 för drift och underhåll, Research Report, LTU 2004:16, (In Swedish).

Hägerby, M., Johansson, M. (2002). Maintenance performance assessment: strategies and indicators. Master thesis, Linköping, Linköpings tekniska högskola, LiTH – IPE Ex arb 2002:635.

Kaplan, R. S. and Norton, D. P. (1992), The Balanced Scorecard: the measures that drive performance, *Harvard Business Review*, Jan-Feb (1992), pp. 71-79.

Larsson. L. (2002). Utvärdering av underhållspiloterna, delrapport 1. Banverket F02-§713/AL00. (In Swedish).

Liyanage, J. P. and Kumar, U. (2003). Towards a value-based view on operations and maintenance performance management, *Journal of Quality in Maintenance Engineering*, Vol. 9, pp. 333-350.

Malano, H. (2000), Benchmarking irrigation and drainage performance: a case study in Australia. Report on a Workshop 3 and 4 August 2000, FAO, Rome, Italy.

Mishra, C., Dutta Roy, A., Alexander, T.C. and Tyagi, R.P. (1998), Benchmarking of maintenance practice for steel plants, *Tata Search* 1998, 167-172.

Moulin, M. (2004), Eight essentials of performance measurements, *International Journal of Health Care Quality Assurance*, Vol .17, Number 3. pp. 110-112.

Oliverson, R.J. (2000), Benchmarking: a reliability driver, *Hydrocarbon Processing*, August 2000, pp. 71-76.

Ramabadron, R., Dean Jr J. W. and Evans J. R. (1997), Benchmarking and project management: a review and organisational model, *Benchmarking for Quality Management & Technology*, Vol. 4, No. 1, pp. 437-58.

Stalder, O., Bente, H. and Lüking, J. (2002), The Cost of Railway Infrastructure. ProM@ain – Progress in Maintenance and Management of Railway Infrastructure, 2, pp. 32-37. http://promain.server.de

Varcoe, B. J. (1996), Business-driven facilities benchmarking, *Facilities*, Vol. 14. Number 3/4, March /April, pp. 42-48, MCB University Press.

Wiarda, E.A. and Luria, D.D. (1998), The Best-practice Company and Other Benchmarking Myths

Wireman, T. (1998), *Developing Performance Indicators in Maintenance*. New York: Industrial Press Inc.

Wireman, T. (2004), *Benchmarking Best Practice in Maintenance Management*. New York: Industrial Press Inc.

Zairi, M. and Leonard, P. (1994). *Practical Benchmarking: the Complete Guide*. London: Chapman and Hall.

Zoeteman, A. and Swier, J. (2005), Judging the merits of life cycle cost benchmarking, in Proceedings International Heavy Haul Association Conference, Rio de Janeiro June,

Åhrén, T. and Kumar, U. (2004), Use of maintenance performance indicators: a case study at Banverket, Sweden, in Conference proceedings of the 5th. Asia-Pacific Industrial Engineering and Management Systems Conference (APIEMS22004). Gold Coast, Australia.

Åhrén, T., Espling, U. and Kumar, U. (2005), Benchmarking of maintenance process: two case studies from Banverket, Sweden, in Conference proceedings of the 8th Railway Engineering Conference, London June 29-30.

Åhrén, T. & Espling, U. (2003), Samordnet/Felles drift av Järnvägen Kiruna – Narvik (confidential). Luleå, Luleå tekniska universitet (In Swedish).

APPENDIX I

Table 1 Failure and delay statistics from Track Areas A-I for the year 2003

Track Area	Train delay hour/track km	Train Delay hour/ turnout	Train Delay hour/ catenaries km	Amount of failures/ track km	Amount of failures /turnout	Amount of failure/ crossing	Inspection remarks/ track km
A	1.07	0.25	0.15	4.2	3.5	2.5	4.7
B	0.88	0.33	0.61	3.7	2.9	1.9	3.1
C	0.73	0.21	0.45	2.5	1.68	1.5	4.2
D	0.57	0.29	0.1	3.6	2.24	1.3	2.7
E	0.93	0.76	0.25	4.7	4.59	1.5	1.4
F	0.97	0.36	0.41	3.8	2.22	1.0	0.9
G	0.35	0.14	0.05	2.8	1.28	1.3	3.5
H	0.32	0.31	0.14	2.0	2.24	1.1	3.0
I	1.18	0.84	0.14	6.5	6.1	1.9	3.2

Table 2 Cost of various maintenance activities in thousands of SEK for each track area for the year 2003

Track Area	Snow removal In thousands of SEK	Corrective maintenance	Preventive maintenance	Contract sum
A	15 325	24 189	14 130	53 644
B	16 801	17 792	12 941	47 534
C	12 908	28 728	10 863	52 553
D	22 085	46 772	20 537	89 394
E	18 074	44 168	21 532	83 774
F	8 250	39 181	15 991	63 442
G	4 336	22 050	26 388	52 774
H	3 041	22 854	19 131	45 026
I	4 976	46 414	31 803	83 193

Normalisation is necessary due to the investment of extra money just for one year to enhance the preparedness to deal with failures causing train delays. The figures in Table 2 are the figures before normalisation.

Table 3 Costs in thousands of SEK for corrective maintenance due to failure reports from s for the year 2003.

Track Area	Maintenance organisation (personnel, machines, spare parts)	Emergency organisation	Actual cost	Fixed Price (lump sum)	Total cost (t SEK)	SEK/ failure
A		2 880[1]	7 989		10 869	5 933
B		4 416[1]	6 145		10 861	5 273
C		3 732[1]	4 128		7 860	4 690
D	4 701		11 448		16 150	5 379
E	4 776		16 078		20 854	5 073
F	4 884		14 095		18 897	5 530
G					12 686	5 838
H		3 512[1]	7 785		11 444	6 065
I			20 274	6 304	28 246	5 145

1) Extra preparedness 2003

Table 4 Cost statistics for corrective maintenance triggered by the failure reporting system 0felia (in thousands of SEK) after normalisation

Track Area	Maintenance organisation	Emergency organis-ation	Actual cost	Fixed Price (lump sum)	Total cost (t SEK)	SEK/ failure
A			7 989		7 989	1832
B		2 156	6 145		8 601	2060
C		1 472	4 128		5 600	1676
D	4 701		11 448		16 150	3002
E	4 776		16 078		20 854	4111
F	4 884		14 095		18 897	3417
G					12 686	2173
H		3 512	7 785		11367	1887
I			20 274	6 304	28 246	5490

Table 5. Reported corrective maintenance caused by inspection remarks classifying faults as requiring **immediate** repair; also including activities such as inspection and condition-based and predetermined maintenance that should have been booked under other codes in the accounting system **(Before Normalisation of the data)**

Track Area	Inspection remarks calling for immediate repair	Mixes of inspection remarks calling for immediate repair and CBM Remarks	Inspection cost including inspection remarks calling for immediate repair	Operation-al actions due to pre-determined main-tenance	Care of electrical assets due to pre-determined maintenance	Condi-tion-based main-tenance	Total Cost
A	13 320						13 320
B	6 931						6 931
C	12 355	1 485				7 081	20 921
D	16 361		7 614	3 558	3091		30 638
E	10 864		1 962	4 732	1 486		19 044
F	9 963		3 194	4 289	2 756	168	20 383
G							9 346
H	11 107					303	11 410
I	18 169						18 168

Table 6. Reported corrective maintenance caused by inspection remarks classifying faults as requiring **immediate** repair; also including activities such as inspection and condition-based and predetermined maintenance that should have been booked under other codes in the accounting system

(**After normalisation**)

Track Area	Inspection remarks calling for immediate repair	Inspection remarks calling for immediate repairbooke d under inspection	Corrective maintenance booked as inspection in the accounting system	New Total Cost
A	13 320			13 320
B	6 931			6 931
C	12 355	995		13 350
D	16 361	1 904	1 506	19 771
E	10 864	491	1 553	12 908
F	9 963	799	8	10 770
G				9 346
H	11 107			11 410
I	18 169		916	19 084

Table 7. Condition-based maintenance bought as extra orders in thousands of SEK, but including the so-called special maintenance activity

Track Area	Original accounting sum	Minus Defective - sleepers	New Sum
A	32 319		32 319
B	43 831		43 831
C	44 139		44 139
D	6 607		6 607
E	81 720	-60 913	20 807
F	53 797	-27 972	25 825
G	50 753		50 753
H	45 198	-7 680	37 518
I	63 426	-12 722	51 004

PAPER VI

Outsourcing as a strategic tool to fulfil maintenance objectives - a railway case study

Espling, U. and Åhrén, T. (2007). Outsourcing as a strategic tool to fulfil maintenance objectives - a case study for railway. Submitted for publication in a Journal.

Outsourcing as a strategic tool to fulfil maintenance objectives - a railway case study

Ulla Espling and Thomas Åhrén, Luleå Railway Research Center, Division of Operation and Maintenance Engineering, Luleå University of Technology, Luleå, SWEDEN

Abstract

In order to increase effectiveness/efficiency, lower the cost, increase innovation, create flexibility and focus on core business and core skills, many companies have outsourced activities that they think somebody else could do better at a lower cost, e.g. maintenance, services, IT-support etc. Another thought is that the owner organisation would enhance its performance if these are put out for competition. It is important before outsourcing to know what the objectives, strategy, method, measurements and skills are both within the owner organisation and the contracted organization. The aim and objective for outsourcing must be well defined. In this paper the pros and cons for outsourcing maintenance are discussed and some basic requirements for outsourcing maintenance are proposed. Different maintenance contracts are then studied within the Swedish Railway Administration (Banverket) concerning scope, objectives, contract forms etc. and outcome. A gap analysis is conducted between the basic requirements and the practice in the outsourced contracts in order to highlight risk and improvement areas. The results point out improvement areas for forming objectives and measurements, and the need for risk analysis concerning issues such as safety and outsourcing core activities and core competence.

Key words: Railway, basic requirements, outsourcing, maintenance.

1. Introduction and background

1.1 Outsourcing maintenance

The market mechanisms driving growth are cost and innovation (Mattison, 2000). Cost will decrease with effective and efficient production, while innovation needs development/renewal and a range of new products. More effort needs to be put into those activities and skills that could increase growth and quality. A trend during the 1980s was therefore to focus on core business/activities and outsource the rest (Kakabadse and Kakabadse, 2000). According to Campbell (1995) one area suitable for outsourcing would be maintenance, e.g. in the US 35 % of companies have outsourced maintenance and Levery (2002) pronounced a shift to maintenance being a non-core activity. The maintenance function is commonly seen as cost and overhead, adding little value to the production and therefore an issue suitable for outsourcing. However, in businesses with significant investment in physical assets maintenance plays an important support function in achieving the organisational goals (Liyanage and Kumar, 2000). The Swedish Rail Administration (Banverket) is treating maintenance as an integral part of the business process, i.e. applying a holistic view to the infrastructure maintenance process in order to fulfil customer requirements (Karlsson, 2004).

Before outsourcing, the company needs to define its own needs and business objectives and it must be crystal clear to the management what the core business, core competence and the resources of the company are (Pietilä, 2007). It must also be clear that outsourcing is done for the right purpose and reasons, i.e. do you know what your own problems are and do you have control over them? A dangerous approach is to think that if you outsource the problem will be solved by the contractor. According to the thumb rule, you start to lose control if the level of corrective maintenance is higher than 20 % (Espling and Kumar, 2007; Wireman, 2004; Blanchard, 1997). A company cannot successfully outsource if it does not understand the nature of its own problem (Kakabadse and Kakabadse, 2000).

In order to know which functions can be outsourced, a company must identify its strategic functions (Pietilä, 2007). There is a need to have clear objectives, and make sure of the reason why outsourcing is good business. The next step is to develop an overall approach plan with complete support from management and the full participation of the people most affected by it (Campbell, 1995).

It should also be known if the outsourced function is on a strategic, tactic or an operative level (Tsang *et al.*, 1999). Strategic outsourcing is done to achieve strategic improvement, cost reduction, enhancement of efficiency, strategic business impact (improving performance) and strategically commercial exploitation. Tactical outsourcing is related to formulations of policies for effective and efficient use of available resources, while operational outsourcing is done to achieve a high level of effectiveness and efficiency in day-to-day business activities (Kakabadse and Kakabadse, 2000).

The reasons to outsource the in-house activities can be summed up (Campbell, 1995; Levery, 2002; Kakabadse and Kakabadse, 2000; Pietilä 2007; Freytag and Mikkelsen, 2007) as a desire to:

- decrease cost,
- lower or stabilise overhead costs,
- focus on core business and develop competitive advantages by concentrating the organisation’s resources and investment on what they do best and outsourcing all other activities for which the company has neither a strategic need nor a special capability, allowing them to maximize the return on their internal resources,
- get a more defined process in the company,
- achieve tighter control,
- maintain and develop core competencies as a way of providing barriers to protect against present and future competitors,
- increase flexibility, e.g. business affected by seasonal fluctuations,
- spread the risk (if there are options),
- gain additional capacity; make full use of external capabilities. Achieve an optimal use of knowledge, equipment and experience, and

- create the belief that a competitive environment will stimulate the wish to develop the activities and drive the development.

Though there are many good reasons to outsource, there is growing evidence that outsourcing does not decrease cost as expected; sometimes outsourcing can even cause cost increase. Some disadvantages are listed below (Campbell, 1995; Kakabadse and Kakabadse, 2000):

- increased dependency of vendors,
- a new relationship has to be built up as well as a preparedness for managing relationships that go wrong,
- risk of communication and organisation problems,
- risk of leakage of confidential information,
- loss of critical skills or developing the wrong skills or losing control over critical functions,
- lowering the moral of permanent employed employees,
- loss of cross-functional communication,
- loss of control over a supplier, and
- short term contracts, based on the lowest winning bid, stifle incentives to innovation.

The outsourcing organisation should also be aware of the need for building up a purchasing and administrating organisation in order to avoid dissatisfaction with the contract that can lead to (Kakabadse and Kakabadse, 2000):

- underestimation of the time and skills needed for the management of the outsourcing contract,
- unrealistic expectations,
- lack of ownership of services,
- uncooperative vendor behaviour, and
- cost of the services being too high.

Poor outsourcing decisions are direct results of an inadequate definition of customer requirements. McCarthy (2007) describes the outsourcing evolution in three generations:

- the first generation is defined as rigid service level agreements and hands-off relationships,
- the second moves from cost-cutting to improving effectiveness, and
- the third is partnership, i.e. proactive outsourcing.

Still outsourcing can be considered as a healthy business, companies with closer relationships can achieve up to a 10 % advantage in service levels, most benefits have come from reducing material costs (McCarthy, 2007) but successful outsourcing often means a long term partnership which creates value for both parties (Pietilä, 2007).

1.2 Outsourcing maintenance at Banverket

The Swedish Railway Administration (Banverket) started to outsource operation and maintenance contracts in July 2001. By the end of 2006 75 % of Banverket's total budget is procured and 24 contracts have been put out to competition. According to Banverket's review of 18 contracts the outsourcing has been successful, see Table 1 (Redtzer, 2006). Table 1 shows an improvement in those areas that have been measured in order to reach the objectives. In general the in-house contractor has improved more, in all areas except for increasing the amount of preventive maintenance. External contractors have been more cost-effective and managed to create a more proactive maintenance strategy by increasing the volume of preventive maintenance and decreasing the amount of corrective maintenance. They have also managed to decrease mean time to repair. From these results Banverket draws the conclusion that outsourcing in competition will continue as planned.

Table 1. Result from Banverket's review of 18 contracts adapted from Redtzer (2006).

	external (7)			in-house (11)			total (18)		
	better	un-changed	worse	better	un-changed	worse	better	un-changed	worse
Decrease Train delays	1	2	4	6	1	4	7	3	8
Decrease failures	2	1	4	6	3	2	8	4	6
Decrease Corrective inspection remarks	3	1	3	8	2	1	11	3	4
Increase Q-factor	2	0	5	3	5	2	3	5	7
Increase Mean Time To Repair	3	1	3	8	0	3	11	1	6
Increase appearance time	7	0	0	8	1	2	15	1	2
Increase safety	0	3	4	0	10	1	0	13	5
Decrease cost	6	0	1	7	2	2	13	2	3
Increase amount preventive maintenance	4	2	1	2	3	6	6	5	7
Total	28	10	25	48	27	23	74	37	48

Although the figures in Table 1 show an improvement, the figures showing the decrease in train delay and failure are rather small, less than 5 %. A more proactive maintenance strategy should have given better results for train delays and Q-factor (track comfort quality measure), but both are unchanged or have become worse. The total amount of failures increased during 2006. One explanation is increased traffic volume which will affect the degradation of the railway system; while another is a new reporting code that came into use, namely "failure disappeared", representing 6 % of total failures.

Other explanations that can affect the outcome in the review are the duration of the contracts and the scope and the standard of the assets. In this case the external contractors have larger amounts of low standard lines where the degradation might cause more failures. Comparing different durations might also affect the outcome, e.g. special conditions affecting train delays, such as floods, storms, derailments leading to increased delays. However, such conditions might also lead to unchanged or even decreased delays, though traffic has to be closed down while removing, for instance, trees from the track. Closed down traffic is not considered as train delays.

2. General Guidelines for Outsourcing Maintenance

If the company is ready for outsourcing and has decided to outsource, there are still some steps to be considered in order to reach a successful outsourcing. Maintenance is a process carried out in order to keep up the performance. As the production and the asset grow more complex and complicated, the issue of maintaining the process gets more difficult. One basic condition before outsourcing maintenance is that there is a basic knowledge about standards, definitions, tools and methods. Some basic requirements for outsourcing maintenance are therefore listed, based on literature research and experience from different case studies within Banverket. The basic requirements consist of nine steps and end up with a reflection mantra, which should be used during the contract's duration.

<u>Step 1. Form the Objective</u>

The organisation needs to determine the scope of its internal activities with reference to its objectives, and correlate them to the overall business objectives (Pietilä, 2007; Tsang, 2002). The objectives should be realistic, a system or component that is worn cannot be returned to its original standard with maintenance, The objective should therefore take into account the actual condition of the system, its reliability, availability, maintainability and safety; that could be measured in the amount of failure, downtime, delays, mean time between failure and so on. Important questions are therefore:

- where are the improvement areas and how are they going to be reached by outsourcing,
- what is the development status for the outsourced activities, and
- is it important in a strategic sense to achieve and sustain long-term competitive advantages in the market place?

<u>Step 2. What to outsource?</u>

Those activities that offer the best potential for outsourcing are usually so called routines, well delineated, that could be measured and managed at arm's length contract (i.e. executive contracts) and are readily provided by established suppliers (Campbell, 1995; McIvor 2000). A maintenance activity of that kind is predetermined maintenance. Predetermined maintenance is done periodically, time based, kilometre or tonnage based. It is often well described in terms such as lubricate, adjust, replace, clean. Another example is periodically well defined inspection activities conducted in a condition based maintenance to determine the condition, and gather information for the future maintenance planning.

Before outsourcing it must be known that access to skilled personnel is more important than finance and technology (McCarthy, 2007). Core activities should stay in-house. Core activities and core competencies are traditionally performed in-house: those critical to business performance, those that create current or potential competitive advantages, activities that will drive further growth, innovation or rejuvenation, or those activities that offer long-term competitive advantage (McCarthy, 2007; Levery 2002).

McCarthy (2007) suggests that a good place to start is to map the skills according to training time and frequency of used skills. Figure 1 makes it clear which are core to the business and which are peripheral. Core activities are those activities critical to business performance that create current or potential competitive advantages, i.e. activities that will drive further growth, innovation or rejuvenation, or those activities that offer long-term competitiveness (Kakabadse and Kakabadse, 2000).

	Frequency of skill used	
	Frequent	Infrequent
Short **Training time required**	Rapid return on investment in training	Periodic refresher/ Single point lesson
Long	Job Requirement for new hires	Potential outsourcing/ subcontracting

Figure 1. Determine core personnel (McCarty, 2006).

Step 3. Determine how to measure

One main objective for the maintenance is to create additional value for the whole business process. This can be measured in higher quality, dependability, availability and reliability and compared to an acceptable cost level. One main object is therefore to be able to deliver the requested function. Value decreasing events are functional failures; however there should always be preparedness for eventual future failures that will come with increasing use and age.

Both client and supplier must clearly understand how the system/component will perform and what will be the system/component condition. Levery (2002) has listed a number of actions to be conducted:

- Identify the system/component condition parameters to be used and apply them to (a) the current situation; and (b) the expected condition on contract completion.
- Establish the system/component operational performance criteria such as outputs, volumes and availability in order to determine the Key Performance Indicator (KPI) that will be applied to the contract.
- Establish KPIs to ensure that they truly reflect system/component performance, and incorporate service measures such as response times if required.
- Reduce the numbers of KPIs in use and focus on core operational performance criteria – too many KPIs cause the focus on system/component performance to be lost.

Typical measures to valuate maintenance effectiveness are (Mishra *et al*., 1998):
- Maintenance rework.
- Reactive maintenance index.
- Plant replacement index.
- Inventory turns.
- Spare versus plant replacement.
- Maintenance asset turnover.

Step 4. Make a plan of how to achieve the objectives

The plan should include the whole outsourcing process, including the purchasing process and the termination process. All activities should be planned in time; responsibilities and authorities should be pinpointed as well as supporting organisations and systems. There is also a need for analysing risk assessment (Farell, 2007).

Step 5. Form an organisation responsible for the outsourcing

To achieve the targets relating to outsourcing of non-core maintenance work, the company may have to develop capabilities in the areas of contract negotiation, contract management and the ability to capitalise on emerging opportunities from changing technology and the changing competitive environment in the maintenance field (Campbell, 1995; Tsang *et al.*, 1999). Though maintenance is a process, a contract is a project. It is therefore important to appoint a project leader and a supporting organisation with purchasing skills, which is responsible for conducting the project in a successful way.

On a regular basis there will be meetings with the contractor in order to discuss the current situation in the contract, note deviation, and discuss innovations or unclear points within the contract. Openness and honest communication are a prerequisite (Levery, 2002). One important task is to make sure that the contractor has understood her/his undertakings. A check must be done before the contract starts, but also a number of checks during the contract's duration.

Step 6. How to put together the tender, and choosing the right contract

The basic input to a tender is necessary to:

- determine the scope and amount,
- describe it in a way so it can be calculated,
- decide if the client or the contractor should own the risk and responsibility,
- decide the forms compensations should take (lump sum, target price, incentives),
- decide the objectives and how to evaluate and measure them, and
- appoint the current status and where it should be when the contract ends.

Depending on the scope there are different ways of forming a contract. According to Levery (2002) a contract:

- has a non adversarial form,
- contains risk and reward, i.e. uses gainshare/painshare to a relevant degree of risk,
- adopts an actual cost-with-fee approach coupled with an annual target to ensure that incentives are applied,
- declares profits; the suppliers' profits should have a reasonable return. A traditional contract where the supplier's profit is not visible often raises suspicions on the client's side that the supplier will compromise performance to maximise profit.

The type of contract that should be chosen depends on the need for control and the need for flexibility, see Figure 2 (Kakabadse and Kakabadse, 2000). Where the need for control is low and the need for flexibility is high, use a short-term contract or a formal contract where the client takes all the risk and responsibility. When the need for flexibility is low, control need is high, so choose a full ownership contract, where the contractor takes all the risk and responsibility. In between, partial ownership or joint development should be used.

Short-term (executive) contracts are often used for routine maintenance tasks that are easy to describe and calculate, e.g. predetermined maintenance, describing maintenance action such as lubrication, adjustment, exchange of components every third month, where the quality of conducted maintenance is easy to check. According to Sundin (2003), the advantages are that the client steers the amount of work and resources and they are easy to procure. The disadvantages are:

- the client must control,
- the client must co-ordinate with other parallel ongoing projects,
- no incentives.

	Need for control	Need for flexibility
Short term (formal) contract	LOW	HIGH
	Partner ownership or joint development	
Full ownership contract	HIGH	LOW

Figure 2. Configurationally arrangements, adapted from (Kakabadse and Kakabadse, 2000).

Total commitment contracts, performance contracts or turnkey projects are usually used when the client moves the risk and responsibility to the contractor. This is often done in order to encourage the contractor to be more innovative, to develop new methods and be more effective. These contracts are usually difficult to describe in detail, also different aspects may affect the performance, i.e. health, safety and environmental demands, which makes it difficult to calculate both the risk and cost. The advantages (Sundin, 2003) are:

+ the client does not need a big organisation to follow up, during the duration time,
+ they can be combined with incentives for innovations or increased performance, and
+ less risk for additional orders.

While the disadvantages are:

- risk of a monopoly situation,
- difficulty of describing the performance so it can be calculated and measured, and
- low flexibility during the duration time.

Step 7. Choose forms for cooperation

There is a need to move from an arm's length business relationship towards a long-term collaborative strategic partnership when complexity increases in a contract (Martin 1997; Olsson and Espling, 2004). These long-term collaborative strategic partnerships demand a new behaviour and call for openness and trust, and are often named partnering or alliance contracts.

Partnering gives improved quality, reduces claims and litigation, reduces costs up to 30 %, and follows the time schedule (Olsson and Espling, 2004). Alliance is a long-term partnership built on trust and information exchange and the utilisation of limited competitive pressure on the supplier. An overview of strategy alliance contracts shows that objectives are obtained, technology is improved, access to specific markets is gained, there is a reduction in financial risk, political risk, and competitive advantage is achieved or ensured (Elmuti and Kathawala, 2001). Both partnering and alliance contracts allow the supplier to make a profit, and encourage him to continuously improve the system/component.

Step 8. Is there a supplier market?

Make sure there is a supplier market. Can you buy what you are going to outsource, do you need to prequalify the supplier and how easy or difficult will it be to replace the contractor, if necessary? The supplier will only survive if there are possibilities to gain profit. A study by Martin (1997) shows that a contractor offers services because it is his primary source of income. If new opportunities arise, e.g. taking over parts of the client's business risks and other (financial) burdens he will be able to sell added value. In this way the contractor can diversify his "product" range and be able to achieve a higher profit. Tsang (2002) states that, if there is a lack of long-term commitment from the client, the supplier makes minimal investment in staff development, plant, equipment and new technologies.

Step 9. Forms for ending the contract

Ensure that the contract is completed to an acceptable standard, according to what was planned before outsourcing (Farrell, 2007).

Learn the reflecting mantra

Through the outsourcing process, it is useful to follow a systematic approach (Campbell, 1995):

1) Does outsourcing make sense?
2) Are your objectives achievable?
3) Is the organization ready?
4) What are the outsourcing alternatives?
5) How is the request for outsourcing proposals structured?
6) What are the negotiating tactics?

These questions should be answered on a regular basis during the whole outsourcing process.

3. Maintenance Outsourcing at Banverket

A reorganisation in 1998 divided Banverket into a client – contractor organisation. In order to increase effectiveness and efficiency, Banverket began to open its production operations to competition in July 2001, at first only for new and rebuilding contracts but from 2002 also for maintenance contracts. Banverket's aim in outsourcing (Redtzer, 2001, Redtzer, 2006) was to:

- Improve the efficiency of its operations.
- Increase the speed of effectiveness/efficiency for both the client and the contractors.
- Get more "railway" for the money.
- Be able to procure maintenance beside re- and new investment and consultancy.
- Follow a belief that maintenance activities put out to competition is one way of achieving the objectives.
- Build up a supplier market that did not previously exist. The goal was to create a market with a few bigger contractors using local small companies as subcontractors.

The objectives were that all the contracts should be out for competition until 2006. The first contracts were on low traffic intensive lines with a low technical complexity in order to keep the consequences of a failure low, by the end of 2006 24 projects have been out in competition.

3.1 Basic conditions within the Swedish Railway Sector

The overall goal is to provide a system of transport for citizens and the business sector all over the country that is both economically effective and sustainable in the long term. Six sub-goals support the overall goal:

1. an accessible transport system,
2. a high standard of transport quality,
3. safe traffic,
4. a good environment,
5. positive regional development, and
6. a transport system offering equal opportunities.

A yearly governmental approval letter has been used to measure whether the maintenance activities are in line with the overall goal. Åhrén and Kumar (2004) identified eight maintenance performance indicators in the government approval document to be used as indicators on the maintenance activities. The eight matching maintenance performance indicators are supporting the sub-goal "a high level of transport quality" and reflecting the performance of the maintenance process in terms of costs, delays and track integrity. These are total numbers of functional disruptions, total numbers of corrective inspection remarks, hours of train delays caused by infrastructure failure, number of train delays caused by infrastructure failure, Q-factor (degree of track standard), amount of speed restriction and maintenance cost per kilometre.

The maintenance strategy chosen to reach the objectives is a mix of condition based, predetermined and corrective maintenance with the focus on having as much condition based maintenance as possible without jeopardizing the safety. The terminology in use is the Standard SS-EN 50126, SS-EN 13306 and SS441 05 05. Banverket has also used these maintenance definitions for the purchasing templates and in the accounting system.

Banverket's annual reports between 1999-2006 show that Banverket is facing the fact that they have a large amount of corrective maintenance, see Figure 3, causing many functional failures, which leads to train delays, health and safety problems and taking resources and time from the preventive maintenance, the value adding part of the maintenance.

The railway assets are rather complex and need different technical skilled personnel, the maintenance has therefore been divided into technical branches, i.e. track, electrical asset, signalling and telecom, instead of performance-wise. Signalling engineers are considered as core competence, though it takes up to five years internal education to be certificated.

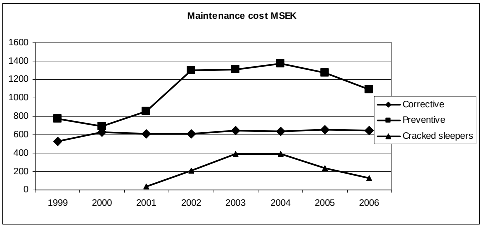


Figure 3. Amount of preventive and corrective maintenance 1999-2006. The increase in preventive maintenance is correlated to the special event of exchanging ill-manufactured sleepers that were put on track in the 1990s.

3.2 The outsourcing approach

In order to create and support the build up of a new supplier market Banverket decided to use big contracts and outsource even so called core activities (e.g. maintenance on signalling assets) (Redtzer, 2001).

At first the contract duration was one to maximum three years with the option to prolong the contract if the outcome was good. The first maintenance contracts were put out as in-house contracts with the in-house contractor and just the basic must-be-done activities such as:

- snow removal,
- corrective maintenance,
- predetermined maintenance and
- the condition inspection part from the condition based maintenance.

The maintenance needed to be done, due to decreasing condition, but was not prioritised to be of a corrective nature according to the inspection remarks. It was either bought as an extra order within the contract, or as a separate contract. Corrective maintenance is often bought for emergency situations. In some cases the client pays a lump sum, while in others he only requests the right competencies to be available when needed. Also, concerning the client's contract with the traffic operator, the contractor has to be in place and start the repair within different specified time limits depending on what lines they are serving.

Special templates for contracts named FU2000 were formulated and the procurement documents were built up according to a special structure.

The contracts were a mix between performance contracts and execution projects, since the internal regulation and the contractor's skills made it difficult to move the responsibility for the performance from the client to the contractor. The recommendation was to use a fixed price (lump sum) in order to encourage the contractor to develop and improve as well as making the follow-up administration easier.

Figure 4 shows the different ways to handle the responsibilities and the risk. In the general contracts the client takes all the risk and responsibilities, while in more complex projects, such as total commitment contracts, all the risk and responsibility is given to the contractor.

	Client	Contractor
General contract, executive contracts	Risk and responsibility	
Total commitment, Performance or Turnkey Contracts		Risk and responsibility

Figure 4. Risk and responsibility in contracts.

The way the contractor is compensated also affects the outcome of the contract. There are different economical classifications in use within Banverket. Maintenance activities might be bought as:

- Fixed price or lump sum contracts: Usually lump sum is used for jobs that are easy to describe and calculate. Lump sum can be used for the whole contract, for parts (e.g. predetermined maintenance, emergency situations) or a period (within the duration).
- Unit price contracts: If the client is unsure of the amount, then it could be a price bill of quality where the client specifies the amount, the contractor puts a price per unit and the payment is related to the actual executed amount.
- Cost reimbursable contracts, i.e. target price with incentive: Target price combined with incentives where the client and the contractor share the win/loss. Target price with incentives is often used when it is difficult to specify and calculate the job, and where there is a need for flexibility.
- Mixed contract types.
- Actual cost, where the client pays the actual cost and the contractor's fee.

Banverket use special templates to evaluate the bid where price is weighted towards other criteria such as earlier experience, asset knowledge or environmental demands.

Different cooperation forms have been tested – arm's length, partnering and formal cooperation in a maintenance contract.

3.3 Objectives in the maintenance contract

The most important and commonly used objective is to increase punctuality for trains, i.e. avoid train delays. A train earns delay minutes if it is five minutes late between two adjacent places along its route (Nyström, 2005). Train delays are measured in hours and the stakeholders' demand is that Banverket should decrease the train delays by a certain percent every year, usually 5 % based on the mean value for train delays for the past three years. In the earlier contracts all the train delays caused by the infrastructure were included, but in the later contracts some causes for the train delays have been excluded if they are considered to be beyond what the contractor is able to have any influence over. Typical failures are failure due to the distribution of power from external power suppliers, animals on the track, abnormal floods, inspection of track after wheel flats or road conditions caused by weather. Demands on increased punctuality are then translated into maintenance objectives such as availability on the railway infrastructure, i.e. keeping the amount of performance failure to a low level.

Objectives for increasing reliability are to decrease the amount of failure reports and inspection remarks classified to be done immediately, i.e. decrease the amount of corrective maintenance. In the latter years one new objective has been introduced: to increase the preventive maintenance by decreasing the corrective, measured in cost; and by doing this more money and time will be transferred to the value adding maintenance process to create a positive spiral (Espling and Olsson, 2004).

Objectives for the track comfort quality (Q-factor) are to increase or preserve the standard. The Q-factor is measured by special inspection vehicles 1-6 times a year in order to ensure safe traffic. Soft objectives are common in partnering contracts and measure the cooperation and the relationship between client and contractor.

Bonuses and penalties are used to regulate the actual outcome of the performance. A bonus is used as an incentive and ensures gains for the contractor if he succeeds in reaching the objectives. Other contracts also include the possibility of a bonus if the contractor can fulfil the demands. Penalties are often connected with other demands in the contract if the contractor does not succeed in reaching them, such as:

- Failure reports should be reported back to the system.
- Inspection remarks should be reported back to the system.
- In time for repair, i.e. the time from when the contactor has been notified about a failure until the contractor is in the place for starting the repair.
- Mean time to repair failures should not exceed prescribed time limits.
- Inspection remarks should be attended according to prescribed time limits.

- Planned maintenance activities on the track should not be exceeded.
- Maintenance activities on the track should not cause train delays.
- All personnel working on the track shall have been informed about traffic and electrical safety demands.

4. Case Study

The case study covers maintenance contracts from 2000 to 2006. Six contracts have been studied in more detail, concerning scope, contract and procurement documents, objectives and steering documents. They have been chosen though the researcher has had the opportunity to participate in assignments during the purchasing phase or the following up phase. Data from Banverket's system for train delays, failure reports, inspection remarks and the track quality system have been analysed besides the assignments. Three of these contracts have been studied both by Banverket and in this paper, see Table 2 contract C, D and E.

An analysis of the economical result has been excluded in this study, though a benchmarking containing nine in-house contracts showed the difficulties in following up the costs (Espling and Kumar, 2007; Espling, 2004). Some clients did not report back according to the accounting structure, there were difficulties in deducing the cost from the original maintenance contract, other maintenance activities were bought outside the contract or buying the contract on a lump sum resulted in returning the economical results to the accounting system in a very rough presentation of costs.

The first contracts in 1998 were so called total commitment contracts, i.e. all risk and responsibilities were moved to the in-house contractor in contracts with one-year duration. The result became an adverse situation and conflicts arose between the client and the in-house contractor. This resulted in an increasing cost situation, which was not acceptable either for the client or for the in-house contractor knowing that he had to strive to be left in the game (Espling and Olsson, 2004). The adverse situation forced both the client and contractor to think along new lines and so called objective driven, executed contracts, with target prices and incentives, were introduced. In order to create a more friendly cooperation situation, partnering was introduced in one of the contracts, see A in Table 2, Espling and Olsson (2004) and Kemi (2001). A common partnering objective, target prices with incentives and partnering rapidly resulted in positive trends (+ 11-19 %) for all the five objectives and a positive spiral for a more proactive maintenance strategy was triggered. The soft objective "better relations between client and contractor" was improved.

The adverse situation culminated in contract B in Table 2 where the focus became to create failure repair heroes, though the client's aim in meeting the TOCs demand on high track availability put the focus on the importance of delivering the services of fixing the failures in the shortest possible time. This resulted in increased costs for corrective maintenance and less money over for preventive maintenance. The next contract was therefore formulated as a minimal service contract C in order to get control back to the client. The service thinking resulted in several deviations from the FU2000 templates.

Instead of having clear definitions for predetermined maintenance, condition based maintenance and inspection, the maintenance activities were mixed together and called service. During the tender phase the client came up with some new innovations such as reporting when maintenance had been conducted according to the client's plan by SMS (Short Message Service to/from mobile telephones**)**, another was to use a new concept for spare part support and logistics (Banverket, 2005).
Contract D with an external contractor is a partnering contract, with objectives, target price and incentives using bonus/penalty as steering tools. In this contract the asset status on the lines is reaching the end of its technical life length and might influence the possibility to keep the amount of corrective maintenance on a steady level. An analysis in August 2007 showed that the train delays decreased by 2 %, the inspection remarks decreased by 22 % while the failures increased by 8 %, but the Q-factor showed a negative trend. The amount of preventive maintenance has increased though. According to the client the incentive for reaching the partnering objectives has reduced the cost by 2-4 %. Adjustment of incentives is done in May and December in order to move money to the next year. The external contractor has been very eager to establish an open and cooperating atmosphere, with the contractor's CEO engagement. Top management has been visiting one of the monthly contract meetings. Unfortunately the contractor has had difficultly getting access to BV systems and has therefore developed their own failure report system. It has also been difficult to get A-class maintenance vehicles from the Swedish Vehicle pool. Since coming to the Swedish market they have employed 80% of the in-house contractor employees and taken on 20 % of new ones.

Contract E is a one of the first Performance Contracts, with lump sum**.** The internal contractor experienced the contract as positive in terms of increased production economy, better internal working relations and better relations with the client. The creativeness and improvement work has increased and the contractor's personnel experience is greater working pleasure and motivation. The contractor focuses on preventive maintenance. A questionnaire sent out to the client's personnel shows that the lump sum is good while it decreases administration time, but makes it difficult to follow up on a detailed level. There are both hard and soft objectives, but the soft has not been followed up. The main objective is to reach high availability, i.e. create an atmosphere for high punctuality. The client feels that the performance contract is aligned with the overall business strategy and objective, and finds the contract easy to follow up and at the same time they feel that they can affect the outcome of the objectives. The client uses penalty and bonus as tools to reach the objectives. According to the client, a penalty gives a positive outcome. Top management for the track area is engaged. The cooperating climate feels open and trust giving, there is also a good information exchange. The disadvantages are the client losing control over the asset condition and becoming dependent on the information from the inspection and failure system. It is also difficult to determine the right price and right degradation patterns, together with the difficulties of measuring the development during the duration time and measuring innovation.

Contract F is a performance contract, see Table 2. The performance demands are to decrease train delays where certain types of train delays are excluded, such as when the contractor cannot affect them. Failure should decrease by 5 percent – some assets are excluded - and the track Q-factor should remain on the same level or increase. The result of comparing a time period two years before the contract with two years of the contract is that the train delays have decreased by 4 %, failures have increased by 1 % and the Q-factor has decreased by 6 %. During this time-period the inspection remarks in total have decreased by 41 %.

These six contracts are summed up in Table 2, where X stands for included or used in the contract, “+” is a positive result, “=” no change and “-” is a negative result.

The trend is that Banverket is moving towards long-duration, objective-driven, lump sum and performance contracts, including almost all maintenance. The number of objectives decreases while demands increase. There are no special demands for an emergency situation in performance contracts since this is up to the contractor to manage within the contract. Lump sum and performance contracts make it difficult for the client to identify cost-driving systems and cost-drivers, there is a risk that the client will lose the cost control. The objectives are rather on an operational level on a yearly base. The aim is to decrease train delays and the amount of failures and keep or increase the track Q-factor. The result from the case study matches the results from Banverket’s own study and shows a trend for increased punctuality and a small decrease in failures.

There are no objectives for innovation and development, but two of the contracts have resulted in innovations. In the first, the client wanted to get back the control and introduced new techniques for getting a receipt for conducted maintenance activities and in the second the external contractor did not get access to Banverket’s system and therefore invented new ways of handling data.

The client uses a pain/gain system to make the contractor steer towards the objectives. There will be a bonus if the contractor achieves the hard objectives, i.e. equipment objectives (increased availability and reliability) and there will be penalties if the contractor fails to fulfil the performance drivers.

During the last three years, there has been a drastic decrease of inspection remarks. This depends on a change in the regulation. The inspection for maintenance needs is no longer regulated internally and therefore not included in the contracts. The amount of safety inspection remarks has also decreased and it has been suggested that this is because the contractor maintains the assets before the inspection, in the performance contracts. In some cases there is also a decreased quality in the reports, i.e. instead of describing the remarks in terms that make it possible to determine what might have caused the defect and what action should be taken; the remarks are shortened to “defect on asset on section X”.

The negative trends for failure and track Q-factor can be explained by the increase in traffic that has increased the degradation grade and in some cases, led to a lowered standard. Because of the competitive situation amongst the traffic companies, it is difficult to get accurate figures for how much freight or passenger traffic is running on the track.

Table 2. Different maintenance contracts, D is a contract with an external contractor. X=included or used + = improvement, - = decreased.

	Contract	A	B	C	D	E	F
Time	Duration (years)	1	2	3	3	3	4
	Option (years)			2	1	1	2
	Time period	2000	2002-2004	2004-2007	2004-2007	2004-2007	2005-2009
Scope	Snow removal	X		X	X	X	X
	Snow organisation	X		X	X	X	X
	Predetermined maintenance	X	X	X	X	X	X
	Inspection condition	X	X	X	X	X	X
	Condition based maintenance				X	X	X
	Corrective maintenance	X	X	X	X	X	X
	Emergency organisation		X		X		
Contract type	Executive	X			X		
	Total commitment		X		X		
	Performance			X		X	X
Forms of Co-operation	Partnering	X			X		
Payment	Fixed price/Lump Sum		X	X		X	X
	Target price	X		X	X		
	Incentives	X			X		
Penalty	Failure report, not in time	X/+			X	X	X
	Inspection report, not in time				X	X	X
	Too late conduction of inspection remarks				X	X	X
	Train delays caused by maintenance				X	X	X
	Too late arrival to repair place			X/+	X		X
	Exceeding planned time				X		X
	Lack of safety information to personnel			X/=	X/-		X
	Repair time within time limit			X/-	-		
Bonus	Bonus for reaching objectives				X		X
	Bonus for fulfilling demands			X	X		
Objectives	Decrease train delays	X/+	X/+	X/+	X/=	X/+	X/+
	Decrease nr of failure reports	X/+	-	X/+	X/-	X/+	X/-
	Increase Q-factor	X/+	-	-	-	X/-	X/-
	Decrease inspection remarks	X/+	-	+	+	+	+
	Decrease cost	X+	-	+	X/+		
	Increase amount of preventive maintenance			-	+		
	Soft objectives	X/+		X/+	+	X/?	
Comment	The contract has resulted in innovations			+	+		

5. Gap Analysis

Basic requirements for outsourcing have been suggested in chapter 2. The reasons and the steps for outsourcing are described in general terms. In Table 3 there is an attempt to compare the basic requirements with the outcome from the contracts and identify the gaps, i.e. deviation between theory and practice.

Table 3. Gap analysis, basic requirements versus case study, “±” no change, “√” fulfilled, “-”.

Basic requirements (theory)	Case study (practice)
1. Form the objectives - strategic	
± Correlate realistic objectives to the overall business objectives √ Find improvement areas and how they are going to be achieved by outsourcing ± The development for the outsourced activities – Sustain long-term competitive advantages – What is the actual condition of the system	The performance indicators from the governmental approval document have been used as objectives, as well as to decrease cost. The improvement area has been to improve the efficiency of its operations and increase the speed of effectiveness/efficiency for both the client and the contractors. However, no measures for this have been established. Another improvement area has been to build up a supplier market and create a market with bigger contracts (Espling, 2004, Espling and Åhrén 2007). The objectives are general, but they are measured in a short-sighted perspective.
2. What to outsource?	
√ Routine, well defined activities √ Predetermined maintenance √ Non-core skill – Core activities should stay in-house	In order to create and support the building up of a new supplier market, Banverket decided to use big contracts and outsource even so called core activities (e.g. maintenance on signalling assets). One reason was to increase the possibilities for the contactor to make a profit in order to be able to survive.
3. How to measure?	
– A clear understanding of how the system will perform √ Identify the system condition parameter for the current situation and the expected √ Establish the system’s operational performance criteria – Establish KPI that reflect the system’s performance <u>Measures for</u>: – Maintenance rework √ Reactive maintenance index – Plant replacement index – Inventory turns – Spare versus plant replacement – Maintenance asset turnover	Measures of the railway system’s performance are: • total numbers of corrective inspection remarks, • hours of train delays caused by infrastructure failure, • number of train delays caused by infrastructure failure, • Q-factor (degree of track standard), • increase the preventive maintenance, • in time for repair, • failure and inspection reports should be reported back to the system The connection between these measures and the performance of the system needs to be enhanced. Measures for material (spare parts), maintenance cost e.g. per asset, asset replacement index are lacking or need to be enhanced.
4. Make a plan how to reach the objectives	
√ The plan should include the whole outsourcing process including the purchasing process and the termination process. All activities should be planned in time, responsibilities and authorities should be pinpointed as well as supporting organisation and system	Templates, purchasing organisation, project organisation, etc. are implemented and in use.
5. Form an organisation responsible for outsourcing	
√ Appoint a contract organization √ Regular meetings √ Check understanding of undertaking	Case studies, interviews, contract document show that this has been implemented, (Espling, 2004). The client has special units taking care of the procurement templates, regional units for contracting out and both regional and local units for conducting the maintenance contract.
6. How to put the tender and choosing contract	
√ Determine the scope and the amount √ Can it be calculated? √ Decide if the client or the contractor should own the risk and responsibility √ Decide the compensations forms (lump sum, target price, incentives) √ Decide the objectives and how to evaluate and	Case studies, interviews, contract document show that this has been implemented. One improvement area is to appoint the current status and the status when the contracts end, this starting status is not mentioned in the contract. Different cooperation forms have been tested. In order to increase cooperation, partnering has been introduced. Risk

measure – Appoint the current status and where it should be when the contract ends √ A non adversarial form, √ Contain risk and reward: i.e. use gainshare/painshare √ Adopt an actual cost-with-fee approach, couple this with an annual target assuring that incentives are applied √ Declare profits	and reward gainshare/painshare is included in the contracts.
7. Chose forms for cooperation	
√ Use cooperation forms as partnering or alliance in complex project	The partnering concept has been used in complex projects, but is not used in the performance contracts.
8. Supplier market	
– Does the supplier market exist?	Did not exist in 2001. But with help of the client a new supplier has been able to enter the market.
9. Forms for terminating the contract	
√ Termination Inspection	Implemented within the procurement/contracting templates.
10. Learn the reflecting mantra	
√ Does outsourcing make sense? √ Are your objectives achievable? √ Is the organization ready? – What are the outsourcing alternatives? √ How is the request for outsourcing proposal structured? √ What are the negotiating tactics?	Is conducted on a regular basis both on a C.E.O. level by special conference and during the procurement phase, while starting new contracts. Though the outsourcing model is regarded as "successful", the question about alternatives for outsourcing has not been raised.

Banverket is very skilled in purchasing, choosing contract forms and forming plans for how to reach the objectives. It also has a clear view of how to organise and how to delegate the responsibilities.

The gap analysis shows improvement or risk areas in:

- Establishing objectives, more strategically, long-term contracts.
- What to outsource. Outsourcing core activities and skills should not be done according to theory.
- How to measure. When the objectives are established the measures will be defined.
- Lack of supplier market.

6. Discussion

Results from the case studies and the gap analysis show areas for improvement as well as risk for failures.

6.1 Decrease cost and increase innovation

Outsourcing is done to decrease cost, increase efficiency and effectiveness, increase production, increase innovation and development. The results from outsourcing maintenance in the municipalities in Sweden were cost reduction because the contractor cut down all unnecessary work, the quality and performance was the same or a little less while the innovation and development work slowed down, though there was a lack of incentives in the contracts in these areas (Mattisson, 2000). One reason for this result can be buying at the lowest price, i.e. buying the contractor who has calculated most badly and submitted the lowest bid. This has a risk: if the contractor ends up in a non-profitable contract then they may not focus on it, perhaps they have another one beside that they can earn more profit from (Levery, 2002; Mattisson, 2000). At Banverket, this has been avoided by weighting the price towards other criteria such as earlier experience and asset knowledge. However buying performance contracts on lump sum gives no incentive to be cost-effective during the duration of the contract, both client and contractor express the view that they are content with the cost level. There is a risk with lump sum performance contracts, according to Levery (2002), the supplier will generally treat a fixed price planned maintenance package as a potential loss leader, knowing that he will make his money on execution of repairs against a schedule of rates. The contractor does not see himself carrying the risk for asset performance as a result of work carried out. His objective is to maximise his return from his resources, and volume generation is the most effective way of securing improved profit. Another risk occurs if the client chooses the contractor with the lowest bid without checking the financial health of the contractor's organisation. In Banverket this is taken into account in both the prequalification and the procurement phase where the contractor has to declare his financial health.

When outsourcing to gain innovation, this is usually assumed to come automatically from the contractor (Mattisson, 2000). The client tends to forget that enhanced business improvement cannot be found in financial data alone. Quality, customer satisfaction and innovation are factors that reflect the growth perspective (Eccles, 1984) and every organisation needs a way to record and appraise its innovation performance (Drucker, 1984). It is therefore vital if the client expects innovations from the contactor that clear objectives and involvement are in place. Before something can be measured, it must be defined and there is an improvement area for measurement of innovation and growth, learning and change (Tsang *et al.*, 1999).

6.2 Defining the objectives

The objective for outsourcing is to provide higher value to the company's customers and impact on current business strategies. It is therefore vital to assess the organisation's capability to achieve these objectives (Campbell, 1995). The reason to outsource should be well defined as well as the functions that are suitable for outsourcing. Banverket outsourced in order to "get more railway for the money", increase efficiency and effectiveness; follow a belief that competition would help to reach the objectives and to build up a supplier market. The results can be seen in the different contracts. One lacking objective for Banverket, is to show how the situation was in 2001 and where to aim in five or ten years. Banverket's objectives in the contracts are on an operational level rather than on a strategic or tactical level, which can lead to short sighted thinking. The objectives should also correlate towards the different contracts, depending on the kind of contract form, scope and duration. Executive contracts perhaps are more suitable for operative objectives to reach effectiveness. In the case study, all the projects have the same main objective, to decrease train delays by a certain per cent each year and measured one year at a time. Every New Year the base line for the total amount of train delays is adjusted and the incoming year objective starts from that level. To get a long sighted more strategic objective, the objective for a five years' duration contract should be expressed as "train delay should decrease by 25 %". In order to get a tactical approach, it would be of interest to analyze which asset causes most train delays and express the objective in such terms as "train delays should decrease by 25 % for overhead wire in five years from now and by 20 % for the rest of the infrastructure assets".

The objective to decrease train delays is used in all contracts, even in contracts for low traffic lines that perhaps have a maximum of ten hours delay per year. If the contractor puts a lot of effort in achieving this objective, one might ask what the gain for the railway system is. On low traffic lines the objectives perhaps should be expressed as decreasing the degradation speed for, e.g. wooden sleepers.

From a psychological point of view it might also be better to express the objectives in a positive way, e.g. instead of decreased delays and failures, speak in terms of improved punctuality and increased reliability.

6.3 Measurements

The objectives should be measurable. Campbell (1995A) classifies common used performance indicators into three categories on the basis of their focus:

- Measures of equipment performance – e.g. availability, reliability, overall equipment effectiveness
- Measures of cost performance – e.g. O&M labour and material costs
- Measures of process performance – e.g. ratio of planned and unplanned work, schedule compliance.

Tsang *et al*. (1999) made an observation that companies which have equipment performance goals in place both lower maintenance costs and lower the proportion of reactive maintenance.

Results from the case study and analyses of data from the inspection remark system show that the quality of reporting the equipment performance tends to decrease due to the new regulation and the performance contracts.

Most of Banverket's measures could be classified as measures for equipment performance, while the demands and penalty clause are performance driven. It could be discussed whether it is suitable to have penalties for performance contracts. It might be a hindrance to the contractor thinking in new ways. According to Tsang *et al.* (1999), there is a need to link performance measures to rewards, instead of penalties as in the performance contracts.

To ensure that both the client and supplier are confident in the risk and reward process (Levery, 2002):

- Reward success absolutely. The supplier must show that he has reached the performance before being rewarded.

- Limit the pain share element of the potential supplier losses. If the losses start to eat into the supplier’s actual costs and overheads then they will no longer perform effectively but will instigate cost cutting measures which may affect asset performance.

Asset based performance contracts shift the focus of the contract from measuring the supplier’s service to measuring the asset performance. Inherently these contracts must be long-term for the supplier to have a stake in the long-term performance of the asset (Levery, 2002).

6.4 Risk

Since one of Banverket’s core activities is to maintain the asset value for the government, a risk evaluation should be performed before putting out the whole maintenance to competition, especially concerning those assets that are core and vital for safety, such as the signalling system. According to McIvor (2000), outsourcing strategic activities can be an attempt to spread risks in areas of technology, among the contractors.

The risk areas identified from the case studies and the gap analysis are:

Risk of losing control over:

- maintenance cost; while buying on lump sum contracts it is difficult to follow the maintenance cost elements, i.e. preventive or corrective maintenance cost per asset, cost drivers, i.e. corrective maintenance or maintenance methods resulting in high cost and low quality.
- asset condition. It is important that asset measuring data, i.e. inspection remarks, track quality, needed for analysing and judging the asset degradation are stipulated in the contract to be reported back, and with a high quality.
- safety demands concerning the contractor’s employees’ knowledge of track safety and asset knowledge.
- core competence and asset knowledge.

7. Conclusions

Banverket has a well-defined organisation and structure for acting as a purchaser of operation and maintenance contracts. The actual situation within Sweden before outsourcing was that of a small supplier market, more than 20% corrective maintenance calls for attention, also there are core skills and core functions that, according to the theory, should have been kept in-house. Still the outsourcing has given positive output such as that the in-house contractor has become more effective, and some new innovations have been developed and a small supplier market has been built up. In recent contracts some alarm bells are ringing. One example is for instance that the safety demands are not always being fulfilled. When buying lump sum performance contracts, it is important that the client develops objectives that are measurable and delivers back data in terms of cost drivers, asset performance drivers in order to keep control over the cost and the assets' equipment condition.

The proposed basic requirements for outsourcing can be used to point out improvement areas as well as areas for risk. One improvement area is to form strategic, sustainable long-term measurable objectives in line with the overall objectives. The measures should reflect equipment performance, cost performance and process performance.

Finally, the case study to some extent confirms that there has been some increased speed in effectiveness/efficiency for both the client and the contractors, the client has got "more railway for the money". The competition is a way of reaching the objectives, the supplier market for maintenance contracts has increased from the in-house contractor and one external, to three external contractors. The in-house contractor still has 60 % of the maintenance contracts.

References

Banverket (2005) Vitbok avseende basentreprenad, drift och underhåll, Borlänge banområde 2004-2007. Dnr A03-831/IN60 (only in Swedish).

Blanchard, B.S. (1997) An enhanced approach for implementing total productive maintenance in the manufacturing environment. Journal of Quality Engineering, Vol. 3, No. 2, pp 69-80.

Campbell, J.D. (1995) Outsourcing in maintenance management, a valid alternative to self-provision. *Journal of Quality Maintenance Engineering*, Vol. 1, No. 3, pp 18-24.

Campbell, J.D. (1995A) *Uptime: Strategies for Excellence in Maintenance Management.* Productivity Press, Portland, Oregon.USA.

Drucker, P.F. (1984) *The Information Executives Truly Need*, Harvard Business Review on Measuring Corporate Performance.

Eccles, R.G. (1984) *The Performance Measurement Manifesto.* Harvard Business Review on Measuring Corporate Performance.

Elmuti, D. and Kathawala, Y. (2001) An overview of strategic alliances. *Management Decision*, 39/3 pp 205-217.

Espling, U. (2004) *Benchmarking av basentreprenad år 2002 för drift och underhåll av Järnväg,* Forskningsrapport, Luleå, Järnvägstekniskt Centrum, Luleå tekniska Universitet, Luleå, Sverige, ISSN 1402 – 1528 (only in Swedish).

Espling, U. and Kumar, U. (2007) Benchmarking of the Maintenance for Railway Infrastructure. "*Maintenance Handbook* ", Chapter 23 Springer Publication.

Espling, U. and Olsson, U. (2004) Partnering in a Railway Infrastructure Maintenance Contract – A Case Study, Part II. *Journal of Quality in Maintenance Engineering,* Vol 10, No. 4, pp 248-253.

Farell, I. (2007) The effective management of Contract Maintenance, *Journal of Maintenance & Asset Management*, Vol. 22, No. 1, pp. 10-14.

Freytag, P.V. and Mikkelsen, O.S. (2007) Sourcing from outside – six managerial challenges. *Journal of Business & Industrial Marketing*, 22/3 (2007) pp 187-195.

Kakabadse, N. and Kakabadse, A. (2000) Critical review – Outsourcing: a paradigm shift. *Journal of Management Development*, Vol. 19, No. 8, pp 670-728.

Karlsson, V. (2005) An overall view of maintenance. *European Railway Review,* 11**,** 3, 11-17.

Kemi, L. (2001) *Funktionskrav och partnering för drift och underhåll av järnvägar,* Licentiate thesis. Luleå University of Technology, ISSN: 1402 – 1757; 2001:39 (only in Swedish).

Levery, M. (2002) Making maintenance contracts perform. *Engineering Management Journal*, April 2002, pp 76-82.

Liyanage, J.P. and Kumar, U. (2000) Measuring maintenance process performance using the Balance scorecard. *Conference proceedings of 15th European Maintenance Conference (Euromaintenance 2000),* Gothenburg, Sweden, March 7-9, pp.25-32.

Martin, H.H. (1997) Contracting out maintenance and a plan for future research. *Journal of Quality in Maintenance Engineering,* Vol. 3, No. 2, pp 81-90.

Mattisson, O. (2000) *Kommunala huvudmannastrategier för kostnadspress och utveckling: en studie av kommunal teknik.* Lund, Lund Business Press (only in Swedish).

McCarthy, D. (2006) What is the secret of successful outsourcing? *Journal of maintenance & asset management,* Vol 22, No. 1, pp 5-9.

McIvor, R. (2000) A Practical framework for understanding the outsourcing process. *Supply Chain Management, an International Journal,* Vol. 5, No. 1, pp 22-36.

Mishra, C., Dutta Roy, A., Alexander, T.C. and Tyagi, R.P. (1998) Benchmarking of maintenance practice for steel plants. *Tata Search* 1998, 167-172.

Nyström, B. (2005) *Punctuality and Railway Maintenance*. Licentiate thesis, Luleå Technology University, 2005:41.

Olsson, U., Espling. U. (2004) A framework for Partnering for Infrastructure Maintenance Part I. *Journal of Quality in Maintenance Engineering,* Vol. 10, No. 4. pp 234-247.

Pietilä, M. (2007) The story of Outsourcing. *Koncranes Magazine*, pp 18-21.

Redtzer, L. (2006) Upphandling av underhåll i konkurrens – en återblick. Semainarium ”Upphandla och arbeta i underhållskontrakt, 2006-11-29, Stockholm, PowerPoint presentation (only in Swedish).

Redtzer, L. (2001) Subjection of Banverket’s production operation to competition, Background material October 2001. *Banverket Track management report.*

Sundin, J. (2003) Procurement of Building contracts forms and tools used by the Swedish Railway Administration. *BV Internal document 20030401memo*.

Tsang, A.H.C. (2002). Strategic dimension of maintenance management. *Journal of Maintenance Management,* Vol. 8, No. 1, pp 7-39.

Tsang, A.H.C., Jardine, A.K.S. and Kolodny, H. (1999) “Measuring maintenance performance: a holistic approach”. *International Journal of Operation & Production Management*, Vol. 19, No. 7, pp 691-715.

Åhrén, T. and Kumar, U. (2004) Use of maintenance performance indicators; a case study at Banverket. *Conference proceedings of the 5th Asia – Pacific Industrial Engineering and Management System Conference (APIEMS 2004),* Gold Cost Australia, December 12-15.

PAPER VII

Development of a conceptual framework for managing maintenance strategy for a client/contractor organisation in a regulated environment

Espling U. (2007). Development of a conceptual framework for managing maintenance strategy for a client/contractor organisation in a regulated environment. Submitted for publication in a Journal.

Development of a conceptual framework for managing maintenance strategy for a client/contractor organisation in a regulated environment.

Ulla Espling, Luleå Railway Research Center, Division of Operation and Maintenance Engineering, Luleå University of Technology, Luleå, SWEDEN

Abstract

Maintenance process is an integral part of the business process ensuring delivery of expected performance from the engineering system involving many stakeholders. To achieve maintenance excellence, the maintenance managers need to have a basic understanding of the business goals and strategy and have the capability to set maintenance objectives at various hierarchical levels in the organization, namely; the strategic level, the tactical level and at the operational level. The trade-off criteria are quality, return on investment, secured health, safety and environment for minimal cost, minimal time and minimal risk. In a complex environment various factors need to be considered. Different parameters, such as; environmental demands, delivery times, product mix and product structure, supply chain, quality demands, production process required, equipment required, safety needs, skills of the workforce need be considered by the management. These are the factors that influence the desired goals. It is therefore, important that the manager identifies and focuses on those factors that are critical for the business outcome, and acts proactively.

In this paper a conceptual framework has been developed to provide the base for a future decision support tool. The framework is built up step wise. The first step is to identify the factors and group them by their affiliation/relationship to the maintenance process. In the second step answers to the following four questions have been searched; is it possible for the manager to manage and affect the factors, is it possible to affect the factors from a strategic, a tactical, or an operative perspective, what are the inter-relationship among these factors, and what are the failure and risk consequences concerning quality (Q), cost, return on investment (ROI), health (H), safety (S) or environment (E)? The first question helps the manager to focus on areas that can be affected. The second question is to lift the focus from the yearly budget allocation thinking to a more proactive resource allocation strategy, the third question is a reminder to the manager that s/he is not the only player on the playground, there are so many, and the fourth one what are the consequences, which are also used to motivate different decision to be taken. Applied to Banverket, the conceptual framework points out key factors, these are: formulation of strategic, tactical and operative objectives for the maintenance plan and the scope for the contract, the execution phase, the contract form and cooperation form, reducing corrective maintenance, implementing more proactive strategy and starting the continuous improvement process.

Key Words: Management, strategy, conceptual framework, multi-criteria, railway, client/contractor organisation.

1. Introduction

Maintenance, when correctly performed increases the value for the whole business process (Liyanage and Kumar, 2003). It is therefore vital that maintenance management becomes integrated with corporate strategy to ensure availability, quality, punctuality and competitive pricing. Improved management plays an important role in achieving cost service advantages (Riis *et al.*, 1997).

The continuous improvement loop implemented in maintenance is the key to enhancing maintenance effectiveness and cannot be executed or implemented in isolation. It is implemented in line with the organisation's planning, execution and feedback cycle; see Figure 1 (Stevens, 2001):

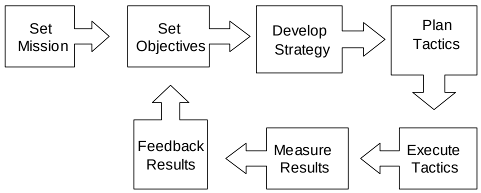


Figure 1. The maintenance continuous improvement process (Stevens, 2001).

Maintenance excellence is the balance of performance, risk and cost, achieving an optimal business solution. In order to reach maintenance excellence there must be basic capability in maintenance management and three types of objectives need to be formulated (Campbell, 2001):

- Strategic objectives telling where the course of the company's destination is set. It is also necessary to determine the human, financial and physical resource requirements.
- Tactical objectives, where a work management and material management system are needed to control the maintenance process and create a preventive and predictive maintenance program with possibilities to measure the performance.
- To create continuous improvement in the maintenance process and adapt best practice.

The trade-off in maintenance is directed to maximize quality, service and output from the maintenance process and at the same time minimize time, costs and risk. Management methodologies seek to balance these factors to deliver the best possible value (Picknell, 2001).

Managing an effective maintenance process in a complex environment is not an easy task. The maintenance management has to consider a large number of factors that have an influence on the outcome from the maintenance process. Different parameters such as; environmental demands, delivery times, product mix and product structure, supply chain, quality demands, production process required, equipment required, safety needs, skills of the workforce have be considered. All these are factors that influence declared goals, market share, economic results, productivity, quality, flow (delivery times, on-time), (Riis *et al.*, 1997). It is therefore important that the manager identifies and focuses on those factors that are critical for the business outcome, and acts proactively.

1.1 Infrastructure maintenance process within the railway

The railway transport system is both complex and regulated. The railway engineering system is divided into infrastructure and rolling stock. These two systems interact closely, but are managed by separate organizations. The infrastructure in Europe is usually owned by the government, while the rolling stock is either publicly or privately owned. For the infrastructure this means that the Infrastructure Manager (IM) has to take into account factors like political decisions and yearly funding. A railway law puts high safety demands on the system, and internal regulations have been put in place in order to meet the safety demands, but also to build a basis for the maintenance program and planning. Both the traffic companies and the infrastructure administration have complex organization. In Sweden it is common for both traffic companies and track owners to be client/contractor organizations. Information about asset condition, traffic operation and so on is collected into different Information, Communication, Technology (ICT) systems. This creates a complex environment where it can be difficult to find and focus on the key factors. All the factors must be considered while conducting the maintenance strategy reaching optimal life cycle cost (LCC) for the whole railway system, i.e. a holistic perspective has to be taken concerning their ability (Espling, 2004).

The current situation in Sweden shows up a high amount of corrective maintenance and an increasing number of failures and train delays. Therefore, it is necessary to describe this multi-criteria situation in order help the IM to steer the maintenance strategy towards a more proactive direction, both in a strategic, tactical and operative environment.

This study will look into the situation for the daily management of basic maintenance activities (renewal and modification excluded) for the local IM, who buys all maintenance from an in-house contractor or an external contractor. In order to create a decision tool, an approach for developing a conceptual framework is undertaken, by identifying and describing factors (can also be obstacles), affecting the chances of forming a more proactive management approach for maintenance, fulfilling overall business goals and objectives. The framework takes into account the factors' ability to be flexible and/or their potential to be used for changing a reactive management and starting a continuous improvement process.

2. Approach

While deciding about a particular methodology to be used, a literature survey over decision support system (DSS) was undertaken. The survey revealed that several methodologies for developing DSS exists, but there is a need for improve our understanding of various decision support systems (Nagarur and Kaewplang, 1999). In many ways, the era of decision support is only just beginning (Forgionne, 2002). There were procedures and steps for applying maintenance strategy, but no study could be found on developing a decisions support system for the railway infrastructure from a strategic point of view. Also, from the interviews, discussions and experiences of railway managers both from Swedish and Euro-rail, it was found out that no study has been undertaken in order to support for decisions making in a regulated railway environment, while using a conceptual framework. The complex environment also calls for attention for using the multi-criteria-analysis methodology.

A conceptual framework of maintenance management can facilitate making effective and efficient decision in maintenance of railway and will act as an essential component of a decision support system. A conceptual framework explains either graphically or in narrative form, the main issues to be studied, the key factors, variables and the presumed relationship amongst them. The methodology used is to set out bins, naming them, and getting clearer about their interrelationship. It is vital to be selective and to decide which variables are most important, which relationships are likely to be most meaningful, and as a consequence, what information should be collected and analyzed (Miles and Huberman, 1994). The methodology for building up a conceptual frame work has been combined with a reduced multi criteria decision analysis (MCDA) (Dodgson *et al.*, 2000). MCDA is a methodology for evaluating options on individual, often conflicting criteria, and combining the separate evaluations into one overall evaluation. MCDA consist of seven stages (Dodgson *et a*l., 2000): 1. Consider context, 2. Identify options, 3. Establish objectives and criteria, 4. Score option on the criteria, 5. Assign importance weights to the criteria, 5. Assign important weights to criteria, 6. Calculate overall scores and 7. Examine results, sensitivity analyses and sorts. This study includes stage 1 to 3 and gives an approach for how to use stage 4 and 5.

The first step is to identify the bins, i.e. factors or obstacles (further on just called factors). Though the aim of the framework is to support the maintenance management process, it means that the factors ought to be found in different phases described in the maintenance process, see Figure 1.

In the next step MCDA has been used to sort the factors as per their significance, whether it is possible to influence on a tactical level (executive infrastructure management level) or on a local level, see Figure 2.

The relationships among the factors are then identified by finding the common denominator which can be money, time, demands etc. Factors that can be influenced by the local IM are those, which have an ability to support the management towards a more proactive approach. In the final step, the consequences of different decisions, e.g. run to failure, are described in terms of risk for losses, in return on investment (ROI), quality, heath, safety or environment. These are to be ranked and rated. Ranking involves assigning each decision factor a rank that reflects its perceived degree of importance relative to the decision being made. The rating is similar to ranking, except that the decision factor is assigned scores between 0 and 100. The score of all elements being compared and must add up to 100.

The method has then been applied for the Swedish Rail Administration (Banverket). Data has been collected from the Banverket's intranet and maintenance systems, interviews, seminars and the work group meeting for "Applied-Maintenance in Co-operation" (TURSAM in Swedish) (Espling, 2005; Espling 2006).

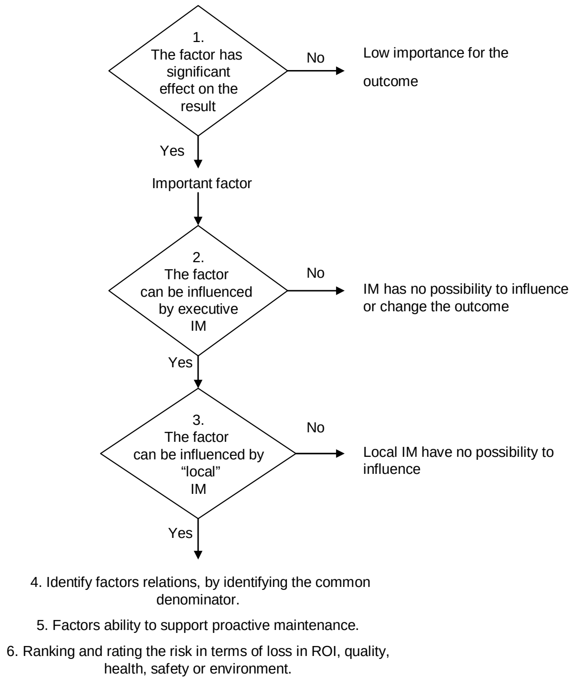


Figure 2. Modified multi-criteria analysis.

3. Maintenance Management Process within Banverket

Banverket is responsible for the railway infrastructure management in Sweden and in 1998, was divided into a client/contractor organization. Banverket's administrative units plan and procure operation and maintenance as well as the conversion and extension of the state railway installations. The orders are placed internally, from the production units, or externally from contractors and consultants (Banverket, 2007). The conceptual maintenance management process is discussed as follows. See Figure 3.

3.1 Objectives and demands

Banverket's activities are steered by Parliamentary transport policy goals. The overall objective is to provide a system of transport for citizens and the business sector all over the country that is both economically effective and sustainable in the long term. Six sub-objectives support the overall objective (Espling and Åhrén, 2007):

1. an accessible transport system,
2. a high standard of transport quality,
3. safe traffic,
4. a good environment,
5. positive regional development, and
6. a transport system offering equal opportunities.

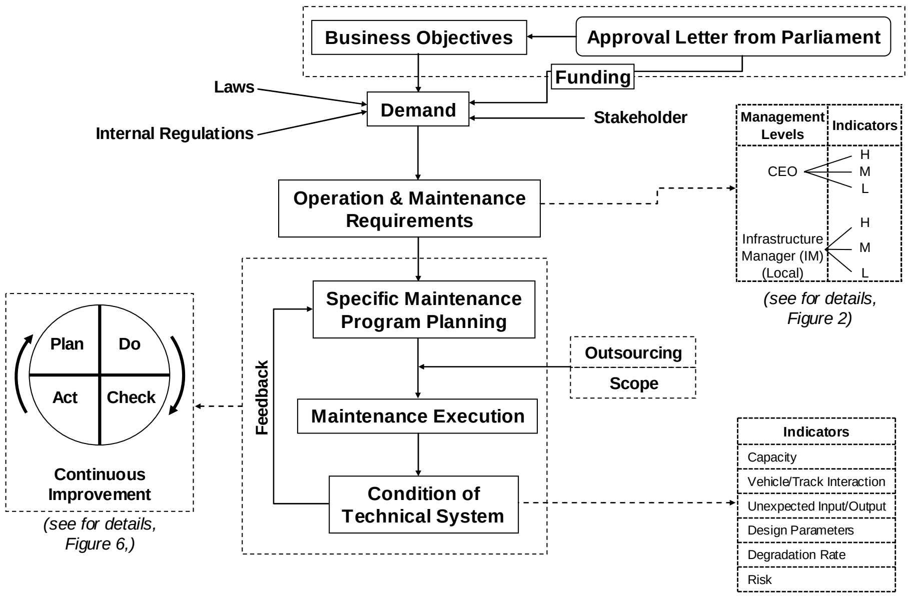


Figure 3. Concept for maintenance management process within Banverket.

These objectives have now been translated into maintenance objectives and a maintenance strategy has been implemented (Banverket, 2007A; Banverket, 2007B; Banverket, 2007C; Banverket 2007D). In Banverket (2007D) the sub-objectives are described in a more detailed way and broken down into maintenance objectives as follows; to maintain an accessible transport system concerning, e.g. speed, axle load; to maintain a high level of transport quality; to maintain a safe traffic level and to secure a good environment. The sub-goals 5 and 6 are also to be maintained, but they are difficult to specify in the daily management, as the activities to fulfil the objectives are the same as in objectives 1 to 4. The objectives are measured in their ability to increase punctuality for the traffic companies, decrease functional failures, and increase the amount of preventive maintenance.

The high safety demands**,** the regulations and the Railway legislations (2004:519) have led to about 1500 internal regulations that stipulate safety and maintenance limits. Internal regulations are considered as rules that must be followed. These internal regulations have to be thoroughly investigated and approved by the Swedish Rail Agency and the internal organization within Banverket before being changed. The stakeholder demands are to be found in the yearly governmental approval letter, demands from the customers, i.e. traffic companies are regulated in the traffic contract. Technical demands can be found in the internal regulations (Espling, 2004).

3.2 Annual Funding

The Swedish Railway Administration Banverket is funded by government grants. The funding for maintenance has historically been approved on yearly basis only one year ahead, often leading to a risk of short-term thinking in maintenance (Andersson, 2002). By studying Banverket's Annual Reports 2000 to 2006, it can be seen that the fluctuation of the funding level for the maintenance budget is seldom over 5%. Still, there must be preparedness for sudden budget deviations in budgetary allocations to up to ± 10%. Espling and Kumar (2004), presents a discussion that due to the prevalent regulations there must always be funding for inspection of asset condition and predetermined maintenance. There must also be funding for the corrective maintenance and snow removal in order to reach the availability objectives (see thick line around inspection and predetermined maintenance in Figure 4).

3.3 Maintenance program

Banverket's maintenance program is structured according to the Swedish Standard SS-EN 13306 and European standard SS-EN 50126, in respect of preventive and corrective maintenance, see Figure 4. The strategy is to have as much preventive maintenance as possible (Espling, 2004). The preventive maintenance is divided into condition based maintenance, including inspection of condition, and predetermined maintenance stipulated by the internal regulations. Due to asset age, traffic capacity, climate aspect, poor asset design, there are also situations within Banverket with a rather high amount of corrective maintenance (Espling and Åhrén, 2007, Andersson, 2002). Snow removal is seen as a separate action beside maintenance, but is included in the maintenance program.

Corrective maintenance includes failure reporting, failure repair and repair of urgent inspection remarks. In the client's accounting system the classification for deferred corrective maintenance is not in use (Espling, 2004A; Espling and Kumar, 2007).

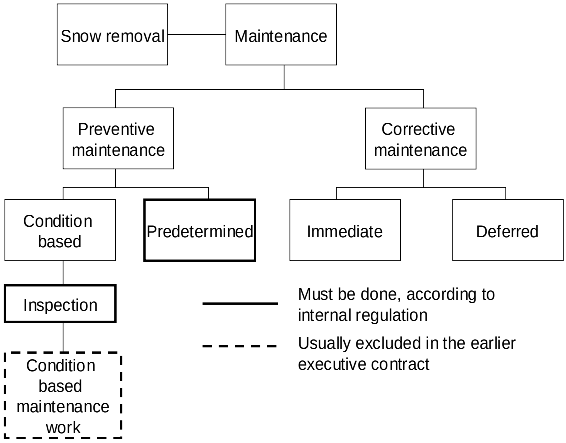


Figure 4. Structure used to describe maintenance, also used as basic structure for the procurement documents and the client accounting system.

3.4 Maintenance planning

Maintenance objectives are expressed in the maintenance strategy and executed in a maintenance plan. The plan also includes maintenance to be done as stipulated in internal regulations.

Maintenance planning is strongly related to the funding process and the train operation process. Unfortunately, there is no alignment between the time given for the trains to operate on the track in the traffic contracts with the traffic companies, and the IM's plan for needed maintenance time on the track. As per planning stipulation, it is observed that, there is a gap of 1,5 years which can be advantageous for the traffic companies train running schedule and the IM's plan for maintenance. This means decreased opportunities for access to the track for maintenance activities. Bigger activities, which will cause interruption to the train traffic, however, should be planned years ahead. Unfortunately, the train time scheduling process is not in phase with the budget process, meaning that when the maintenance budget is set, and perhaps with funding for extra maintenance, it will be very difficult to find train free time on the track. Another obstacle is that the decision for the yearly funding is taken in December, just one month in advance (Espling, 2004).

Plans for inspection and predetermined maintenance are time based or based on intervals according to a certain amount of traffic running over the asset. Condition based maintenance is planned as per the need. For corrective maintenance and snow removal, special readiness plans are prepared in order to reach a high service level for reducing delays caused by functional losses or failures.

Maintenance cannot be done without resources, i.e. personnel, material, maintenance equipment. The IM must have detailed knowledge of what kind of skills, material and equipment are needed for conducting the maintenance plan even if the maintenance is outsourced, in order to keep control over core maintenance activities.

The maintenance plan is also related to the technical systems, the amount, the complexity, but also the actual condition. An asset at the end of its life cycle often needs more maintenance in order to deliver the right quality.

3.5 Execution

The execution of outsourced maintenance demands a supplier market, and the client must be prepared to compensate the contractors so that they can make a profit. Through a system called TransQ the suppliers can get a prequalification in Scandinavia for delivering products or services within the Scandinavian transport market. Every month these suppliers are being checked by Skatteverket (Administration for Sweden's various taxes) concerning their ability to pay demanded fees and taxes (Banverket, 2007). The execution process includes the purchasing, contracting phase and the termination of the contract.

Being a government administered organisation, Banverket must follow the provision of the Public Procurement Act, LOU (SFS 1992.1528) which is mandatory. This means that special procedures have to be followed in the procurement process. All assessments and decisions must be on objective grounds that are based on financial effects in the individual agreement concerned. A special inspection authority "The Swedish Committee for Public Procurement" sees to it that the rules are obeyed (Sundin, 2003).

Planned maintenance and snow removal are bought either from the in-house contractor or in competition with external contractors. The structure for the procurement document is the same as for the maintenance program and the accounting system (Espling, 2004A). The scope of the contracts varies, from so called service level contracts, just including a minimal level of maintenance such as corrective maintenance, inspection and predetermined maintenance to total scope contracts including all basic maintenance (Espling and Åhrén, 2007). When the service level contract is used, the additional condition based maintenance is either bought as an extra order within the contract or as a separate contract put out for new tender. Such orders or separate contracts could contain tamping, maintenance on turnouts, ditching and so on (Espling, 2004).

The resources required for conducting the maintenance contract are:

- Skilled personnel; All personnel working on the track must have been educated in the safety demands for working on track. For certain tasks, e.g. maintenance of signaling asset or welding there is a demand for personnel with certification. (Espling, 2004).
- Material: In order to fulfill the high safety demands all systems and components used within Banverket have to be tested and approved before being put into the

track. Those systems and components that are considered vital for the railway system and safety are classified as railway specific material. Material Service is a special unit within Banverket, which is responsible for purchasing this material and handling the logistics within Sweden. The IM has to specify all railway specific material used in the contract within the contract documents. Both the client and the contractor are required to use the services of Material Service (Espling, 2004).

- Maintenance equipment. In railway maintenance, there is a need for special maintenance equipment and vehicles. The maintenance vehicle pool within the in-house contractor's organization is responsible for providing maintenance vehicles and equipment to the in-house and external contractors (Espling, 2004).
- Information; There is a continuous flow of information during the maintenance process. Information is delivered through different sources, e.g. through Banverket's telecom systems, but also through, e.g. systems for asset information, the material system, the inspection and failure system. All these systems are available for the in-house contractor, but not always to the external contractor.

3.6 Technical railway system

The railway system is a transportation system offering the community and the customers a large range of transport alternatives, from high speed passenger traffic to slow going heavy haul transport of bulk freight.

The technical system for the railway is divided into the infrastructure system (including traffic operation system) and the rolling stock (passenger trains and freight trains). The infrastructure system is usually divided by technical branches into:

- Track, i.e. permanent ways (ballast, rail, sleepers, fastenings, turnouts, substructure including bridges, tunnels).
- Electric systems, including power supply to the rolling stock.
- Signaling systems for steering and controlling the train running operation.
- Telecom system for mobile communication and wayside monitoring equipment monitoring defects on the rolling stock, alarming when the defects reach the safety limit.

Depending on stakeholders' demands, the railway infrastructure complexity varies. The outcome of availability is affected by turnout density, the length of bridges and tunnels, the length of multiple-track sections, the proportion of curves, the degree of electrification, the rate of utilization of a network, the number of trains, the average tonnage, etc.

The inbuilt capacity and capability of the infrastructure line depends on type substructure, ballast, sleepers, rails, fastenings, length of meeting yards, age of asset, degradation rate and so on. The degradation rate is described in terms of asset age and how many million gross tonnes have been operating on the track. There are a number of different information systems for asset assessment conditions, e.g. systems for asset information, inspection, failure, track quality, detectors. There are often thresholds for maintenance stipulated in the internal regulations, but these are in some cases just for safety, especially for monitoring the condition of the vehicles (Espling, *et al.*, 2007; Nissen *et al.*, 2007). To make it possible for the client to follow and analyse the actual condition of the asset, it is important that the quality of reporting is of high standard. It is essential that all actions and changes to the asset are reported back to the system for all maintenance actions, also for corrective maintenance where a deviation can be seen, i.e. short length of track due to rail breaks are not reported back into the asset information system (Kumar *et al.*, 2007).

To be able to plan for the maintenance the IM needs to know about the interacting technical systems, i.e. traffic companies' vehicles and how the assets are used, how the track is operated, what type of vehicles are used, what is their condition (bad maintenance, bad behaviours, increased degradation), how many of them are there, what speed and what axle load? Due to for example, climate, unexpected input in terms of storms, floods may occur causing unexpected outputs, such as, train delays.

3.7 Continuous improvement process

There should be objectives for creating a more proactive maintenance approach, like decreasing the amount of corrective maintenance, decreasing cost, e.g. for preventive maintenance in order to suggest new solutions. By different analysis methodologies, e.g. root cause analysis, failure modes and effects' analysis, new solutions will be suggested and tested. One way of finding improvement areas is to identify cost drivers. Factors forcing up the costs are the cost of personnel, material costs (also the costs of sub-contractors involve a certain proportion of material cost), see Table 1. The cost of overheads, at a proportion of 15 % of the infrastructure costs, is rather high. Subcontractors cause a third of the total costs. Permanent way and substructure together with bridges and tunnels, cause 58 % of the total maintenance costs or 68 % of the renewal costs, respectively (Lichtberger, 2005; Stalder *et al.*, 2002).

Table 1. Factors forcing up the cost (Lichtberger, 2005).

Designation	Cost proportion in the annual maintenance costs (%)	Cost proportion in the annual renewal costs (%)
Overheads	15	15
Personnel	46	12
Subcontractors	25	46
Material	7	22
Machinery	4	3
Other	3	2

More metrics, i.e. indicators and a measurement framework, should be developed and reconfigured for maintenance, making comparisons possible, for example from the Life Cycle Cost perspective *vis-à-vis* the business perspective. In railway administrations, one critical improvement area is the enhancement of the quality of the incoming data. This can be achieved (Espling and Kumar, 2007):

– by giving details of the status of the assets (age and degree of wear), the total traffic volume per year and the available time on track for infrastructure maintenance. This information should be incorporated as a correction factor in the analysis,
– by well-structured economic feedback reports on maintenance activities. This should be implemented, so that it is possible to differentiate resources, which are consuming corrective maintenance activities and those consuming preventive maintenance activities. The structure of the economic feedback reports on maintenance should be designed, so that it may be possible to differentiate between operation and corrective and preventive maintenance,
– by separating the specially targeted maintenance investment from normal "maintenance activities"; efforts to enhance punctuality in a special campaign form are an example of the former.

4. A conceptual framework for infrastructure management in a regulated environment

There is a need to steer a reactive management attitude towards a proactive approach. In a complex environment situation, there is a need to focus on those variables that can be affected and promote a value increasing output. A decision support tool can facilitate the management, and as a first step a conceptual framework can be used. In the following, the methodology presented in chapter 2 is applied on Banverket.

The first step is to identify the important factors and group them according to the maintenance process, see Table 2 column 1 and 2 and Figure 5. Though the objectives in a public organization often are related to governmental demands and funding and usually have large impact on the maintenance process, these factors have been enhanced in the framework; also the planned maintenance depends on type of technical system and its condition and the outcome of the condition due to maintenance. The results are measured and feedbacks are important bricks in the continuous improvement process. Next question asked is, how important this factor i.e. what significance affect it has to affect a proactive maintenances process, see column "Significance". In the next step MCDA has been used to sort the factors on significance, whether it is possible to influence on a corporate and managerial level or on a local level, see Figure 2 as an example of for outcome of a conceptual framework.

As a result of; data collection, from interviews, seminars and the work group meeting for "Applied-Maintenance in Co-operation" (TURSAM in Swedish), this conceptual framework has been built up by asking four different questions:

1. Is it possible for the manager to affect the factors on a high, medium or low level?
2. Is it possible to affect the factors from a strategic perspective, a tactical perspective, or an operative perspective?
3. What are he inter-relationship between the factors?
4. What are the failure and risk consequences concerning quality (Q), cost, return on investment (ROI), health (H), safety (S) or environment (E)?

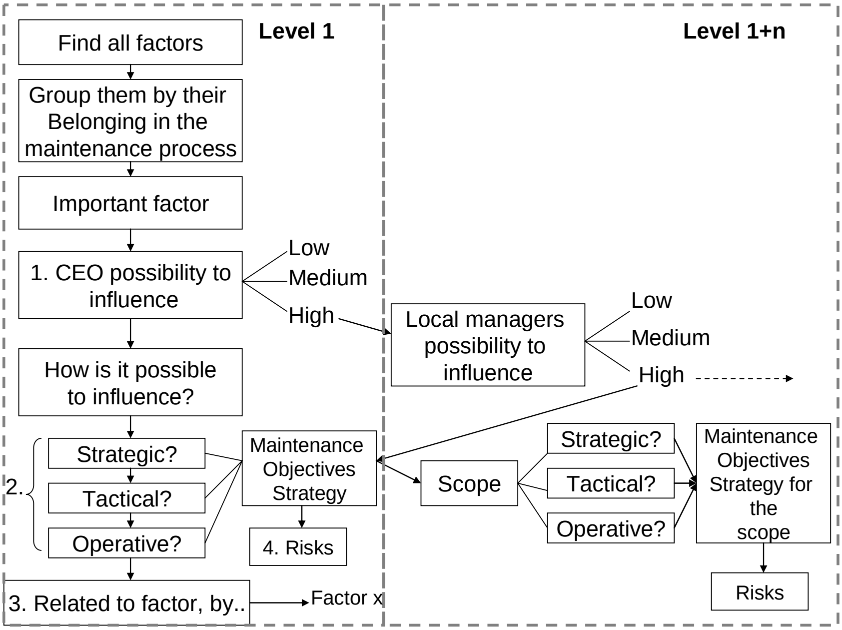


Figure 5. Maintenance strategy framework process.

The first question helps the manager to focus on areas that can be affected. The first level is the CEO's possibilities to influence the infrastructure management by e.g. discussions with the stakeholders or funding allocation. The CEO might have a high to medium influence on the overall objectives, but have a high influence of forming the maintenance objectives e.g. strategically increase punctuality by 25 %, tactically by focusing on solving e.g. the problems causing most train delays, operational mean time to repair less than 2 hours. CEO has also to consider the risks associated with these objectives and how this strategy may affect another factor in the framework.

In the following levels, the framework application cascades down through the hierarchy and on each level, the responsible manager answer the same question, see column Local IM Influence.

The second question is to lift the focus from the yearly funding approach to a more proactive based on need (see column "strategic", "tactic" and "operative") e.g. a high transport quality needs to be placed strategically by increasing the punctuality with 25 %, tactically by finding the asset which causes the highest amount of delays; and find proactive solutions to decrease these delays and operationally, to have a high service level. The third question is a reminder (see column "related to)" e.g. if more funding is received for maintenance activities, time on track for conducting them must be negotiated with the customers, i.e. train operating companies. The fourth question is what the consequences are of doing or not doing maintenance. These are also used to motivate the different decisions to be taken (See Figure 5).

By using the methodology and answering the question, the local IM is presented with those factors that he has the ability to influence in a proactive direction. The local manager can affect the objectives, the maintenance program and plan by setting strategic and tactical objectives on how to reduce corrective maintenance, mainly by implementing the continuous improvement programs. This conceptual framework can also be used on an overall strategic level by focusing on those factors answered, having high significance for the maintenance process and possible to be influenced on a CEO level.

The framework also suggests an approach for identifying the consequences and the risk for management failure. However, this has not been applied in this study, because there is often a need for expert knowledge and different methodologies or tools to be used, depending on what management failure is to be assessed (Akersten and Espling, 2005).

Examples of factors' internal relationship are, like; predetermined maintenance is related to the demands of internal regulations, or the customers' demands are related to changes in the maintenance program.

The outcome from the questions, data analysis, interviews and the answers resulted in formulating the framework shown in Table 2 is summed up as:

- Objectives; the objectives for the maintenance process are set in the internal regulation, but on a rather general level. Depending on the scope, it is possible both for the executive IM and for the local IM to break them down into strategic, i.e. to establish and communicate a long-sighted objective for the whole organization, tactical (to reach local success) and/or operative (short sighted, current steering) levels.

- In the budgeting process for next year's funding, the cost for predetermined maintenance and inspection will be fixed and not possible to reduce, though the internal regulation stipulates that this must be done according to safety demands. In order to act more proactively in the budgeting process, a strategic objective for the corrective maintenance funding would decrease the level with a certain percentage per year by analyzing and finding the cost drivers and suggesting improvement activities that will solve the problems (Espling and Kumar, 2004).

- In the maintenance program and maintenance planning phase, it is possible to influence both corrective maintenance and condition based maintenance by starting a continuous improvement process. Also, it is possible to influence snow removal by using the personnel to do preventive maintenance during snow free periods (Espling and Olsson, 2004). Factors, which cannot be influenced, are predetermined maintenance and inspection, which have to be done according to internal regulations (Espling, 2004).

- Depending on the scope, the kind of contract, payment forms and cooperation forms, the local IM has different possibilities to influence the outcome in the executive phase. The scope is determined by the type of traffic running on the track, the amount of traffic, the track standard, geographical position, climate, presumed degradation. Stakeholders' and customers' demands are the basis when the objectives for the scope are set; these are also the objectives for the contract. In order to control the client's needs, specify what feedback is required from the contractor and what measures are important for following the maintenance cost, measuring the asset condition and the quality is important (Espling, *et al*., 2007; Larsson, *et al.,* 2007, Nissen, *et al.,* 2007)

- Finally, the continuous improvement phase is a must for a proactive IM. By measuring the objectives, analyzing and finding improvement areas, costs can be decreased and quality will improve. In this phase it is important to collect and gain access to the right data needed, it is also important that the maintenance history is traceable.

5. Discussion

The main objective of this research is to find tools and methodology to support the management of a complex and regulated railway infrastructure. The railway infrastructures under a regulated environment have high demands due to varying and complex requirements from both internal and external stakeholders, compounded with changing political decisions. These demands make the infrastructure managers' decision making process to manage the operation and maintenance of the railway infrastructure more difficult and complex. Further, higher corrective maintenance, rather than a balanced corrective and predictive maintenance makes the infrastructure manager in a loose-loose situation. To overcome this situation, and to support the infrastructure manager, the decision support conceptual framework is considered, discussed and suggested. In table 2, the possible key issues of activities, like; objectives, demands, funding, maintenance program and maintenance plan, and execution of sourcing process, technical system and continuous improvement; of an maintenance process are given. These key issues can be affected through proactive approach at both strategic, i.e. setting objective at the CEO level under a dynamic situation; and in the other phase, at executive/tactical level through execution, measurement and feedback for a continuous improvement cycle.

Table 2. Conceptual framework

Flow / Key Issues	Factors	Significance	CEO IM influence	Local IM Influence	Objectives: Strategic	Objectives: Tactic	Objectives: Operative	Risk of affecting (Ranking x Rating): Q	ROI	H	S	E	Related to
Objectives (O)	an accessible transport system	High	Medium	Low			Keep the level						F
	a high standard of transport quality	High	High	Medium	x	x	x	x	x				F, ES, CI
	safe traffic	High	High	High	x	x	x			x	x	x	TS, ES
	a good environment,	High	High	High	x	x	x					x	TS, ES
	positive regional development and	High	Low										
	a transport system offering equal opportunities.	High	Low										
Demands (D)	Laws	High	Low	Low									
	Internal regulations	High	High	Low									
	Governmental approval letter	High	Low +	Low									
	Customers demand	High	High	Low									MP (time)
	Technical demands	High	High	Low	New innovations?								
Funding (F)	Snow removal	High	Medium			Historical							
	Predetermined maintenance	High	High	High			Funding reserved				x		D
	Corrective maintenance	High	Medium		x	x							CI
	Condition based inspections	High	High	High			Funding reserved				x		D
	Condition based maintenance	High	Medium										
Maintenance program (MP) and Maintenance plan	Snow clearence	High	Medium	Medium				x					CI
	Predetermined maintenance	High	High	Low			Follow regulations						D
	Condition based inspections	High	High	Low			Follow regulations						D
	Condition based maintenance	High	High	High	x	x	x	x	x				CI, F
	Corrective maintenance	High	High	High	x	x	x	x	x				CI
Execution, Sourcing process (ES)	LOU	High	Low	Low									D
	Scope	High	High	High	x	x	x		x				O, MP, TS
	Contract form	High	High	High	x	x	x		x				O, MP, TS
	Payment form	High	High	High	x	x	x		x				O, MP, TS
	Cooperation form	High	High	High	x	x	x	x	x				O, MP, TS
	Mateial resource requiernmet	High	High	Medium									D, MP
	Maintenance equipment resource requireme	High	High	Low									
	Skilled personnel resource requirement	High	High	High		x	x						D, MP, TS
Technical system (TS)	Standard/condtions	High	Medium	Low									
	Used capacity	High	Medium	Low									
	Degradation speed	High	Medium	Medium									
	Interaction track/vehicle	High	Low	Low									
	Un expected input	High	Medium	Medium									
	Un expected output	High	Medium	Medium									
	Design	High	High	Low									
Continuous improvement (CI)	Reporting (feedback data)	High	High	High	x	x	x	x	x				O, MP, ES
	Analysis	High	High	High	x	x	x	x	x				O, MP, ES
	Improvement activities	High	High	High	x	x	x	x	x				O, MP, ES

Note: CEO=Chief Executive Officer, Q=Quality, ROI=Return on Investment, H=Health, S=Safety, E=Environment

The key to the proactive approach is the successful implementation of a continuous improvement process. This is usually combined with maintenance strategies like RCM, Reliability Centered Maintenance or TPM, Total Productive Maintenance (Campbell, 1995). These techniques provide strategic frameworks that support the continuous improvement process. A proactive management process is not a short term activity. RCM Reliability Centered Maintenance consumes time and resources, but by using RCM in the New South Wales rail industry, the rewards have been significant, beside money earned also structured knowledge and cost effective improvement practice has been reached. An investment on $250 000 AUD in RCM resulted in real saving of $1 000 000 AUD. (Kennedy, 2001). RCM, was introduced for the aviation industry, when the current predetermined maintenance lead to a situation of high maintenance cost and high amount of downtime caused by predetermined maintenance activities. It is seen that predetermined maintenance is up to 40 % more costly than RCM (Moubray, 1997). It is also well known that a failure-based maintenance constitute a substantial part of workload. Failures occur randomly and require a high degree of flexibility in case the failure require urgent repair (Martin, 1997). Failures cost money and increases risk for bad quality, risk for health, safety and environment all this leading to, low Return on Investment (ROI).

Looking at Banverket's high amount of corrective maintenance, which indicates that the improvement process must be enhanced, one suggestion might be to add, e.g. TPM into the maintenance program. By studying Banverket's annual reports between the years 2000-2006 it can be seen that the amount of corrective maintenance level is steadily around 35 %, the failure rate has increased as well as the number of failures, thereby causing train delays. This is an indication that the continuous improvement process is in its infancy. One reason might be that the regulated, multi-variable, one year funding environment makes it difficult for the manager to find ways for affecting the maintenance decisions, since, no structured approach and facilitating organizational support existing. By using a conceptual framework, it is possible to point out those management activities that can be affected, i.e. reducing the amount of corrective maintenance.

There is also a need to create knowledge and methods that will help the IM to find the most potential improvement areas within each factor, e.g. to find failure-drivers, train-delay-drivers or cost-drivers.

A more proactive and detailed maintenance process can be illustrated, as in Figure 6. This Figure has been adapted from NPD (1998) and slightly modified by adding the effects of yearly funding, equipment for maintenance as a resource and also quality and return on investment (ROI) as important output from the technical system. Annual funding affects the objectives in the contracts and in the shortsighted maintenance program and planning.

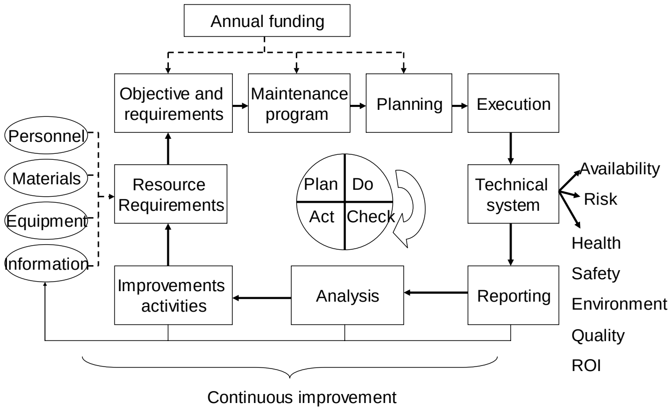


Figure 6. Elements of maintenance process, adopted from NPD 1998.

Today, there is criticism of traditional performance measures, that they focus on financial measures, also that they lack strategic focus and that there is a need to establish a link and understanding between performance measures and performance improvement (Amaratunga and Baldry, 2003, Parida et al., 2003). Successful industrial companies are characterised by maintenance and reliability performance being considered as significant parts of the corporate strategy (Ahlmann, 2002). There exists a need to develop clear maintenance objectives and goals, to define key variables for measuring and controlling maintenance activities, to ensure better linkage between maintenance and production (Riis, *et al*., 1997). In Banverket, the six sub-objectives are expressed in rather general terms; these are broken down for measuring the performance in the contract and expressed as (Espling and Åhrén, 2007):

- Increase punctuality caused by infrastructure by 5 %, based on a mean value for train delays for the previous three years.
- Increase reliability by decreasing functional failures caused by infrastructure and failures that can be affected by the contractor.
- Keep Q-factor track comfort quality.
- Increase amount of preventive maintenance.

The performance measures are; train delay hours, number of failures, track quality factors and amount of preventive maintenance as a percentage of total maintenance costs (Åhren, 2005). These are measured more on an operative level than on a tactical or strategic level. These objectives are also used in both low traffic lines and high traffic lines.

6. Concluding Remarks

With recognition that maintenance creates added value in the business process, there is an all-round efforts to enhance the effectiveness and efficiency of maintenance process. This necessitates correct decision making by maintenance mangers responsible for maintaining infrastructures so as to meet the transport goal. The paper presents an approach for the development of a conceptual framework for the management of the infrastructure maintenance. Furthermore, its application is discussed for the local IM in a client/contractor-organisation. The developed conceptual framework has been tried out for Banverket and has been found helpful to the IM to steer and manage critical factors in a proactive way. It also forces the IM to lift the perspective and ask if this action planned is going to be just proactive or if it is possible to influence the management process on a strategic level, and while lifting it over the operational level, there is a need to follow up how the strategic management will be affected, which can trigger the start of a continuous improvement process.

REFERENCE

Ahlmann H. (2002). From traditional practice of the new understanding; the significance of life cycle profit concept in the management of industrial enterprise. *IFRIMmmm Conference*, Växjö Sweden, 6-7 May 2002.

Akersten, P.A. and Espling, U. (2005). Postponed Replacement – A Risk Analysis, Case Study. *Proceedings of 9th International Conference of Maintenance ICOMS*, Hobarts Australia 31 May.

Andersson, M. (2002). *Strategic Railway Track Management Planning – State of the Art.* Stockholm, Kungliga Tekniska Högskolan, ISSN 1651-0216.

Amaratunga, D. and Baldry, D. (2003) A conceptual framework to measure facilities management performance. *Property Management* Vol. 21, No. 2, pp 171-189.

Banverket (2007), TransQ, http://knuten/templates/BvMenuPage.aspx?id=63395, 2007-10-19.

Banverket (2007A). STRAT 800 Banverkets Underhållstrategi, HK 06-4446/OR20 (in Swedish).

Banverket (2007B.) BVF 800 Övergripande regler för Banverkets underhållsverksamhet, HK 06-4446/OR20 (in Swedish).

Banverket (2007C). Standard BVS 803 Åtgärder i järnvägsnätet, Huvudprocessen utveckla och underhålla anläggning, HK 06-4446/OR20 (in Swedish).

Banverket (2007D). BVH 800 Vägledning till Banverkets underhållstrategi, HK 06-4446/OR20 (in Swedish).

Campbell, J.D. (2001). *Maintenance Excellence, Optimizing Equipment Life-Cycle Decision*s. Marcel Dekker, Inc, New York.

Campbell, J.D. (1995). *Uptime: Strategies for Excellence in Maintenance Management.* Productivity Press, Portland, Oregon.USA.

Dodgson, J., Spackman, M., Pearman, A. and Phillips, L. (2000) Multi-Criteria Analysis: A Manual. Department of the Environment, Transport and the Regions, London, http://www.communities.gov.uk/archived/publications/corporate/multicriteriaanalysismanual, (2007-11-07).Productivity Press, Portland, Oregon, USA.

Espling, U. (2004). *Ramverk för en drift- och underhållsstrategi ur ett regelstyrt infrastrukturperspektiv*. Luleå University of Technology, Licentiate Thesis 2004:45, (in Swedish).

Espling, U. (2004A) *Benchmarking av basentreprenad år 2002 för drift och underhåll av Järnväg*, Luleå University of Technology, Luleå, Sverige, ISSN 1402 – 1528 (in Swedish).
Espling, U. (2005). *Arbetsgrupp TURSAM, Årsrapport 2004.* Luleå University of Technology, Tekniks Rapport, 2005:28 (in Swedish).
Espling, U. (2006). *Arbetsgrupp TURSAM, Årsrapport 2005*. Luleå University of Technology, Teknisk rapport 2006:17 (in Swedish).
Espling, U. and Kumar, U. (2004). Development of a Proactive Maintenance Strategy for Railway Infrastructure; A case study. In: *Workshop Proceedings of the International Maintenance Congress Euromaintenance 2004,* Barcelona May 11-13, pp 31-38.
Espling, U. and Kumar, U. (2007). Benchmarking of the Maintenance for Railway Infrastructure. *Maintenance Handbook*, Chapter 23 Springer Publication.
Espling U., Nissen, A. och Larsson, D. (2007). *Strategi och metodutveckling av underhållsgränser för fordons- och banunderhåll, sett ur ett ekonomiskt perspektiv*, Luleå University of Technology, Forskningsrapport 2007:07 (in Swedish).
Espling, U. and Olsson, U. (2004). Partnering in a Railway Infrastructure Maintenance Contract – A Case Study-Part II. *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 4, pp 248-253.
Espling, U. and Åhrén, T. (2007). Outsourcing as a tool to fulfil maintenance objectives, a case study for Railway. Submitted to a Journal.
Forgionne, G. (2002). Chapter 1 -An Architecture for the Integration of Decision Making Support Functionalities. *Decision-Making Support System; Achievement and Challenges for the New Decade*, Hershey, PA, USA.
Kennedy, J.R. (2001). Establishing Due Diligence and Continuous Improvement in Preventive Maintenance. *Conference Proceedings IHHA 7th International Heavy Haul Conference*, Brisbane date, pp451-460.
Kumar, S., Espling U. and Kumar, U. (2007). A Holistic Approach towards Rail Maintenance – An Overview of Swedish Iron Ore Line. Submitted to a Journal.
Larsson, D., Espling, U. and Nissen, A. (2007). Vehicle classification Based on Wayside Monitor Data – A Case Study. *Conference Proceeding IHHA International Heavy Haul Association Congress*, Kiruna 11 - 13 June, 2007, pp 471-477.
Lichtberger, B. (2005). *Track Compendium; Formation, Permanent Way, Maintenance, Economics.* Eurailpress, Hamburg.
Liyanage, J., P. och Kumar, U. (2003). Towards a value-based view on operational and maintenance performance management. *Journal of Quality in Maintenance Engineering*, Vol. 9, No 4, pp. 333-350.
Martin, H.H. (1997). Contracting out maintenance and a plan for future research, *Journal of Quality in Maintenance Engineering,* Vol. 3, No. 2, pp 81-90.
Miles, M.B. and Huberman, A.M. (1994). *An Expanded Sourcebook; Quality Data Analysis; Second Edition.* California, SAGE publications Thousand Oaks.
Moubray, J. (1997). *Reliability-centered maintenance.* Oxford; Butterworth Heinemann.
Nagarur, N.N. and Kaewplang, J. (1999). An objected-oriented decision support system for maintenance management, Journal of Quality in Maintenance Engineering, Vol. 5, No. 3, pp 248- 257.

Nissen, A. Larsson, D. and Espling, U. (2007). Moving from Safety Limits towards Maintenance Limits. *Conference Proceedings IHHA International Heavy Haul Association Congress*, Kiruna 11 - 13 June, 2007.
NPD (1998). *Maintenance baseline study, a method for self-assessment of maintenance management system*. Norwegian Petroleum Directorate, Stavanger, Norway.
Parida, A; Åhrén, T. and Kumar, U. (2003). Integrating maintenance Performance with Corporate Balanced Scorecard, COMADEM 2003, *Proceedings of the 16th International Congress*, 27-29 Aug 2003, Växjö, Sweden (pp 53-59).
Picknell, J.V. (2001). Maintenance Management Methodologies. *Maintenance Excellence, Optimizing Equipment Life-Cycle Decisions*, Marcel Dekker, Inc, New York.
Riis, J.O., Luxhøj, J.T. and Thorsteinsson, U. (1997). A situational maintenance model. *International Journal of Quality & Reliability Management*, Vol. 14, No. 4, pp 349-366.
Stalder, O., Bente, H. and Lüking, J. (2002) The Cost of Railway Infrastructure. *ProM@in - Progress in Maintenance and Management of Railway Infrastructure*, 2, 32-37.
Stevens, B. (2001). Measurement in Maintenance Management. *Maintenance Excellence, Optimizing Equipment Life-Cycle Decisions*, Marcel Dekker, Inc, New York.
Sundin, J. (2003). Procurement of Building contracts forms and tools used by the Swedish Railway Administration. *BV Internal document 2003040*, Banverket, Borlänge.
Åhrén, T. (2005). *A study of maintenance performance indicators for the Swedish Railroad System*. Luleå University of Technology, Licentiate Thesis, 2005:47