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Svante Johansson

SOCIO-ECONOMIC IMPACTS OF ROAD CONDITIONS ON LOW VOLUME ROADS

Results of literature studies, interviews and calculations with a model and some proposals for road management policies

Executive Summary

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EXECUTIVE SUMMARY

July 2006

Svante Johansson
Roadscanners Sweden AB

PREFACE

The report that follows is an executive summary of the 2005 ROADEX II reports "Socio-economic impacts of road conditions on low volume roads" by Svante Johansson, Roadscanners Sweden AB and "Road management policies for low volume roads – some proposals" by Svante Johansson, Roadscanners Sweden AB, Seppo Kosonen, Finnish National Roads Administration, Eilif Mathisen, Norwegian Public Roads Administration, Frank McCulloch, Forest Enterprise, Scotland and Timo Saarenketo, Roadscanners OY, Finland.

It aims 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. It also gives some draft proposals for new road management policies in order to upgrade the most fragile roads. Thereby we hope that more resources will be allocated to the low volume roads.

The report is not intended to replace the many excellent reference works and text books available on the subject but it is hoped that the summaries outlined will give the reader a greater understanding of the issues and some ideas how to increase the possibilities to improve the road conditions on low volume roads in the rural areas of the Northern Periphery of Europe.

The report was written by Svante Johansson from Roadscanners Sweden AB. Ron Munro, project manager of the ROADEX III Project, checked the language. Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout.

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The photo on the front cover is taken by Ralph Shackleton, The Western Isles Council.

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Chapter 1. Introduction

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between roads organisations across northern Europe that aims to share roads related information and research between the partners.

The Project was started in 1998 as a 3 year pilot co-operation between the roads districts of Finnish Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and this was later followed up with a second project, ROADEX II, from 2002 to 2005.

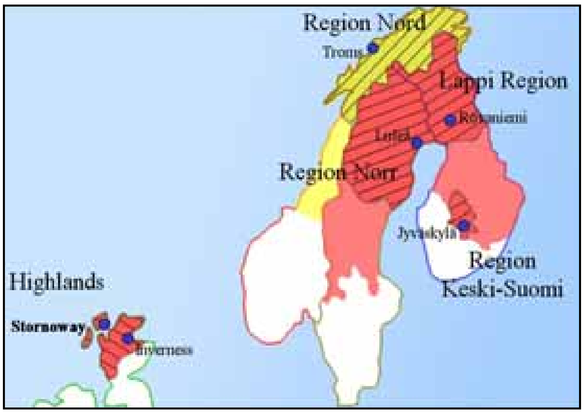

Figure 1.1 The Northern Periphery Area and ROADEX II partners

The partners in the ROADEX II Project comprised public road administrations, forestry organizations, forest companies and haulage organizations from regions in the Northern Periphery. These were The Highland Council, Forest Enterprise & The Western Isles Council from Scotland. The Region Nord of The Norwegian Public Roads Administration and The Norwegian Road Haulage Association, The Northern Region of The Swedish Road Administration and The Lappi and Keski-Suomi Regions of The Finnish National Roads Administration. (These latter Finnish Regions also received aid from their local forest industry organisations of Metsähallitus, Lapin Metsäkeskus, Metsäliitto & Stora-Enso.)

The goal of the project was to develop ways for interactive and innovative road condition management of low traffic volume roads integrating the needs of local industry, society and roads organisations. Eight formal reports were published together with a project DVD and full copies of all reports are available for download at the ROADEX web site at www.roadex.org.

This Executive Summary report is one of 8 summaries that have been prepared under the direction of the ROADEX III project (2006-2007), a new Project where the named project Partners above were joined by the additional Northern Periphery Partners of the Municipality of Sisimiut, Greenland, The Iceland Public Roads Administration and the Finnish Road Administration Region of Savo-Karjala.

1.2 THE CONCEPT SOCIO-ECONOMIC IMPACT

It is usual when talking about socio-economic impact in relation to road condition to look at the costs both for road users and road managers. Road user costs are related to the road conditions so that a road with high roughness and rutting will cost users more than an even road. Keeping a road in good condition however incurs costs on the road manager such as rehabilitation costs and costs for normal and routine maintenance. As a result road managers aim to minimise the total costs, which are the sum of the road user costs and their own costs. This can be done by using different types of socio-economic models employing cost-benefit analyses (CB-analyses). Most of these models however work at the road network level and are not suited to low volume roads. This is particularly the case in the Northern Periphery of Europe where we deal mostly with rural low volume roads. We therefore need to look at other complementary methods and models to justify good road standards on our low volume roads. These models need to stress the social benefits accruing from having roads in rural areas in good condition. But these social benefits 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 of people living in rural areas. These people normally have long distances to travel for public services, cultural events and all other needs. If the road is 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 projects. They can also be included in the road maintenance codes and in the routine maintenance contracts.

For these reasons we will try to give the concept of socio-economic impact a wider meaning in this report. We have examined some of the prevailing methods and models used today in literature and in the member countries and identified those which promote our aims.

1.3 DESCRIPTION OF THE PROBLEMS JUSTIFYING THE TASK

When it comes to low volume roads it is very difficult to find economic reasons to justify good road conditions. Budgets for road maintenance and rehabilitation are generally allocated in competition with other sectors in society like medical provision, education and social welfare. They also have to compete with other budgets for other transportation alternatives like railway and air transportation in addition to fighting the general resource needs for maintenance of high and medium trafficked roads in urban and rural areas.

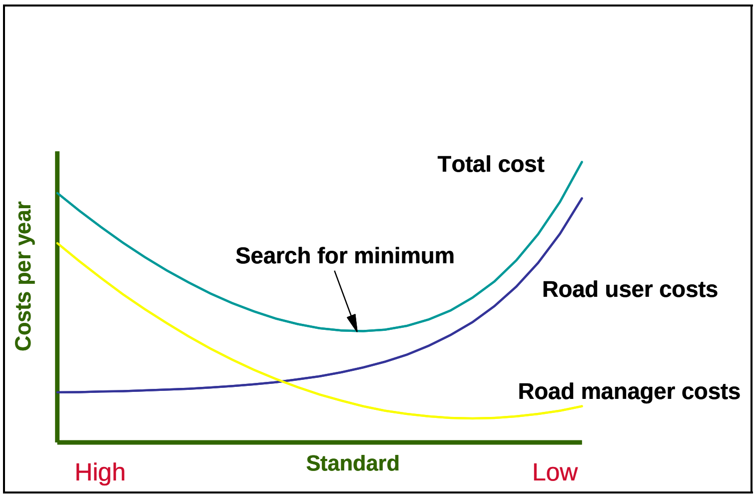

Figure 1.2. Principles for minimizing the socio-economic costs for road maintenance (3)

Conventional socio-economic models for road user costs will not generally include costs and benefits for comfort, influence on social life and influence on industrial production and investment. These types of costs and benefits are difficult to calculate, sometimes even impossible. 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 in the road condition of a low volume road will give a small reduction in road user costs for society as a whole whilst a small improvement on a highly trafficked road will give a bigger reduction for society. Optimising the socio-economic costs on a network level can minimise the total annual costs arising from the road manager costs and road user costs (see figure 1.2). A network model will therefore give priority to good road conditions on high trafficked roads in order to keep the total costs at the lowest level.

It has been shown in different World Bank reports (4 and 5), that cost-benefit analyses for investments in transportation infrastructure seldom give a good 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.

There is therefore a growing need to point out the consequences and disadvantages to the whole of society when low volume roads are left to deteriorate. If we want the rural areas in the Northern Periphery to be populated a basic requirement is that the life nerves, the road networks, needs to be able to work properly and be in a serviceable condition throughout the year.

Chapter 2. Background

2.1. GENERAL

The road network in rural areas is, in most cases, the only means of moving 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 affects many of the essential elements of society, like

- Business profitability
- Investments
- Tourism
- Service levels
- Social life.

The condition of the road also has a great impact on the road user. 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 an impact on the economy. A road in poor condition will increase vehicle cost, increase travel time and even damage the loads carried. It will also influence the accident rate and the comfort of road users as well as the environment. For this reason socio-economic consequences should always 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 DIFFERENT WAYS TO IMPROVE THE ROAD CONDITIONS ON LOW VOLUME ROADS

Road conditions on low volume roads can be improved in many ways, but all require increased resources to accomplish improvement. Two possible ways to improve the road standards on low volume roads are:

- By **using road condition standard levels based on socio-economic models**. As mentioned above models used today do not favour low volume roads so for these to be useful they have to be adjusted with some social benefit factor. More about this is given in chapter 3.
- By **using road condition standard levels based on road user needs**. The ROADEX partner areas use reasonably well defined road condition standard levels for their different road user needs. Examples of the road condition standard levels used in the partner countries are presented in chapter 4.

The chapters that follow will give executive summaries of the two ROADEX II reports of “Socio-economic impact of road conditions on low volume roads” written by Svante

Johansson, Roadscanners Sweden AB and “Road management policies for low volume roads – some proposals” written by Svante Johansson, Roadscanners Sweden AB, Seppo Kosonen, Finnish National Roads Administration, Eilif Mathisen, Norwegian Public Roads Administration, Frank McCulloch, Forest Enterprise, Scotland and Timo Saarenketo, Roadscanners OY, Finland. The initial chapter of the summary will give a brief description of the socio-economic situation today, mainly in the partner countries of the ROADEX project, based on literature studies, interviews and some calculations with a model. The second part of the summary report will give some proposals for road management policies giving low volume roads in fragile rural areas a better ranking in road condition standard. Readers wishing further details on these reports can download them from the ROADEX web page at address www.roadex.org.

The work on this subject will be continued in ROADEX III in Task B4 “Road condition management policies.”

Chapter 3. The use of models

3.1 INTRODUCTION

As mentioned above, existing socio-economic models have not been designed to benefit low volume roads. A range of models are used in the Nordic countries mainly in the budget dialog with the Transportation Departments. Some of these models are described briefly in paragraph 3.2 and the use of local models by the road administrations in partner countries is described in paragraph 3.3. In paragraph 3.4 the use of a model by the Swedish forest industry is described and finally some ideas of how to proceed with models adapted to road user needs on low volume rural roads are given in paragraph 3.5.

3.2 EUROPEAN USE OF MODELS

This section describes some recent European projects concerning socio-economics used in road infrastructure management. In the **Road Infrastructure Maintenance Evaluation Study, (RIMES)** (3) completed in 1999 (3), a survey was carried out to examine

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

The study was carried out 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 and 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.

The general ‘road user cost’ model employed was of the form:

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

All models shown in RIMES are based on economic considerations but without consideration of social aspects. The models are not designed to take account of the special circumstances of low volume rural roads.

Road investments in developing countries have during the last 20 years been planned and prioritised based on economic appraisal models like **Highway Development and Management Tools, HDM-4**. These models are mainly used to evaluate primary and secondary roads and do not deal well with the economic justification of low volume roads in rural areas. Lately developing countries, as well as donors, have increasingly been asking for guidance on how social benefits can be incorporated within the transport appraisal. This will require on an increased emphasis on poverty reduction and social considerations. Following discussions on how to include social benefits in the model a trial project was started in 2003 entitled "Framework for the Inclusion of Social Benefits in Transport Planning" (4). This project is at the starting phase and is funded by the Department for International Development (DFID). The report identifies some circumstances where social benefits are most likely to be very significant:

- When there is a desire to 'weight' benefits to different classes of 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.

3.3 MODELS USED BY ROAD AUTHORITIES IN THE ROADEX PARTNER COUNTRIES

Norway, Sweden and Finland currently use the Finnish model HIPS (Highway Investment Programming System) for road network level considerations. This divides the road network into partial networks depending on climate zone, road type and traffic class. Socio-economic road user costs are calculated depending on the road condition parameters. Finland has the most developed model and they use the condition variables: longitudinal unevenness, rut depth, defect index and bearing capacity ratio

This model requires inputs from extensive measurements on road network level. 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.

By dividing the road network into a number of partial networks each partial network can be calculated separately. Road condition parameters are divided into classes and measured values are used as input. The development of the road condition is modelled by the probability of going from one condition class to another within a determined time, normally one year. Maintenance actions are defined and costs and effects are determined for each action. 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 as shown in figure 1.2. This model is mainly used in budget dialogs with the Transportation Department and the aim is to reach a long term socio-economic equilibrium.

The model does not however treat the rural low volume road network in any special way and social considerations are not included. Sweden has also a simple Excel-model which can be used on road network or on project level but it is only used experimentally.

3.4 MODEL USED TO DEMONSTRATE THE IMPACT OF ROAD STANDARD FOR THE FOREST INDUSTRY

The forest industry in the Northern Periphery has a considerable need for the transportation of its forest products on roads. Forests are spread over great areas of the Partner countries, from which the timber is collected and then stored. Most of the raw material from the woods is hauled on heavy trucks and in most cases the transport will start on the low volume roads and move on to main routes.

Competition today in the forest industry from other products and other markets is intense. 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 optimised timber stocks. As almost 100 % of the timber is transported on roads, the road condition has a major impact on the situation today for the forest industry.

In these circumstances a road with a permanent or temporary load restriction will cause problems for the industry especially with the raw material supply. To demonstrate the consequences of bad roads the Swedish forest industry carried out a survey to show the impact of road condition entitled “The impact of the road standard on the transportation work and the supply of high quality raw material for the forest industry" (17).

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

- No bearing capacity improvements; only normal maintenance.
- 14% of the bearing restricted roads rehabilitated before 2007 in accordance with the county plans.
- 11% of the bearing restricted roads rehabilitated before 2007 in accordance with the forecast from the Swedish National Road Administration.

The consequences of the 3 scenarios were evaluated in costs derived from the road standard of each scenario and their results are summarised in Figure 3.1 below. Further information on this project can be found in the ROADEX II report "Socio-Economic Impacts Of Road Conditions On Low Volume Roads."

It can be seen from this figure that the extra costs for the "only maintenance" option is approximately 674 millions SEK the year 2007. The 11% investment level will reduce the costs for the forest industry by about 160 million SEK/year and the 14% investment level will cut costs by 186 million SEK compared to "only maintenance". The figure also shows that the main costs are stock costs.

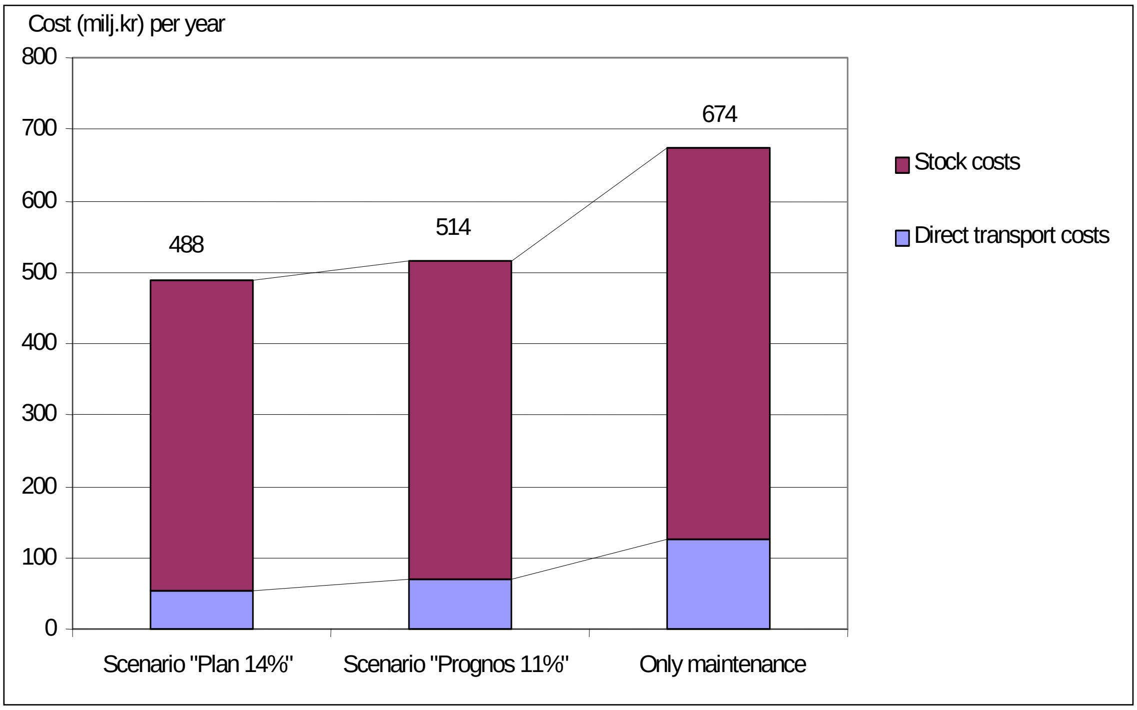

Figure 3.1. Extra costs per scenario caused by lacking bearing capacity (17).

3.5 SUGGESTIONS FOR MODEL ADJUSTMENTS

A critical feature with most socio-economic models is that, although they can calculate the road manager costs, including rehabilitation costs and costs for planned and routine maintenance very accurately, the benefits for the road user and society are not so well dealt with. The importance of the road condition in rural areas from a social point of view is not considered. Questions that should be asked could include: How does the road condition influence peoples' access to education, health care, cultural events, sports and leisure time activities? And how should that influence be transferred into monetary terms? How does the road condition influence the economic survival of small villages in rural areas? Could a road in bad condition be an obstacle for business establishment, tourism or outdoor life? And if so what is the value of that? On one hand there are the very well defined costs for the management of the road but on the other hand are the undefined benefits for the existing and potential road users.

If the prevailing socio-economic models are to be used for the whole road network then low volume road areas need to be given their own special part networks. These networks can then be given a "social factor" to influence the budget distribution and sort out the candidates for maintenance and rehabilitation. Many good ideas are presented in literature but work is required to form useful and approved "social factors".

As can be seen in the results from the report on Socio-economic Impact from ROADEX II (1) most of the calculation models for minimizing socio-economic costs will only work at a network level. If these models are also to be utilised for low volume roads there is a definite need to add a social benefit factor to the user benefits. Use of the 'Transportation Need Index', as outlined in Section 5.5 later, is of potential benefit to rural low volume roads. It is suggested here that the TNI-value be converted to a Social Benefit Factor (SBF) for the road user benefits. The factor can be used to multiply the sum of the road user benefits in the models. The following conversion is suggested:

TNI	SBF
4-6	1,25
7-9	1,50
10-12	1,75
13-16	2,00

Chapter 4. Using road condition standard levels

4.1 INTRODUCTION

Road condition standards can be implemented and used in a number of ways. For example, different service levels for different road standards can be defined as:

- Basic Service Level
- Minimum Service Level
- Target Service Level
- Optimum Service Level

These levels can be used for a range of purposes. For instance the minimum service level can act as trigger value in a routine maintenance contract. The trigger values can differ depending on, for example, the traffic class and the speed limit. A step towards a better adaptation to road user needs and social structure is being carried out in Finland. There a new “planning cube” is used, as shown in figure 4.1, which describes the “cells” for the policy. The aim is to complete all the cells in the planning cube to form socio-economic road condition levels adapted to road user needs, goals of society and economy.

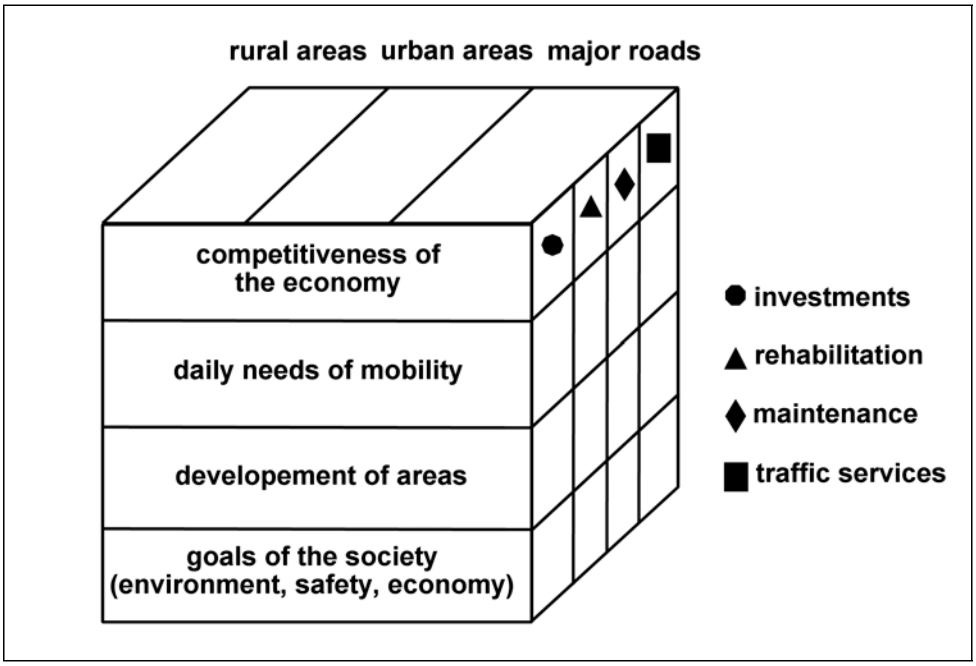

Figure 4.1 Possible social benefits and costs of improved road infrastructure (6).

4.2 USE OF ROAD CONDITION STANDARD LEVELS FOR PLANNED MAINTENANCE

Road condition standard levels can be used at the road network level as target standards to be achieved if resources are available. The target standard levels for the road surface of low volume roads on road network level in Sweden, Norway and Finland are presented in table 4.1 below.

Table 4.1 Road condition standard levels on low volume road networks.

Country	Rutting (mm) max	Roughness (IRI mm/m) max	Comment	Level within
Sweden (7)	19	6,0	Average 20 m	90 %
Norway (8)	18,5	5,0	Median 20 m	90 %
Finland (6)	20	5,5	Average 100 m	88 %

Figure 4.2 Rutting on a small paved road in Northern Sweden.

These requirements in the three countries are broadly similar at the road network level and are of course much lower than those of the high volume road networks. At the road section level the requirements are even lower, as can be seen in table 4.2, but it is not reported how well these standards are achieved, if at all.

Table 4.2 Road condition standard levels on low volume road sections.

Country	Rutting (mm) max	Roughness (IRI mm/m) max	Comment	Level within
Sweden (7)	35	9,0	Average 20 m	100 %
Norway (8)	25	7,0	Median 20 m	90 %
Finland (6)	21	8,0	Average 100 m	99 %

4.3 USE OF ROAD CONDITION STANDARD LEVELS FOR ROUTINE MAINTENANCE

Traditionally routine maintenance in the partner countries have been performed by the local road managers' own crew to a locally defined specification. Nowadays routine maintenance activities on the public road network are often delivered by to performance contracts by contractors in full competition. These performance contracts are governed by performance specifications and the requirements of the performance criteria will affect the practicability and the comfort for the road users. Some examples of road standard level requirements for paved roads from a Swedish performance specification in Region North (9) are given below:

STANDARD	**REQUIREMENT**	**ADDITIONAL**
Essential	Frost damages shall be repaired as soon as possible, weather permitting, and not later than 1st of July.	Temporary repair shall be done with suitable material permitting permanent repair later.
'Regularity' (availability and accessibility"	The road network shall be passable for all classes of vehicles permitted by the local road authority. Exceptions may be accepted on parts of the road network during the thaw period or when the bearing capacity is not sufficient.	Vehicles of 12 tons gross weight shall normally be allowed during periods of load restriction. The road network shall always be practicable for exempt vehicles and vehicles with 4 tons gross weight. The client shall be informed of any need in changes of the load restrictions.
Level differences and edge deformation	During the period 1st of June to 30th of September level differences along or across the road on a length of 2.0m shall not be bigger than 20mm on national roads, 30mm 0n other roads.	Measurements shall be performed with a 2 m straight edge.

Dewatering	Ditches, culverts, daywater and drainage piping and wells shall be kept open to ensure 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 paths shall be done immediately with sand or gravel. Carriageways on national roads and pedestrian and cycle paths 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. 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 which can reduce friction.	Examples of materials that can cause problems are clay, leaves, oil spill.

4.4 TEMPORARY LOAD RESTRICTIONS

Temporary load restrictions are common traffic obstacles on northern European low volume rural roads especially in Finland and Sweden where the spring thawing of roads results in water saturated road structures and reduced bearing capacity. To avoid premature road deterioration in these cases the road authorities usually introduce temporary load restrictions for a limited time period. In some cases roads are closed completely as the road condition will not allow any vehicle to pass. In Norway, decisions have been taken not to introduce temporary spring thaw load restrictions. The decision was taken in 1995 after completion of a four year research project (10). According to the results from the project there was a national socio-economic profit in allowing unrestricted traffic year around and to repair the spring traffic damages if and when they came up.

4.5 FRAGILE AREAS AND LIFELINE ROADS

A number of policies have been introduced in the Highlands in Scotland to highlight the situation of the lightly populated rural areas. One interesting project is the identification ‘fragile areas’ which are areas where there is a risk that the local communities may not be strong enough to survive (11). There, ‘fragility’ has been divided into 8 classes and the most fragile areas are shown coloured in dark red in figure 4.3. Fragile areas are defined as communities “being in decline or in danger of decline” as a result of certain fragility indicators described later in section 5.3.

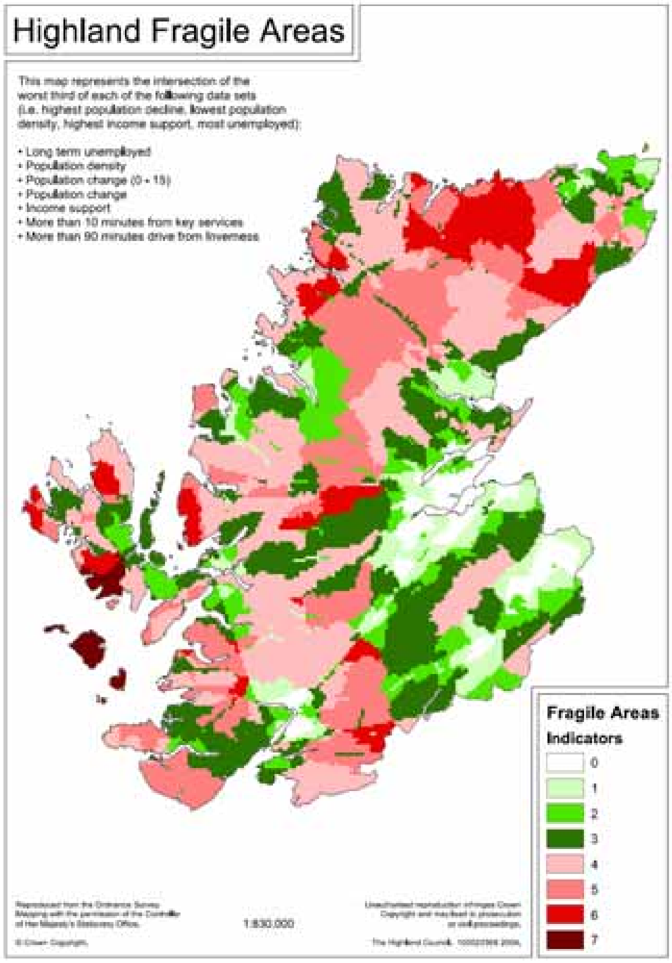

Figure 4.3 .Fragile areas in the Highlands 2003 (from the Highland Council,11).

We consider this to be a good idea that makes the most fragile areas of a country or a region visible so that they can be given a higher road condition standard to support their survival and development.

Another interesting project concerning rural roads in Scotland is the concept of 'Lifeline Rural Roads'. The Highlands and Islands Strategic Transport Partnership, (HITRANS) report "Investments in Lifeline Rural Roads" (12) defines a 'lifeline road' as "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 HITRANS study was 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 investment in lifeline rural roads.

As a result of this assessment 9 key roads were identified as possible candidates for improvement. The candidates served areas of Highlands and Islands that suffered from varying degrees of economic and social deprivation. The appraisal of each road was carried out according to STAG (Scottish Transport Appraisal Guidance, (13)) with complete analyses of Transport Economic Efficiency (TEE) and Economic and Locational Impacts (EALIs).

Figure 4.4. Single-track lifeline road in the Western Isles (photo Ralph Shackleton, The Western Isles Council).

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.

Several of the roads selected were considered to be ‘unfit for purpose’ in providing a sufficient access to ensure sustainable economic and social prosperity of the communities they served. An upgrade in the road condition was needed to provide long term sustainability of the communities. Economic analyses showed that the benefits in many cases were sufficient to cover the costs when calculated over a period of 30 years. Additionally many of the proposed road schemes would give indirect benefits like increased employment, reduced transport costs and better accessibility to markets and customers.

These Scottish ideas to classify fragile areas in the society and to define lifeline roads are considered to be very valuable mechanisms to highlight the special need for good road conditions on low volume roads in rural areas.

4.6 ROAD CONDITION STANDARD LEVELS BASED ON HEALTH CONSIDERATIONS

Road surfaces can be more or less comfortable for the road user to travel on. The usual way to express the roughness of a road surface 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 of the vehicle. The IRI-value is most affected by irregularities with a wavelength between 1-30 metres. 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 large research study. It was found that there was a connection between the truck cab vibrations and traffic safety and that the vibrations could also affect the truck drivers' health (14). It was also reported that vibrations should be eliminated as much as possible at the source. Within the EU, Directive, 2002/44/EC (15) limits the exposure of vibrations and in clause 7 rests responsibility on employers: "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 these EU vibration requirements will fall on road managers.

In the Swedish report "Whole-body vibrations when riding on rough roads" (16), it is said that the road surface irregularities and texture will cause different types of strains to human beings because of, for example, noise, infra sound and shakings of the body. 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).

Based on the results of 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 road surface conditions on paved Swedish State roads shows that more than 25 % of the road network has an IRI exceeding that figure and most of these roads are low volume roads. To fulfil the named recommendation on the Swedish road network there is a need for a substantial increase in the road maintenance budgets.

Chapter 5 Proposal for new road management policies

5.1 INTRODUCTION

This chapter introduces some new proposals for road management policies that aim to favour the most fragile low volume roads in rural areas. The work is intended to give new ideas to road managers, politicians and other decision makers for handling the road condition on low volume rural roads. As road conditions on low volume roads are most often described subjectively by visual inspection a new measurement method is offered which still is under development. The measurement equipment is a simple accelerometer placed, for example, on a wheel axle of a car measuring the vertical acceleration. In Sweden a research project is underway using accelerometers fitted to post vans (see figure 5.1).

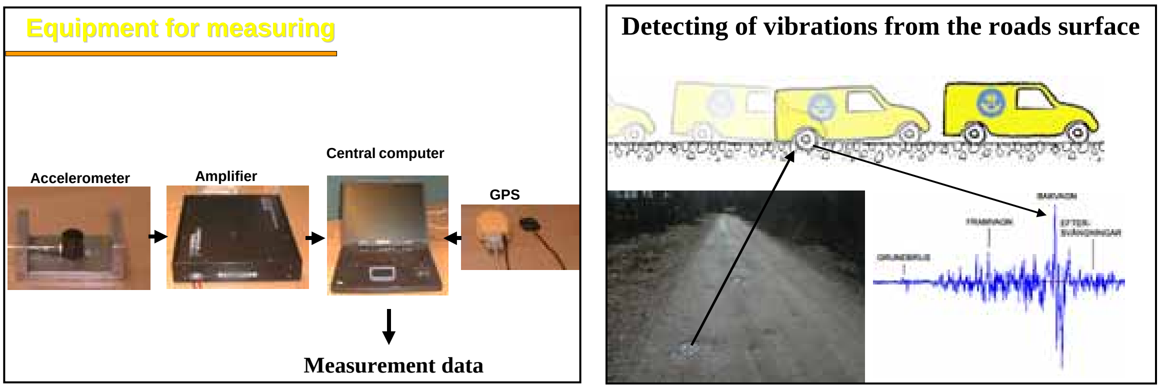

Figure 5.1. Equipment and measurement principles for roughness measurements with accelerometer (from Lars Forslöf et al)

The road management policies and the figures for roughness measured with accelerometer that follow are only drafts and should be regarded with care. Further details will be provided in the ROADEX III project task B.3: “Health considerations”. Full background on the present proposals can be found in the ROADEX II report “Road management policies for low volume roads – some proposals” (2). This work will continue in Task B.4 “Road condition management policies” in ROADEX III.

5.2 PROCESS OF INTRODUCING NEW ROAD MANAGEMENT POLICIES

The process of introducing new Road Management Policies should be done step-by-step. A possible process is described in figure 5.2. The process consists of the following steps:

- Identify ‘fragile areas’
- Identify ‘lifeline roads’

- Identify road user needs
- Establish road condition standards – defining the service levels
- Defining procurement strategies and policies to secure the required service level
- Follow up.

The first four steps are described closer below and the last two steps will be further developed in ROADEX III, task B.4 "Road condition management policies".

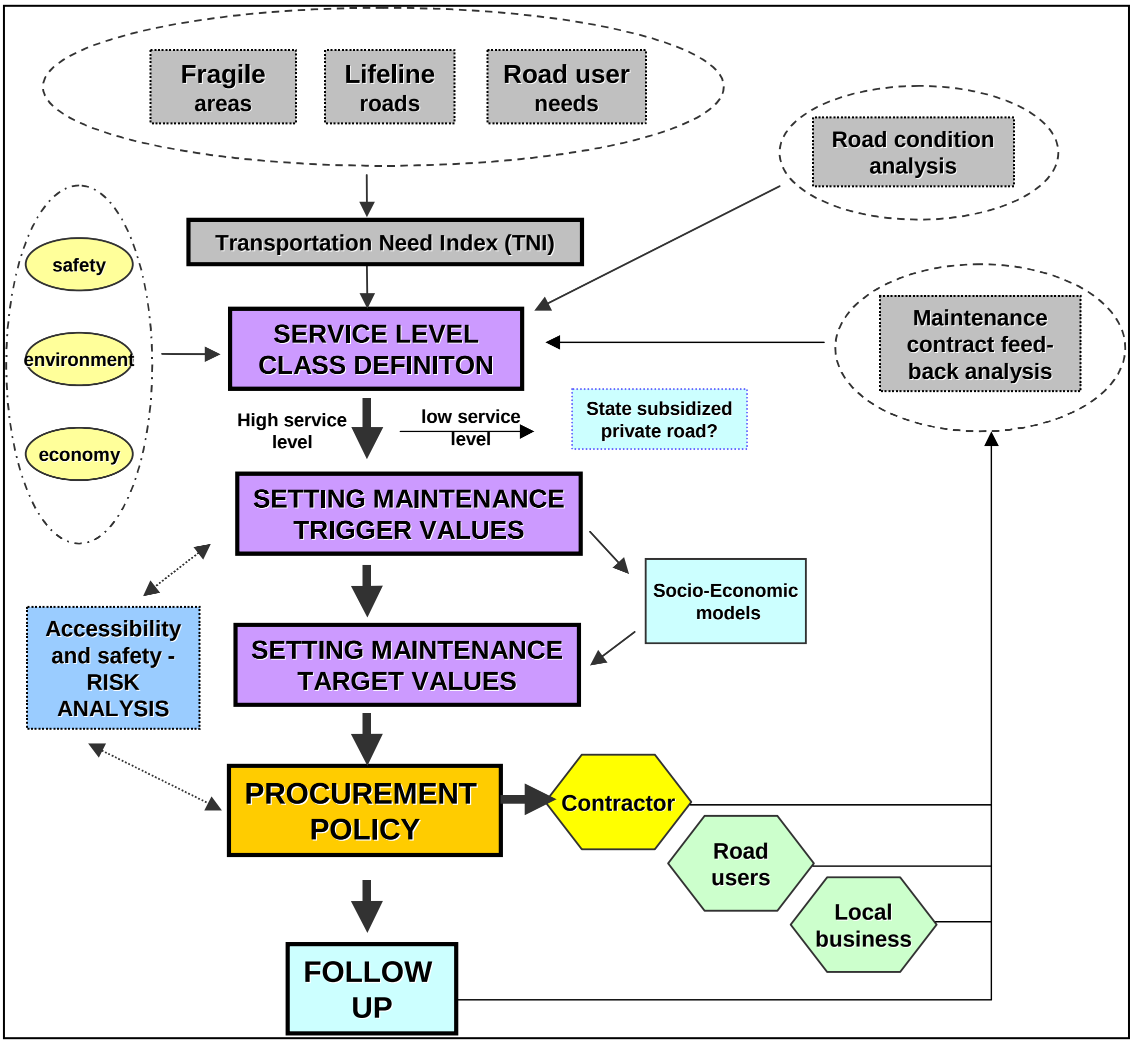

Figure 5.2. Road Management Principles for routine and planned road maintenance.

5.3 FRAGILE AREAS AND LIFELINE ROADS

5.3.1 Fragile areas

All of the ROADEX partner countries have large rural areas where basic social services are difficult to maintain due to limited resources. Here, there is a risk that some areas will be left unpopulated unless the political will to direct more resources towards keeping people living in rural areas increases. These areas, which are suffering from this decline in inhabitants, can be deemed fragile areas (11).

Fragile areas can be defined as communities being in decline or in danger of decline as a result of the following suggested fragility indicators:

- Social fragility – population
    - Population decline in % (latest 10-year period)
    - Population decline 0-15 years in % (latest 10-year period)
    - Population density latest year in persons/km²
    - People retired because of health or age latest year in %
- Economic fragility – unemployment
    - Long term unemployment rate – latest year in %
    - Income support claimant rate – latest year in €/person/month
- Accessibility indicator – to key services
    - Population residing outside of a 20 min one-way drive to 5 key services
        - Post Office
        - Primary School
        - Food Shop
        - GP Surgery
        - Petrol Filling Station
- Remoteness indicator – from the main service centre (City)
    - Population residing outside of a 1.5 hour one-way drive from city.

The fragility (F) of an area can be assessed using the follow guidance:

Choose the smallest identifiable geographical area of the county or region from which statistical data regarding the social and economic fragility indicators can be identified. Collect information regarding the selected indicators and enter the results in a table e g in Excel. Rank the results in order of size for each fragility indicator. Assign the value 1 to the best and then the value ‘n’ for the worst of each indicator. Add the indicators to obtain a sum for each geographical area. Select 25% of the geographic areas with the highest fragility ranking. Regard them as ‘fragile areas’ and then divide them into 3 groups, equally sized, ranging from the lowest to the highest within the fragility group. The remaining 75% will be ‘class 1’, no fragility. Use a GIS computer program, e g Arc View, to show the map and attach a specified colour to each fragility class. Start with a light colour for the best and then use increasingly darker colours as shown in the example in figure 5.3. Then use the GIS program to identify the accessibility and remoteness indicators. (A radius of 25 km for the accessibility and 125 km for remoteness has been used in the example to simplify the procedure.) Areas with good accessibility can then be designated as ‘urban areas’ and marked as white areas on the GIS map as shown in figure 4. The areas within a remoteness distance of 125 km have been changed to one class less fragility. Now the fragility can be classified into 5 different classes shown on the GIS map in figure 5.3 and in table 5.1.

Table 5.1. Fragility classes (F).

0.	Urban area	Omitted areas in the survey
1.	No fragility	75 % of the surveyed areas regarded not fragile
2.	Little fragility	The highest rated of the three groups
3.	Medium fragility	The medium rated group
4.	High fragility	The lowest rated group.

The process result can be seen in an example of a small fragility survey in the county Norrbotten, in the furthest north part of Sweden. The work was carried out to confirm how the process worked in ranking 14 communes based on fragility and the results are presented in different colours on a GIS-map in figure 5.3.

5.3.1 Lifeline roads

Low volume roads in rural areas are often the only means for small communities and villages to transport people and goods. These roads are needed in order to access local business, health care, education, cultural events etc. The distances involved are often long, and if road conditions are also bad, difficulties can be multiplied. The transport links to such areas can be lifeline roads (12), vital arteries for the areas. The definition of a lifeline road is given in clause 4.5 above.

One way to classify the lifeline roads depending on its importance is shown in table 5.2 and some examples are shown on the GIS-map in figure 5.3.

Table 5.2 Lifeline classification (L).

1.	The road is not a lifeline road
2.	The road has a substitute that presents a minor increase in time and cost
3.	The road has a substitute that presents a major increase in time and cost
4.	The road has no substitute.

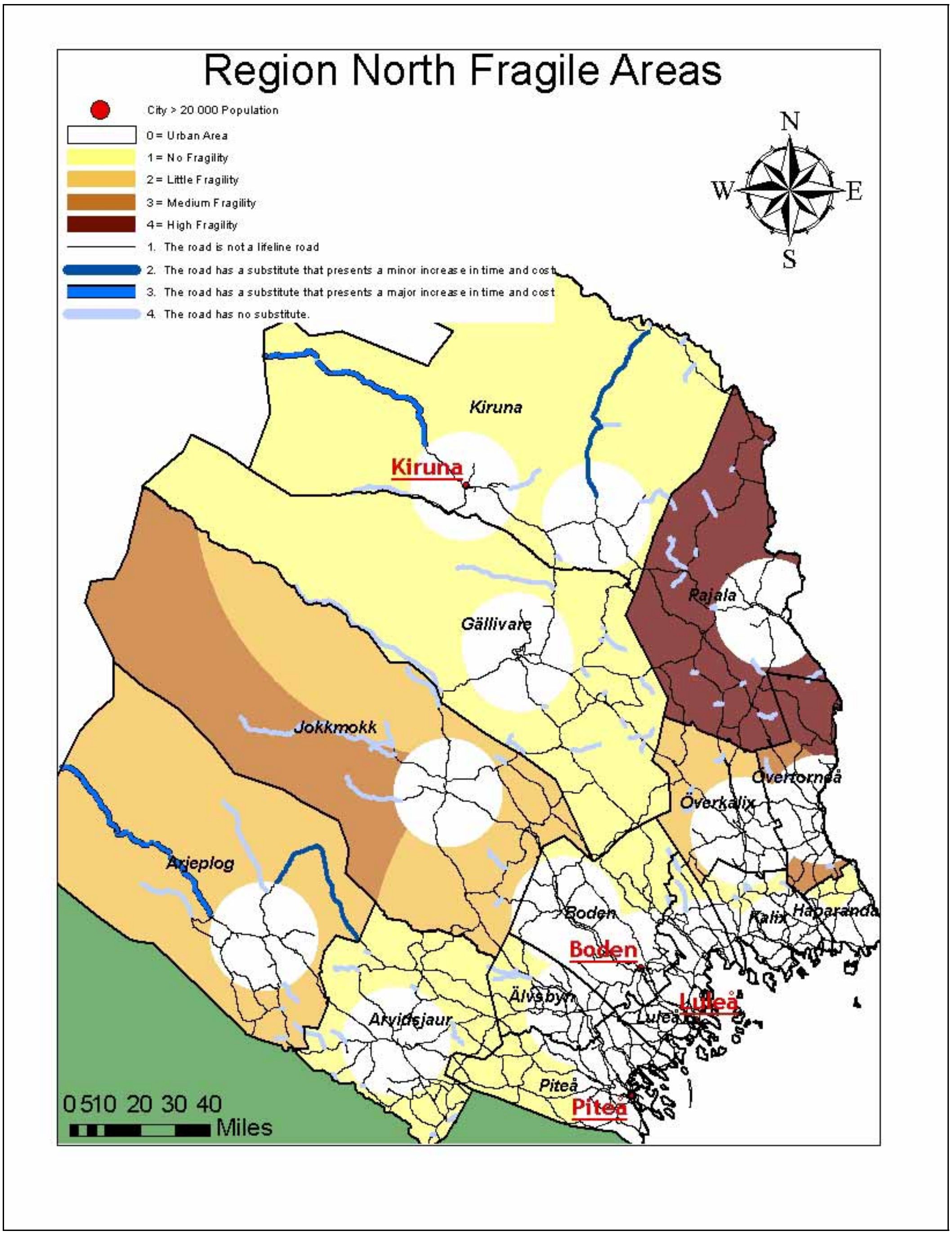

Figure 5.3. Fragile areas and Lifeline roads in Norrbotten.

5.4 ROAD USER NEEDS

The two main types of road transportation needs can be defined from the two primary categories of road users:

- People

- Business.

Both categories have transportation needs with different priorities depending on the reasons for travelling. For people, transportation to schools and workplaces are examples of essential transport needs and, for business, daily mail and other scheduled transportation services are examples of high priority needs.

The transportation need for people depends on the number of road users that use the actual road section. But it also depends on the road users’ reasons for travelling. A classification based on these parameters is shown in table 5.3 below.

Table 5.3 Transportation need for people (P)

1.	Few road users, only temporary use
2.	There are only a few permanent residents with no time scheduled access need
3.	School children and commuters
4.	High priority use (school children, commuters, daily bus routes)

The importance of business traffic is independent of whether if the road is an urban or a rural road and frequency and accessibility are factors influencing the priority classification. For roads with seasonal variations in traffic, like tourist traffic and timber haulage, the classification should be based on the busy season. A suggested classification is shown in table 5.4 below.

Table 5.4 Transportation need for business (B).

1.	No business traffic
2.	Only a few businesses with no need for regular daily transportation
3.	Few businesses with needs for regular daily transportation
4.	Several businesses requiring daily transportation service with high accessibility needs

5.5 TRANSPORTATION NEED INDEX

From the first three steps named above it is possible to arrive at a numerical value, which describes the need for a good road standard. By summarising the social, economic and road user needs a ‘transportation need index’ (TNI) can be developed. This index is the sum of the classifications of fragility (F), lifeline urgency (L) and the road user needs for people (P) and business (B):

TNI = fragility class + lifeline class + people road user needs + business road user needs.

The TNI-value, ranging between 4 and 16, can be used as a ranking figure for choosing between maintenance and/or rehabilitation candidates. The highest figure indicates the highest transportation need.

Chapter 6. Road service levels and intervention levels for paved roads and gravel roads

6.1 INTRODUCTION

Many low volume roads are often poor and variable in condition and some can be extremely poor at times particularly during spring due to frost damage. One way to improve this situation is to introduce specified standards for road condition service levels.

In this system the service level of a specified road section would be determined based on the TNI classification defined in Chapter 5 for public paved roads and gravel roads. The 'intervention' level should be regarded as the lowest acceptable standard limit or "trigger value" indicating that a maintenance or rehabilitation measure should be taken. The 'target' road standard level is a much higher standard and, as such, it should be used in setting the goals for maintenance contracts.

6.2 ROAD SERVICE LEVELS

The road service level priority can be divided into four levels based on the transportation needs of Fragility (F), Lifeline (L), People (P) and Business (B) already described.

ROAD SERVICE LEVEL PRIORITY	
1. Lowest priority: lowest accessibility, quality; can be close to the "shame value"	Classes F1, L1, P1, B1 and government subsidised private road
2. Standard priority (no fragile areas, medium lifeline, medium user need)	Classes F2 and/or L2, P2 and/or B2.
3. Raised priority (area development has great weight) (high fragility, high life line points)	Classes F3-F4, L3-L4, and/or P3, B3.
4.Highest priority (high road users and business needs), should have: good ride comfort and high accessibility	Classes P4 and/or B4

This priority system gives roads in high fragility areas and lifeline roads a better ranking than they would have if only traffic figures are used and it also provides a higher priority to those roads that have high road user and business needs.

The system can also be used in other areas, e.g. for winter maintenance and rural tourism investments.

6.3 INTERVENTION LEVELS FOR PAVED ROADS

In any situation where defects can be a danger to people or vehicles, danger signs should be placed without delay. For paved roads 4 different service levels based on drive comfort, traffic safety, load restrictions and accessibility are suggested. For driving comfort, trigger values for roughness using 10 m average values are suggested. This will increase the likelihood of finding the short poor areas which can be dangerous and unpleasant for road users. If longer averages are used these short areas may be hidden in the average. The following tables present our proposals for the requirements for drive comfort, traffic safety, load restrictions and accessibility.

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 1, PAVED ROADS		
Drive comfort	Speed > 100 km/h	10 m average IRI < 13 mm/m
	Speed 80-100 km/h	10 m average IRI < 15 mm/m
	Speed < 80 km/h	10 m average IRI < 17 mm/m
	No potholes	
Traffic safety	Surface friction	> 0,5
	Rutting	20 m average < 50 mm
Load restrictions	Temporary load restrictions allowed	
Accessibility	Lowest maintenance standard	

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 2, PAVED ROADS		
Drive comfort	Speed > 100 km/h	10 m average IRI < 12 mm/m
	Speed 80-100 km/h	10 m average IRI < 14 mm/m
	Speed < 80 km/h	10 m average IRI < 16 mm/m
	No potholes	
Traffic safety	Surface friction	> 0.5
	Rutting	20 m average < 40 mm
Load restrictions	Temporary load restrictions allowed	
Accessibility	Standard maintenance standard	

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 3, PAVED ROADS		
Drive comfort	Speed > 100 km/h	10 m average IRI < 10 mm/m
	Speed 80-100 km/h	10 m average IRI < 12 mm/m
	Speed < 80 km/h	10 m average IRI < 14 mm/m
	No potholes	
Traffic safety	Surface friction	> 0.5
	Rutting	20 m average < 30 mm
Load restrictions	Temporary load restrictions allowed during severe spring thaw conditions	
Accessibility	Raised maintenance standard	

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 4, PAVED ROADS		
Drive comfort	Speed > 100 km/h	10 m average IRI < 9 mm/m
	Speed 80-100 km/h	10 m average IRI < 11 mm/m
	Speed < 80 km/h	10 m average IRI < 13 mm/m
	No potholes	
Traffic safety	Surface friction	> 0.5
	Rutting	20 m average < 20 mm
Load restrictions	No load restrictions allowed	
Accessibility	Highest maintenance standard	

When the condition of the road falls below any of these listed intervention levels the road becomes a candidate for maintenance or rehabilitation. Selection and prioritisation of identified candidates can then be carried out using the 'Transportation Need Index' from Chapter 5.

6.4 INTERVENTION LEVELS FOR GRAVEL ROADS

As in the case for paved roads, in any situation where defects can be a danger to people or vehicles, danger signs should be placed without delay. The intervention levels for gravel roads can be defined in various ways. They can be done by specifying levels of road surface defects, by using some sort of a comfort value for a specified road section or by a combination of defects and a comfort value. The following tables present a range of suggested requirements for drive comfort, traffic safety, load restrictions and accessibility. The measurement for roughness values by accelerometer is taken from a Finnish proposal (19). This measurement should be carried out at a speed of 80 km/h or at the design speed if the road is designed for lower speed.

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 1, GRAVEL ROADS	
Drive comfort	The road has in general good cross fall and the surface is in most areas firm and even
	Larger areas of deformation, potholes and corrugations (wash-boarding) can occur but not for more than seven days.
	Roughness measured by accelerometer 10-15 m/s^2
Traffic safety	Loose gravel may be found on the surface and along the roadway
	Dust is rather frequently generated by the vehicles.
Load restrictions	Temporary load restrictions allowed
Accessibility	Lowest maintenance standard

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 2, GRAVEL ROADS	
Drive comfort	The road has in general good cross fall and the surface is in most areas firm and even
	Larger areas of deformation, potholes and corrugations (washboarding) can occur but not for more than three days.
	Roughness measured by accelerometer 6-10 m/s^2
Traffic safety	Loose gravel may be found on the surface and along the roadway
	Some dust is generated by the vehicles.
Load restrictions	Temporary load restrictions allowed
Accessibility	Standard maintenance standard

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 3, GRAVEL ROADS	
Drive comfort	The road has in general good cross fall and the surface is in most areas firm and even
	Unevenness and potholes exist in some areas
	Roughness measured by accelerometer 3-6 m/s^2
Traffic safety	Loose gravel may be found on the surface and along the roadway
	Some dust is generated by the vehicles.
Load restrictions	Temporary load restrictions allowed during severe spring thaw conditions
Accessibility	Raised maintenance standard

TRIGGER VALUES FOR SERVICE LEVEL PRIORITY 4, GRAVEL ROADS	
Drive comfort	The road has necessary cross fall and the surface is firm and even
	Some potholes may occur
	Roughness measured by accelerometer < 3 m/s^2
Traffic safety	Some loose gravel may be found on the surface.
	Not much dust is generated by the vehicles.
Load restrictions	No load restrictions allowed
Accessibility	Highest maintenance standard

Gravel roads were not discussed in any depth within the ROADEX II report "Socio-economic impacts of road conditions on low volume roads" but they will be considered in greater depth in the ROADEX III project, Task B.4, "Road condition management policies".

Chapter 7. Forest roads

7.1 INTRODUCTION

Forest roads differ from other paved and gravel roads in that they are designed and constructed for a specific business requirement. Their purpose is to enable access to forests to assist in general management, timber extraction and recreation. The class of the road is directly related to the business need linked to the forest and the challenge is to construct a road capable of carrying large and heavy vehicles while meeting all of the environmental criteria at a cost commensurate with the quality and volume of the timber produced. The forest road is a key component of the supply chain to the timber industry and as the industry moves towards "just in time" stock control many forest roads must remain serviceable throughout the year in all weather conditions even during the spring thaw period. This must happen when the road is needed for harvesting the forest. As forests grow slowly this might mean that a road section should be fit for timber hauling with long time intervals where the forest company is the sole user.

7.2 ACCESSIBILITY

Forest roads can be divided into different classes dependant on road user access need. Primarily forest roads are made for the transportation of timber and use by heavy vehicles but throughout the Northern Periphery area recreational use is increasing and demands are being made to keep forest roads serviceable throughout the year. Our proposal for accessibility is presented in four classes in the table below.

ACCESSIBILITY CLASSES FOR FOREST ROADS	
Class A	The road shall be able to carry traffic from heavy vehicles and personal cars throughout the year.
Class B	The road shall be able to carry traffic from heavy vehicles the whole year except for the spring thaw period. The road shall be able to carry personal cars throughout the year.
Class C	The road shall be able to carry traffic from heavy vehicles the whole year except for the spring thaw period and periods with heavy rainfall. The road shall be able to carry personal cars throughout the year except for the spring thaw period.
Class D	The road shall be able to carry traffic from heavy vehicles mainly when the road structure is frozen. The road shall be able to carry personal cars also in the summer.

7.3 INTERVENTION LEVELS FOR FOREST ROADS

The intervention levels suggested are based on type, severity and extent of defects. The values for roughness measured with accelerometer are from the Finnish proposal (19) introduced as trigger values in the tables for gravel roads. The roughness measurement shall be carried out at a speed of 50 km/h or at the design speed of the road if the road is designed for lower speed. The intervention levels are presented in the following tables.

INTERVENTION LEVEL 1 FOR FOREST ROADS		
Defect	**Extent intervention level**	**Activity**
a) Depth of wearing course gravel 0 mm	On > 20 % of sub-length.	Relaying of pavement including supply and placing of imported material
d) Roughness measured with accelerometer	20-30 m/s^2	

INTERVENTION LEVEL 2 FOR FOREST ROADS		
Defect	**Extent intervention level**	**Activity**
a) Defect depth > 150 mm or water ponds	On > 20 % of sub-length.	Heavy formation grading including re-watering and compaction.
b) Crossfall < 3 % or > 7 %	On > 20 % of sub-length.	
d) Roughness measured with accelerometer	10-20 m/s^2	

INTERVENTION LEVEL 3 FOR FOREST ROADS		
Defect	**Extent intervention level**	**Activity**
a) Crossfall < 3 % or > 7 %	On > 20 % of sub-length of 1 km	Medium formation grading including re-watering and compaction
b) Ruts, potholes and corrugations > 50 mm deep	On > 20 % of sub-length of 1 km	
c) Roughness measured with accelerometer	5-10 m/s^2	

INTERVENTION LEVEL 4 FOR FOREST ROADS		
Defect	**Extent intervention level**	**Activity**
a) Soft or slippery areas; loose material	On > 5 % of a sub-length of 1 km.	Light formation grading. Repair of general defects.
b) Safe travel speed < 80 % of safe driving speed	On > 20 % of sub-length	
c) Ruts, corrugations, potholes < 50 mm depth	On > 20 % of sub-length.	
d) Roughness measured with accelerometer	< 5 m/s^2	

7.4 ROAD STANDARD PRIORITY LEVELS

In any situation where the discovered defect is a danger to people or vehicles, danger signs should be placed without delay. Where a sign is required, the time taken to erect the sign will depend on the road accessibility class. Some forest roads will not be open to private cars and the priority level of these roads can be decided solely on business need. The road standard priority is described in four levels based on transportation need and intervention level. This ranking describes the acceptable response time between the reporting that an intervention level has been reached and action taken to restore the actual defects.

ROAD STANDARD PRIORITY LEVEL ON FOREST ROADS

Accessibility class	Intervention level	Priority
A	4	Action against substandard within 3 days.
	3	Action against substandard immediately.
B	4	Action against substandard within 7 days.
	3	Action against substandard within 3 days.
	2	Action against substandard immediately.
C	4	Action against substandard within 14 days.
	3	Action against substandard within 7 days.
	2	Action against substandard within 3 days.
D	3	Action against substandard within 14 days.
	2	Action against substandard within 7 days.
	1	Action against substandard within 3 days.

Chapter 8 Conclusions

This report offers some new proposals for Road Management Policies that can be used to improve the ranking of low volume roads in order to benefits the living conditions of people in the Northern Periphery Area. Some conclusions of the report are:

- Identifying fragile areas and lifeline roads is a good method for showing rural road user needs;
- Combining fragility, lifeline class and accessibility needs for people and business into a Transportation Need Index gives opportunities to form a better ranking for low volume roads;
- Defining service levels in different priority levels and short average 'trigger values' should produce better road conditions for road users;
- The new proposals for objective 'trigger values' for roughness measured with accelerometer should be tested and adjusted in ROADEX III and then trigger and target values can be adjusted;
- The 'follow up' process in maintenance contracts is very important to secure the quality and to improve the performance requirements;
- The use of a Social Benefit Factor in the socio-economic models can improve the possibilities of a fairer allocation of resources between high and low volume roads.

Work continues in the ROADEX III Project to test and improve these policies and 2 further reports will be produced, one on paved and gravel roads and one on forest roads within the new Project.

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