# EVALUATION OF ATTEMPTS FOR EFFICIENT ROAD MAINTENANCE

**By**

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# ١ Background

As funding resources for road infrastructure are seldom sufficient, road authorities are facing the following challenges:

- insufficient funding sources to face the increased need for new road infrastructure (Prarche ٢٠٠٧), increased demand for proper management of both newly constructed and existing roads;
- Increased maintenance backlogs (Gahm ٢٠٠٨);
- Increased demands for safety, accessibility and use of advanced traffic management systems to reduce socio-economic costs in terms of reduced maintenance-related environmental impacts, traffic disturbances and fatalities.

Due to the funding challenges, road authorities are facing a great need for increased efficiency and reduced expenditures. Focus is on efficient road maintenance, as maintenance costs constitute approximately ٥٠% of the annul road infrastructure financing (Prarche ٢٠٠٧). To increase maintenance efficiency, different strategies and contract forms have been used by road authorities. This includes outsourcing of maintenance activities in competitive markets, development of life-cycle cost models, as well as new funding and subsidiary forms. Even if these attempts have reduced maintenance costs considerably, the general opinion is that some efforts have resulted in reduced maintenance standards and impaired road conditions, as focus mainly has been on reduction of the rate of recurring maintenance activities.

# ٢ Objective

The aim of this study was to:

- Compile experiences regarding attempts made by road authorities to satisfy the needs for efficient maintenance and the results of these efforts; and
- Evaluate the extent to which maintenance aspects are considered during road planning and design as an improvement potential for maintenance efficiency.

# ٣ Studied attempts

The studied attempts were outsourcing of maintenance, consideration of maintenance aspects during road design, life cycle cost analyses for road infrastructure, Public-Private Partnership Project (PPP projects) and performance-based contracting.

## ٣.١ Outsourcing maintenance activities

Outsourcing maintenance activities in a competitive market has been used as an option to increase maintenance efficiency and reduce costs. Due to maintenance outsourcing in Sweden between ١٩٩٢ and ٢٠٠١, transaction costs for maintenance contracts for the outsourced maintenance areas, e.g. bid preparation and contract monitoring and evaluation, were estimated to be at least ٥% lower than for non-outsourced maintenance areas (Liljegren ٢٠٠٣). In Sweden, outsourcing of several maintenance areas in a competitive market during the first year reduced bid prices on average with ٢٢–٢٧% compared to in-house maintenance costs (Arnek ٢٠٠٢). These cost reductions are often attributed to reorganisation and reduction of personal rather than to technical progress in machinery and methods (Stenbeck ٢٠٠٦).

Such reforms have also been used by the Swedish government as an incentive to cut grants for road maintenance. However, these reforms have negatively affected road maintenance, primarily for pavement and bridge maintenance, because short-term maintenance measures, such as winter maintenance, cleaning and grass mowing, have been prioritised. The situation is the same in all Nordic countries (Gahm ٢٠٠٨). Studies of road-user opinions have indicated increased dissatisfaction regarding road maintenance, which, in turn, indicates that the maintenance standards in Sweden have decreased after the reforms, primarily on roads in sparsely populated areas (Österberg ٢٠٠٣).

By outsourcing maintenance activities, road authorities have tried to encourage contractors to develop technical improvements. Unfortunately, effects of outsourcing on innovation have been limited (Stenbeck ٢٠٠٧; Thorsman and Magnusson ٢٠٠٤). Development interest among contractors has been low because development costs are often high compared to the benefits obtained. In addition, contractors often have refused to share knowledge with others in order to maintain competitiveness. As a result, Stenbeck (٢٠٠٧) claimed for example that long-term technical developments have decreased. He also mentioned that maintenance costs for outsourced contracts in

Canada were ٢٦% higher than for in-house contracts. The quality and technical development were neither noticeably higher nor lower in outsourced contracts than in in-house contracts.

## ٣.٢ Consideration of maintenance aspects during the road planning and design process

Problems faced while conducting maintenance activities often trigger debates on road planning and design as a crucial underlying factor (Freer-Hewish ١٩٨٦). The cost of a road project over its service life is, among other things, a function of design standards, construction quality control, maintenance strategies and maintenance quality. These aspects control the rate of road deterioration and dictate the maintenance workload throughout the life of the road (Figure ١). However, very few studies considering the interrelationship between these components have been found in the literature.

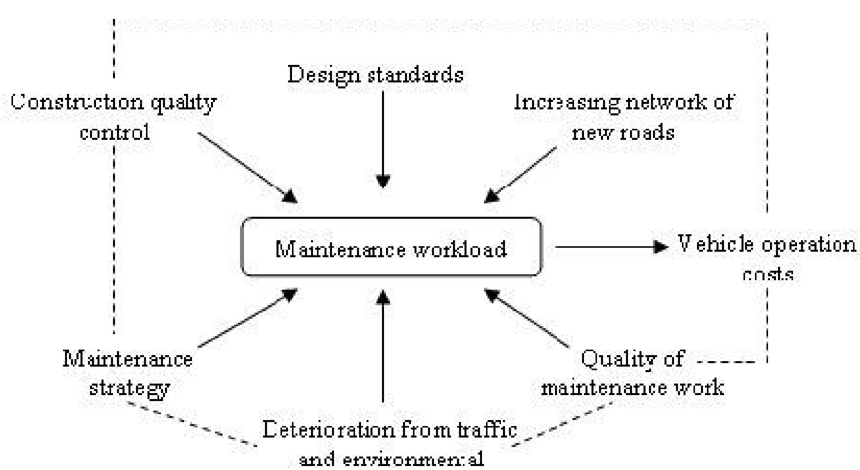

***Figure*** *١ Development of maintenance workload (Freer-Hewish ١٩٨٦)*

According to Thorsman and Magnusson (٢٠٠٤), insufficient consideration of maintenance aspects as well as inadequate support for the designers during the planning and design process are two major factors contributing to high maintenance costs. They suggest the following improvements:

- Improving methods and technologies for reducing maintenance costs through reduction in intervention time and use of efficient tools;
- Creating functions for supporting designers and coordinating maintenance-related consulting between involved parties; and
- Improving coordination and information sharing between contractors.

Gaffeny and Gane (١٩٧٠) compiled a list of some aspects of road design, which contribute to decreasing the need for future road maintenance. Based on experience from the United States, some general advice is given concerning design of cuttings, embankments, bridges, bridge abutments, steelworks, street lighting, pavement types, pavement thicknesses and surface types. Regrettably, calculations for quantifying the positive effects were not performed.

Olsson (١٩٨٣) describes a new method for road construction design using annual cost calculations. The major factors, which prevent consideration of road management and maintenance costs during the road design process, include difficulties in quantifying administration costs, time shortage and inadequate experience of road maintenance among road designers. A road design model is recommended consisting of the following three steps:

- Study different design alternatives and calculate annual costs, including investment and maintenance costs, to choose an optimal design;
- Clarify the calculation suppositions to offer enough information for decision makers concerning calculations and included cost items; and
- Estimate calculation accuracy statically or based on practical experiences.

Other studies concerning design of pavements, bridges and specific roadside components have also indirectly considered maintenance aspects. A study made by (Neuzil and Peet ١٩٧٠) examined the fill height of embankments, whereby flattening slopes proved to be cheaper than installing guardrails. Wolford and Sicking (١٩٩٧) developed guidelines to determine the need for road barrier installations based on cost-benefit analyses. Mattingly and Ma (٢٠٠٢) compared different road barrier end-terminals in order to identify the most profitable ones in order to decrease future maintenance needs. This study was based on practical experiences, which did not include life-cycle cost analyses or any evaluation of how factors, such as traffic volume and road design would, affect maintenance costs of the end-terminals.

## ٣.٣ Life-cycle cost analyses

Life-cycle costs for road objects are considered as a more important decision basis than only investment costs, and, consequently, road authorities are encouraged to overweigh life-cycle cost analyses and provide calculation methods (Bajaj et al. ٢٠٠٢; Gransberg and Molenaar ٢٠٠٤). Life-cycle costs are also suggested as a parameter for selecting road designs or evaluating bids (Adams and Kang ٢٠٠٦; Stenbeck ٢٠٠٤). Both road authorities' costs and socio-economic costs must be included in the calculation of life-cycle costs. Road authority costs consist of costs for planning, design, construction, maintenance and rehabilitation. These costs are usually covered by governments using tax revenue. Socio-economic costs include:

- Road users' costs, such as vehicle operation costs, and costs for the time people spend on the road;
- Accident costs; and
- Environmental costs.

Many road authorities have developed models for life-cycle cost analyses with the intention of reducing the total cost for the road infrastructure and maximize the socio-economic benefits. Some models are simple and include only road authority costs. Other models are very complex including calculation of socio-economic costs and models for prediction of road deterioration. A study of life-cycle cost models used in the Nordic countries showed that these models often considered the road authority’s costs, such as investment costs, maintenance costs and to some extent, user and environmental costs (Holmvik and Wallin ٢٠٠٧). Still none of the models can be used as a standard model without considerable improvements, since they are developed for specific road projects. The disadvantages of the studied models also included use of roughly calculated maintenance costs and insufficient consideration of how design influences maintenance costs.

Huvstig (١٩٩٨) has studied several models for calculation of life-cycle costs made by road authorities such as, COMPARE (Great Britain), QUEWZ (Australia), Whole Life Costing System (USA) and Highway Design and Management (HDM I to IV) developed by The World Bank. These models have mainly been used for design of road construction and pavement types.

Life-cycle cost is suggested as a parameter when selecting road designs or evaluating bids (Adams and Kang ٢٠٠٦; Stenbeck ٢٠٠٤). Unfortunately, life-cycle cost analyses are still of less importance in bid evaluations due to, among other things, difficulties related to the absence of reliable data and methods for calculating life-cycle costs for road objects (Karim ٢٠٠٨). Lack of maintenance and investment related data is attributable to the fact that most road authorities do not have proper methods for systematic data collection or follow-up procedures regarding planning, design, construction and maintenance. Absence of reliable life-cycle cost methods is due to lack of accurate road deterioration models as well as models for calculating societal costs. Current deterioration models are based on experience and empirical models (Huvstig ٢٠٠٤). Such models can give acceptable results, if the historical circumstances are similar to future circumstances. However, such circumstances seldom exist for a road construction due to, among other things, traffic development, use of heavier vehicles and new types of tires.

Life-cycle cost analyses may in some cases result in higher investment costs. The lowest possible yearly life-cycle cost has been tested as an award criterion (Stenbeck ٢٠٠٧). This has resulted in higher investment costs, causing budgetary problems. A conspiratorial explanation, according to the same study, is that the contractors are taking advantage of the situation, trying to sell expensive solutions with long-term speculative promises that can't be verified or corrected until too late.

It is worth noting that the above mentioned life-cycle cost models have been established for structural road design as a tool for selecting the most economical solution for investment and maintenance. The geometrical road design is ignored in almost all the models despite the fact that geometrical road design, such as road alignment and road restraint systems, affects costs during the road'ns life-cycle (Freer-Hewish ١٩٨٦).

## ٣.٤ Public-private partnership projects

Road authorities aspire to develop new funding forms to bridge infrastructure funding gaps. Public-Private Partnership Project (PPP project) is a new funding form used to deal with the increasing demand for new road infrastructures (Arnek et al. ٢٠٠٧). In PPP projects, governments, or another public sector, assign the obligation to finance, design, build, operate, maintain and rehabilitate an infrastructure project to a private-sector partner (the concessionaire). The concession duration is usually ٥ to ٣٠ years. The archetypal PPP project is a build–operate–transfer project (Queiroz ٢٠٠٧). Other forms of contract are also possible, such as operation-maintenance projects. The concessionaire collects revenue from users by way of road tolls, while the balance of the revenue comes from the government. When the volume of traffic, combined with the agreed toll, do not generate sufficient revenue to cover all costs, governments must accept shared costs.

Benefits of PPP projects include increasing efficiency during the design, construction and operation phases of a project, enhancing implementation capacity, mobilizing financial resources and freeing scarce public funds for other users (United Nations ١٩٩٨).While PPP projects in the road sector only recently have been used in the United States and Europe, they are common in countries such as Chile, Argentina, South Korea, Malaysia, Chad and The Philippines (World Bank ٢٠٠٢).

basic principal of PPP projects is the consideration of maintenance aspects during planning and design, especially the influence of road design on maintenance. This will lead to increased maintenance efficiency and reduced overall costs. As the contract is awarded to the concessionaire who provides the highest value, often at the lowest cost over the term of the concession, the bidders strive to minimize the overall cost of the project, not only the initial cost for design and construction, but also the costs for operation, maintenance and rehabilitation. This leads to a solution that is not derived from the availability of funds, but is determined by what is most cost efficient (Prarche ٢٠٠٧). However, a review of guidelines developed by the World Bank (٢٠٠٢) and the European Commission (٢٠٠٤) for PPP projects shows that consideration of maintenance aspects in the planning and design process is not prioritized. Experiences from the Nordic countries and other European countries indicate that the influence of geometrical road design on road maintenance has been ignored in most of the PPP projects carried out up to now (Karim and Magnusson ٢٠٠٦).

## ٣.٥ Performance-based contracts

Performance-based contracting in the infrastructure sector means that public sector representatives and a commercial enterprise sign a contract for both construction and maintenance, or solely maintenance, of an infrastructure object. The contract terms are based on certain specified services that must be given to future users, and not for the fulfilment of technical specifications. It is the performance of the assets over the contracting period that matters (Nilsson et al. ٢٠٠٦). Performance-based contracts have mostly been used for road pavements with a span of ٤ to ١٠ years. The main reasons for using performance-based contracts are to:

- Maximize performance by allowing contractors to deliver the required service based on their own best practices and the customers desired outcome;
- Maximize competition by encouraging innovation from the supplier by using performance requirements;
- Minimize burdensome reporting requirements and reduce the use of contract provisions and requirements;
- Shift risk to contractors so they are responsible for achieving the objectives through the use of their own best practices and processes; and
- Achieve solutions which give optimal life-cycle cost.

The most important characteristic of performance-based contracts is to give contractors freedom to decide the best methods and materials based on the road authorities□ direction of road performance. Performance-based road management and maintenance contracts preserve road assets according to predefined performance standards on a long-term basis. The most challenging task is to develop performance-related specifications, which ensure that the objective is achieved as efficiently as possible. These performance-based specifications provide guidelines for the design and construction of the road project (Carpenter et al. ٢٠٠٣). Payments are based on how well the contractor manages to comply with the performance specifications defined in the contract, and not on the amount of work and services executed. According to Zietlow (٢٠٠٤), development of "right" performance specifications is a challenging task, since they have to satisfy a set of goals such as:

- Minimizing total system costs, including the long-term cost of preserving roads, bridges and traffic assets and costs for the road users;
- Satisfy road users" comfort and safety.

Introduction of performance-based contracts in USA, Australian and New Zeeland has resulted in cost reductions of between ١٠% and ٢٠% compared to traditional contract forms (Carpenter et al. ٢٠٠٣). In Latin America, ٤٠ ٠٠٠ km of the national roads are maintained under performance-based contracts. Rough estimates indicate that performance-based contracts in Latin America have resulted in cost savings of around ١٠% compared to traditional unit price contracts (Zietlow ٢٠٠٨).

There are also examples of performance-based contracts that have turned out to be more expensive than traditional contracts. A study of four performance-based contracts showed an increase in costs between ١٠% and ٥٠% compared to traditional contracts (Stenbeck ٢٠٠٧). Regarding quality aspects, studies also show different results. In Denmark, a summary from six years of experience of performance-based maintenance contracts for a total of ٣٠٠ km roads indicates that in the first year of the contracts, municipalities experienced a more frequent rate of surface renewal than the budget typically allows (Baltzer ٢٠٠٧). Experience from two performance-based contracts in Sweden shows significant road quality improvement (Ydrevik ٢٠٠٩). However, Stenbeck (٢٠٠٧) presents an anonymous case where a performance-based contract resulted in inferior quality. According to the study, unsuccessful cases could be due to lack of experience in implementing long-term maintenance contracts for road projects and absence of sufficient follow-up procedures. Despite many successful performance-based contracts, acceptance of this kind of contract is limited. According to Carpenter et al. (٢٠٠٣), the primary reasons for this can be hypothesized as follows:

- Lack of knowledge in implementing long-term maintenance contracts in the road construction sector;
- The extra work involved in developing specifications for such projects;
- Lack of research and evaluation comparing in-house maintenance with outsourced maintenance;

- Road authorities are not sure what types of projects benefit most from performance-based contracting;
- Road authorities have concerns about the ability of the contractors to manage the road over long-term warranties;
- Contractors are not willing to take great risks; and
- Road authorities are concerned about losing their knowledge base.

An evaluation of the above presented studies of performances-based contracts do not give any reason to believe that the interrelationship between geometrical road design and future maintenance measures has been sufficiently considered.

## ٤ Discussion & Conclusion

To face road infrastructure gaps, road authorities have continuously made efforts to increase efficiency, especially maintenance efficiency. Some of these efforts have resulted in reduced costs. However, in some cases, such as outsourcing of maintenance contracts, it seems that sometimes standards have deteriorated. In the ambition to increase maintenance efficiency, focus often has been on cost-cutting through reducing the recurrent rate of maintenance activities, prioritising some measures before others, e.g. the prioritization of winter maintenance, cleaning and grass mowing over bridge and pavement maintenance. Road authorities should consider such efforts as cost-savings rather than an increase in efficiency as the definition of efficiency is to get more value from the same resources or to get the same value from less resources. This might explain why some efforts to increase maintenance efficiency have been less successful.

Implementation of performance-based contracts, PPP projects and life-cycle cost analyses requires the consideration of maintenance aspects during the planning and design phase. However, in almost all the projects and literature evaluated in this study, focus has been on structural design, such as pavement design, rather than geometrical design. In guidelines for these types of contracts, recommendations to analyse the influence of geometrical design on maintenance are seldom considered. Despite this fact, performance-based contracts and life-cycle cost analyses have, in many cases, resulted in reduced maintenance costs and improved road structure quality. However, these contract types and analyses are still uncommon in the road sector owing mainly to a lack of knowledge in implementing long-term maintenance contracts and poor follow-up procedures for these contracts. The bidders have perceived a higher risk and the contracts have been more expensive than traditional contract forms (Stenbeck ٢٠٠٧). There are also reasons to believe that road authorities in many cases have used performance-based contracts and PPP projects only to transfer risk to the contractors and to obtain a financing partner.

One of the most important characteristics of performance-based contracts and PPP projects is to give the contractors freedom to decide upon the best design and construction method and materials for the road project. In some cases, especially in PPP projects, this can be difficult, since the concessionaires are often foreign companies with a limited experience of risks and conditions existing in a specific country. In these cases, contracts may become more expensive than traditional contracts as the concessionaires are taking higher risks. In the long run this could lead to poor competition in the infrastructure market, as only large actors will have the required knowledge and resources for these contract types. In addition, road authorities may lose valuable knowledge, if only contractors prosecute technological development.

It is obvious that road authorities have mostly emphasized reducing costs in the construction or maintenance stages, instead of in the design stages. According to Emblemsvåg (٢٠٠٣), such emphasise leads to a reactive cost management, as opposed to reducing costs before they are incurred; proactive cost management. Reactive cost management is insufficient as ٨٠% of the total costs for a product are committed to the activities prior to production. Many organisations or companies realize this fact but still employ reactive cost management. Emblemsvåg (٢٠٠٣) claims that this might simply be a matter of bad habits or that people dislike learning new things, unless the consequences of not learning are worse than those of learning.

All maintenance efficiency attempts evaluated in this study have one thing in common, namely ignorance of the interrelationship between geometrical road design and maintenance as an efficient tool to increase maintenance efficiency. Focus has mainly been on improving operating practises and maintenance procedures. This might also explain why some attempts at increasing maintenance efficiency have been less successful. Ignorance of maintenance aspects during the planning and design process is a well-known issue. However, there are very few studies published concerning the underlying factors (Freer-Hewish ١٩٨٦), which is confirmed in this study by the limited amount of literature found. This fact was the reason for conducting a study highlighting the problems and difficulties preventing due consideration of maintenance aspects during the road planning and design process.

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