Svante Johansson

SOCIO-ECONOMIC IMPACTS OF ROAD CONDITIONS ON LOW VOLUME ROADS

Results of literature studies, interviews and calculations with a model

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ROADEX II
NORTHERN PERIPHERY

SOCIO-ECONOMIC IMPACTS OF ROAD CONDITION ON LOW VOLUME ROADS

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October 2004

Svante Johansson
Roadscanners Sweden AB

PREFACE

This is a report from Phase II of the Roadex II project, which is a technical transnational cooperation project between the Highland Council, the Western Isles Council, and Forest Enterprise from Scotland; the Northern Region (formerly Troms district) of the Norwegian Public Roads Administration and the Norwegian Road Haulage Association; the Northern Region of the Swedish National Road Administration; and from Finland the Regions of Central Finland and Lapland of the Finnish Road Administration, as well as Metsähallitus Region of Eastern Lapland, the Forestry Centre of Lapland (Lapin Metsäkeskus), Stora Enso Metsä, and Metsäliitto, Procurement Area of Northern Finland. The Roadex project is partly financed by the Interreg IIIB Northern Periphery Programme. The lead partner in the project is the Highland Council from Scotland and project consultant is Roadscanners Oy from Finland. The Roadex II project Chairman is Ron Munro from the Highland Council and project manager is Timo Saarenketo from Roadscanners.

Many people have contributed to this report. From Sweden I want to thank Jaro Potucek, SNRA, for good discussions, approval to use SNRA's socio-economic model and interesting reports. From Finland I want to thank Pertti Virtala, FinnRA, and the two consultants Vesa Männistö, Inframan OY, and Juha Äijö, 100 Gen OY for interesting meetings and important facts for my report. In Norway I want to thank Geir Berntsen and Kjell Solberg, NRA, for valuable information about the Norwegian conditions. From Scotland I like to thank Richard Evans and his staff and Howard Brindlay, HITRANS, for interesting meetings and many interesting reports. From Western Islands I want to thank Ralph Schackleton and David Smart, WIC, for interesting information and nice photos.

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Mika Pyhähuhta from Laboratorio Uleåborg designed the graphic layout.

Roadex II Lead Partner: The Highland Council, Transport, Environmental & Community Service, HQ, Glenurquhart Road, Inverness IV3 5NX Scotland, Project co-ordinator: Mr. Richard Evans.

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ABSTRACT

One task in the Roadex II project, which is a co-operation project on low volume roads in the Northern periphery of Europe, part-financed by the European Union, is to examine the socio-economic impacts of the road conditions on low volume roads. Regional road administration bodies in Scotland, Norway, Sweden and Finland participate in the project along with regional industries, such as forest industries and fishing industries. The aim is to get better understanding of the importance of having good road conditions for people, companies and societies in rural areas, which are dependent on the low volume roads. In many cases these roads are lifelines for people and societies.

Low volume roads in rural areas are often in bad condition. Traditionally the road conditions on low volume roads have been neglected. The main reason is the economic resources, which are insufficient to cover all the needs. But there are also other reasons why the low volume roads are kept back in the road maintenance programs. Available socio-economic models to describe the maintenance need, normally deal with road user costs consisting of time delay costs, vehicle costs and accident costs. But as the amount of traffic always is the dominating figure in the calculations, the models will favour a very good condition on high volume roads and only keep the low volume roads alive. That will give the highest benefits for the society with the existing models. To change this, in order to give people living in rural areas better life conditions, there is a need for new thinking to find alternative ways to describe the significance of having good road conditions especially in the rural areas.

Socio-economic impacts have to be considered in a wider context. There is a need to take a closer look at the social improvements for people living in rural areas if the road conditions are improved. Reports from the World Bank have identified the need for new socio-economic models with focus on social welfare and social development together with economic development, besides the normal road user costs consisting of accident costs, time costs and vehicle operation costs. A Swedish report about road users' willingness to pay for better road conditions shows that road users are prepared to pay extra to ride on better roads.

Socio-economic considerations in road management can be taken in different ways:

- Socio-economic models can be used
    - to justify budget levels on road network level
    - to select maintenance project
    - to choose between different maintenance alternatives
- Policies can be used to aim for a certain road condition standard level, e g
    - specified target limits for properties like roughness, rutting and bearing capacity, used for instance in routine maintenance contracts
    - lowest acceptable road condition on certain properties, so called "shame values"
    - aims for practicability.

A survey was done to map the socio-economic considerations taken by the road management of the partner countries involved in the project. The survey was done by meetings and an enquiry following an agenda shown in Appendix 1.

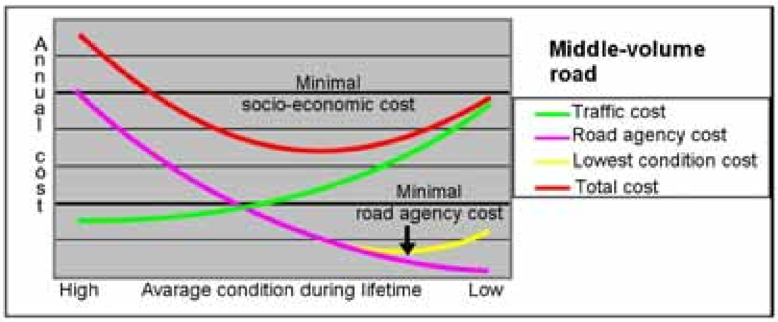

Figure. Principles for minimising the socio-economic costs for road maintenance (2).

In **Sweden** the Road Authorities have used socio-economic models to motivate budget need in the discussions with the Transportation Department. The budget level should be high enough to keep the total costs for the society at the lowest possible level on long-term basis. The total costs are the sum of the road manager costs for maintenance and rehabilitation, and the road user costs as shown in the figure above. Another model, described in this report, has been used to compare different maintenance methods and maintenance strategies on network and project level. A model has also been used by the forest industry to show the need of better roads to be competitive. The model is briefly described in the report. Work has been done by the Swedish Road Administration to form a standard for road condition, but it has not yet been finished. Certain target standards are given regionally in the routine maintenance contracts. Regional policies are also used to limit the temporary load restrictions used at spring thaw.

In **Norway** the socio-economic model HIPS is used to find the optimal long-term road condition. That is when the total costs for the society are the lowest. The total costs are the sum of the road manager costs to maintain and to improve the road condition, and the road user costs. In this case the road user costs are time costs, vehicle operation costs, accident costs and the costs caused by road works. HIPS works only on road network level and can also be used to distribute the budgets between different road classes and Road Managements Regions. Recent measurements have shown that the road condition in Norway today is somewhat worse than the goals defined by the Road Administration and that an increase in the road maintenance budgets is needed to reach the long-term socio-economically optimal road condition.

For routine maintenance contracts a national road condition standard is developed to be used as “trigger values” for maintenance actions. In Norway there are no temporary load restrictions at spring thaw. They were abolished in 1995 as a result of a big survey. Efforts have been made to find a socio-economic model for drainage condition but so far no model has been found or developed.

In **Finland** the Road Management uses a socio-economic model named HIPS to motivate money from the Ministry and to allocate money for the Regions. HIPS is used to calculate the road conditions on network level, which give the lowest total costs for the society. There is no special attention paid to the low volume roads in rural areas in the model. In meetings with FinnRA and a couple of consultants (15) though a couple of encouraging things were found:

- There is work going on to get another view over the influence of the road condition on the whole society, which might change the view of the low volume roads.
- There is work going on to develop socio-economic models for gravel road management.

These things can be of greatest interest for ROADEX. Findings in that work might be useful to improve the budget allocation for low volume roads and thereby road conditions in rural areas.

It has been found that there are four administrative levels, which have to be influenced if a real change in view of the low volume rural roads shall be a reality:

- The Parliament
    - Making the state budget
- The Ministry of Transport and Communications
    - Making general guidelines and targets for state agencies
- FinnRA’s Central Administration
    - Making targets for Regions, policies and allocation of funds
- Regional offices
    - Making programs of paving works and replacement investments with the related funding.

Information is needed on all these levels to influence the decision makers.

In a few cases in Finland paved roads in very bad condition and with very high maintenance costs have been changed back to gravel roads again. This is an extraordinary measure, which might be of benefit for the road users.

For the moment socio-economic models are not used regularly in the Road Maintenance Management in **Scotland**. When it comes to new investments in Transportation Infrastructure it is quite different. Then there is a requirement for a socio-economic survey as the basis for the final judgement of the investment candidates.

Much work is done in Scotland to find ways to preserve and develop small communities in rural areas. Fragile areas have been identified by means of properties like population density, long term unemployment and income support. An interesting project run by the Scottish co-operative transportation organisation HITRANS is named "Investments in lifeline rural roads". The definition of a lifeline road is "A transport link which has no substitute, or where the substitute entails a considerable increase in time or money expenditures, where any diminution in the quality, reliability or availability of the former, is likely to have a significant impact on the social or economic viability of an affected community." In the project nine key roads were identified as possible candidates for improvement. The candidates served areas of Highlands and Islands that suffer from varying degrees of economic and social deprivation. The appraisal of each road was carried out according to the Scottish Transport Appraisal Guidance (STAG) with complete analyses of Transport Economic Efficiency (TEE) and Economic and Locational Impacts (EALIs). Several of the selected roads were considered not to be in a 'fit-for-purpose' condition to offer a reasonably good accessibility to give sustained economic and social prosperity in the served societies. An upgrade in the road condition is needed to provide long-term sustainability. The economical analyses have shown that the benefits in a few cases are sufficient to cover the costs calculated over a period of 30 years. Additionally many of the proposed road schemes will give indirect benefits like increased employment, reduced transport costs and better accessibility to markets and customers.

In a research project on Scottish forest gravel roads the HDM 4-model has been used to evaluate different methods for gravel road maintenance.

There is also a need to look at the **health impacts**, especially for professional drivers, if rural roads are left to deteriorate. The conclusions from Swedish research reports are that the major impacts on body vibrations of drivers are caused by the road surface irregularities. The vibrations vary depending on e g vehicle type, type of suspension, speed and wavelength of the roughness. It is found that uneven road surfaces are a probable reason for elevated risks for disturbance of the body movement mechanisms on professional drivers. The costs for the society from health problems caused by uneven road surfaces are not yet possible to calculate, but should be kept in mind as extra costs when calculating road user costs. Based on the results from a field study and a literature survey a "shame level" for the roughness expressed as IRI is recommended. The recommended value as an average of 20 m is $IRI_{20} < 3$ mm/m.

The **conclusions** are that much work has been done and is going on in the socio-economic area in the partner countries. Target standards for the general road conditions and lowest acceptable standards are more or less expressed and socio-economic models are used for budget discussions and budget distribution. But for the low volume roads there are still much work to do.

It is **recommended** to follow the Scottish example to sort out the fragile areas of the partner countries. Then to define the lifeline roads which are of critical importance for the people in the rural areas. This should be demonstrated to the politicians and used in the budget negotiations with the Transportation Departments in the partner countries to have an increased understanding for the low volume roads. Then the lifeline roads should be treated with special care in the maintenance and rehabilitation programs.

It is also recommended to try to find a common standard for "shame levels" of the road conditions in the partner countries and to improve the models to better fit also the low volume roads.

KEY WORDS: Health Impact, Low Volume Roads, Road Condition, Roadex, Socio-Economic Impact, Socio-Economic Models.

1 Introduction

1.1 Project overview

This report is a part of the project Roadex II, which is a co-operation project on low volume roads in the Northern periphery of Europe (see figure 1), part-financed by the European Union. The aim of the Roadex II project is to develop ways for interactive and innovative road management on low volume roads in the Northern region of the European Union. Regional road administration bodies in Scotland, Norway, Sweden and Finland participate in the project along with regional industries, such as forest industries and fishing industries.

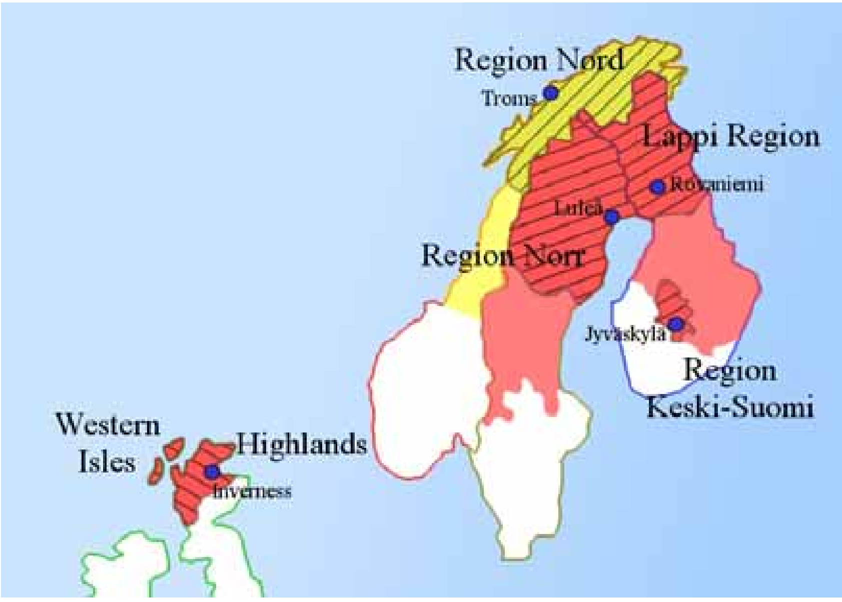

Figure 1. Geographic project area.

The Roadex II project, which continues the work of the pilot Roadex I project 1998 – 2001, is divided into three phases, which are partly carried out at the same time. The three phases are

- Phase I – identification of problems, fieldwork,
- Phase II – analysis of problems and identification of their reasons; and
- Phase III - new innovations and their testing.

Phase I includes field tests in at least one selected small area in each participating country and a questionnaire was sent out to find out the road user comments of the roads in the selected areas.

Phase II included 7 different tasks:

- Permanent deformation
- Material treatment
- Spring thaw weakening
- Socio-economic impact
- Peat roads
- Drainage
- Environmental guidelines.

This report is a result of the task **socio-economic impact** in Phase II.

And finally Phase III includes the following tasks:
- Basis of Road Management Policies
- Tools for focussing Actions
- Structural Innovations
- Monitoring communications.

Roadex II was started in 2002 and will be finished during 2005.

1.2 The concept Socio-Economic Impact

Usually when talking about socio-economic impact in relation to road condition we are looking at costs for road users and road managers. The road user costs are related to the road conditions. A road with high roughness and rutting causes bigger costs than an even road. To keep a road in good condition will cause costs for the road manager like rehabilitation costs and costs for normal and routine maintenance. The road managers are aiming for minimising the total costs, which are the sum of the road user costs and the road manager costs. This can be done by using different types of socio-economic models dealing with **cost-benefit analyses** (CB-analyses). Most of these models are working on road network level and are not suited to the low volume roads. In the Northern Periphery of Europe we are dealing in most cases with low volume roads in rural areas and in cold climate, so the currently available models will not be useful to give good road conditions. Therefore there is a need to look at other complementary methods and models to justify a good road standard also on low volume roads. In this case there is a need to lay stress upon the social benefits of keeping roads in rural areas in good condition. The social benefits though are often very difficult to measure in monetary terms.

Different policies and strategies can be used to keep roads in a proper condition. One policy can be to introduce minimum road condition levels on different parameters like roughness and rutting, sometimes called “shame levels”. These levels can be defined from comfort considerations and road user costs. They can also be defined locally from social considerations for people living in rural areas. They normally have a long way to go for public services, cultural events and all other needs. If the roads are in bad condition travel will be both long and uncomfortable. The levels can also be defined from professional drivers’ work environment requirements. The levels can be included in the Pavement Management Systems and be used to select maintenance candidates. They can also be included in the road maintenance codes and in the routine maintenance contracts.

Depending on the reasons mentioned above we will give the concept **socio-economic impact** a wider meaning in this report. We will examine the prevailing methods and models used today in the literature and in the member countries and try to sort out the good parts, which promote our aims.

1.3 Description of the problems justifying the Task

Bad road conditions will create big problems and costs for the society but it is not so easy to show the magnitude of these costs compared to other needs in the society. The budgets for road maintenance and rehabilitation will be allocated in competition with other sectors in the society like medical attendance, education and social welfare. The budgets also have to compete with other budgets for other transportation alternatives like railway and air transportation. When it comes to low volume roads it is very difficult to find economic motives to justify good road conditions. In the budget competition they have to fight the resource need for maintenance of high- and medium trafficked roads in urban and rural areas.

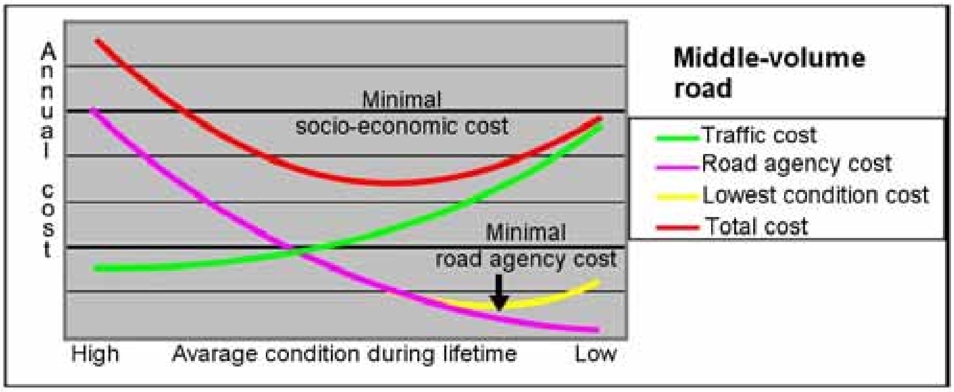

Figure 2. Principles for minimising the socio-economic costs for road maintenance (2)

Conventional socio-economic models for road user costs will generally not include costs and benefits for comfort, influence on the social life and for influence on industrial production and investments. These types of costs and benefits are difficult or sometimes even impossible to calculate. The road user cost (RUC) models usually deal with accident costs, vehicle operation costs and travel time costs. Traffic is a significant factor affecting the road user costs. A big improvement of the road condition on a low volume road will give a small reduction in road user costs for the whole society. A small improvement on a high trafficked road will give a big reduction for the whole society. An optimisation of the socio-economic costs on network level will minimise the total annual costs consisting of road manager costs and road user costs (see figure 2). A network model will therefore give priority to good road conditions on high trafficked roads to keep the total costs on the lowest level.

It has been shown in different World Bank reports, that normally cost-benefit analyses for investments in transportation infrastructure are insufficient to give correct rate of return. The reason is that benefits from increased social welfare like improved possibilities for attending schools, health- and other services are not included. Other benefits which are omitted are increased dissemination of knowledge and technology, increased market competition, increased possibilities for starting business like tourism and thereby possibilities for creating new jobs. One example describing other ways to show benefits from road investments is given by Canning and Bennathan (1). They have estimated social rates of return to paved roads by looking at their effect on aggregated output and comparing this to their costs of construction. Then by a statistical approach they have compared rate of return from road investments with rates of return from other capital investments. They found that in most countries the rate of return from road investments is in par with or lower than other capital investments. In some middle-income countries though they found proof that road investments generated very high rates of return. These high rates seem to follow after a period of economic growth when investments in roads have been lagged behind investments in other capital.

Anyhow it is a growing need to point out the consequences and the disadvantages for the whole society when low volume roads are deteriorating. If we want also the rural areas in the Northern Periphery to be populated a basic provision is that the life nerves, the road network, is working properly and is in good condition around the year. There is a need to facilitate the transportation possibilities to improve the life conditions in rural areas.

1.4 The aim of the Task

The aim of this Task, which is a part of Phase 2, is to improve the understanding of the significance of the low volume roads and the road conditions for people in the rural areas of the Northern Periphery of Europe. Thereby we hope that more resources will be allocated to the low volume roads. The means to accomplish this is to collect information of the socio-economic impact of the road conditions from the literature, by interviews and by calculation with a model and try to look at the consequences to industries and local residents if funding for low-traffic rural roads is not sufficient to ensure the serviceability of the local road network. Then we want to spread this information to people on all levels in the society, to politicians and to road administrations in order to have a better understanding for an increase of the budgets for low volume roads and thereby create better life conditions for people in the rural areas of Northern Europe.

The Task is not dealing with winter problems and winter maintenance.

2 Background

2.1 General

In rural areas the road network is in most cases the only possibility to move goods and people from one place to another. It is the vital nerve for many people in the Northern periphery. If the road does not work properly it will affect many urgent things in the society, like

- Business profitability
- Investments
- Tourism
- Service levels
- The social life.

The road condition will also have a great impact on the road user in action. It will affect his behaviour on the road e g make him change speed, force him to do turning movements or even make him take another road if possible. It will also have impact on his economy. A road in bad condition will increase vehicle cost, increase travel time and might even give damage to the carried loads. It will also influence the accident rate and the comfort for the road users. This means that there are many reasons why the socio-economic consequences should be taken into consideration when allocating budgets for low volume roads, when selecting roads for maintenance and rehabilitation and when choosing maintenance strategies for the selected roads.

2.2 Factors affecting socio-economic impacts

There are many factors on road networks, which are affecting the socio-economic impacts for areas, people and the society. There are for instance:

- The road condition
    - Roughness
    - Rutting
- Friction
    - Cracking
    - Bearing capacity
    - Edge deformation
- The road alignment
    - Horizontal curves
    - Vertical curves
- The road width
- Amount of traffic
- Load restrictions
    - Permanent restrictions
    - Periodical restrictions
- Speed limits
- Environment.

Roughness and rutting are the most common factors used in different models for calculation of road user costs depending on bad road conditions, probably because these factors are visible, easy to feel for the road user and easy to measure. In Finland bearing capacity and a damage index are also used and in the latest Finnish model even environmental costs are included.

2.3 Other projects

Here a few European projects are described in order to give a little information of what has been done in the latest years about socio-economics used in the area of road infrastructure management.

2.3.1 The RIMES project

In a European project named RIMES finished in 1999, Road Infrastructure Maintenance Evaluation Study (2), a survey has been done to examine

- Economic models used for life cycle costs of road infrastructure
- Standards and strategies for road infrastructure maintenance

The study was made by a consortium, consisting of several European states, with economic support from EU. In the study the use of socio-economic models in road management in Europe was surveyed. The objective of the project was to develop economic models and specifications for modelling and monitoring road infrastructure condition to provide a common standard for EU road authorities based on current knowledge. For that purpose questionnaires were sent to 17 European countries about Pavement Management Systems (PMS). Thirteen of the 17 states were operating a PMS. The most commonly collected road condition data were in order of significance:

- Rutting
- Roughness
- Skid resistance
- Deflection
- Cracking

Seven of these 13 states used road user costs either directly or indirectly, but only four of the systems optimized or prioritised on an economic basis.

In the project a literature review on economic models was also carried out. Many different models were used for calculation and for deterioration. The general road user cost model is of the form:

Road User Costs (RUC) = Accident Costs + Vehicle Operation Costs + Travel Time Costs

The significant factor affecting budget allocation was the existing and the forecast condition of the pavement. Traffic volumes and geographical distribution were the next significant, though the final decision for a maintenance action was taken by the road authority staff.

Based on the review it was found that the models were needed on three different levels:

- Project level – Computer models for life cycle cost analyses of maintenance alternatives
- Work programming level – Computer models for optimal timing and location of road maintenance projects
- Network level – Models for calculation of the optimal road network condition distribution and the budget need to achieve and maintain this condition.

Figure 3 shows the principles of the connection between the levels.

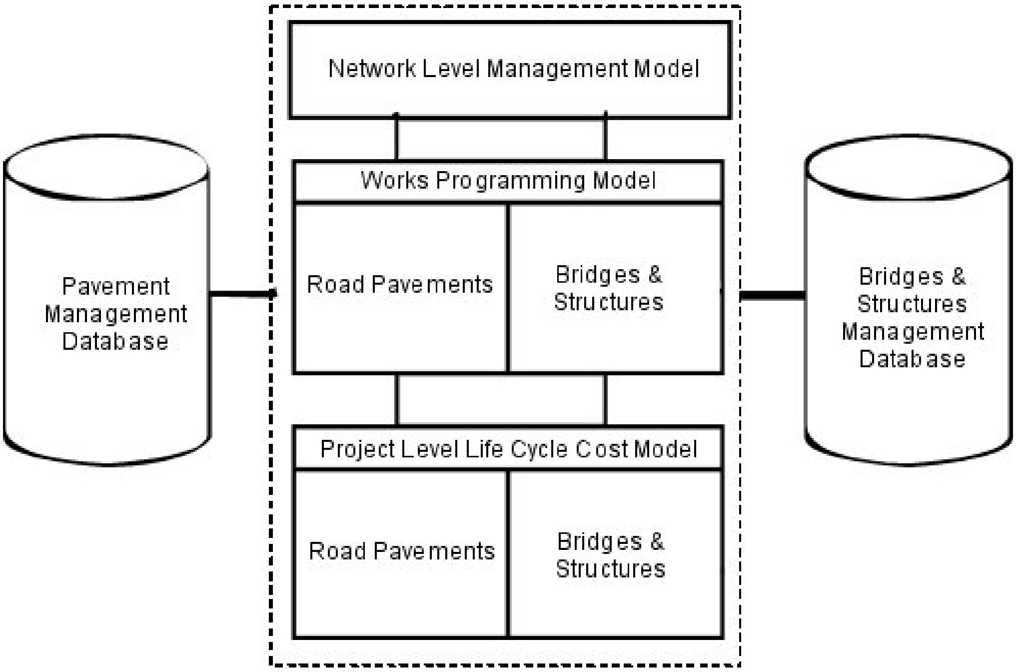

Figure 3. Principles for the total road management concept (2).

Figure 4 shows an example from Sweden how PMS is used at the different levels in the road management process.

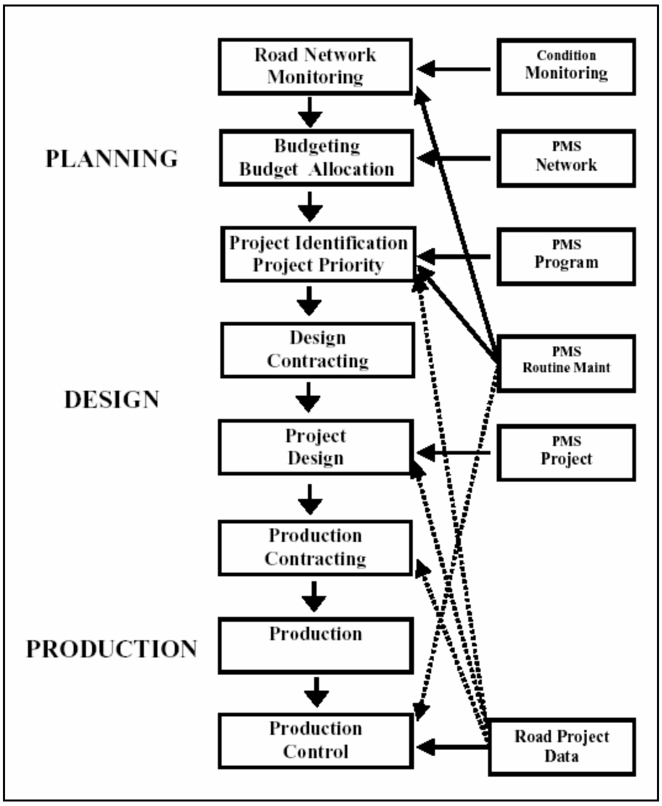

Figure 4. Sketch showing how PMS is used in the road management process (2)

All models shown in RIMES are based on economic considerations and the social aspects are not discussed especially. The models are not designed to take special care of the low volume rural roads.

2.3.2 The appraisal model Highway Development and Management Tools, HDM-4

Road investments in developing countries have during the last 20 years been planned and prioritised based on economic appraisal models like HDM-4. The models are mainly used to evaluate primary and secondary roads. These models do not cater very well for economic justification of low volume roads in rural areas. In later years developing countries as well as donors have increasingly been asking for guidance to incorporate social benefits within transport appraisal. This depends on an increased emphasis on poverty reduction and social considerations. It has been discussed lately in the management of HDM-4 to include a part with social benefits in the model and a project was started in 2003, named "Framework for the Inclusion of Social Benefits in Transport Planning" (3). The project is at the starting phase and it is funded by the Department for International Development (DFID).

The report identifies some circumstances when social benefits are most likely to be very significant:

- When there is a desire to weight conventional benefits to different classes of existing users (e g provide higher weightings to the poor)
- Where investments can provide a very significant improvement in vehicle access
- Where existing traffic volumes are very low or where the population is very remote.

In the project social benefit indicators have been proposed as results of better road infrastructure as follows:

- Economic opportunities (financial capital)
    - Developing the economy
- Capability (human capital)
    - Developing human capital and life quality
- Empowerment (social capital)
    - Participation in political and social processes and network
- Security (physical capital)
    - Reducing sudden shocks for poor people.

Possible social benefits and costs from improved road infrastructure are described in table 1.

Table 1. Possible social benefits and costs of improved road infrastructure (3).

Social benefit indicators	**Economic opportunities**	**Capability**	**Empowerment**	**Security**
Social costs and benefits	1. Access to employment	1. Access to health services	1. Participation in planning/policy-making/management	1. Personal security
	2. Access to education and training	2. Incidence of HIV/AIDS	2. Knowledge/ information – user involvement	2. Road safety/safety in operation
	3. Employment within transport sector	3. Access to education and training	3. Development of social capital/ social networks	3. Environmental inputs
	4. Affordability of transport	4. Access to water	4. Participation in political processes at different levels	4. Time use/time poverty
	5. Access to farm inputs, raw materials, natural resources			5. Access to land and housing
	6. Opportunity to own transport			6. Access to water
	7. Access to transport services			7. Access to energy
	8. Access to markets, trading opportunities			8. Access to social capital/networks
Expected outcomes	Improved economic conditions	Enhanced human capital and quality of life	Increased political participation and gender equality	Greater economic and physical security

These benefit indicators are identified for developing countries but some of them will also be suitable to use for our aims.

2.3.3 Choosing rural road investments to help reduce poverty

A World Bank report, named as the title of this paragraph (4) and written by Dominique van de Walle, examines how rural road investments should be selected and proposes a method for the choice. A key problem is that an important share of the benefits cannot be measured in monetary terms. The proposed method aims to identify places where poverty is high, economic potential is high and access is low.

From a given budget the method describes how to rank the possible candidate road links for maintenance or rehabilitation. It is assumed that each road link has a set of encompassing communities (EC). The benefit for a user in the EC is estimated from data on existing road infrastructure, human development, economic regional potential and other factors, which may influence the marginal gains from a road investment. The total benefit is then calculated by multiplying with the total amount of people in the EC and then the benefit-cost ratio for the link can be calculated. This treats every EC equally. In order to promote poor areas we need to use a social weight to each EC to create a socially weighted benefit-cost ratio. The formula for Social Welfare (SW) is defined as

$SW = \Sigma S_i B_i N_i$ where
S_i = the social equity value for an average road user on link i
B_i = the efficiency benefit for an average road user on link i
N_i = the number of people at the EC of the link i.

The estimated SW is then divided to the total cost C_i of the link to give a benefit-cost ratio. The ratios are then used to rank the proposed road links and the first disbursement goes to the link with the highest ratio. The method looks interesting and might be possible to adjust to the conditions in our rural areas.

2.3.4 Motorists apprehension of pavement maintenance management

In a Swedish report "Motorist's Evaluation of Road Maintenance Management" (5) the car users' monetary valuations of riding quality are surveyed. The survey is done on the Swedish State road network. The aim was to investigate motorists' apprehension of pavement maintenance management and the final goal was to find out their willingness to pay for different levels of road maintenance management. The values obtained might later be used in cost-benefit models to justify budget levels and maintenance activities.

Many surveys have been done to compare objectively measured roughness as IRI-values with subjective valuations like road user satisfaction for the same road network. An example in figure 5 shows that there is good correlation between high IRI-values and low degree of satisfaction.

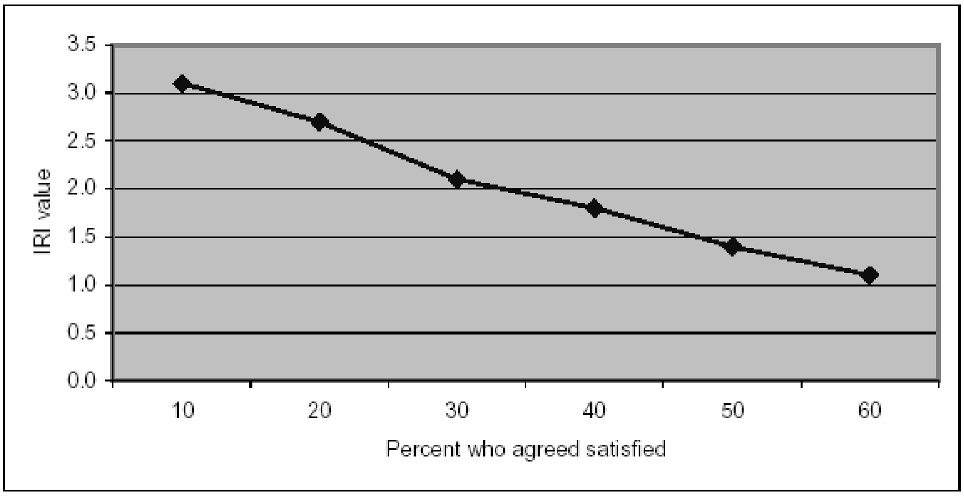

Figure 5. Relationship between IRI and other user ratings (5).

The survey was to a great extent done by interviews. It was found in the interviews that the interviewed persons were rather aware of different road conditions and could identify various road damages on photographs and videotapes. They were willing to accept small cracks in the road surface but did not like to drive on roads with rutting, damage repair work, significant roughness and potholes. The main survey also revealed that road maintenance standard was an essential comfort factor for the motorists, in fact more essential than the behaviour of other road users, type of car, road design and weather conditions.

The willingness to pay for a better pavement standard was rather high. The level was 0,5 to 1,5 SEK/km. Cost-benefit analyses showed that most maintenance activities easily pay return at that level. The author's remark about this is that the pavement damages shown to the interviewed persons were very severe so the willingness to pay reflects the change of the road condition from IRI about 5 to IRI about 1. Therefore it is probably necessary to scale down the willingness to pay a little.

2.4 Summary

It was found in the RIMES report (2) that many different models existed in Europe to calculate the socio-economic costs of road users and road managers for the society. It was also found that social impacts were not accounted for in the models.

In the inception report concerning adding a social model to the HDM-4 model (3) many social impacts depending on road conditions were discussed. The report also clearly shows that there is a need for models, which better mirror the social effects of road conditions, especially concerning low volume roads in rural areas. Some interesting benefit indicators are proposed for developing countries but some of them will also be suitable to use for our aims.

An interesting method to rank possible candidates for maintenance or rehabilitation is described in a World Bank report (4). The method includes social equity values to favour poor areas in the ranking of possible road links. The method looks interesting and it might be possible to adjust it to serve our aims.

In the Swedish report about motorists' perception of road maintenance management (5) it seems like road users consider road conditions as critical factors and also that they are willing to pay for improved road conditions.

3 Handling of socio-economic impact in Sweden

3.1 Introduction

In Sweden socio-economic models are used by the Swedish National Road Administration to forecast the maintenance need at network level to be used in budget discussions with the Transportation Department. A little about this is mentioned in clause 3.2. A simpler model for use on road network and project level, shown in chapter 8, has also been used. Work has been going on for long time with a road code for road maintenance introducing lowest acceptable road condition standards, briefly described in clause 3.3. Road condition levels are also given in the routine maintenance contracts drawn up with different contractors. Some condition levels acting as “trigger values” for maintenance actions are described in clause 3.4. Finally in clause 3.5 there is a short description of a Swedish policy for temporary spring thaw load restrictions.

3.2 General

An interview with Jaro Potucek, Swedish National Road Administration (SNRA), gave a general view of the use of socio-economic considerations in Swedish road management (6). SNRA is using socio-economic considerations to form the target standard for the road network. Socio-economic considerations are also partly included at the choice of maintenance actions, determining the road condition at maintenance and deciding temporary load restrictions even though much is done by using long time experience. In the contracts for routine maintenance there are also described standard levels for actions determined by regional preferences (see example below). On road network and on project level cost-benefit models (see chapter 8) are used to a minor extent. As a minimum standard, to be reached within four years, SNRA says that all state roads shall be passable for vehicles ≤ 3,5 tons at a speed of 30 km/h all year around. Low volume roads in rural areas are not treated in any special way, but money is earmarked for frost protection and improvement of the bearing capacity, which might favour the low volume roads.

3.3 The Swedish road code for road maintenance, paved roads

During the year 2001 the Swedish National Road Administration (SNRA) worked on a code for road maintenance. It ended up with a draft in December 2001 named “Code for road maintenance” (ReV 2001-12-06 (7). It was built up with limit values coming from three different main aims:

- Traffic safe practicability (for the road user)
- Preserving of road capital (for the road manager)
- Calculated profitability by a model (socio-economic calculation).

The document describes the aim for the minimum road standards in Sweden when funds are available. The limit values, slightly changed, were then used to calculate the backlog of road maintenance and rehabilitation in Sweden set up in the document “Paved roads – Aim for road standard and bearing capacity 2002” (Belagda vägar – målstandard och bärighetsmål 2002) (8). Here is a short description of some limit values in the last mentioned document.

3.3.1 Traffic safe practicability

The purpose of the limit values for the road condition is to preserve the practicability and to give an acceptable level of traffic safety and comfort. Here are some limit values:

- The roadway shall be free from cracks wider than 10 mm
- The roadway shall have a surface friction > 0,5
- The cross fall shall be minimum 1,5 % and max 4,0 % on roads with double-sided cross fall
- Rutting as an average of 20 m shall be max 20 mm
- IRI as an average of 20 m shall be max 6 at a speed limit of 70 km/h or more
- IRI as an average of 20 m shall be max 7 at a speed limit of 50 km/h or less

Figure 6. Rutting on a small paved road in Northern Sweden.

3.3.2 Preserving of road capital

The limit values have the purpose avoiding premature deterioration. Here are a couple of examples:

- There shall be no cracks in the salted roads when the winter comes
- The formation of potholes shall be prevented
- The dewatering shall be working
- The bearing capacity shall
    - Be good enough the whole year on all urgent roads for the commercial and industrial life
    - Other roads with 10 heavy vehicles ADT or more, max 3 weeks of bearing restrictions
    - Other roads with less than 10 heavy vehicles ADT shall be open around the year for min 30 km/h for cars

3.3.3 Calculated profitability by a model

A rough estimation with the calculation model, described in chapter 8, will give limit values for IRI shown in table 2 and 3.

Table 2. Limit values for IRI, 20 m average.

ADT	IRI mm/m	
	≥ 90 km/h	≤ 70 km/h
> 4 000	4	5
2 000 – 4 000	4,5	5,5
500 – 2 000	5,5	6,5

Table 3. Limit values for IRI, 400 m average.

ADT	IRI mm/m	
	≥ 90 km/h	≤ 70 km/h
> 4 000	3	4
2 000 – 4 000	4	5

3.3.4 Shortcomings in the road condition

When sudden shortcomings in the road condition have arisen and a measure has not been able to perform, times for repair are suggested as follows.

- When there is a traffic safety risk for personal injuries or damage risk for third party a measure shall be done within 2 hrs.

In other cases:

- ADT ≥ 8 000 vehicles
    - A measure shall be started within 5 hrs and be finished within 5 days.
- ADT 2 000-7 999
    - A measure shall be started next day and be finished within 10 days.
- Other roads
    - A measure shall be started within three working days and be finished within 20 days.

At traffic safety risks a first measure can be to put out danger signs and after that the repair may proceed as for other shortcomings.

3.4 Performance- and standard descriptions at routine maintenance

The Swedish National Road Administration buys routine maintenance on state roads from the market by tendering in full competition. To describe the standard levels every contract is based on a “Performance- and standard description” (FSB). There is a National base document, which is changed by the regional offices depending on local conditions. Here are examples of requirements in the FSB of the Northern Region of SNRA (9).

3.4.1 Paved roads

Pre-requisites
Frost damages shall be repaired as soon as possible, weather permitting, at latest 1st of July.

Temporary repair shall be done with suitable material permitting permanent repair later.

Practicability
The road network shall be practicable for vehicles with allowed loads according to the county announcements. Exceptions might be accepted on parts of the road network during the thaw period and when the bearing capacity is not sufficient. At load restrictions normally 12 tons gross weight shall be allowed. The road network shall always be practicable for vehicles with 4 tons gross weight and exempt vehicles.

The client shall be informed about any need in changes of the load restrictions.

Level differences and edge deformation
Level differences along or across the road on a length of 2,0 m shall not be bigger, during the period 1st of June to 30th of September, than

- On national roads 20 mm
- On other roads 30 mm.

The measurements shall be performed with a 2 m straight edge.

Dewatering
Ditches, culverts, daywater- and drainage piping and wells shall be kept open to secure dewatering. At least 80 % of the cross section of culverts and piping shall be working.

Slopes
Slopes shall not have loose stones or rocks. Washouts shall not be deeper than 300 mm and broader than 400 mm.

Cracks and holes
Temporary repair of cracks with width > 20 mm on the carriageways and > 15 mm on pedestrian and cycle ways shall be done immediately with sand or gravel. Carriageways on national roads and pedestrian and cycle roads shall be free from holes with depth > 15 mm and width > 100 mm. Carriageways on other roads shall be free from holes deeper than 30 mm and wider than 200 mm.

Figure 7. Crack from uneven frost heave on a paved road in Northern Sweden.

Holes appearing on national roads and roads with speed limit of 90 and 110 km/h shall be repaired immediately. On other roads holes shall be repaired within 3 days. Holes repaired on roads belonging to class 1 and 2 shall be sealed.

Friction
Carriageways and pedestrian and cycle roads shall be free from loose stones and loose sand or other materials (e.g. clay, leaves, oil spill) which can reduce friction.

Edge strips
Edge strips shall be at the same level or < 25 mm lower than the adjacent pavement edge.

Manhole covers
Manhole covers shall be 0-15 mm lower than adjacent pavement. Covers shall be undamaged and in the right position.

3.4.2 Gravel roads

Practicability
In connection with thaw and surface softening an easy grading shall be done to repair damages and to get air into and to dry the road surface.

During thaw wearing/base course materials shall be added on surface softened and damaged road sections when there is a risk for getting stuck or getting damages on the vehicles. To start with warning signs should be placed.

Unevenness, degree of bound surface and cross fall
The client considers it important that the gravel road should be maintained in a professional way. This means e g that the road width shall be kept constant by a yearly pull-in of edge material.

The standard of the gravel surface shall correspond to at least condition class 2 according to SNRA Method Description 106, “Judgement of gravel road surfaces.” Conditions meeting class 3 can be accepted but not for more than 5 days in succession

The road surface shall at latest by the 31st of August every year be free from stones coming out through the road surface. Stones dangerous for the road users shall be taken away as quickly as possible.
The cross fall shall not be less than 3,0 %, with exception for road bends.

Dewatering
Similar requirements as for paved roads above.

Slopes
Similar requirements as for paved roads above.

Friction
Road surface shall be free from spillage, e.g. soil, oil or log cutting remains.

Frost heave
Frost heave damages shall be repaired if they, in spite of warning signs, are regarded as dangerous for road users.

Gravel maintenance
The contractor shall take out about 5 samples of wearing course per 10 km as a base for the proportioning work. The added material shall be such that it together with the upper 20 mm of the wearing course will correspond to the grading curve in the Road Code. Added material shall be mixed in and homogenized with the existing wearing course.

3.5 Policy for frost damage restrictions

In Sweden there are no national temporary load restrictions. All of the 7 road regions have their own policy even if they are rather similar. Here are examples of the policies in Region Mitt (10).

3.5.1 Aim

There shall be no restrictions on:

- National passages
- Regional passages
- Local passages

3.5.2 Strategy

Restrictions are not allowed on national and regional passages.

For local passages and other local roads the following will be applied:

- Restrictions are not allowed on roads in a separate list. Restrictions mean a limited gross weight on vehicles to 4 or 12 tons.
- Paved roads
- Restrictions shall be introduced when damages are feared giving evident rutting or directly prevent practical traffic flow on > 1 % of a road link.
- Gravel roads and roads with surface dressing on gravel
- Restrictions shall be introduced on a local passage when frost damages demanding repair in order not to prevent traffic with allowed vehicles will arise on > 1 % of the length of the actual road link
- Restrictions shall be introduced on other local roads when frost damages demanding repair in order not to prevent traffic with allowed vehicles will arise on > 5 % of the length of the actual road link
- Restrictions shall be cancelled when the requirements for the restriction are not valid.

Figure 8. Load restriction to 12 tons.

3.6 Summary

In Sweden socio-economic models are used to forecast the need for resources to maintain or improve the road conditions. Work has been done to form a lowest acceptable standard of the road condition but it is not finished yet. Road condition standards for routine maintenance and for temporary load restrictions are used by the Road Management Regions.

4 Handling of socio-economic impact in Norway

4.1 Introduction

An inquiry was sent to the Norwegian State Road Administration (NSRA) about the use of socio-economic considerations in the Norwegian road management. The answers, given by Kjell Solberg, Geir Berndtsen and Hans Silborn at NSRA, gave a good overview of what is done in Norway in the area (11). NSRA uses a socio-economic model named HIPS for estimation of the budget need and for distribution of the budget to the Road Administration Regions. HIPS works on road network level and cannot be used on projects e g to compare different maintenance actions. The model, which comes from Finland, is used also in Finland and Sweden. The low volume roads are not treated in any special way in the models. The standard of these roads is determined regionally depending on budget levels and local conditions. Discussions have been going on in Norway about the need of a model also for the low volume roads.

The investment policy for the low volume roads classified as national highways is to reach a low but acceptable standard within 30 years. The work will focus on improvement of existing roads instead of investments in new roads. To meet the requirements from the road users NRA co-operates with different transportation organisations both on regional and on district level. NRA has an agreement with the Norwegian Truck Alliance that the drivers will inform the road managers about missing routine maintenance. Meetings are also held with different road user categories to discuss transportation questions.

The handling of socio-economic impact of road conditions in Norway by using the HIPS model is described in a report named “Socio-economic consequences of different action levels in road maintenance” (12) (Samfundsmessige konsekvenser av forskjellige innsatsnivåer innen drift og vedlikehold), edited by Norwegian State Road Administration (Statens Vegvesen) 2002. It deals with different areas within road maintenance of which two parts are of particular interest for the Roadex-project, namely:

- Maintenance of carriageways
- Maintenance of drainage

The main content in these parts is described down below in clause 4.2 and 4.3. The road condition levels for maintenance are defined in the document “Standard for routine maintenance and planned maintenance. Handbook 111” (13). The routine maintenance is carried out by means of performance contracts. The road condition standards for maintenance are briefly described in clause 4.4. How the temporary load restrictions are handled in Norway is described in clause 4.5.

4.2 Maintenance of carriageways

4.2.1 Introduction

The Norwegian State Road Administration is using a model to analyse the socio-economic cost-benefits on road network level. The pre-requisites to use the Norwegian model are knowledge of:

- The road condition development
- The effects of the adopted maintenance actions
- The socio-economic consequences of the road condition.

The report mentioned above is divided into three main parts:

- A summary of the model and its use
- An evaluation of the implemented analyses
- Recommendations of maintenance strategies.

The model used by the Norwegian Road Administration is a network model based on a model used by the Finnish Road Administration, named HIPS (Highway Investment Programming System). The program is used to calculate the socio-economic costs for paved roads on network level to assist in distributing the maintenance budget.

4.2.2 Methodology

Here is a short description of the model used:

- The road network is divided into partial road networks based on climate zone, road type and traffic class. In Norway 15 partial road networks are identified.
- The road condition parameters unevenness and rutting are used. Damages and bearing capacity are wanted but reliable data are not available. The road condition parameters are divided into 9 classes, including three for unevenness and three for rutting.
- The development of the road condition is modelled by the probability of going from one condition class to another within a determined time, in this case one year. The model is based on measured values of unevenness and rutting in at least two consecutive years.
- Maintenance actions are defined and costs and effects are determined for each action. In Norway 4 different main actions are used.
- The road user costs are calculated from the distribution of the road network in each road condition class. Then dynamic programming is used to find the optimal distribution of the road condition classes to get the lowest sum of the road user costs and the road manager costs. Quantification of socio-economic costs is regarded as a long-term goal.
- The system can also be used to find the effect on the distribution of the road network condition at a given budget level over several years. Then it is possible to examine the effects of different budget levels and to identify optimal maintenance strategies to slowly approach an optimal road condition level with limited budgets.

Figure 9. View of a secondary road in Senja.

4.2.3 Input data

Analysis has been done of 26 500 km of paved roads in Norway. Road condition data from 1997-1998 and 1999-2000 were used. The effects of different maintenance actions are based on assumptions and not measured data. The models of deterioration though are based on measurements performed in each part network.

The unevenness is measured with laser and the rutting is measured with ultra sound. The measurement data are stored in 20 m medians, and the target condition standard is expressed as a level where 90 % of these 20 m medians shall be in a particular road network.

The maintenance actions used are:

- Routine maintenance (seals, crack fillings, pot hole repairs)
- Easy actions (rut fillings, thin lifts, surface dressings)
- Wearing courses (including planing, levelling and binder course)
- Rehabilitation (including base course, binder course if needed and wearing course).

The costs for each maintenance action are based on information from the regional road offices.

4.2.4 Deterioration models

The development of the condition is modelled by the probability of going from one road condition class to another within a determined time. It means that the method calculates the percentage of the roads in an actual road network, which moves to another class. The model deals with a whole part network of roads. It cannot be used to calculate single road sections. There is one model for each part network. In the calculations the condition measured as IRI and rutting is used as 100 m average values of the 5 actual medians for 20 m. Markov-chain models are used to simulate the deterioration.

The models are affected by the different maintenance actions so that an action will lift the road standard to a better class. Specialists have estimated the effects of each maintenance action from experience.

4.2.5 Road user costs

The road user costs included in the analyses are:

- Time costs
- Vehicle operation costs
- Accident costs
- Delay costs depending on road work

The calculations are divided into two parts:

- Calculation of a basic level for the road user costs
- Calculation of added costs depending on road condition

The basic level is calculated with the program EFFEKT. This basic level can be described as the road user costs when the user is riding on a road in perfect condition. For each part network average values are used for road width, traffic, accidents etc, and a speed limit matched to the actual network and a suitable factor for vertical and horizontal alignment.

The calculation of the influence of the road condition, expressed as IRI and rutting, is based on a Finnish report named “The Effect of Pavement Condition on Road User Costs”. The model can handle time costs, accident costs and Vehicle Operation Costs. The delay costs are default values as follows:

- Easy actions 5 000 NKr/km
- Wearing courses 50 000 NKr/km
- Rehabilitation 100 000 NKr/km.

4.2.6 Optimization

To reach the optimum the aim is to minimize the socio-economic costs for the road manager, the road user and the rest of the society. In road maintenance this means to aim for the lowest sum of these costs as shown in a sketch in figure 10. If the budgets are too small the roads will deteriorate and the road user costs will increase.

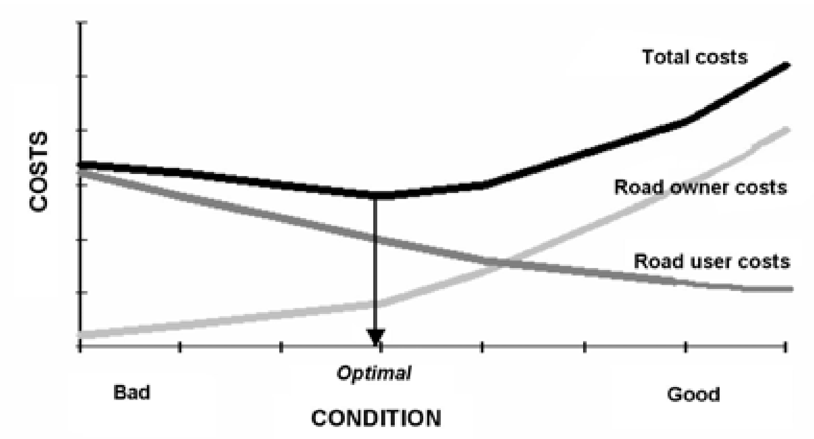

Figure 10. Principle sketch of an optimal road network condition (12).

4.2.7 Results of performed analyses

The calculated yearly level for the maintenance budget to keep the road network at an optimal condition is about 800 millions NKr. Four different short-term scenarios are also surveyed:

- Extremely low budget 400 MNKr/year
- Low budget 600 MNKr/year
- Medium budget 750 MNKr/year
- High budget 850 MNKr/year.

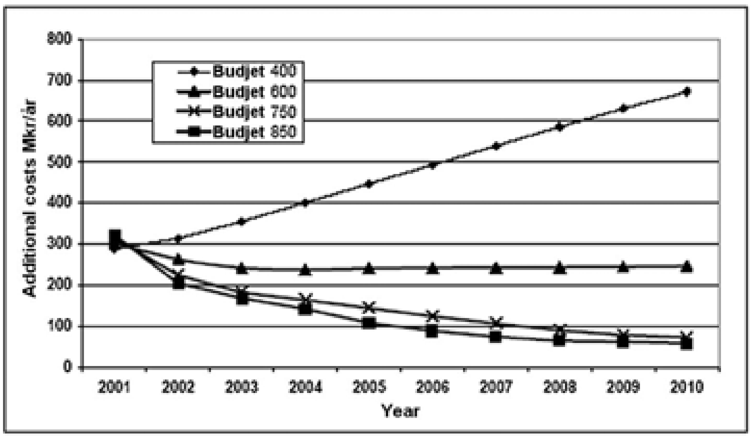

Figure 11. Additional costs for the road users depending on budget levels (12).

For every budget level the optimization models will try to minimize the difference between the current condition and the optimal condition. The analyses of the four different budget levels are done over a 10-year period. Figure 11 shows the added costs for the road user depending on the budget level. The marginal cost-benefit ratio, shown in table 4, shows that an increase of the budget from 400 to 600 millions NKr will give good return on the investment. But that budget level will only keep the distribution of the road condition at the same level as today and will not approach the long-term optimal goal. By an increase of the budget level to 750 MNKr the long-term optimal road condition distribution will be reached within 20 years. The difference between the road user costs today and the road user costs at the long-term optimal road condition distribution is 265 MNKr/year.

Table 4. Marginal cost-benefit ratios at stepwise increase of the budget level (12).

Budget step Milj NKR/year	**Marginal benefit**	**Marginal ΔD (incl Tax factor) (Change in road manager costs)**	**Marginal Net Benefit**	**Marginal NNK**
400-600	7 877	3 764	604	1,22
600-750	2 647	3 146	-89	-0,03
750-850	350	1 634	-1 071	-0,66

4.2.8 Conclusions

The main conclusions of the Norwegian method test are:

- The distribution of the condition on the Norwegian roads today is somewhat lower than the long-term socio-economic optimal level.
- A budget level of about 750 MNKr/year is needed to approach the long-term optimal level from today's level within 20 years.
- When the optimal road condition distribution level is reached a budget of 800 MNKr/year is needed to maintain that level.
- More work is needed on the models e g
    - Improvement of the deterioration models
    - Modelling of the effects of the different maintenance actions
    - Verifying of the added road user costs depending on road condition
    - Sensitivity analyses.

4.2.9 Evaluation of the implemented analyses

The main efforts have been focused on the road engineering part. Models from foreign countries have been used to determine the road user costs. The use of the HIPS-method implies that it is not possible to handle single road sections. On the other hand using average data for road networks gives possibilities to use statistical methods. Critical parameters used in the analyses are listed below:

- Sub-division into partial road network is difficult and affects the results
- The road condition parameters used are only unevenness and rutting. Wanted parameters are data of damages, bearing capacity and drainage.
- The limited number of road condition classes can prevent the extraction of more detailed results of the analyses
- The road condition development. It is difficult to know if the deterioration models adopted give a good picture of the real deterioration.
- There are only four different maintenance actions used in the analyses. Many other actions are used with different costs and effects.
- The road user costs dependent on the road condition are uncertain.
- The dynamic programming used for optimization is a well-known method that will not increase the uncertainty.

- The HIPS model consists of many sub models and it seems that the model is sensitive to changes in the sub models. The analyses give road manager costs at the optimal level, which are equal to the prevailing budget. The uncertainty in the method is assumed to be ±100-200 MNKr, which is of the same magnitude as the differences between the surveyed budget intervals. Thereby it can only be used to frame the strategy for the road maintenance.

4.2.10 Recommendations

The survey shows that the distribution of the road network condition is somewhat worse than the goals for the Norwegian standard. It is also worse than the long-term optimal condition distribution resulting from the HIPS analyses.

The method is evidently not calibrated to the actual cost level, but a total evaluation indicates that it should be socio-economically profitable to increase the resources in road maintenance. The analyses are not good enough to give an exact magnitude, but a rough estimation points to an adjustment of the magnitude 100-200 MNKr/year. The extra resources should be used in the first place to maintain the worst condition classes to reach the goal for the Norwegian standard. After that high volume roads should be favoured.

4.3 Maintenance of drainage

4.3.1 Introduction

As mentioned above one part of the Norwegian report (12) deals with socio-economic costs for inadequate drainage. It is emphasised that the drainage, to a great extent, influences the road condition and thereby also the costs for the road manager and the road user. The aim is to develop a method to judge the socio-economic impacts of different drainage conditions, as there is no method available. Development of such a method demands knowledge of the following:

- How the road condition develops in different drainage situations
- What effects different maintenance activities on the drainage will give
- Socio-economic consequences of different drainage conditions.

The report is only an introduction to give a state-of-the-art comment on the subject.

4.3.2 Possible consequences of insufficient drainage

Different cases are described where inadequate drainage can be a reason:

- Premature development of unevenness and rutting
- Ice on the roadway caused by insufficient ditches
- Overflow of water resulting from under-dimensioning or lacking maintenance
- Unstable road slopes as a consequence of under-dimensioning or lacking maintenance.

The first of the alternatives is the most important one from a socio-economic point of view.

4.3.3 The influence from the drainage on the road condition

The drainage seldom solely influences the road condition. It acts together with rain- and snowfall and the unbound materials in the pavement and the subgrade. For example aggregates in the pavement containing much fines are normally water holding and in frost conditions this can cause formation of ice lenses and frost heave. Then at thaw this will create much water in the upper layers, which will increase the risk of rutting from heavy vehicles. At that point there is a need for good drainage to minimize the damages. The drainage is needed to keep the road structure as dry as possible. A dry structure is strong and will normally have a slow deterioration process.

Figure 12. Severe rutting on road 229 in Senja.

4.3.4 Results of a literature survey

In the project several reports have been examined to find possible models for use:

- FHWA, the LTPP-program in SHRP.
  By regression models it has been found that the water content in the unbound aggregates will affect the development of road unevenness (IRI)
- The World Bank – HDM-4.
  HDM-4 consists of several models. Some of them, e g the model for the development of the unevenness, are dependent of the drainage. It is used as a correction factor for the bearing capacity expressed as a Structural Number.
- LTPP-sections in Sweden
  Regression models for cracking are developed but drainage is not used as a parameter.
- Road condition models developed by SINTEF
  SINTEF has developed several models during the last decade, and e g for the model of the elasticity of the aggregate adjustment factors are used for the drainage.

4.3.5 Parameters needed for the model

A discussion is held about needed parameters to develop a model for road deterioration depending on drainage. Here is a short description:

- Climate data - must be included, from weather stations
- The road cross profile - analyses per lane
- Water content in the subgrade - difficult to measure, GPR might be used
- The road structure - layer thickness, FWD-data
- Road condition data - from measurements of IRI and rutting
- Road damages - cracks, potholes and other damages are not registered in Norway.

4.3.6 Conclusions

More research work is needed before models of deterioration caused by (lack of) drainage can be used. There is a need for following up observation sections. It is emphasized that a drainage model should be linked to the HIPS model used for road deterioration modelling. Some sort of "Bearing capacity" parameter should be used to divide the road network.

The report ends up in a proposal for a project to follow up roads in order to form a model. The project is outlined to be 5 years, which shows that there is a long way to go before the socio-economic impact from drainage conditions can be decided.

4.4 Recommended standard levels

The Norwegian State Road Administration has given recommended road standard levels in the document: "Standard for routine maintenance and planned maintenance. Handbook 111" (13). The recommendations on road network level are shown in table 5.

Table 5. Rutting and roughness. Aim for 90 % of a road network (13).

<table>
<tr><th rowspan="3">ADT</th><th colspan="2">Rut depth (mm)</th><th colspan="2">Roughness (IRI)</th></tr>
<tr><th colspan="2">90 % level</th><th colspan="2">90 % level</th></tr>
<tr><th>Highway</th><th>Other national roads</th><th>Highway</th><th>Other national roads</th></tr>
<tr><td>0-300</td><td rowspan="2">17,5</td><td>18,5</td><td rowspan="2">3,5</td><td>6,0</td></tr>
<tr><td>301-1 500</td><td>18,0</td><td>5,0</td></tr>
<tr><td>1 501-5 000</td><td>17,0</td><td>17,5</td><td>3,0</td><td>4,0</td></tr>
<tr><td>> 5 000</td><td>16,5</td><td>17,0</td><td>2,5</td><td>3,0</td></tr>
</table>

The recommendations on road project level are given in table 6.

Table 6. Rutting and roughness. Aim for 90 % of a road project (13).

<table>
<tr><th rowspan="2">ADT</th><th colspan="2">Rut depth (mm)</th><th colspan="2">Roughness (IRI)</th></tr>
<tr><th>Highway</th><th>Other national roads</th><th>Highway</th><th>Other national roads</th></tr>
<tr><td>0-300</td><td rowspan="2">25</td><td>25</td><td rowspan="2">5,0</td><td>7,0</td></tr>
<tr><td>301-1 500</td><td>25</td><td>6,0</td></tr>
<tr><td>1 501-5 000</td><td>25</td><td>25</td><td>4,5</td><td>5,1</td></tr>
<tr><td>> 5 000</td><td>25</td><td>25</td><td>4,0</td><td>4,6</td></tr>
</table>

There are also other requirements, e g for friction, cracks, potholes and cross fall. The maximum time delay for maintenance actions is also determined.

For gravel roads there are also some requirements as follows:

- Roughness values shall not be higher than that the normal speed limit minus 20 km/h can be used
- Cross fall shall be as for asphalt pavements ± 2 %.
- Dust shall not be so bad as to obscure a vehicle from following vehicles.

The standard levels are used in routine maintenance contracts.

4.5 Handling of spring load restrictions in Norway

In a paper from the Fifth BCRA Conference the strategy for handling the spring load restrictions in Norway is described (14). The Norwegian State road network is about 53 000 km of roads divided into 26 000 km of main roads and 27 000 km of secondary roads. In 1994 more than 50 % of the main roads and about 80 % of the secondary road network in Norway had spring thaw axle load restrictions for about 8 weeks every year. The restrictions were generally imposed when the thaw was at a depth of 20-25 cm and lifted at a thaw depth of 100-125 cm. The spring load restrictions on main roads were normally a reduction from 10 tons to 8 tons, and on the secondary roads a reduction from 8 tons to 6 tons.

In 1994 a 4-year research program named “Better utilisation of the bearing capacity of the road network” (BUAB) was completed. One important task of the research project was to evaluate the economic effects of not imposing any spring load restrictions at all on the state road network.

The road owner costs were calculated as a reduction in surfacing service life. The 10-tons roads, which typically had a 10-year resurfacing cycle, were estimated to have a cycle reduction to 8 years if spring load restrictions were skipped. The 8-tons roads, which typically had a resurfacing cycle of 15 years, were estimated to have a cycle reduction to 11 years. It was also estimated that shorter sections in some cases should collapse and thereby have a need for rehabilitation. The total costs for the described extra need for maintenance and rehabilitation were calculated to be 80 millions NOK on the main road network and 65 millions NOK for the secondary roads, together 145 millions NOK. The sum was calculated as a minimum to keep the road surface condition at the same level as before.

The reduction in road user costs was also calculated. If there were no spring thaw axle load restrictions the heavy vehicles could carry heavier loads for each trip and a reduced amount of trips should be needed. Then the production equipment of industries could be better utilised, the quality of the products could be improved and the need for extra stock should be reduced. It might also to some degree affect the localisation of industries. The socio-economic road user profits were calculated to 190 millions NOK on the main roads and 140 millions NOK on the secondary roads, all together 330 millions NOK in socio-economic profits.

The net socio-economic profits were 330 – 145 = 185 millions NOK.

In January 1995 the Norwegian Road Administration took away all spring thaw load restrictions and increased the maintenance budget with 145 millions NOK extra per year. After 4 years without spring load axle restrictions on the state roads it can be concluded that the extra allocation of 145 millions NOK was enough to keep the roads in the same condition as before. The first period with some local collapses seemed to be over even if some severe spring thaw still might arise.

4.6 Summary

In Norway the socio-economic model HIPS is used to find the optimal long-term road condition. That is when the total costs for the society are the lowest. The total costs are the sum of the road manager costs to maintain and to improve the road condition, and the road user costs. In this case the road user costs are time costs, vehicle operation costs, accident costs and the costs caused by road works. HIPS works only on road network level and can also be used to distribute the budgets between different road classes and Road Management Regions. Recent measurements have shown that the road condition in Norway today is somewhat worse than the goals defined by the Road Administration and that an increase in the road maintenance budgets is needed to reach the long-term socio-economically optimal road condition.

For routine maintenance contracts a national road condition standard has been developed to be used as "trigger values" for maintenance actions. In Norway there are no temporary load restrictions at spring thaw. They were abolished in 1995 as a result of a big survey.

Efforts have been made to find a socio-economic model for drainage condition but so far no model has been found or developed.

5 Handling of socio-economic impact in Finland

5.1 Introduction

To find out general things about the use of socio-economic considerations taken in Finland meetings were held with Pertti Virtala, Finnish National Road Administration, and two consultants, Vesa Männistö, Inframan OY and Juha Äijö, 100 Gen OY (15). This is described in clause 5.2. A report of the Finnish Pavement Management (16) has described the management used in Finland and some figures from the current road condition were handed over by Virtala. The management process is described briefly in clause 5.3. The use of the socio-economic model HIPS is described briefly in clause 5.4.

One way to improve the road condition on a low volume paved road can be to change it back to a gravel road. This is described in a Finnish conference presentation (18) reported in clause 5.5.

5.2 General overview

Meetings with people from the Finnish Road Administration and a couple of consultants working in the socio-economic area gave an overview of how the socio-economic impact of road condition is handled in Finland (15). FinnRA is using a model named HIPS for justification of needs for money coming from Ministry of Transportation in Finland. The model HIPS (Highway Investment Programming System) is used to make cost-benefit analyses. HIPS is used for different purposes, namely

- At budget level to reach the long-term optimum on the road network, which will arise when the total socio-economic costs are at minimum.
- How to get to the optimum. The state today is that 6 000 km of roads are classified as sub-standard roads. The optimum is to have about 3 000 km of sub-standard roads and in order to reach that level there is a need for an extra allocation of 55 milj euros/year for the next 10 years. If bridges and gravel road improvement are to be included there is a need for 800 milj euros extra. Substandard roads are mainly low volume roads. The substandard is defined by the figures below.
- How to allocate money for sub road networks and districts
- How to update systems and how to keep on the right course (the need is increasing in the North).

According to Männistö (15) the ranking of projects is done to about 60 % weighting on road condition and about 40 % on other things like industrial needs or political reasons. He also claims that when ADT is less than 1 000 vehicles there is no use making socio-economic calculations with the models used today. They will not give enough benefits to justify maintenance.

The unofficial “shame values” for Finnish roads are shown for roughness and rutting in tables 7 and 8 (15). Then a maintenance measure should be done if money is available and no other candidates are worse.

Table 7. Limit values of roughness expressed as IRI in mm/m (15).

ADT/Speed limit	120-100	100-80	80-60	60-
0	5,5	6,5	8	9,5
1 500	3,0	3,7	4,8	6,0

Table 8. Limit values of rutting in mm (15).

ADT/Speed limit	120-100	100-80	80-60	60-
0	17	19	21	24

There is work going on to use socio-economically based levels of the road condition. The level can be decided e g with regard to the direct influence of the road condition for an industry or a tourist area. Possible service levels are as follows:

i. Basic Service Level
ii. Minimum Service Level
iii. Target Service Level
iv. Optimum Service Level

There is a new "planning cube" which describes the "cells for the policy" shown in figure 13. The aim is to go through all the cells in the planning cube to form socio-economic road condition levels adapted to road user needs, goals of society and economy.

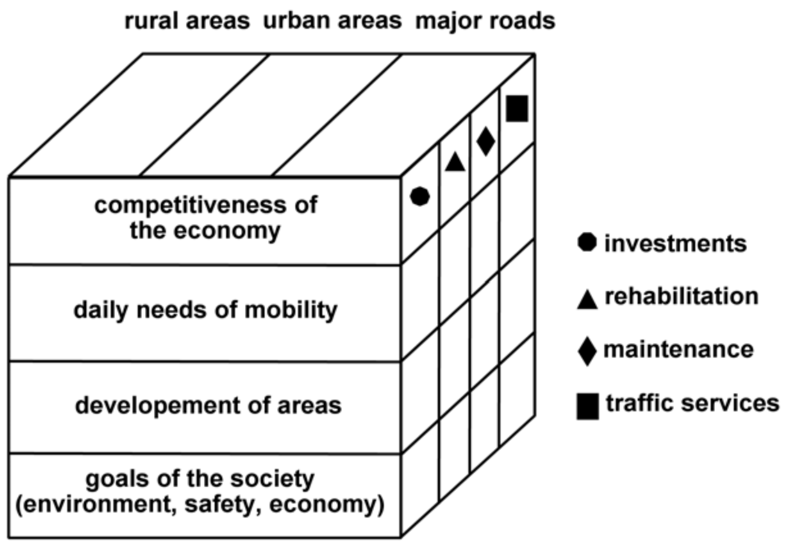

Figure 13. The Finnish "planning cube" (15).

In Finland there are discussions of whether low volume roads are worth keeping in relatively good condition. In some cases paved roads have been changed back to gravel roads again as a result of high maintenance costs for low volume roads. See clause 5.5 below (19). Paved low volume roads in Finland are divided into three groups:

a) Surface dressing roads
b) Soft Asphalt roads
c) Hot Mix Asphalt roads.

For the moment there are no special measures taken of the low volume roads. The opinion of Virtala (14) is that low volume roads should be taken away from the main network and get their own standards and after that a calculation of the optimum budget level should take place.

The gravel roads are classified visually in 5 classes by the surface condition, the spring thaw weakening and the structural condition. According to Äijö (15) there is a research project going on to develop a socio-economic model for decision making on gravel roads.

5.3 Pavement management in Finland

5.3.1 Introduction

Pavement management in Finland is described in the report "Pavement management policies and guidance" (16). The Finnish state road network comprises about 80 000 km of which about 64 % is paved roads. Though the traffic since 1950 has increased steadily (see figure 14) the budgets for maintenance and rehabilitation have gone in the opposite direction in the last ten years (see figure 15). This has created a changed age distribution of the paved road network in Finland as can be seen in figure 16. There is an existing maintenance backlog as a consequence of insufficient budgets and this affects in the first place the condition on the low volume road network, which is verified by the results from a road user survey shown in figure 17.

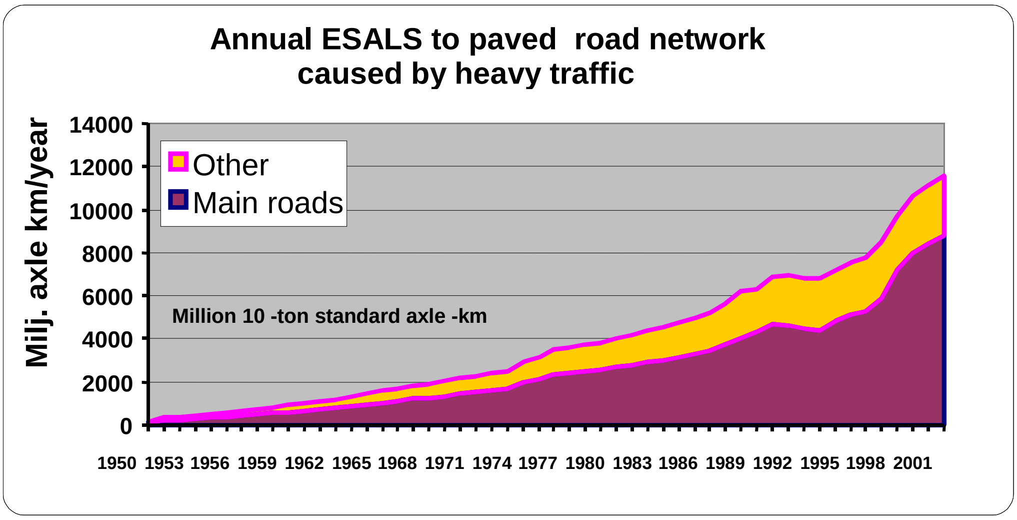

Figure 14. Annual ESALS on the paved road network caused by heavy traffic in 1950-2001 (rough calculation)(Virtala, 15).

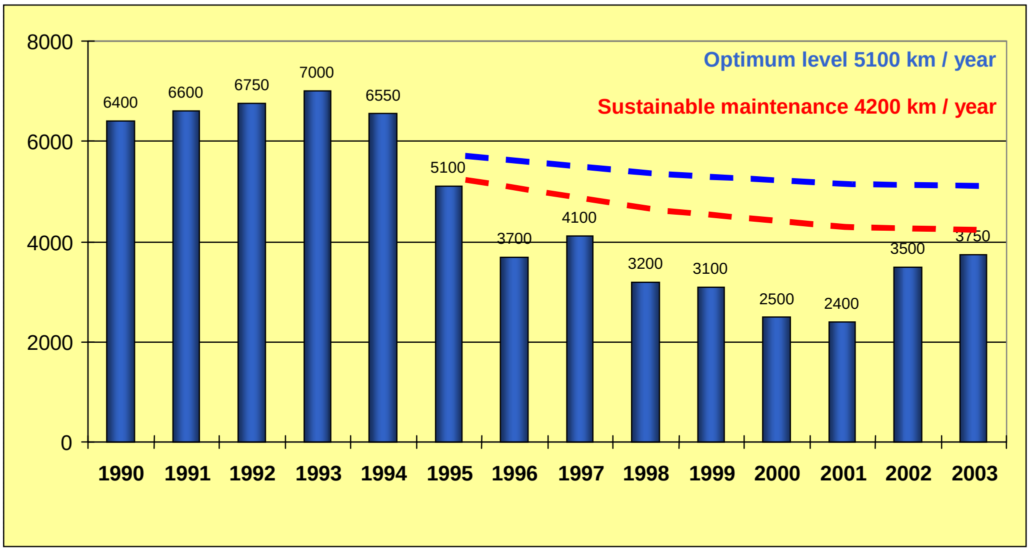

Figure 15. Pavement restoration in kilometres 1990 – 2003 (including structure improvements) (Virtala, 15)

5.3.2 The pavement management administration

The decision-making concerning the management of the road maintenance and rehabilitation takes place at three levels:

- The Ministry of Transport and Communications
  - Making general guidelines and targets for state agencies
- FinnRA's Central Administration
  - Making targets for Regions, policies and allocation of funds
- Regional offices
  - Making programs of paving works and replacement investments with the related funding.

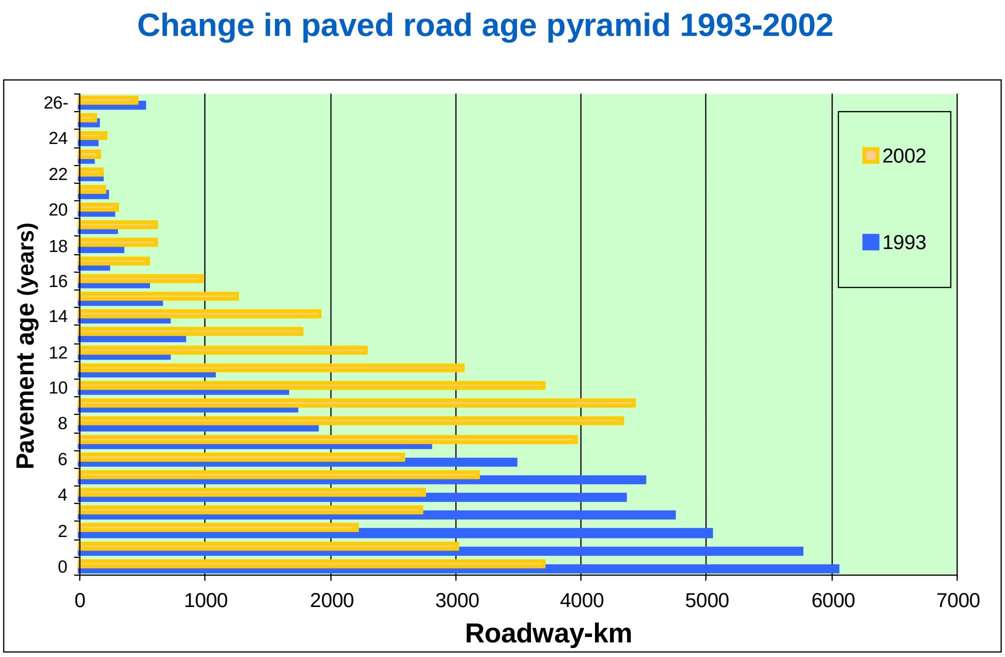

Figure 16. Pavement age has gone up notably from 1993 (Virtala, 15).

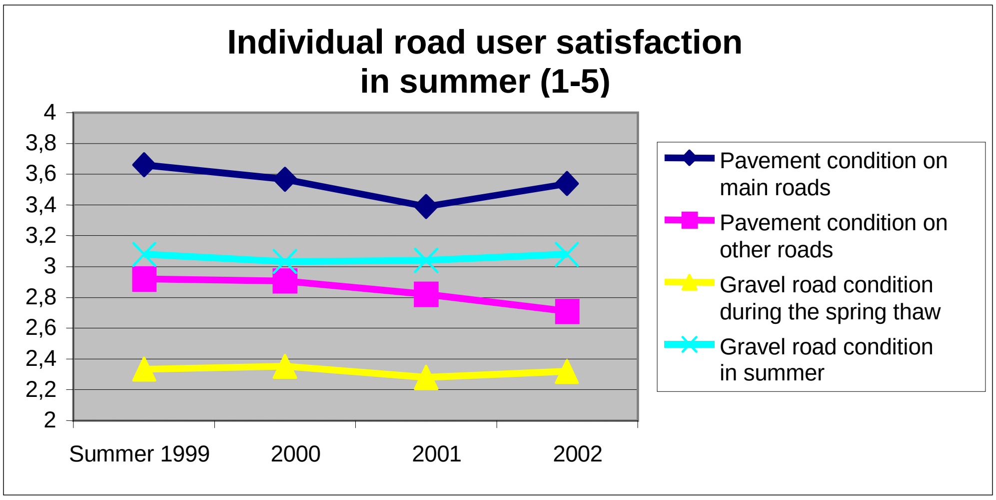

Figure 17. Individual road user satisfaction on road network summer condition 1999-2000 (Virtala, 15).

5.3.3 The aim of the management

The long-term aim for the Ministry of Transport is to implement infrastructure projects motivated by socio-economical considerations so that the condition and the capital value of the road network is maintained at a level ensuring low costs for the society and the road users. The present Government programme is expressed briefly as "The traffic networks in the entire country will be maintained in a condition that meets traffic needs". In management of the road network the priority is on the condition and the standards on the main traffic networks. The actions taken will be in the following priority:

- Maintenance
- Replacement investments
- Expansion investments
- New investments.

FinnRA will try to fulfil the program within available budgets. They are aiming for keeping a high standard of trafficability on the main road network and a satisfactory standard elsewhere also with regard to traffic safety. Regional equality is governed by offering an adequate service standard. As the budgets have been decreasing over recent years the aim has been to keep the main road network in approximately the same condition and the secondary network has been allowed to deteriorate somewhat in a controlled way. As mentioned above in 5.2 there are some new winds blowing about the low volume rural roads. By going through the planning cube shown in figure 13 a new approach for management of rural roads might be the result. In that case more attention is given to the impact of the road condition in a wider sense, e g on road user groups, coverage areas and social benefits shown in figure 18.

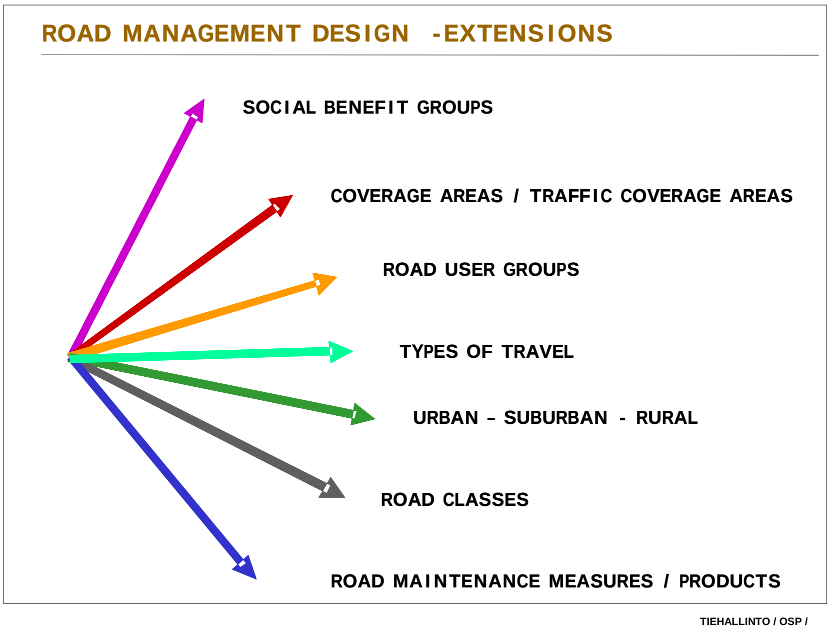

Figure 18. Road management design – extensions (Virtala, 15).

5.3.4 Condition standards and guidance tools

The condition standards are determined based on:

- Surface condition expressed as
  - Roughness as IRI in mm/m, measured on main roads every year and on other roads every second year
  - Ruts in mm, measured with the same frequency as roughness
- Structural condition expressed as
  - Defects, a weighed sum in m^2 of defects like cracking, potholes, ravelling and settlements, measured every third year by visual inspections.
  - Bearing capacity measured with Falling Weight Deflectometer at intervals of 3-5 years.

The road condition standards are suited to the amount of traffic and traffic speed. Examples are shown in figure 19. The performance target set by FinnRA is that they permit a determined percentage to fall below the acceptable standard as shown in table 9. The aim is that not more than 6 277 km of the paved road network is allowed to fall below the standard.

Table 9. Condition standards and permissible failure to meet them by traffic volume (16).

ADT	**Surface condition**		**Structural condition**		**Permissable sub-standard roads* in %**
	Roughness IRI in mm/m	**Rut depth mm**	**Sum of defects m^2**	**Bearing capacity ratio in %**	
< 350	5,5	-	140	70	18
350-1 500	4,1	20	80	70	14
1 500-6 000	3,5	20	60	70	7
> 6 000	2,5	20	30	70	7

* Roads, which do not meet the standard as a percentage of the road length in the ADT-class

The tools to check that the aim standard levels are kept are:

- The condition of the road network and the amount of traffic
- Available finance
- Societal costs.

The road condition and the traffic are measured. The amount of available finance will determine the achievable level of standard by road maintenance. The societal costs including road manager costs and road user costs are calculated by using a model named Highway Investment Programming System (HIPS), which is also used to find the road condition distribution which gives the minimal costs for the society. More about HIPS is presented in clause 5.4.

5.3.5 Pavement management policy

The pavement management policy is based on the state budget from the Parliament and on the appropriations and objectives outlined by the Ministry of Transport and Communications. The principle guidance tool is the annual performance target. The long-term objective, calculated by using HIPS, is to have sub-standard on 3 500-4 500 km. Today the figure is about 6 000 km arising from insufficient financing.

The budget allocation for the Regions managed by FinnRA is also based on cost-benefit analyses with HIPS on road network level. The aim is to get a condition standard according to the target levels given in table 9. If the budget is cut the permissible sub-standard percentage is changed accordingly. FinnRA is checking by road condition measurements named above that the Regions are fulfilling the targets.

The Regions are working with three-year plans resulting from a Pavement Management System (PMS) program. The selection of candidates is based on the road condition and the traffic class. In addition regional preferences may affect the final choice. There might be special attention paid to e g traffic safety, environmental issues or needs of local societies.

Selection of measure and material is done according to FinnRA's guidelines. The ambition is to choose the measure, which is the most economical in terms of annual costs.

5.4 The Highway Investment Programming System (HIPS)

5.4.1 Introduction

In Finland HIPS is used by the Finnish Road Administration (FinnRA) at network planning and the budget allocation is based on minimising the costs for the society, which are the road user costs and the road manager costs. HIPS uses different road user models and the system is described in the report "The effect of pavement condition on road user costs" (17). The objective of the report was to investigate the influence of the road condition on road user costs.

The road network is divided by traffic into 8 ADT-classes shown in table 10. The road condition is described by four road condition variables:

- Longitudinal unevenness
- Rut depth
- Defect index
- Bearing capacity ratio

Of the road condition variables the longitudinal unevenness has the greatest impact on the road user costs. The target road condition standard in each class is determined by FinnRA.

Table 10. Traffic classes used in Finland (17).

AC Pavements	Cold mix AC Pavements
ADT Vehichles/day	**ADT Vehichles/day**
> 6 000	> 1500
> 1 500	> 800
> 350	> 350
< 350	< 350

5.4.2 Road user cost models in the HIPS-program.

The sub-models for road user costs in HIPS are models for:

- Vehicle Operation Costs (VOC)
  Costs for tyres, spare parts etc for different types of vehicles caused by the road condition.
- Time Costs (TC)
  Costs for delay caused by the road condition, unit rates depending on vehicle type
- Accident Costs (AC)
  Accidents caused by the road condition divided into fatal accidents, severe injury, material damage and traffic accident in average and each accident type has a default cost.
- Environmental costs caused by the road condition (used since 2000)
  Costs for noise, nitrogen oxides, hydrocarbons, particles and carbon dioxide
- Additional costs because of maintenance works
  Default costs/km depending on traffic class, vehicle type and maintenance measure.

The models will not treat the rural low volume roads in any special way.

5.4.3 Comparison with other road user cost models

A comparison was done between the following models:

- The Finnish model HIPS as reference
- The Swedish RUC models
- The Norwegian RUC models
- Highway Development and Management Tools, HDM-4.

It was found that the Norwegian model gave much higher road user costs than the other models since it puts a lot more emphasis on the longitudinal roughness. The Finnish and the Swedish models give quite similar costs. With HDM-4 the optimal budget is lower and the road network condition is worse. The HDM-4 model is complicated and needs to be calibrated to Nordic conditions. Including environmental effects in the calculations will not influence the optimal condition, as its dependence on road condition is unknown.

5.4.4 The use of HIPS

HIPS uses 10 condition states, 4 condition variables and 3 classes of each variable, which means that there are 81 different condition classes for Finnish roads. The 4 condition parameters are rutting, unevenness expressed as IRI in mm/m, a pavement distress sum index and a bearing ratio based on measurement with FWD. The road condition variables are shown in figure 19. With HIPS the road condition distribution giving the lowest total costs for the society can be calculated. The costs include road management costs and road user costs calculated with sub-models mentioned above. If the road condition is improved on the low volume road network this will only give a marginal cost reduction on the whole due to the low number of road users. Therefore HIPS will favour the road condition on high traffic roads.

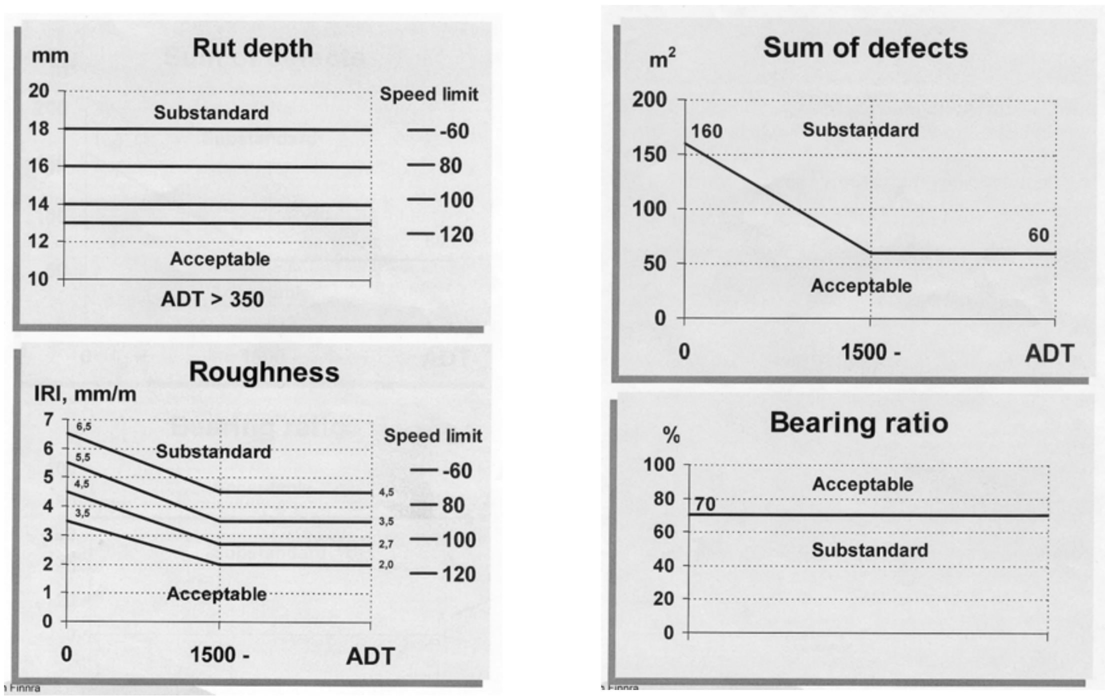

Figure 19. Road condition variables used in HIPS (15).

5.5 Changing paved roads back to gravel roads

One unusual example of getting better road conditions on low volume roads is described in a report by Lintilä, Mustonen and Mäkiö (18). During the late 80's many Finnish low volume gravel roads were paved due to a low price of bitumen. The roads were paved without any structural rehabilitation and were meant to last some five years. Some of these roads reached 10-15 years of age about year 2000, badly deteriorated, still without any proper reconstruction. The maintenance costs of the roads were increasing and the deterioration was getting worse. The main reason for the problems is the decreasing budgets. In a few cases the Regional offices have taken the decision to change paved roads back to gravel roads. At that time at least 30 % of the total road length of the actual road has been in poor shape. Before such a radical step is taken an investigation is done of the actual road section as follows:

- The condition level
- The number of inhabitants along the road, social and economical aspects
- Traffic volume and vehicle fleet distribution
- Economical estimation of each possible alternative action
- Land use in the particular area, agricultural and industrial factors
- Network significance of the road.

These roads were typically paved more than 10 years ago, with a thin layer of soft asphalt or a surface dressing on gravel. The road condition is so bad that road users feel inconvenience or even danger when driving on the road. The road manager will notice it as an increase in complaints and even compensation demands for burst tyres, broken vehicle suspensions etc.

Figure 20. Grader on a Finnish gravel road.

Socio-economic cost-benefit analyses must be done before changing a paved road into a gravel road. A method of calculation has been developed, which includes agency costs, vehicle operation costs and a road user's comfort factor. A cost comparison is made for three different alternatives:

- Changing the paved road back to a gravel road
- Only necessary maintenance
- Reconstruction and repaving.

The results are shown in figure 21. The figure shows that changing a paved road into a gravel road is economically reasonable if the average daily traffic is less than 200, if there is no need for rehabilitation. If rehabilitation is needed the limit is ADT 500. In most cases only roads with ADT less than 250 are possible candidates. As mentioned above the traffic flow is only one parameter to judge from. There are also other considerations, which have to be made, that might totally change the picture of the choice between a paved road and a gravel road.

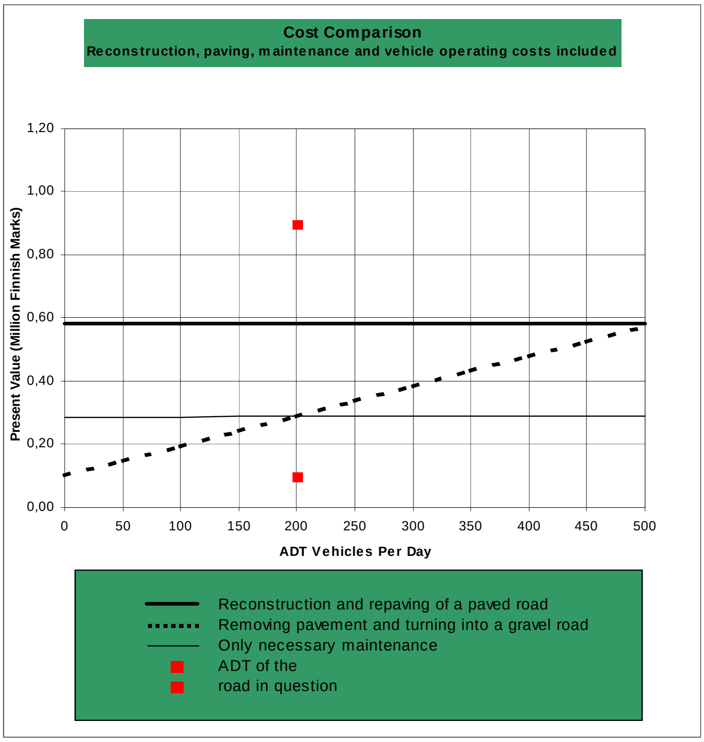

Figure 21. Cost comparisons of different actions (18).

5.6 Summary

In the Finnish pavement management a socio-economic model named HIPS is used to motivate money from the Ministry and to allocate money for the Regions. HIPS is used to calculate the road conditions on network level, which give the lowest total costs for the society. There is no special attention paid to the low volume roads in rural areas in the model. In meetings with FinnRA and a couple of consultants (15) though a couple of encouraging things were found:

1. There is work going on to get another view over the influence of the road condition on the whole society, which might change the view of the low volume roads.
2. There is work going on to develop socio-economic models for the gravel road management.

These things can be of greatest interest for ROADEX. Findings in that work might be useful to improve the budget allocation for low volume roads and thereby road conditions in rural areas.

It has been found that there are four administrative levels, which have to be influenced if a real change in view of the low volume rural roads is to become a reality:

- The Parliament
  - Making the state budget
- The Ministry of Transport and Communications
  - Making general guidelines and targets for state agencies
- FinnRA’s Central Administration
  - Making targets for Regions, policies and allocation of funds
- Regional offices
  - Making programs of paving works and replacement investments with the related funding.

Information is needed on all these levels to influence the decision makers.

In a few cases in Finland paved roads are in very bad condition requiring very high maintenance costs have been changed back to gravel roads again. This is an extraordinary measure, which might be of benefit for the road users.

6 Handling of socio-economic impact in Scotland

6.1 Introduction

Several attempts have been made lately in the Highlands to highlight the situation for the low populated rural areas. One thing is identification of the fragile areas in the Highlands, where it is a risk that the societies are not strong enough to survive. The most fragile areas are shown in dark red colour in figure 22.

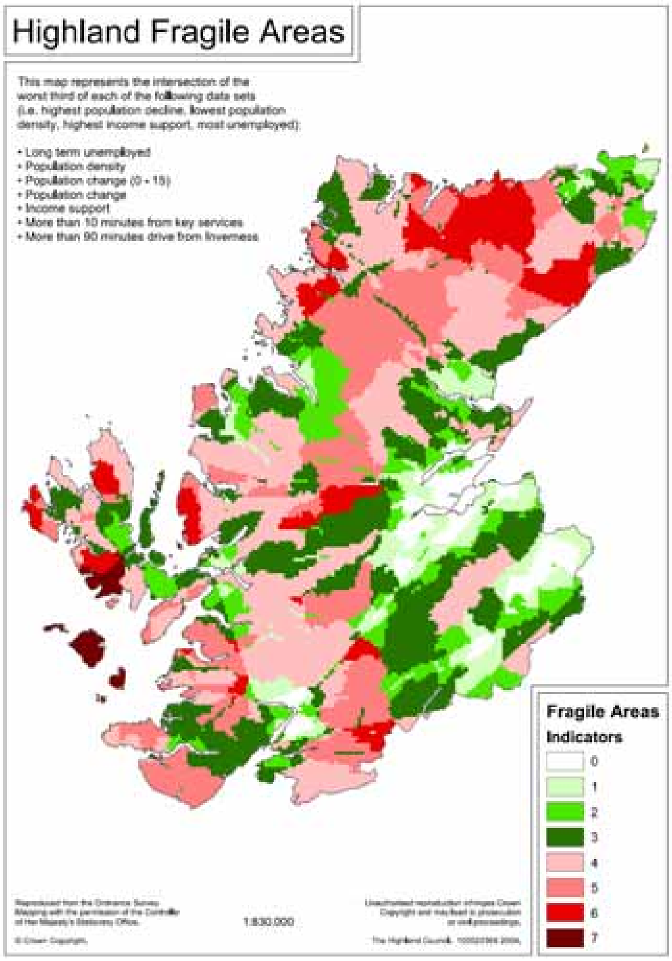

Figure 22. Fragile areas in the Highlands 2003 (from the Highland Council).

Another thing is a transport study made by Sutherland Partnership, named North Sutherland Community Transport Study (22). It reveals the need for economic support and co-operation to give people transport possibilities to secure access to education, health services and social services in rural areas. It is also found that the Community Transport is doing a good job supporting the Public Transport.

Meetings held in Inverness in June 2004 gave interesting information on Scottish Road Pavement Management and on methods used for socio-economic calculations on investments. More information about that is given below in clause 6.2-6.6. There is also one report from the forest industry described in clause 6.7.

6.2 General overview

In a meeting with people from the Highlands Council (19) several things were discussed. One of the things was the Scottish Design Manual for Roads and Bridges (DMRB). One interesting part of the DMRB concerning socio-economic assessments was Volume 15, Economic Assessment of Road Schemes in Scotland. The assessments were made by means of a computer program named Network Evaluation from Surveys and Assignments (NESA) (23). NESA was mainly used for investments in new roads and in rehabilitation projects and was also used to calculate traffic forecasts. Clause 6.3 gives more information about NESA. Another interesting part of the DMRB for this project is Volume 14, Economic Assessment of Road Maintenance. This assessment is done by means of another computer program named Queues And Delays at Roadworks (QUADRO) (24). The program is aimed at managing the maintenance on existing roads. More details of QUADRO are given in clause 6.4. A rather new document discussed in the meeting was designed for use in all new investments in the transport sector in Scotland. It was named Scottish Transport Appraisal Guidance (STAG) (25) and is briefly described in clause 6.5.

Figure 23. Single-track road in the Western Isles (photo Ralph Shackleton, The Western Isles Council).

In another meeting with people from Highland Council (20) road management was discussed. The population in Highlands is about 210 000 and the road network is some 6 500 km. The road network is divided into different classes depending on traffic and urgency:

- Class A Strategic roads
- Class B Regional distributor roads
- Class C Local distributor roads
- Class U Unclassified, local municipal roads

In class U there are also single-track roads serving communities in rural areas (see figure 23).

For a couple years HC has been working in a project named Scottish Road Maintenance Condition Survey (SRMCS). The goal is to find the methods and analyse systems to get repeatable and reliable information of the road surface condition, and the performance indicators are:

- Rutting
- Roughness
- Texture depth – friction indicator
- Edge deformation
- Cracking

The road condition is shown on GIS maps where the condition severity is described in different colours (see figure 24). The colours are:

- Green Acceptable condition
- Amber Further investigation is needed to see if treatment is needed
- Red Repairs should be considered

From the performance indicators the need for structural maintenance and routine maintenance can be calculated. The results are used in the budget discussions and the aim is to get more money for road maintenance. For the moment Highlands resurface about 3,4 % of the surface dressed roads every year which gives a life cycle of about 30 years. The hot mix resurfacing is about 1,26 %, which gives a cycle time of about 80 years. The budget need for hot mix and surface dressing resurfacing is estimated to about £13 million, and the present budget is about M£2. The budget situation is similar to the situation in the other partner countries.

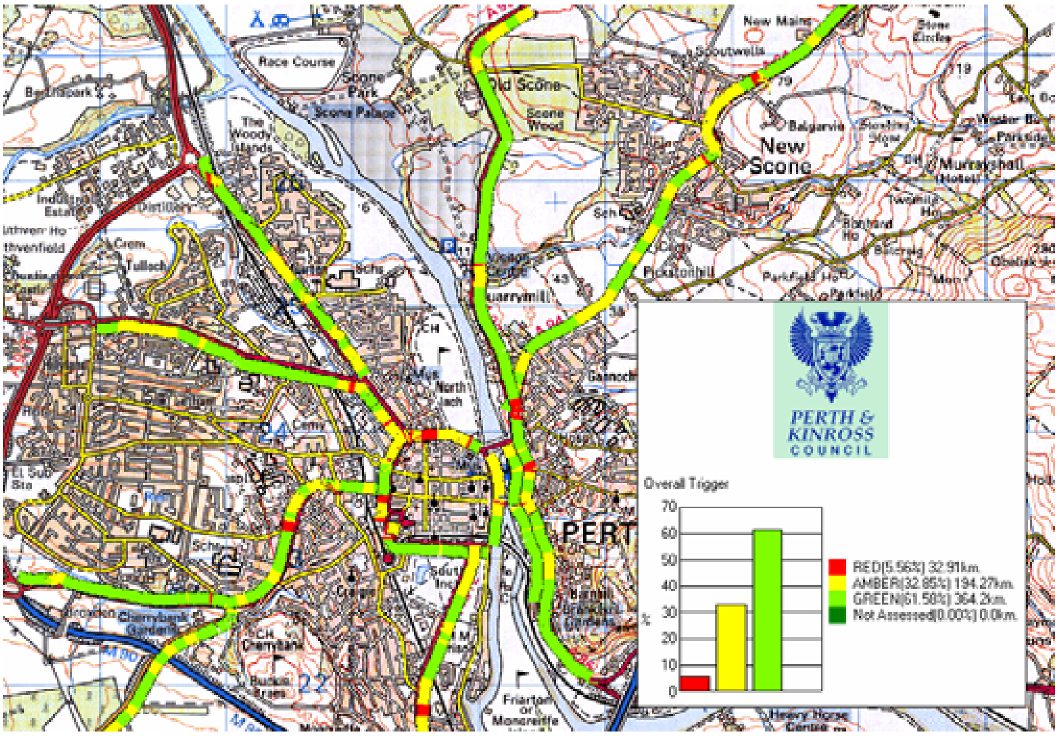

Figure 24. Examples of measured road conditions shown on GIS map (20).

At the meeting, (20), discussions were held on the socio-economic conditions related to road condition in the management of Scottish roads. It was found that there were no expressed policies for socio-economic considerations for level and distribution of budgets, choice of maintenance action, service level or load restrictions. Highlands has no "shame levels" on road condition, but there is work going on to introduce such values. About 85% of the routine maintenance is carried out in-house and the rest by contractors. The "trigger values" for the routine maintenance are defined by the road manager. In Highlands there are no longer any state owned gravel roads. There is a big maintenance need on the low volume roads and there is a desire for models showing the needs for the politicians to get more resources.

In a third meeting with people from Highlands Council, HITRANS and Western Isles (21) there was a discussion of an interesting report on Lifeline roads, "Investment in Lifeline Rural Roads" (26). HITRANS is short for "The Highlands and Islands Strategic Transport Partnership", which is an association with partners from councils and transport companies in Highlands and Islands (27). The objectives are:

- A cost reduction for transportation of people and goods
- A reduction in journey times by investments in the infrastructure
- An improvement of the integration in the public transport system.

HITRANS has identified five key issues:

- Economic development - good transport services will increase attraction for investments and people
- Accessibility and integration – by improvements of the infrastructure
- Lifeline services – vital links to islands and remote rural areas
- Environment – transport services with care of the environment
- Delivery – sustainable funding for the infrastructure.

The report about Lifeline roads is one activity of HITRANS, which is described further in clause 6.6.

6.3 Network Evaluation from Surveys and Assignments (NESA)

NESA (23) is a part of the Scottish design manual for roads and bridges (DMRB). It is a part of Volume 14 titled "Economic Assessment of Road Schemes in Scotland. The road scheme appraisal includes the outcome of operational, economic and environmental assessments, shown in figure 25.

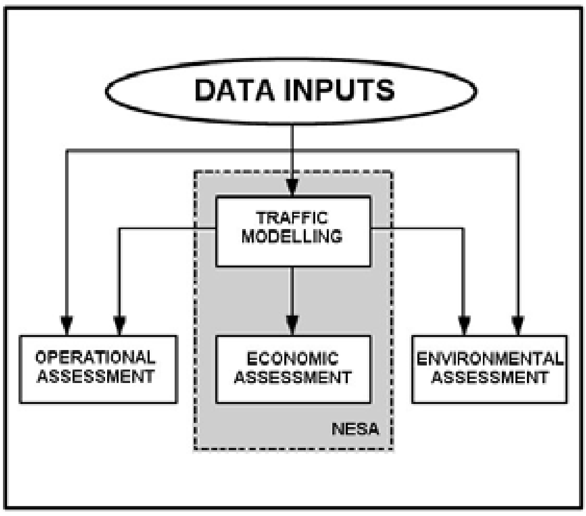

Figure 25. The components of a road scheme appraisal (23).

As can be seen in the figure NESA is only one part of the total assessment. NESA is a computer program used for socio-economic assessments, which calculates the user costs, benefits and economic return for road investments. The program converts all costs and benefits to monetary units. It is mandatory in Scotland to undertake a formal economic assessment for all trunk road schemes costing more than one million pounds. The normal time period used is 30 years. Central in NESA is the cost-benefit analysis. A comparison is done between the existing network, "do-minimum", and one or several alternatives, "do-something". The analyses are designed to measure the net social benefit of a scheme by comparing the sum of benefits generated to the sum of costs generated. The sums are discounted to present values by a fixed discount rate at 6 % and the net profit is described as the Net Present Value. Thereby it is possible to judge the "value for money" for a proposition. The principles are shown in figure 26.

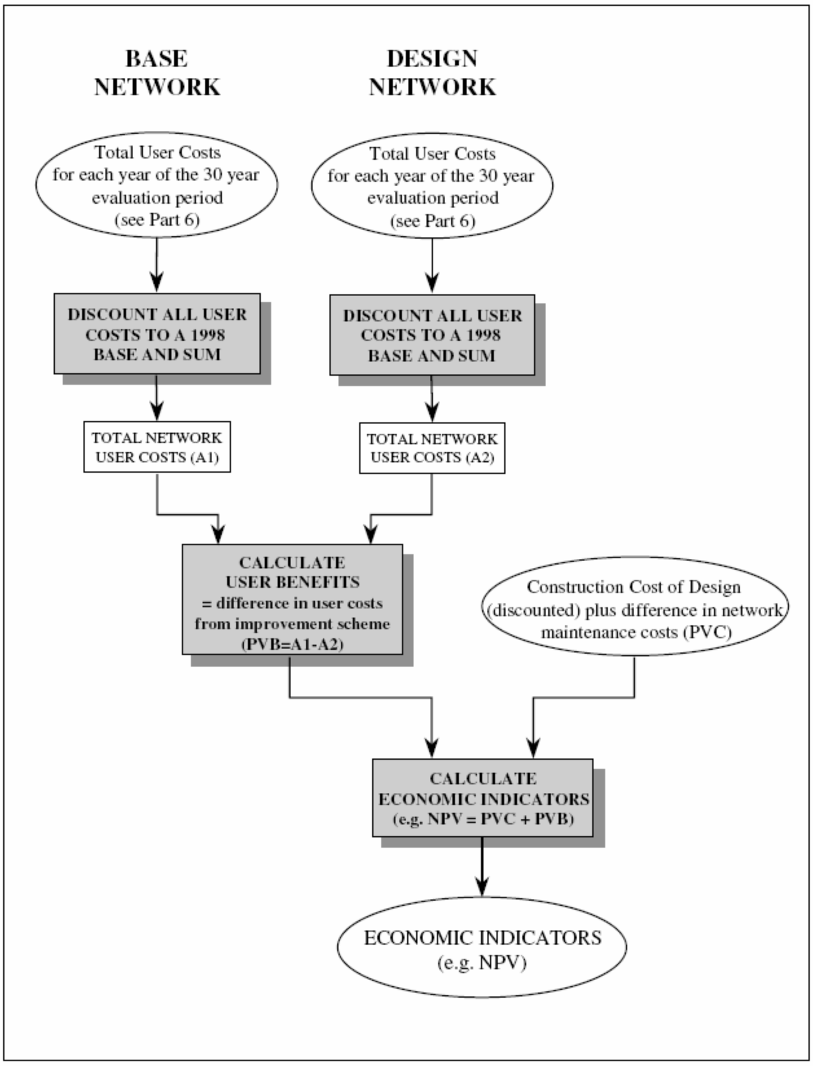

Figure 26. The NESA economic appraisal method (24).

The cost types used in NESA are:

- Capital costs of the road improvement
- Maintenance costs
- Travel time costs
- Vehicle operating costs
- Accident costs.

The benefits are the reductions in road user costs consisting of travel time costs, vehicle operation costs and accident costs generated in the design network. Fundamental to the analysis is the traffic flow calculated by NESA. Naturally networks with high traffic flow will be favoured by the model as the aggregated benefits for these will be bigger for the society than on networks with low traffic flow. Road user costs for road works and for road surface conditions are not included in the model.

The model is suited to investments in road networks with medium and high traffic, but it has some interesting features, which might be of use in our project.

6.4 Queues And Delays at Roadworks (QUADRO)

Another interesting part of the Scottish Design Manual for Roads and Bridges (DMRB) for this project is Volume 14, Economic Assessment of Road Maintenance. This assessment is done by means of a computer program named Queues and Delays at Roadworks (QUADRO) (24). The purpose for the program is to provide a method for assessing the total costs of major road maintenance works like resurfacing and reconstruction. QUADRO calculates the costs for the maintenance works and the road user costs caused by the maintenance works. That includes costs for extra time and for vehicle operation costs and accident costs caused by the maintenance works. The extra costs are calculated as the difference between the total road user costs with and without maintenance work. The program can be used for assessing an individual job or for a life cycle, normally used is 30 years. When assessing a life cycle the maintenance actions and their individual durability are determined from engineering experience.

To use the program the project size must be big enough to affect the traffic flow significantly over a reasonably period of time. QUADRO does not calculate road user costs for road surface conditions during the road lifetime.

6.5 Scottish Transport Appraisal Guide (STAG)

The third interesting tool used in Scotland for appraisal of projects is the Scottish Transport Appraisal Guide (STAG) (25). It is a document to aid transport planners and decision makers in the development of transport policies, plans, programs and projects in Scotland. That includes projects in all modes of transport ranging from local pedestrian or cycle paths to major projects involving roads, railways, ferries and air services. STAG is to be used for appraisal of all projects supported or approved by the Scottish Executive. The key aims with the document are:

- A strong economy
- A clean environment
- An inclusive society.

These aims were supported by the five appraisal objectives:
- Environment
- Safety
- Economy
- Integration
- Accessibility.

The appraisal is divided into two parts:

- Part 1 – is a simple and quick assessment of one or more alternatives to see if they meet the planning objectives and appraisal objectives. If they are promising and meet the objectives they will pass to
- Part 2 – which is a detailed appraisal. The process is shown in figure 26.

Both parts end up in an Appraisal Summary Table (AST).

The appraisal process has three main purposes:

- To demonstrate whether a proposal is socially, environmentally and economically deliverable and is technically and financially suitable
- To reveal the extent to which a proposal fulfils the planning objectives
- To demonstrate the possible impacts of the proposal on the Government's five objectives, environment, safety, economy, integration and accessibility.

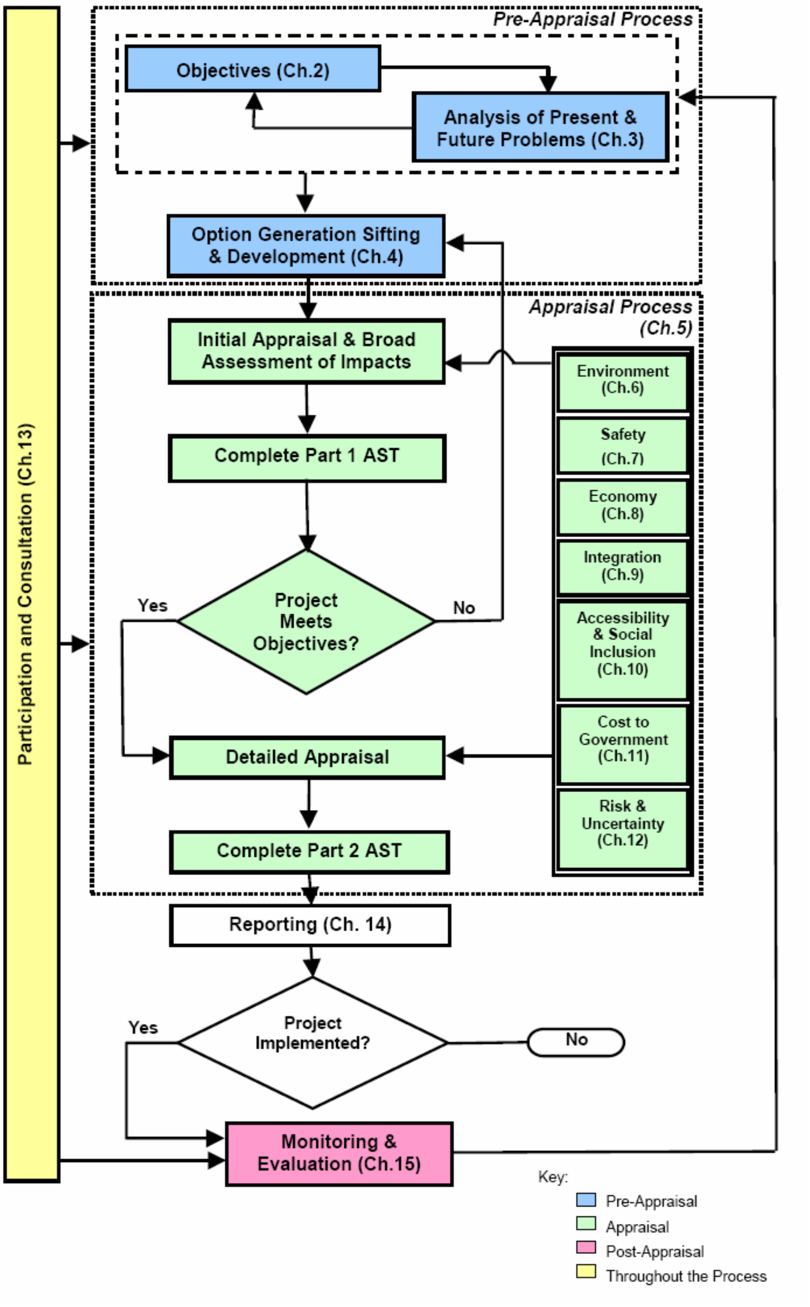

Figure 26. Planning and appraisal process in STAG (25).

Here is a short description of the Part 2 appraisal process against the Government's objectives named above.

6.5.1 Environment

The environmental aspects of a proposal shall be appraised in terms of:

- Noise and vibration
- Air quality
- Water quality
- Geology
- Biodiversity
- Visual amenity
- Agriculture and soils
- Cultural heritage
- Landscape.

Collected data is to be appraised by magnitude and significance.

6.5.2 Safety

The safety objective has two parts:

- Accidents – appraisal built on established practice, assessment of accident savings
- Security – appraisal for perceived safety of road users and their vehicles.

6.5.3 Economy

The appraisal of economic impacts is divided into two sections:

- Transport Economic Efficiency (TEE) – economic welfare impacts assessed in terms of road users' willingness to pay to use the road and financial impact on private sector transport providers. The road user benefits includes travel time savings, user charges, vehicle operating cost changes, quality benefits and reliability benefits.
- Economic Activity and Location Impacts (EALIs) – assessment of any national, regional or local impact on employment/GDP and impacts associated with land-use.

6.5.4 Integration

Integration has three elements in STAG:

- Transport integration – aimed to give seamless public transport system and ticketing
- Transport land-use integration – check against policies
- Policy integration – fit between the proposal and wider policy aims in Scotland.

6.5.5 Accessibility and Social Inclusion

Two items are tested:

- Community accessibility
    - Public network coverage – impact of the proposal for each group in the society
    - Access to local services – possibilities to walk or cycle to services and facilities
- Comparative accessibility – assessment of the distribution of accessibility impacts by people group and location.

6.5.6 Results of Part 2 Appraisal Summary Table (AST).

The final section of AST is a summary of the monetised information. The value for money should be calculated as Net Present Value (NPV) of the project and the Benefit/Cost to Government Ratio. The usual life length used at the calculation of NPV is 30 years and the discount rate used is 3,5 %.

The calculated value for money is only one part of the assessment, which might be of help in the ranking of competing road proposals. For the final decision the non-monetised impacts on e g environment, social inclusion and different groups in the society must also be assessed.

6.5.7 Comments on STAG

For projects costing less than £5million a reduced STAG is enough and STAG is not required for maintenance actions. STAG has some interesting features though, which might be useful in providing more money for the rural roads. It deals with accessibility and social inclusion. The road surface conditions during the road lifetime is not explicitly shown to affect the road user costs but might be considered in the road users willingness to pay.

6.6 Lifeline Rural Roads

6.6.1 Introduction

A very interesting study about rural roads in Scotland reported by HITRANS has used the concept Lifeline Rural Roads. HITRANS is short for the Highlands and Islands Strategic Transport Partnership, which is an association promoting regional transport as mentioned above in clause 6.2. The report is named "Investments in Lifeline Rural Roads" (26a, 26b) and the definition of a lifeline road is "A transport link which has no substitute, or where the substitute entails a considerable increase in time or money expenditures, where any diminution in the quality, reliability or availability of the former, is likely to have a significant impact on the social or economic viability of an affected community." The aim of the study is to investigate the causal link between the condition or availability of the lifeline road and the social and economic vitality of a particular community. The final goal was to support the campaign for further investments in lifeline rural roads.

Nine key roads were identified as possible candidates for improvement. The candidates served areas of Highlands and Islands that suffer from varying degrees of economic and social deprivation. The appraisal of each road was carried out according to STAG with complete analyses of Transport Economic Efficiency (TEE) and Economic and Locational Impacts (EALIs) as mentioned in clause 6.5 above.

Figure 27. Lifeline rural road in the Western Isles (photo Ralph Shackleton, The Western Isles Council).

6.6.2 Baseline audit

A survey was done on each of the selected roads to check the prevailing road condition. It was found that most of the roads were not 'fit-for-purpose' and that the proposed scheme improvements were required to maintain adequate accessibility to the served communities. Existing travel times were high and had big variations depending on bad road conditions and occasionally partly or total closure.

6.6.3 Business survey

A business survey was also done and the key results were:

- The majority of firms were geographically immobile and heavily dependent on the transport network
- More reliable and cheaper transport was considered to be an important factor
- 75 % of the businesses considered transportation of goods and supply to be very important for the business
- 50 % of the firms expected a road scheme improvement to reduce the transport costs and allow for an increased turnover
- 33 % of the firms considered that a road scheme improvement would allow them to expand their employees by 10 % or more.

6.6.4 TEE results

The TEE analyses included calculation of road user benefits over 30 years in three forecasts, low forecast, central forecast and high forecast depending on the anticipated time savings and volumes of travel. The present values were calculated with a discount rate of 3,5 %. These monetary benefits were compared to the outline costs. The results at the central forecast indicate that for almost half of the selected roads the benefits will cover the costs. At the high forecast seven roads are profitable and at the low forecast none is profitable.

6.6.5 EALI results

The EALI analyses have found that the lifeline roads have great importance for sustaining economic activities in rural areas. Primary industries have long way to go to the markets. Good accessibility is also needed to encourage tourism into rural areas.

6.6.6 Conclusions

Several of the selected roads were considered not to be in a 'fit-for-purpose' condition to offer a reasonably good accessibility to give sustained economic and social prosperity in the served societies. An upgrade in the road condition is needed to provide long-term sustainability. The economical analyses have shown that the benefits in a few cases are sufficient to cover the costs calculated over a period of 30 years. Additionally many of the proposed road schemes will give indirect benefits like increased employment, reduced transport costs and better accessibility to markets and customers.

6.7 Scottish forest roads

6.7.1 Introduction

In a Scottish research project named “Review of Timber Haulage and Forest Roads – Solutions for Cost-effective Transport and Strategic Benefits in Scotland” (27), commissioned by the state-owned Scottish company Scottish Enterprise, some socio-economic considerations are made. The overall aim of the project is to provide guidance, which leads to reduced maintenance costs on forest roads and encourages initiatives that reduce the impact of timber haulage on the public. It is focused on three inter-related subjects:

- Forest road materials and specification
- Forest vehicle specification
- Management of traffic.

6.7.2 Forest road and materials specification

The report gives recommendations for road design and gives advice on qualities and grading of unbound aggregates used in the road pavement. One of the many pieces of good advices given is to test the strength of the aggregate and the subgrade by using a loaded lorry rolling forward and backwards over a test construction section at the site.

Figure 28. Naver forest access road in Scotland (photo Andrew Dawson, Nottingham University)

6.7.3 Forest vehicle specification

Much attention is paid to the trucks and trailers used to transport the timber from the forest to the client. Different vehicle types with different types of wheel configurations are examined. Fuel economy is also examined in the project. It is found that travelling with a loaded vehicle on a forest gravel road will increase fuel consumption with about 100 % compared with travelling with the same load on a tarmac road. If it was allowed to use rebated heavy oil (red diesel) instead of using derv (white diesel) this would give a significant saving in cost. Also, other vehicle costs are compared between vehicles used for timber haulage and vehicles transporting general goods. The result is that it is about 80 % more expensive with timber haulage. A new type of vehicle designed for timber haulage on forest roads is tested and compared with existing types. The results are promising showing lower costs and less road damage.

6.7.4 Management of traffic

In a study concerning road network management for forest roads the Highway Design and Maintenance Standards Model (HDM-4) was used. The HDM-4 is an analytical framework based on life cycle analyses of road pavements. It deals with:

- Road deterioration
- Roadwork effects
- Road user effects
- Socio-Economic and Environmental effects

The Model was calibrated and adapted to local conditions in the Galloway area in Scotland. Then it was used on 9 different road sections. From each road section, data on road length, width and vertical and horizontal alignment were collected. Also pavement data on road surfacing and subgrade material characteristics were collected. Then the annual average daily traffic was determined and pavement condition data were surveyed. The nine sections were analysed over a period of 20 years and the discount rate used was 5 %.

Six different maintenance strategies were investigated:

- Base alternative, grading once/year, spot repair by replacing 20 % of material loss when thickness falls below 50 mm
- Alternative 1, Resurfacing every 10 years, grading once/year, spot repair by replacing 20 % of annual material loss when thickness falls below 50 mm
- Alternative 2, Resurfacing every 10 years, grading twice/year, spot repair by replacing 20 % of annual material loss when thickness falls below 50 mm
- Alternative 3, Resurfacing every 7 years, grading once/year, spot repair by replacing 20 % of annual material loss when thickness falls below 50 mm
- Alternative 4, Resurfacing every 7 years, grading twice/year, spot repair by replacing 20 % of annual material loss when thickness falls below 50 mm
- Alternative 5, Resurfacing every 14 years, grading once/year, spot repair by replacing 20 % of annual material loss when thickness falls below 50 mm.

The best strategy for each road section depends mainly on the traffic level and the road geometry. For sections with AADT between 10-20 the base alternative is the most economic one. On section A, with a little more traffic, it is noticed that Alternative 2 gives the best economic result. As the only difference between alternative 1 and 2 is the grading frequency it emphasises the importance of the grading activities. This can be seen also by comparing Vehicle Operation Costs (VOC) on section A between alternative 2 and the base alternative. The VOC costs for a Volvo FM12 truck is about 4 % higher for the base alternative.

It is stated that HDM-4 is useful to develop solutions for cost-effective transport and strategic benefits in Scotland, but still a more detailed calibration of the model is needed.

6.8 Summary

For the moment socio-economic models are not used regularly in the Road Maintenance Management in Scotland. When it comes to new investments in Transportation Infrastructure it is quite different. Then there is a requirement of a socio-economic survey to do the final judgement of the investment candidates.

Much work is done in Scotland to find ways to preserve and develop small communities in rural areas. Fragile areas have been identified by means of properties like population density, long term unemployment and income support. An interesting project run by the Scottish co-operative transportation organisation HITRANS is named "Investments in lifeline rural roads". The definition of a lifeline road is "A transport link which has no substitute, or where the substitute entails a considerable increase in time or money expenditures, where any diminution in the quality, reliability or availability of the former, is likely to have a significant impact on the social or economic viability of an affected community." In the project nine key roads were identified as possible candidates for improvement. The candidates served areas of Highlands and Islands that suffer from varying degrees of economic and social deprivation. The appraisal of each road was carried out according to STAG with complete analyses of Transport Economic Efficiency (TEE) and Economic and Locational Impacts (EALIs). Several of the selected roads were considered not to be in a 'fit-for-purpose' condition to offer a reasonably good accessibility to give sustained economic and social prosperity in the served societies. An upgrade in the road condition is needed to provide long-term sustainability. The economic analyses have shown that the benefits in a few cases are sufficient to cover the costs calculated over a period of 30 years. Additionally many of the proposed road schemes will give indirect benefits like increased employment, reduced transport costs and better accessibility to markets and customers.

In a research project on Scottish forest gravel roads the HDM 4-model has been used to evaluate different methods for gravel road maintenance.

7 Health aspects of road conditions

Road surfaces are more or less comfortable for the road user to travel on. The usual way to express the roughness of road surfaces is by measuring the International Roughness Index (IRI). It is based on a quarter-car model travelling on a road surface at a constant speed of 80 km/h and it describes the vertical shaking in a vehicle. The IRI-value is most affected by irregularities with a wavelength between 1-30 meters. It is measured by laser or ultra-sound and expressed in mm/m.

The influence of vibration exposure on health for truck drivers was surveyed in USA at the end of the seventies in a big research study. It was found that there was a connection between the truck cab vibrations and traffic safety and that the vibrations may also affect the truck drivers' health (28). It was also reported that the vibrations should be eliminated at the source as much as possible. In a EU directive, 2002/44/EC (29), limits for exposure of vibrations are outlined. The responsibility rests on the employers as expressed in clause 7: "Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to vibration, with a view to improving the safety and health protection of workers." Naturally a basic way to reduce the vibrations in vehicles driving on roads is to improve the road condition and in the end the requirements will reach the road managers.

It has been stated in a Swedish report recently (30) that the measure IRI is far from enough to describe the impact, which road surface irregularities have on human bodies. Horizontal acceleration, which is not taken into account in the IRI-value, has a major impact on human bodies travelling on uneven roads. The report suggests a new type of roughness index, a Human Roughness Index (HRI), related to humans. It has also been found that the methods used today to measure roughness will not mirror the roughness affecting heavy vehicles. The heavy vehicles will give deflections on soft roads, which will create another roughness pattern not measurable with normal measurement equipment. Therefore a new measurement method is proposed in a Swedish report (31).

In a Swedish report named "Whole-body vibrations when riding on rough roads" (32), written by Johan Granlund, it is said that the road surface irregularities and texture will cause different types of strains to human beings because of e g noise, infra sound and shakings of the body. They can be divided into three different categories, for which criteria can be posed and limit values can be assessed:

- Feelings of discomfort
- Influence on activities (the ability of performance)
- Influence on health

The effects depend on the magnitude and intensity of the disturbance, the individual properties and the actual situation.

The body vibrations related to health aspects when travelling on uneven roads are discussed. It is stated that the vibrations are related to three different factors:

- The road surface irregularities
- The properties of the vehicle
- The driver behaviour (including driving speed).

A field test was performed on road 90 on 32 km, most of it in bad shape, where the roughness expressed as IRI-values reached almost 15 mm/m. Measurements were performed of the whole body vibrations on people travelling in a truck and in an ambulance. From the results of the measurements it was possible to find the regression line between the roughness expressed as IRI and vertical vibrations in the driver seat shown in figure 29. By the regression analyses with different vehicles driven at different speeds mathematical models could be formed to calculate the acceptable roughness for different vehicles at different speeds shown in figure 30.

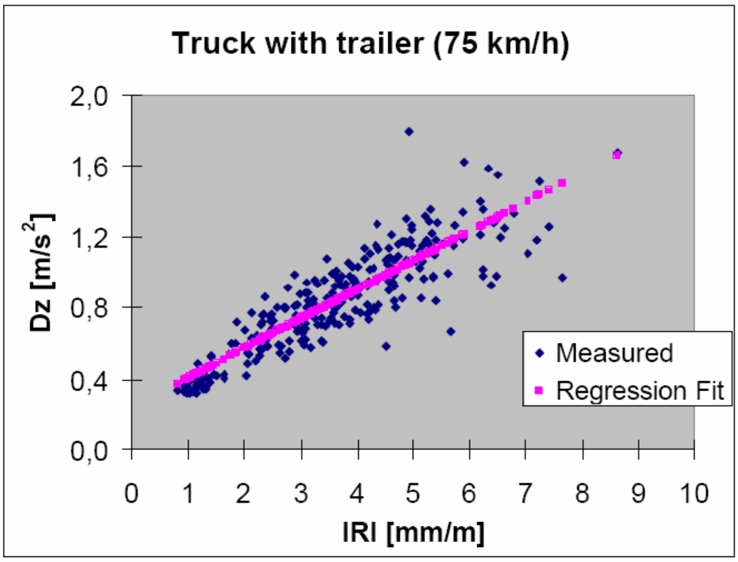

Figure 29. Regression analyses for vertical translational vibrations at the seat in the truck (32).

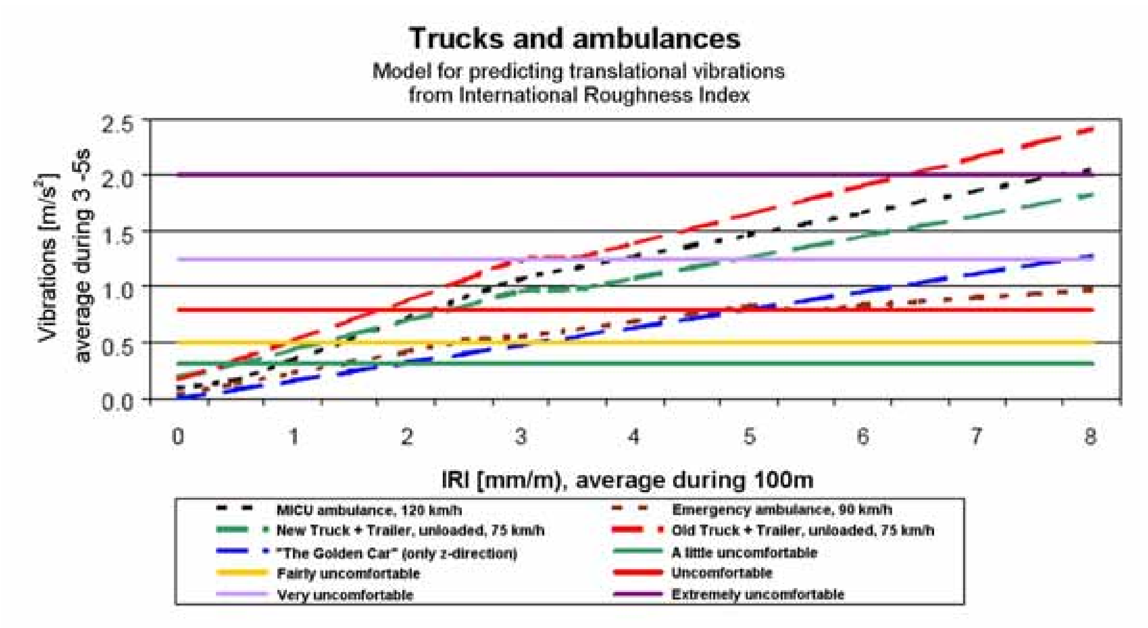

Figure 30. Model for (x-, y-, z-) vector translational vibrations as a function of road roughness (32).

The results were commented by the Professor Ronnie Lundström, who participated in the project as an expert on whole-body vibrations: “The findings from this pre-study clearly show that drivers and passengers/patients travelling in logging trucks/ambulances on the rough stretches of National Highway 90 were exposed to an unacceptably high vibration load in connection with several of the driving conditions measured.” It was found that a level of about 5 mm/m in IRI, as shown in figure 31, required a very low speed to keep the vibrations at an acceptable level. As can be seen from figure 32 similar road surface conditions can be found also elsewhere in Sweden, especially in the Central and the Northern region.

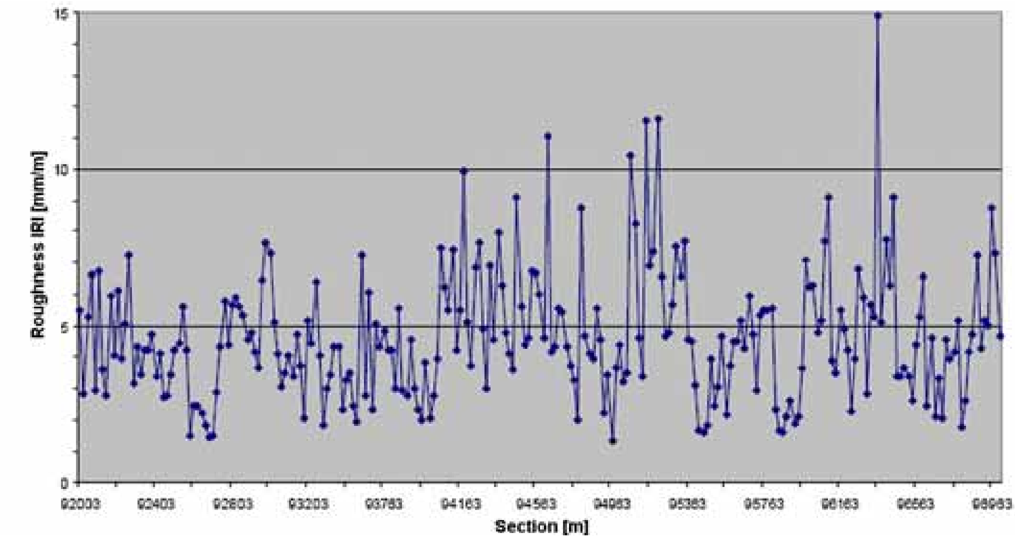

Figure 31. IRI-values from the uneven part of road 90 (32).

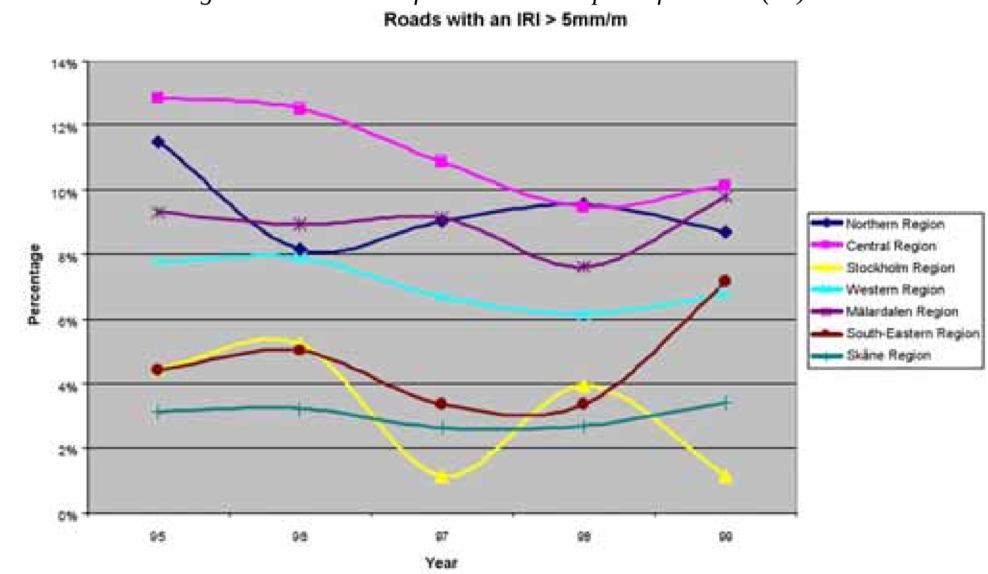

Figure 32. Development of severe roughness on the paved state road network expressed as time series of IRI_{20} > 5 mm/m per road management region (32).

The conclusion is that the major impact on body vibrations is caused by the road surface irregularities. The vibrations vary depending on e g vehicle type, type of suspension, speed and wavelength of the roughness. The vibration level in the cab is about 2-3 times higher in a truck than in a normal car, which can be seen in figure 30. The report finds that uneven road surfaces are a probable reason for elevated risks for disturbance of the body movement mechanisms on professional drivers. It is not possible to calculate the costs for the society from health problems caused by uneven road surfaces, but shall be kept in mind as extra costs when calculating road user costs.

Based on the results of the field study and the literature survey a "shame level" for the roughness expressed as IRI is recommended. The recommended value as an average of 20 m is $IRI_{20} < 3$ mm/m. The road surface conditions on paved Swedish State roads are shown in figure 33. As can be seen from the figure most of the roads with high roughness have an average day traffic < 2 000 vehicles. There are good reasons to believe that most of the high roughness roads are low volume roads in rural areas. To fulfil this recommendation on the Swedish road network there is a need for a substantial increase in the road maintenance budgets.

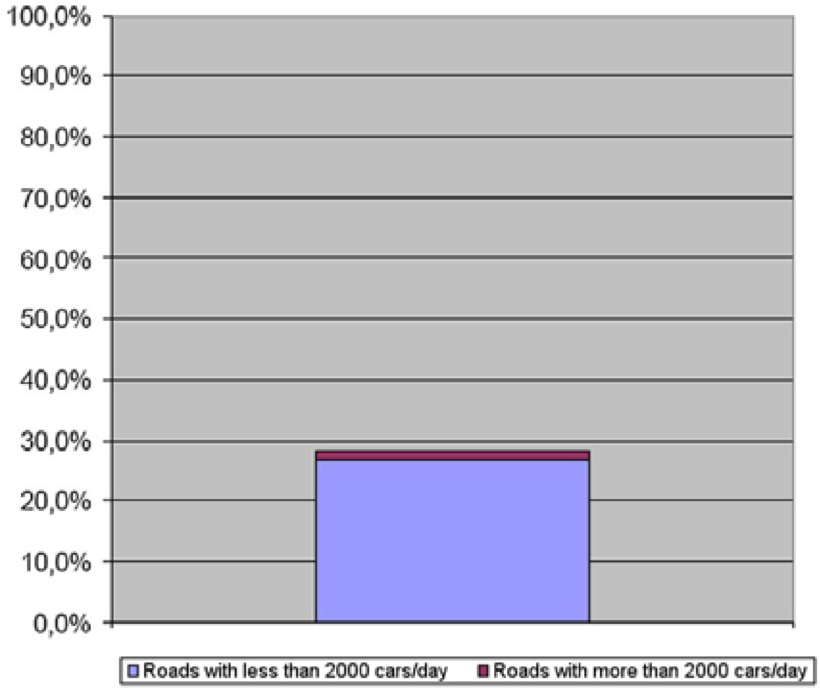

Figure 33. Paved state roads in Sweden with IRI_{20} > 3 mm/m. Blue colour AADT < 2 000; red colour AADT > 2000. Summer conditions (32).

8 Examples of modelling

8.1 Introduction

To calculate the socio-economic effects of different levels of surface properties is no easy task. Models of different types have been created in different countries. Described here is a Swedish model used by SNRA and a model used by the Swedish Forest Industry.

8.2 The calculation model used by SNRA

The model was developed by the Swedish National Road Administration over the years and still it is only a draft version. The model is included in an Excel file and consists of the following parts (33):

- One part with road specific data
- One part with general data
- One part with maintenance and rehabilitation procedures.

8.2.1 Road specific data

The following data are inputs from the user of the calculation model:

- Project name
- SNRA Region (climate region)
- Road length
- Road width
- Average daily traffic
- Percentage heavy vehicles
- Traffic growth
- Speed limit
- Initial IRI-value
- Initial rut depth
- Max allowed IRI before maintenance
- Max allowed rut depth before maintenance
- IRI-value after maintenance step
- Rut-value after maintenance step
- Time gone since last maintenance step

When the Region is marked in the model it will automatically give traffic growth, percentage heavy traffic, rut and IRI after a measure has been done and the number of winter days (these cells are marked yellow in the model).

8.2.2 General data

The following data are default values used in the model:

- **Growth in IRI** is determined as a linear function decided by SNRA's PMS and set in the program by traffic and region
- **N-factor II** is a exponential function which can be used e g on roads with structural problems to predict a faster deterioration
- **Growth in ruts** is determined as a liner function decided by SNRA's PMS and set in the program by traffic and region
- A normal **accident cost** has a default value of 439 000 SEK
- **Calculation interest** to calculate present values. SNRA uses 4 %.
- **Tax factor I** is a compensation for VAT, production factors, customs etc. SNRA uses 23 %.
- **Tax factor II** is a compensation for efficiency losses by tax financing of road maintenance. SNRA uses 30 %.
- **Capital shortness factor** shall mirror the lack of funds for maintenance. SNRA uses 1,0.
- **Cost index** for the road user costs is a way to update the costs. SNRA uses 1,0.

Growth in IRI and growth in ruts are automatically given when the Region is marked. These data come from the Swedish PMS-system (these cells are marked yellow in the model).

8.2.3 Maintenance and rehabilitation procedures

In the calculation model there is a list of maintenance and rehabilitation measures. The list consists of 36 different measures. In annex 2 the measures are described and also the effect each measure has on the road surface condition and on the routine maintenance. The calculation model operates according to the effects outlined in the annex. From this list the user shall choose the different measures, which are suitable for the actual road project during the time of the maintenance strategy. The costs for each measure are given in the model but can be changed by the user. By means of the data on road length and road width the model will calculate the cost for each selected measure. The model adds an administration fee of 10 % to the cost of each maintenance measure.

For certain maintenance steps the condition of the road surface after the maintenance step is calculated by means of some special formulas. It is mainly for simpler activities done on parts of the road surface. The formulae used are as follows:

Ruts (year n) = *42,2 * ln [(% treated surface)/10 + 1] * 4 [initial rut] / 100 + (100-42,2 * ln [(% treated surface)/10 + 1]) / 100 * rut (year n-1) / 100*

IRI (year n) = *42,2 * ln [(% treated surface)/10+1] * 2,5 [initial IRI] / 100 + (100-42,2 * ln[(% treated surface)/10+1]) / 100 * IRI (year n-1).*

The condition after maintenance step is a function of among other things the condition before the maintenance action and the surface area treated.

8.2.4. Routine maintenance

The normal cost for routine maintenance at year 0 is described by the following formula:

*Cost = road width * road length * (-1+1,06s)*

in which s = the time from last maintenance measure at year 0 given by the user.

For surfaces treated with normal whole covering measures the model shall not start giving costs until after 5 years, as follows:

*Cost = road width * road length * (-1+1,06t-5)*

When treating only a part of the surface the following formula is used:

If 1,4*portion treated surface [%] < 100

Year 0-5 *Cost = road width * road length * [(100 - 1,4* portion treated surface)/100 * (-1+1,06s+t)]*

Year 6- *Cost = road width * road length * [(100 - 1,4*portion treated surface)/100 * (-1+1,06s+t) + 1,4*portion treated surface/100 * (-1+1,06t-5)]*

in which t = time since the measure was performed.

If 1,4*portion treated surface [%] > 100 shall the routine maintenance cost for the actual road project be from year 6:

*Cost = road width * road length * (-1+1,06t-5).*

8.2.5 The calculation part

The calculation takes place in an Excel file. At first the necessary road data from the road project have to be filled in. Then a maintenance strategy consisting of a number of maintenance measures shall be put in for a desired time period. It could be done for instance so that the IRI-value always is below a determined value. Then the model starts to calculate the costs for each measure and also the routine maintenance needed during the whole time period. All the values will then be calculated to present values.

The program also calculates the road user costs including time costs, vehicle costs and accident costs. When the max IRI-value chosen is reached the model stops counting road user costs until a new maintenance measure is put in to reduce the IRI.

The model for time costs
The model for time costs depending on the road surface standard is a modified model from HDM-4 (34). It uses the time values 120 SEK/h for a personal car and 150 SEK/h for a truck.

The model for vehicle costs
The model for vehicle costs depending on the road surface standard is also a modified HDM-4 model (35).

The model for accident costs
The model for accident costs is based on research of the Swedish National Road and Transport Institute (36). The accident costs are depending mostly on the IRI-values. The rutting has a minor influence. In the model a cost per accident of 439 000 SEK is used.

Depending on the rut values, the IRI-values, the traffic volume and speed and the climate the program calculates the road user costs for the selected time period and transforms the costs to present values. It can be observed that the IRI-value has a major influence on the road user costs and the rutting has a minor influence.

The model can be used so that for a chosen project a comparison alternative (JA), which can use a maintenance strategy which gives a surface standard equal to the lowest allowable according to the "Code for maintenance" shown above. Then this alternative can be compared with different investigation alternatives (UA) using maintenance strategies giving better surface standards than the comparison alternative.

8.2.6 The Net Present Value method

One way to show socio-economic profitability for different types of investments is by using the net present value method. The net present value is defined as **summarized benefit minus summarized cost capitalized to present values over a time period.**

Costs in this case are related to need of resources to maintain a certain standard on a road project, which means in this case **costs for maintenance measures** and **costs for routine maintenance** and possible **costs for rest values.**

The benefit in this case can be described as a reduction in traffic costs by a maintenance measure or a maintenance strategy, which improves the surface standard in terms like:

- Reduced time costs
- Reduced vehicle costs
- Reduced accident costs
- Reduced comfort costs

The key figure motivating a maintenance measure with respect to **calculated profitability** is the **net present value quotient (NNK)** defined as the **summarized benefit minus the summarized costs capitalized to present values over a time period, divided by the costs**. Or simpler socio-economic benefits divided by socio-economic costs minus 1. Mathematically it can be described as follows:

$$NNK = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=1}^{T} \frac{C_t}{(1+i)^t} + \frac{S}{(1+i)^T}}{\sum_{t=1}^{T} \frac{C_t}{(1+i)^t}}$$

Where:

B = sum of profit as described above
C = sum of costs for measures and routine maintenance
S = rest values at the end of the time period
i = discount interest (used by SNRA 4%)
t = time period expressed in years
T = time horizon

Maintenance measures or maintenance strategies for road projects are judged by SNRA to be profitable when NNK > 0,9. Then the projects should be performed if funds are available and no other projects have better NNK.

8.2.7 Examples of calculations with the SNRA model

Here are three examples of using the calculation model on three low volume roads in the Region North test area in Sweden.

Road BD 841 Övertorneå-Korpillombolo
The road has a wearing course of surface dressing on gravel and some parts with oil gravel. The spring bearing capacity is not good enough so the road has load restrictions in the spring. It has a length of 59 668 m and a width of on average 6,2 m. The traffic is about 150 ADT. As a comparison alternative (JA) a maintenance strategy of IRI 7,0 mm/m is used and the investigation alternatives (UA) are:

- UA1 giving a max IRI of 6,0
- UA2 giving a max IRI of 5,0
- UA3 giving a max IRI of 4,0
- UA4 giving a max IRI of 3,0.

The maintenance measures are put in so that the max IRI stated will never be reached over the chosen time period, which in this case is 40 years. The start values are for IRI 2,0 mm/m and for rutting 3,0 mm. At latest 8 years after a whole measure a seal on 10 % of the surface is used for survival. All strategies have got a whole covering measure in the end of the strategy at year 40.

The calculations give the following results, presented in table 11 for the net present value quotient (NNK).

Table 11. NNK-values for JA-IRI 7,0 and ADT 150.

JA	UA	IRI 6	IRI 5	IRI 4	IRI 3
IRI 7,0	NNK	51,95	2,66	0,1	- 0,63

In this case it seems like IRI between 4,0 and 5,0 is the level where the road user benefit equals the road manager cost.

Road BD 857 Svanstein-Rantajärvi
The road has a wearing course of mostly surface dressing on gravel but on some parts there are soft asphalt. In the spring the road has load restrictions. It has a length of 9 819 m and a width of 6,5 m. The traffic is ADT 360 vehicles.

The same principals are used as for road BD 841 above. The results are given in table 12.

Table 12. NNK-values for JA-IRI 7,0 and ADT 360.

JA	UA	IRI 6	IRI 5	IRI 4	IRI 3
IRI 7,0	NNK	120,21	7,38	1,52	- 0,14

In this case the model shows that a maintenance strategy close to IRI 4,0 is recommended.

Road BD 799 Ekfors-Palo
This road has a wearing course of surface dressing on gravel. It has a length of 13 900 m and a width of 4,0 m. The traffic is only ADT 15 vehicles.

The same principals are used as for road BD 841 above. The results are presented in table 13.

Table 13. NNK-values for JA-IRI 7,0 and ADT 15.

JA	UA	IRI 6	IRI 5	IRI 4	IRI 3
IRI 7,0	NNK	4,9	- 0,6	- 0,88	- 0,96

In this case the model gives an IRI-level between 5,0-6,0.

8.2.8 Costs if a road is left to deteriorate

If road BD 857 Svanstein-Rantajärvi, which is about 10 km long, is left to deteriorate with only routine maintenance and a small measure of spray patch every eighth year during a 40-year period, we will have results according to table 14. That gives an IRI of about 13 mm/m in year 40.

Table 14. Present values for road manager costs and road user costs for road 857 in SEK x 1 000

Max IRI mm/m	13	7	6	5	4	3
Road **M**anager **C**osts						
Planned maintenance	768	1 831	1 968	2 291	3 362	6 032
Routine maintenance	2 021	853	723	586	340	117
Sum RMC with tax factors	4 267	4 106	4 118	4 402	5 664	9 408
Road **U**ser **C**osts						
Time costs	53 847	42 425	41 645	41 084	40 495	40 310
Vehicle costs	64 290	56 472	55 863	55 367	54 568	54 212
Accident costs	4 302	4 099	4 084	4 067	3 998	3 940
Sum RUC	122 439	102 966	101 592	100 518	99 061	98 462
Total socio-economic costs	126 706	107 072	105 710	104 920	104 725	107 870

The table shows that the costs for the planned maintenance measures increase with lower IRI-values. It also shows that the routine maintenance costs increase greatly when no planned measures are done during a long period. In total for a final IRI of 13 mm/m the road manager costs are still rather low.

The table also shows that the road user costs are decreasing with decreasing IRI-values. As can be seen in the column for IRI 13 mm/m there will be a substantial cost increase for the road users if the road is left to deteriorate.

8.3 The impact of road standard for the forest industry

8.3.1 Background

The forest industry in the Northern periphery has a considerable need for transportation of products on roads. Forest areas are spread over great parts of the countries from which the timber is collected and stored. Most of the raw material from the woods will be hauled on big trucks. In most cases the transport will start on the low volume roads and continue on bigger roads.

The competition situation today in the forest industry from other products and other markets is tough. During recent years the requirements for high quality, user suited and environmentally friendly products from the market have increased. High quality paper products require fresh raw materials with specific fibre properties. This increases the need for capital rationalization, continuous deliveries of fresh raw materials and decreased timber stock. As almost 100 % of the timber is transported on roads, the road standard will have a major impact on the situation for the forest industry.

Roads with permanent or time limited load restrictions will cause problems for the industry especially with the raw material supply. To demonstrate the consequences of bad roads the Swedish forest industry has done a survey to show the impact of the road standard, “The impact of the road standard on the transportation work and the supply of high quality raw material for the forest industry” (37).

The aim of the survey was:

- To investigate how the standard of the state road network will affect the possibilities to provide the industry with fresh raw materials and how the costs for the raw materials are affected.
- To demonstrate the effects of changed premises for the forest industry because of increased requirements for continuous deliveries of fresh raw materials.
- To describe the regional distribution of the profitability for performing rehabilitation measures to increase the bearing capacity.

The survey is restricted to the needs of the Swedish forest industry and is limited to state roads only. The survey uses three scenarios for the period 1999-2007:

- No bearing capacity improvements; only normal maintenance.
- 14 % of the bearing restricted km shall be rehabilitated before 2007 according to county plans.
- 11 % of the bearing restricted km shall be rehabilitated before 2007 according to the prognosis from the Swedish National Road Administration.

8.3.2 The transportation network

The state road network in Sweden is about 102 000 km. All ground data for the roads in the survey was collected for each county and put together in Regions. The figures used for the lumber are average values of the production 1996-1998.

Bearing capacity of the road network
Swedish National Road Administration (SNRA) has supplied the basic data for the bearing capacity of the road network. The Swedish road network is divided into 3 classes depending on how heavy vehicles the road can carry (see table 15):

- BK1 60 tons
- BK2 51,4 tons
- BK3 37 tons

Table 15. Bearing capacity classes on the Swedish road network (37)

Status 1998						
Region	BK1	BK2	BK3	Portion BK1	Portion BK2	Portion BK3
Norr	15318	2084	507	0,855	0,116	0,028
Mitt	17098	1612	869	0,873	0,082	0,044
MD	13674	1554	39	0,896	0,102	0,003
Väst	17424	1814	76	0,902	0,094	0,004
Syd	25314	480	200	0,974	0,018	0,008
Riket	88828	7544	1691	0,906	0,077	0,017

Transportation on roads in BK2 and BK3 means that the trucks will have lighter loads and thereby the transportation costs will increase.

Road surface irregularities
Uneven road surfaces will cause increased wear of the vehicles and will increase travel time. The extra costs for the transportation caused by surface irregularities and load restrictions are shown in table 16.

Table 16. Direct transportation costs (SEK/m^3) for surface irregularities and load restrictions per m³ in resp region and scenario (37)

Region	Plan 14 %	Prognosis 11 %	Only maintenance
Norr	1,49	1,87	3,33
Mitt	1,76	2,13	3,59
MD	0,49	0,71	1,61
Väst	0,53	0,73	1,59
Syd	0,12	0,25	0,78
Riket	1,02	1,29	2,39

Load restrictions
Because of low bearing capacity especially during the spring thaw period some roads are closed or restricted to heavy traffic. Both the time for restrictions and the road length have to be taken into consideration. In this case therefore day-kilometres have been used. The costs are shown in table 16 together with the costs for road surface irregularities.

8.3.3 Calculation methodology

To describe the consequences of the different scenarios the costs have been calculated from the road standard of each scenario. The costs are based on **direct transportation costs** and **stock costs**.

The **direct transportation costs** are caused by:

- Load restrictions
- Uneven road surfaces.

The **stock costs** are from the stock, which has to be built up during the wintertime to guarantee the raw material supply. The costs comprise:

- Interest costs
- Extra transportation and cutting costs because of uneven supply
- Handling and watering at the stock
- Extra transportation at the stock
- Quality costs

The distribution between the different costs is shown in figure 34 for scenario 11 %.

The calculations are done with a calculation model described in the reports (37) and (39).

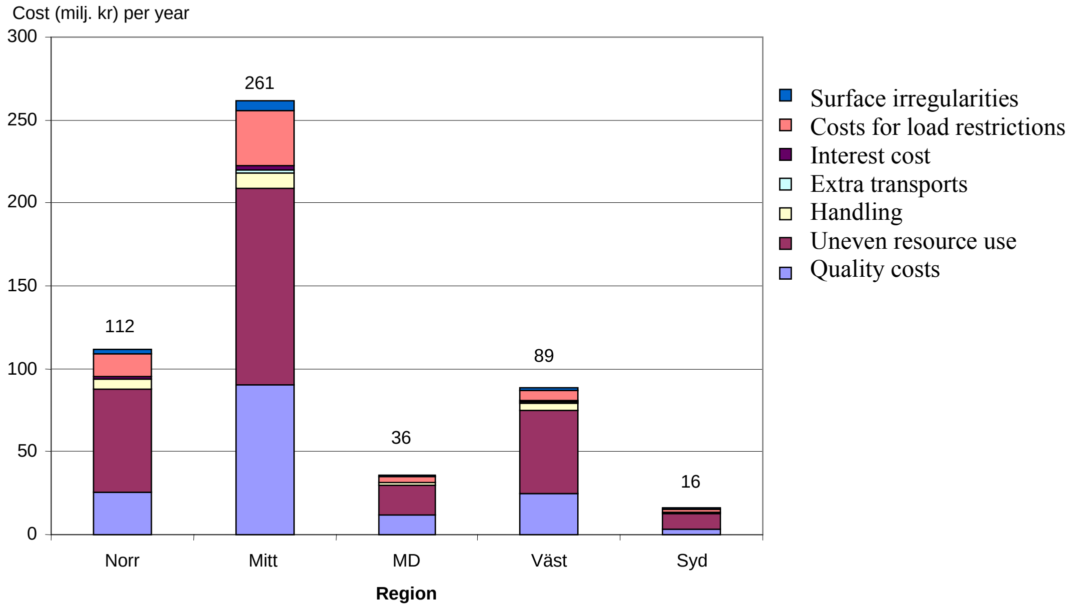

Figure 34. Costs for road restrictions per region and year, Scenario 11 % (37).

8.3.4 Results

The extra costs caused by lacking bearing capacity are shown in figure 35. It can be seen by the figure that the extra costs for the alternative "only maintenance" is about 674 millions SEK the year 2007. The investment level 11 % will reduce the costs for the forest industry by about 160 milj SEK/year and the investment level 14 % will cut costs by 186 milj SEK compared to the "only maintenance" alternative. The figure also shows that the main costs are in the North, Mitt and West region, which all have big forests.

The results have also been calculated for the different industries in each region (38) to be used in discussions with the local politicians and Road Authorities.

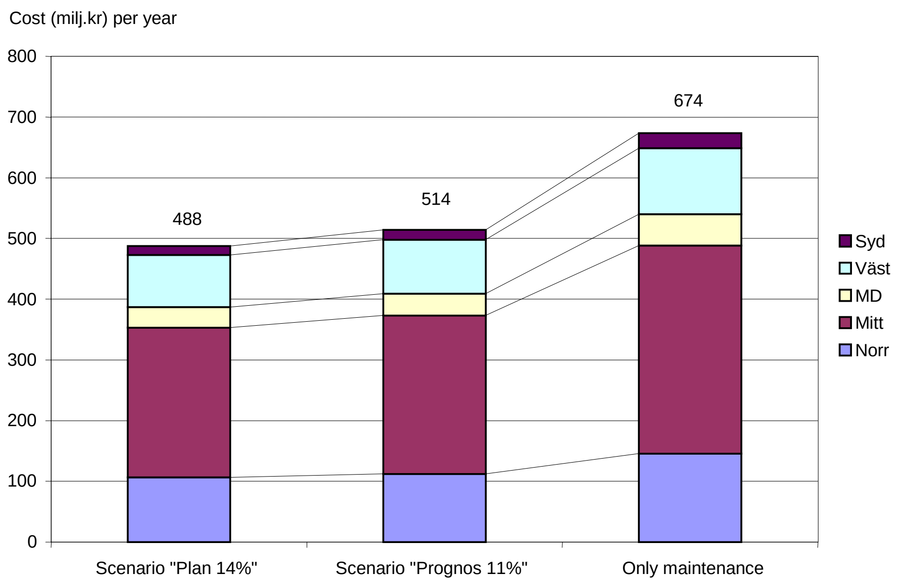

Figure 35. Extra costs per scenario caused by lacking bearing capacity (37).

Figure 36 shows that most of the extra costs are stock costs.

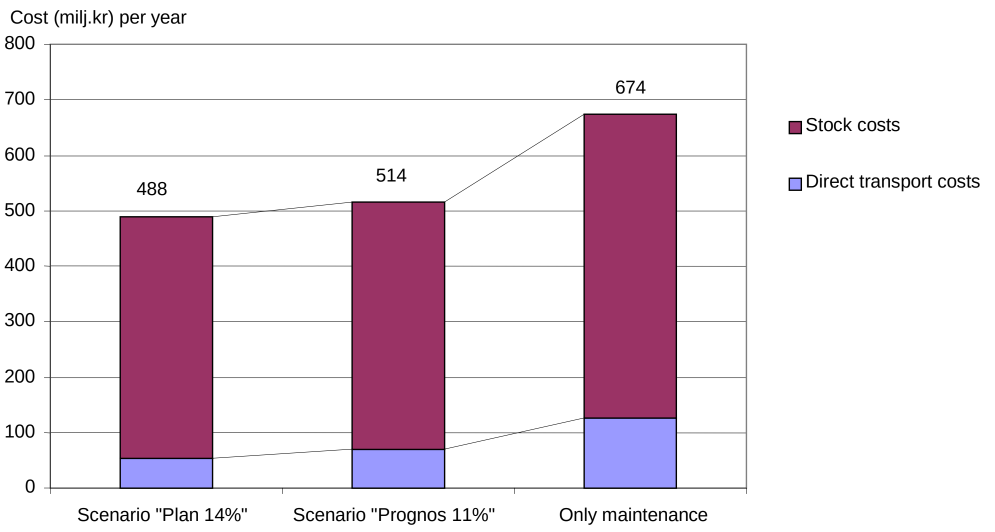

Figure 36. Total extra costs per scenario divided into main costs (37).

8.3.5 Sensitivity analyses

The calculations are based on the supposition that the stocks of timber can be dimensioned after theoretically known spring thaw extensiveness. In reality it is necessary to build up the stock for a worst case to guarantee the raw material supply. A calculation showing the real costs has been done (Effects in practice). Another case is also described showing costs for maximal lumber production that is possible with regard to the growth (Higher harvesting in practice). The alternatives are compared to "only maintenance". The results are shown in figure 37. The figure shows that the alternative 'Effects in practice' will increase the costs for the forest industry to more than 900 milj SEK/year. The highest costs are in Region Mitt as they have most of the forests and the industries. But the costs are high also in Region North where we have our test areas.

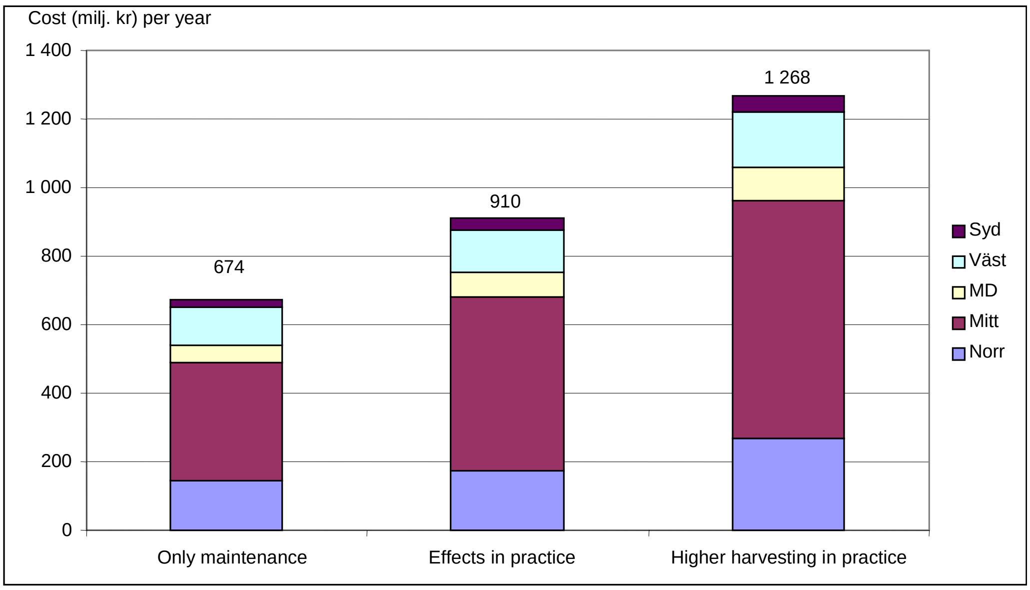

Figure 37. Total extra costs for three alternatives (37).

Calculations of the profitability of the investments for increasing the bearing capacity have also been done. It is calculated as net profit for the forest industry divided by road rehabilitation costs also described in paragraph 8.2.6 above (Net present value quotient = NNK). The results for investments in the scenarios 14 % or 11 % of the road network with the restricted bearing capacity are shown in table 17. The criteria for profitable investments are in this case NNK ≥ 0,4. The results show that the investments for the tested levels are profitable in all Regions but one.

Table 17. Profitability expressed as NNK for investments of 11 % and 14 % in alternative "Effects in practice" (37).

Region	NNK Plan 14 %	NNK Prognosis 11 %
Norr	0,8	0,8
Mitt	2,6	2,6
MD	2,1	2,2
Väst	0,2	0,2
Syd	1,3	1,4
Total	1,4	1,4

8.4 Summary

The key figure to motivate a maintenance measure with respect to calculated profitability is the net present value quotient (NNK) defined as the summarized benefit minus the summarized costs capitalized to present values over a time period, divided by the costs. Or simpler socio-economic benefits divided by socio-economic costs minus 1

Costs in this case are related to the need for resources to maintain a certain standard on a road project, which means in this case costs for maintenance measures and costs for routine maintenance and possible costs for rest values.

The benefit in this case can be described as a reduction in traffic costs by a maintenance measure or a maintenance strategy, which improves the surface standard in terms like:

- Reduced time costs
- Reduced vehicle costs
- Reduced accident costs

The model developed by Swedish National Road Administration was used for assessments at a project level on a couple of low volume roads in Sweden. Road investments in Sweden should reach NNK > 0,9 to be approved in general if resources are available and no other projects are more favourable. Calculations for three low volume roads gave the following results for a maintenance strategy of 40 years:

- ADT 360 vehicles/day => NNK > 1 at roughness IRI about 4 mm/m
- ADT 150 vehicles/day => NNK > 1 at roughness IRI about 5 mm/m
- ADT 15 vehicles/day => NNK > 1 at roughness IRI about 6 mm/m.

It means that the benefits for the society are good at these IRI-levels according to the calculations.

Results from calculations made by the Swedish forest industry with another model show, using NNK as the profit indicator, that investments in road rehabilitation on the worst parts of the road network in all regions but the Western region are profitable from a socio-economic point of view.

9 Conclusions

Some interesting work on socio-economic impacts of road conditions is going on in the partner countries. Different ways of handling the socio-economic impacts are used in the partner countries. In all countries some type of target road condition standard is used based on long-term experience on central and regional level originating from some socio-economic considerations. The levels of the standards depend on e g traffic, road category and economy.

There are also in the partner countries some types of lowest acceptable road standards, sometimes mentioned as "shame levels". They can be found as "trigger values" in routine maintenance contracts or in some policy document like the Norwegian Handbook 111.

The socio-economic models used in the partner countries do not treat the low volume roads in some special way. The models are normally used on network level to minimize the long-term costs for road maintenance and rehabilitation and, as traffic is a dominating figure in the calculations, the low volume roads will be kept at a low standard level.

Low volume roads in rural areas are often the only possibilities for small communities and villages to get access to health care, education and cultural events. The distance is often long and if the road condition is also bad it gives an extra burden for people living in rural areas. Much attention has been paid to achieve better road conditions for people in such areas in Scotland by looking at fragile areas of the country with decreasing population, long-term unemployment and high levels of income support. The transport links to such areas are defined as lifeline roads, which are the vital life nerves for those areas. Work is also going on in Finland to look at the impact of the road condition in the rural areas with a different view including competitiveness of the economy, daily need of transport, development of areas and goals of the society. If we want the rural communities to survive and possibly develop, good road conditions are necessary pre-requisites.

The road conditions also have a substantial influence on health. Recent research in Sweden and other countries has shown that health is affected by body vibrations, (particularly that of the professional truck drivers). The conclusion is that the major impact on body vibrations is caused by road surface irregularities. The vibrations vary depending on e g vehicle type, type of suspension, speed and wavelength of the roughness. It is not possible to calculate the costs to society from health problems caused by uneven road surfaces, but shall be kept in mind as extra costs when calculating road user costs.

10 Recommendations

It is recommended to follow the Scottish example to sort out the fragile areas of the partner countries. Then to define the lifeline roads which are of critical importance for the people in the rural areas. This should be demonstrated to the politicians and used in the budget negotiations with the Transportation Departments in the partner countries to have an increased understanding for the low volume roads. Then the lifeline roads should be treated with special care in the maintenance and rehabilitation programs.

An interesting task is to try to form a policy for a common lowest acceptable road condition standard for the partner countries. It must be a target standard to reach if resources are available and no other needs are more urgent.

If the prevailing socio-economic models are to be used for the whole road network the low volume roads need to be in their own part networks. Some sort of “social factor” for lifeline roads could be used to influence the budget distribution and to sort out the candidates for maintenance and rehabilitation.

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Appendix 1 Agenda for socio-economic meetings

1. In what way are the socio-economic consequences of road condition considered in your country for:
   a. Levels and distribution of budgets
   b. Choice of maintenance action
   c. Road condition level at maintenance
   d. Load restrictions

2. Have you socio-economic models for road maintenance on
   a. Road net level
   b. Road project level

   or are these model needed at all?

3. Have you any “shame levels” for maintenance steps? If you have what are the levels?

4. Have you performance contracts for routine maintenance with “trigger values? If you have what are the trigger values?

5. Have you any special socio-economic considerations on low volume roads? If not should there be a model and what kind?

6. Have you any special socio-economic considerations (models?) on gravel roads? If not should there be a model and what kind?

7. What is your opinion of road users (local enterprise) specified service level?

8. What is your investment policy for low volume roads in the future?

Appendix 2 – Motive for and description of effects from different maintenance steps in the model, 2002-10-16

Designation	Code nr	Motive	Effect on IRI and rutting	Effect on routine maintenance
Dr20 = Drainage/ dewatering on 20 % of the road project	1	Measures for dewatering and drainage will affect the road deterioration. This will give rise to a reduction in the growth of ruts, cracking and unevenness and thereby it also reduces the need for routine maintenance.	The growth for IRI and rutting is reduced after the measure as follows: year 1 = increase x 0,85 year 2 = increase x 0,90 year 3 = increase x 0,95 year 4 = increase x 1,0	The yearly cost growth for routine maintenance is reduced after the measure as follows: år 1 = increase x 0,85 år 2 = increase x 0,90 år 3 = increase x 0,95 år 4 = increase x 1,0
Dr40 = Drainage/ dewatering on 40 % of the road project	2	- ” -	The growth for IRI and rutting is reduced after the measure as follows: år 1 = increase x 0,75 år 2 = increase x 0,80 år 3 = increase x 0,85 år 4 = increase x 0,90 år 5 = increase x 0,95 år 6 = increase x 1,0	The yearly cost growth for routine maintenance is reduced after the measure as follows: år 1 = increase x 0,75 år 2 = increase x 0,80 år 3 = increase x 0,85 år 4 = increase x 0,90 år 5 = increase x 0,95 år 6 = increase x 1,0
Dr70 = Drainage/ dewatering on 70 % of the road project	3	- ” -	The growth for IRI and rutting is reduced after the measure as follows: år 1 = increase x 0,5 år 2 = increase x 0,6 år 3 = increase x 0,7 år 4 = increase x 0,8 år 5 = increase x 0,9 år 6 = increase x 1,0	The yearly cost growth for routine maintenance is reduced after the measure as follows: år 1 = increase x 0,5 år 2 = increase x 0,6 år 3 = increase x 0,7 år 4 = increase x 0,8 år 5 = increase x 0,9 år 6 = increase x 1,0

F10 = seal coat/surface dressing 4-8 mm on 10 % of the roadsurface	4	A seal coat/surface dressing Y1B 4-8 stops the water from migrating into the road structure and stops the growth of ruts, unevenness and the need for routine maintenance during some time.	No influence of ruts and IRI	No cost growth during the first year after the measure.
F50 = seal coat/surface dressing 4-8 mm on 50 % of the roadsurface	5	- " -	No growth of ruts and IRI the first year after the measure.	No cost growth during the two first years after the measure.
F100 = seal coat/surface dressing 4-8 mm on 100 % of the roadsurface	6	- " -	No growth of ruts and IRI the first two years after the measure.	No cost growth during the three first years after the measure.
Y1G = surface dressing on gravel	7	Used on old YG. Gives small improvement of rutting and IRI. Demands early routine maintenance.	The measure will give 10 % reduction in the existing rut- and IRI-values. But shall never give lower values than what the model gives default after measure in cell E3 and E5.	At measures of Y1G the routine maintenance shall start the first year after the measure:: *Cost = road width * road length * (-1+1,06*^{t}***)** (see also in pt 2.4)
SPY50 = Track paving with surface dressing on 50 % of the surface	8	The maintenance measure SPY will give a reduction of the rutting but has little influence of the IRI. The need for routine maintenance is reduced.	Rut after maintenance, cell E3, shall be multiplied by 1,5 when using SPY and thereafter the figure shall be put into the formula for partial maintenance given in pt 2.3 (initial rut) There will be no growth of IRI the first year	The costs for routine maintenance shall be reduced according to pt 2,.4 above.

SPY100 = Track paving with surface dressing on 100 % of the surface	9	- ” -	Rut after maintenance, cell E3, shall be multiplied by 1,5 when using SPY and thereafter the figure shall be put into the formula for partial maintenance given in pt 2.3 (initial rut). There will be no growth of IRI year 1 och 2.	- ” -
J5 = levelling course with hot mix on 5 % of the surface	10	A levelling course on parts of the surface will reduce ruts and unevenness as well as costs for routine maintenance. The reduction will be somewhat bigger than the surface area the treatment is used on as the treatment is used where the defects are biggest	Ruts and unevenness are reduced according to pt 2.3 partial treatments above.	The costs for routine maintenance are reduced according to pt 2.4 partial treatments above.
Jm10 = levelling course with cold or semi-hot mix on 10 % of the surface	11	- “ -	- “ -	- “ -
J10	12	- “ -	- “ -	- “ -
Jm15	13	- “ -	- “ -	- “ -
J15	14	- “ -	- “ -	- “ -
Jm20	15	- “ -	- “ -	- “ -
J20	16	- “ -	- “ -	- “ -
J25	17	- “ -	- “ -	- “ -
J30	18	- “ -	- “ -	- “ -
J50	19	- “ -	- “ -	- “ -

MJOG = 40 mm of semi-hot mix with type MJOG with soft binder	20	All thicker whole-covering measures are supposed to get the effects given by the model by means of default data on ruts and IRI after the maintenance step and growth on ruts and IRI from SNRA's PMS-system.	According to growth data from PMS.	Routine maintenance costs starting year 6 according to pt 2.4.
ABT = 40 mm Dense Asphalt Concrete (hot mix)	21	- " -	- " -	- " -
FR+80AB = Planing + 80 kg/m^2 Dense Asphalt Concrete	22	- " -	- " -	- " -
TS = planing + Very Thin Asphalt of chip type.	23	- " -	- " -	- " -
J+ABS = levelling 20 kg/m^2 + 80 kg/m^2 Split Mastix Asphalt	24	- " -	- " -	- " -
FR+80ABS = planing + 80 kg/m^2 Split Mastix Asphalt	25	- " -	- " -	- " -

VB = Repaving alt Remixing	26	Repaving/remixing are judged to have somewhat shorter life cycles than other whole-covering measures and thereby the routine maintenance shall start somewhat earlier than other alternatives.	- ” -	Start year 4 principally according to pt 2.4.
JMJOG = 100 % levelling with 90 kg/m^2 semi-hot mix of MJOG	27	Same as code 20	- ” -	Same as code 20
SPTP = track-paving with hot mix	28	Track-paving will reduce the ruts but will have small effect on IRI. The need for routine maintenance will be reduced.	The rut will be reduced to *Rut after measure* (cell E3) x 1,5. IRI will be reduced to the IRI-value the year before measure x 0,95.	Start year 2 principally according to pt 2.4.
MAG+MJOG = rehab with 80 kg/m^2 semi-hot asphalt gravel and 80 kg/m^2 wearing course	29	Same as code 20	Same as code 20	Same as code 20
MRek1 = rehab with Bit Gravel 50 % and unbound roadbase 50 % + Wearing course of AC	30	- ” -	- ” -	- ” -

MRek2 = rehab 130 kg/m^2 binder layer + 90 kg/m^2 SMA	31	- ” -	- ” -	- ” -
MRek3 = planing + binder layer +90 kg/m^2 SMA	32	- ” -	- ” -	- ” -
Gbl+Y1G = unbound roadbase + surface dressing on gravel	33	- ” -	- ” -	Routine maintenance starts year 1 principally according to pt 2.4.
FR(mb)+Y1G = stabilisation with binder + surface dressing on gravel	34	- ” -	- ” -	- ” -
AG+Y1 = bitumenised gravel + surface dressing	35	- ” -	- ” -	Same as code 20
J+Y1 = levelling with AC + surface dressing	36	- ” -	- ” -	- ” -

Roadex Publications

ROADEX II

- ROADEX II - Focusing on Low Volume Roads in the Northern Periphery DVD
- User Perspective to ROADEX II Test Areas' Road Network Service Level
- Permanent deformation
- New material treatment techniques
- Managing spring thaw weakening on low volume roads
- Socio-economic impacts of road conditions on low volume roads
- Dealing with bearing capacity problems on low volume roads constructed on peat
- Drainage on low traffic volume roads
- Environmental guidelines
- Environmental guidelines, pocket book
- Road management policies for low volume roads – some proposals
- Structural Innovations
- Monitoring, communication and information systems & tools for focusing actions

ROADEX I

- Roadex Multi-media CD-ROM
- Road Condition Management of Low Traffic Volume Roads in the Northern Periphery
- Winter Maintenance Practice in the Northern Periphery,
- Generation of 'Snow Smoke' behind Heavy Vehicles

Roadex II Lead Partner: The Highland Council, Transport, Environmental & Community Service, HQ, Glenurquhart Road, Inverness IV3 5NX Scotland.