

A MULTI OBJECTIVE FRAMEWORK TO OPTIMISE PLANNING OF ROAD WORKS.

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ABSTRACT

Road maintenance is required to keep roads in acceptable condition. However, with increasing traffic volumes and decreasing spare capacity, maintenance has more frequent and more severe impacts on society. These impacts involve both traffic obstructions and traffic externalities, together defined as traffic hindrance. Road agencies are currently facing the problem of coping with traffic hindrance on a network level. Effectively estimating traffic hindrance is essential to accurately schedule and perform maintenance with reduced traffic hindrance. To assist road agencies in deciding on maintenance method, traffic management and scheduling, we aim to develop an infrastructure management system that provides the trade-off between total costs and traffic hindrance. The system is based on our theoretical framework that defines the relationships between road maintenance characteristics, traffic effects, maintenance costs and traffic hindrance for any single road maintenance project. The framework is based on a combination of state-of-the-art research in the fields of road construction, traffic modelling and impacts on society. This innovative approach aims to evaluate the balance between the key objectives total costs, pavement quality and traffic hindrance. Major decision variables include pavement material, maintenance method and traffic management. To evaluate maintenance strategies for multiple projects and a longer time period, scheduling is added as decision variable.

Keywords: traffic hindrance, road works, planning, road management

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1. INTRODUCTION

The use of the Dutch infrastructural network has substantially increased during the last few decades. As a result, road maintenance is required more often. This puts a strain on the availability of the road network for motorists and for road works. In the Netherlands, as in other densely populated areas, next to throughput, much attention is given to the externalities of traffic, such as noise, air quality and traffic safety. This also holds in case of road works, where there is a specific focus on hindrance and nuisance. Different factors may influence these, such as: the way the work is executed and the way traffic management measures do guide the remaining flows as good as possible through the network. Nowadays, limitation of traffic hindrance and nuisance is part of the tender procedures. The EMAT (Economically Most Advantageous Tender) principle [1] is implemented by the national Dutch authorities in order to create fair competition between contractors. However, within road construction projects, not only quality of the road works in terms of improvement of the road pavements is important, but also the road space needed for constructing the road works during a defined time slot (with a certain amount of hindrance and nuisance as a consequence). The costs of a project are determined not only by road engineering aspects but also traffic engineering and even a bit of psychology are relevant. The balance between all those variables is crucial in planning road construction works in the right manner, at the right time and in good co-operation with all stakeholders.

The focus within the University of Twente project “*Road management with limited hindrance and nuisance*” is to find a balance between acceptable costs of road building projects, quality improvement that those projects will realize and the amount of traffic hindrance and nuisance that those projects will cause (provoke). This paper discusses a theoretical framework (fig 1), where for each road maintenance strategy for a certain region cost and impact on traffic flows and, as a result, the effects on externalities can be determined. This framework can then further be used to determine road maintenance strategies that perform best. Costs are determined using regular methods used in the research area of road maintenance. The impact on traffic flow is determined using the altered road network in combination with management measures that may influence travel demand and traffic behavior. For this the well known four-step model that is generally used in transport planning [2] is used. Thus the framework consists of three main parts:

1. cost of road maintenance,
2. impact on traffic flows of the combination of road works using traffic and demand management,
3. externalities with emphasis on objective and subjective traffic hindrance and nuisance.

During the project both traffic and road engineering aspects are topic of study. This is a topic of interest for both traffic engineers and road engineers. We therefore explain both aspects in a detailed manner.

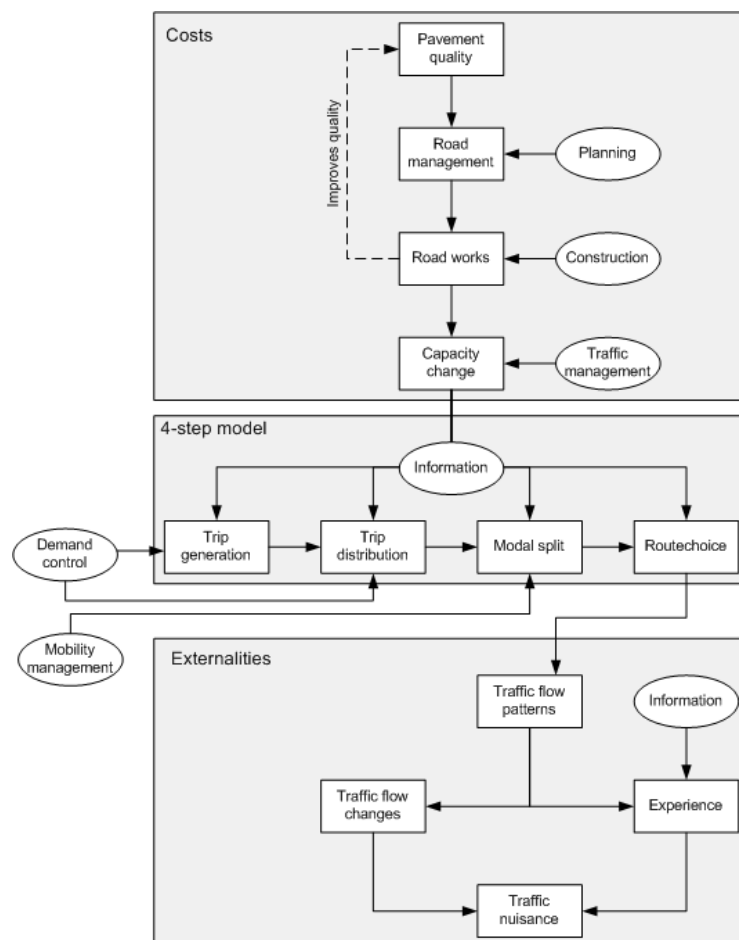


Figure 1: The developed theoretical framework.

Definition:

In this article we often use the words (traffic) hindrance and (traffic) nuisance. With hindrance we mean that a part of the road is blocked or the road is completely blocked. Compared to a “normal situation” there is no traffic or limited throughput. With nuisance we mean all external effects or externalities as a result of limited or changed traffic patterns, not only at the location of the roadwork, but for the whole infrastructure network

2. THEORETICAL FRAMEWORK

2.1 Road maintenance

The transport network is a public private commodity; it is of high value for society and it represents a huge capital investment. To be able to keep the value of this commodity at a high level it is important to properly maintain this in order to avoid capital loss by poor functionality of the system. If the quality of the road network can be kept above some predefined threshold level, safe traffic and transport will be possible and accessibility will be ample. This can only be achieved by a sufficient level of road maintenance. As a result maintenance is included in the theoretical framework which is shown in figure 2.

2.1.1 Road management and maintenance

The starting point within the proposed theoretical framework is the quality of the pavement. Most administrations base their strategy for road maintenance on the present state of the pavement (condition based maintenance) and the importance of the pavement within the road network [3]. Especially the network structure and its robustness are important to consider in determining a maintenance strategy. The network robustness provides a way of prioritization (see for instance Scott et al. [4]), in which critical links need more effort in mitigating traffic hindrance. Based on such a maintenance scheme we can then look at several strategic or policy options to restrict traffic nuisance. The “Planning” consists of a series of road works, including the time of execution and the pavement material (e.g. concrete versus asphalt). These are the decision variables in relation to the road maintenance. Following this planning a maintenance strategy can be derived, where for each location the frequency of maintenance is included. Both CROW [5] and the European Concrete Paving Association [6] have concluded independently from each other that concrete pavements do last longer and need less maintenance compared to asphalt. Verra [7] states that the average lifespan for concrete pavements is about 30 years whereas the lifespan for porous asphalt is about 12 year (top layer) whereas the lifespan for dense asphalt concrete layers is about 20 years (although this carries disadvantages with regards to noise reduction). This implicates that when choosing concrete as pavement material major re-construction works are needed less frequently, resulting, off course, in less frequent hindrance and/or nuisance.

Maintaining infrastructure pavements can be done cyclic or condition dependent (choosing one or the other as part of the maintenance strategy). Cyclic maintenance is planned maintenance in a fixed frequency. Between two periods of maintenance there is no road works (except emergencies) and thus no hindrance and/or nuisance. Cyclic maintenance makes it possible to plan different road works within a network in such a way that the nuisance is acceptable. BB&C studied in 2008 three cases of maintenance at motorways. Among others, the study focused on the differences between cyclic and condition based maintenance. The conclusion stated that there is no big difference in costs when costs are compared between cyclic maintained pavements and condition based maintenance [8]. During that study subjective nuisance was not taken into account. Cuelho [9] concluded in his study that inside the US almost no pavements are maintained “cyclic”. This means all the road works are planned based on condition.

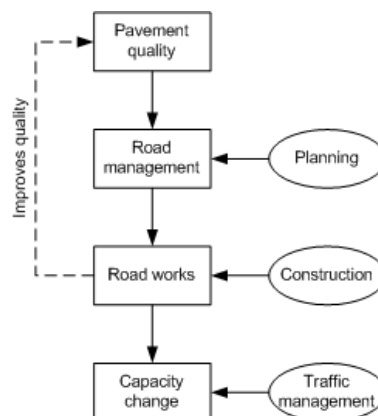


Figure 2: The road maintenance part of the theoretical framework.

2.1.2 Doing Road Works: The construction phase.

Based on the maintenance strategy, road work projects are planned for a specific time and place. During the construction phase there are possibilities to reduce traffic hindrance and/or nuisance. This can be done by choosing the most appropriate way of construction given the condition of the road and also considering the desired level of throughput of the road link [10, 11]. Taking this into account, the way the project is executed can be seen as a decision variable. By choosing a specific method of construction one can tune on the amount of remaining traffic throughput, which also determines the level of service of the remaining traffic flows. Choosing the method of construction means; deciding on the amount of equipment needed, planning (management) of phases and choosing construction methods and/or procedures and work hours, day or night. In practice the construction method and traffic management are designed simultaneously to ensure minimum hindrance and cost, and maximum throughput.

The main aspects of maintenance operations are: location, time, costs and effectiveness. Each measure has its own impact on throughput itself but also safety margin is needed as well as construction time and sufficient budgeting [12]. The result of such a measure is improvement of the actual quality and the life span of the pavement [10].

Within the framework we calculate the changes in capacity of the road link based on construction site and construction duration. For realizing work and safety space part of the road/lane must be used. Roadblocks and hindrance are in this case unavoidable. This statement proves that both variables 'workspace and mobility management and regulations regarding safety' are strongly interdependent [5]. The framework can calculate the traffic effects and traffic nuisance based on the final choice of the construction measure as well as predicting costs and effectiveness. The framework is a tool or a model that may help in deciding what the best construction measure should be (costs and effectiveness) in relation to acceptable traffic hindrance and/or nuisance, in other words: *"acceptable nuisance in combination with a usable construction manner"* [13]. ``

2.2 Traffic effects during road works

2.2.1 Infrastructure capacity during Road Maintenance

In order to maintain and/or improve our infrastructural network, room to work and an extra safety margin will be needed during the duration of road maintenance works. That in itself reduces the traffic capacity of the road network. Capacity reduction takes place just along or on the road link under construction. A complete road block will obviously reduce the capacity to zero, whereas roadwork on the shoulder reduces the road capacity only in part [14]. The use of traffic measures and traffic management affects the capacity of the network both at the location of the road works as well as at other places within the network. For motorways this has been studied extensively [15–17]. On secondary roads, however, much less is known about capacity reduction as a result of road works on traffic capacity is not known at all and expertise is very limited. Discussion with road authorities indicates that on secondary roads, when road maintenance must be carried out, a complete road block is necessary most of the time for safety reasons. In our research we are proposing to use a theoretical framework in order to estimate hindrance as a side effect of road works. Part of that framework consists of the four-step model set out below. However, a change in traffic capacity as a result of road works, will be used as input for the traditional four-step model [2]. A part of the four-step model, the so-called traffic effects, are illustrated in figure 3.

2.2.2 The four step model;

The four-step model consists of: Trip generation, Trip distribution, Mode choice and Route assignment. The layout of the infrastructure road network is important input for the four-step model. The availability of the network and its individual links determine [2]:

- Does a traveller make a trip (Trip generation),
- Where does the trip go (Trip distribution),
- Which transport mode is used (Mode choice), and,
- What route is used (Route assignment).

In the first step travellers decide to make a trip or not. In the second step for each origin travellers that have decided to make a trip choose a destination. Then, in the third step it is decided which type (mode) of transport to use, and in the final step, routes are chosen and the network is loaded with trips. The decisions that are taken depend on the socio-economic characteristics of the origin and destination zones, and the people in these zones, in the network characteristics, and the costs and travel times that are linked to each of the choice alternatives such as route or modes. Under regular circumstances (no road works, no road blocks) it is assumed that the transport system is at equilibrium which means that no traveller can improve his or her own situation by unilaterally changing route. Once road construction is taking place this situation may no longer hold. It will very much depend on the impact on capacities in the network [22], on the provision of information and on additional traffic measures how travellers will respond.

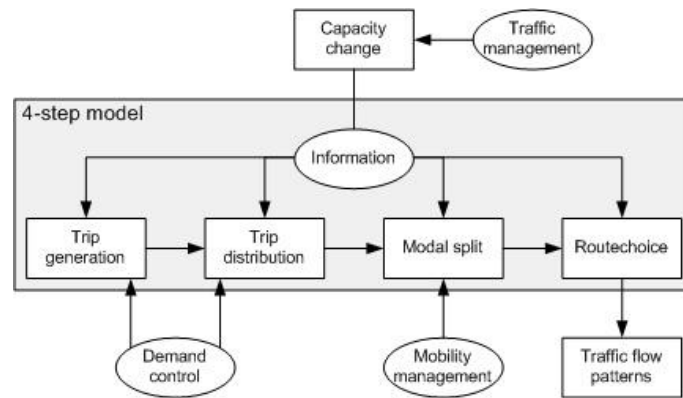


Figure 3: The four-step model.

During the period 2003-2007 major reconstruction works at the highway A10 west haven been executed. This concerns the busy infrastructure corridor around Amsterdam in the Netherlands [19]. This was an unfamiliar traffic engineering strategy until that moment; the variables “influence demand” and “Mobility management” were implemented to make road users travel different routes and/or to motivate people not to travel at all. Major road works were planned at the A9 Gaasperdammerweg and the A4/A10 –junction going south. This was one of the first cases in the Netherlands where, on this level and in this manner communication was applied to inform potential road users and the effects where enormous. Thousands of day-to-day travellers changed their travel behavior resulting in less trips, different routes and different mode choices. It is not completely clear where all the traffic did go but the fact remains, that within this congested area with a large amount of daily traffic jams the traffic jam situation was acceptable during this major road work reconstruction [19, 20]. Effects of the variables traffic information, traffic influence demand and mobility management resulted in different choices in route assignment and, as a result of that, traffic patterns. This also proved to be the case during the road works on the A9 and A4/A10 around Amsterdam and similarly it was proved that users did follow pre-described routes and/or alternative detour routes.

The existence of detour routes and rat-run traffic are examples of changed traffic patterns. Evaluation of the complete roadblock during road works at the N50 Hattemerbroek – Kampen-South showed that over large distances detour routes are mostly not followed. Instead local detours and alternative local routes are chosen [21]. Changing traffic patterns and the results of road works altogether are a source of traffic hindrance, and thus the four-step model can be useful in studying and forecasting the results of traffic hindrance.

2.3 Road works externalities

2.3.1 Traffic hindrance and nuisance

Traffic patterns and changes thereof can objective been measured. Changes of traffic patterns as a result of roadworks may provoke traffic hindrance and/or nuisance. Because these can be measured clearly we can speak of objective traffic nuisance. Apart from objective traffic nuisance we can also determine that there exists a subjective component of traffic hindrance [23]. The severity of traffic hindrance depends on the manner in which people experience hindrance. However, that experience may be affected by additional measures such as the provision of information. In particular when travellers are informed about upcoming traffic problems they may be able to change their behaviour as modelled in the four-step model.

Subjective hindrance, however, is in relation to, objective hindrance, not easily measured. Objective and subjective traffic hindrance together form traffic hindrance. It is possible that people experience hindrance where we are not measuring (objective) hindrance at all. Vice versa it is possible that we measure hindrance but we do not observe subjective hindrance [24]. In figure 2 we illustrate the variables objective and subjective hindrance and the relationship with other variables within the theoretical framework. These variables and links together with the four-step model form the components of our theoretical framework.

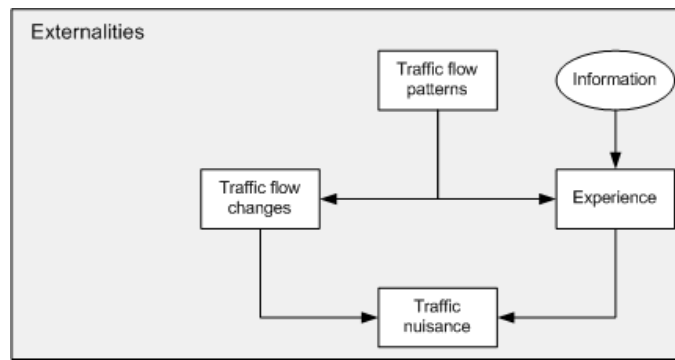


Figure 4: The externalities as an output from road works and traffic management.

2.3.2 Objective traffic hindrance

Objective traffic hindrance can be determined at three levels. The first level is the link or network based. Hindrance can be determined based on traffic volumes, speeds or traffic densities. Evaluation of traffic patterns are typical measurements on this level [19]. The second level is traveller based. Indicators for hindrance on this level are; travel times, travel distance and travel delays. Rijkswaterstaat's hindrance categories, make use of that particular level which measures the delay per minute or time used to travel the detour. The third level is area based. Here, for the whole area externalities such as traffic accessibility, traffic safety, air quality, noise and economical effects are determined [25].

2.3.3 Subjective traffic hindrance

Subjective traffic nuisance results in complaints and dissatisfaction. Complaints **are** directed to the main road authority, the contractor (if applicable) or the media [26]. Currently there is not a reliable indicator to quantify subjective traffic nuisance. Often we use information provision (to the traveller) as a decision variable [24]. Public information management, for instance, has been shown to improve the involvement of companies near work zones [27]. However, the experience of traffic nuisance depends, apart from others, on information provision about the hindrance (accurate and timely), credibility of the administration and/or road contractor, duration of the road block, time and location of the disturbances. Experiencing hindrance also depends on personal characteristics of the concerned individuals. The latter factor may be the reason that subjective traffic nuisance is experienced differently sometimes substantially so, from one individual to the next individual as is also the case for e.g. noise nuisance [28, 29].

Experience of traffic nuisance can also differ from group to group; motorists, residents, contractors, service suppliers and public transport companies. These groups each have their own experience of nuisance [26].

On the one hand more and more use is made of objective traffic nuisance to classify the effects of road works, whereas on the other hand heavily is being invested in affecting the experience of nuisance by way of information services and communication with travellers and/or residents. In practice both types of nuisance (objective and subjective) have not been coupled yet. However, at the moment we are using Best Practice and decide at each situation what the best approach will be [13, 30].

By applying various measures we try to influence the experience of nuisance in such a way that motorists and residents have an understanding of the actual nuisance to avoid annoyance. Examples of these measures are; raising the speed limit in lanes next to the road works from 70 to 90km/u, use of signs and variable message signs with information of the road works and avoiding long static roadblocks without any visible activities. On time and accurate information services before but also during road works does create better understanding of the road works [26].

2.4 Application of the developed framework

The developed theoretical framework does contain the following six process steps which are related to the framework decision variables:

1. The way of planning of road maintenance,
2. By what method construction work will be done,
3. Traffic management,
4. Manipulate the level of trip generation and/or trip distribution,
5. Information on expected travel times, road blocks and re-routing,
6. Mobility management on mode choice.

The road administration should use the framework to optimize their planning with regard to (expected output):

- a. quality improvement of the physical infrastructure,
- b. availability of the infrastructure in time, and,
- c. satisfaction of the client (motorists and neighbours).

Each combination of choices of the variables related to a (combination of) road work(s) is leading to an output in costs, improvement of construction quality and externalities (e.g. hindrance and nuisance). Together, road administrations and contractors, are challenged to tune the measures related to the road works and traffic management in such a way that concerning the output variables an optimum exists. Such an optimum would preferably include; a. a rise of road construction service level, b. acceptable costs, and c. acceptable level of externalities.

The proposed theoretical framework assists the exploration of the possible effects of choices during planning of road works in combination with possible traffic measures. Some relations between process steps and decision variables are clear and can be quantified. Other links, however are not clear enough, not clear at all and/or causality can even be dubious. Within the UT project "*Road management with limited hindrance and nuisance*" our target is to further clarify and quantify those links during additional projects.

Current projects within the UT research theme "Road management with limited hindrance and nuisance" are:

- a. Matching/coordination of different road works over the infrastructural network in time and place,
- b. Exploration of the effects of traffic management on traffic flow patterns, and,
- c. Study of the causality between subjective traffic nuisance and objective traffic hindrance.

3. CONCLUSIONS

- As a result of the road management maintenance strategy one can plan road works cyclicly or condition dependent. BB&C Shows that cyclic planning of road works will not increase the costs dramatically while planning road works in this manner also reduces the hindrance and nuisance.
- Within the theoretical framework the well-known four-step model plays a central role. In fact our? theoretical framework exists out of two extensions of the four-step model; one before the four-step model and one after the four-step model. Within the theoretical framework, there are three decision variables related to the four-step model in combination with road works:
 - a. demand (traffic) control related to trip generation and trip distribution,
 - b. modality management related to mode choice, and
 - c. information relating to all steps of the four-step model.
- The first extension before the four-step model deals with management of road maintenance. Road maintenance is unavoidable to keep pavements in good shape but reduces the capacity of throughput. The results of choices made in this stage deduce the remaining capacity over a time period. Within this part of the framework/model we see three decision variables:
 - a. "planning of road works"
 - b. "construction of road works", and
 - c. "traffic management".
- The second extension of the four step model, deals with changed traffic flows as a result of road works; objective traffic hindrance, subjective traffic nuisance and the final outcome; total traffic hindrance and nuisance. Within this part of the model we can only give information to the client to deduce the experienced effects of subjective nuisance.

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