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SUMMARY OF DRAINAGE ANALYSIS IN THE UMEÅ AREA, SWEDEN

- SEASONAL TESTS**

- TOOLS FOR OUTLET DITCH INVENTORY**

ABSTRACT

It is a general fact that road structures work better when they are kept dry, and that good drainage is always a critical factor in sustainable road design and maintenance. Despite this knowledge however the ROADEX projects have shown that poor condition is the one of the biggest problems on roads in Northern Europe.

“Drainage analysis” was developed by ROADEX to locate those critical sections needing improvement on roads, and after that regular attention and maintenance. Usually a drainage analysis is done visually from a moving car and later from digital videos with input from road historical performance data (roughness and rutting). ROADEX has also tested whether thermal cameras and laser scanners can provide additional useful information for these analyses.

This report describes the results of a ROADEX drainage analysis in the Umeå Södra maintenance area in 2010, together with some results of tests of new tools to improve the analysis.

During the surveys the drainage condition was found to vary considerably across the roads surveyed. In some sections the drainage was flawless, and in others the drainage was found to be extremely poor. Typically poor drainage was found in road cuts and in the vicinity of clogged or missing access road culverts.

Tests were also carried out to identify the effects of the timing of measurements on results. The time for drainage analyses in spring is short (after the snow has melted and before the vegetation starts to flourish). Comparisons were made on the results of the springtime inventory and the late fall inventory. These tests were made on seven selected roads. The tests showed that the drainage analysis could be performed satisfactorily in autumn.

In addition to the above work, the project also aimed to find tools to improve the surveys of outlet ditches, i.e. location and condition, clogged or well-working. It was found that a third camera, aimed at an 90° angle from the road towards the side, proved to be an excellent tool for checking the condition of outlet ditches.

Keywords

Drainage, analysis, verge, pavement, lifetime, rutting, IRI, outlet ditch

PREFACE

This task "*Drainage analysis in the Umeå area, Sweden; seasonal tests and tools for outlet ditch inventory*" was carried out in the ROADDEX IV Work Package 3, "*Local demonstrations*". The field measurements were organised by Tomi Herronen. Seppo Tuisku, Tomi Herronen and Jani Irvankoski carried out the field measurements. The measured data was handled by Anna Maijala, Elmo Haavikko, Eetu Pussinen and Sami Tuisku. The ROADDEX drainage analysis was carried out by Tomi Herronen, Seppo Tuisku and Annele Matintupa. Mikko Pajula made the statistical analysis of the seasonal tests. Other statistical analyses were made by Matti Saarenketo. This report was written by Annele Matintupa and Seppo Tuisku. Timo Saarenketo steered the demonstration project as lead manager of the D1 "*Drainage Maintenance Guidelines*" group. The software specialists were Timo Saarenpää, Pekka Maijala and Jani Irvankoski. All above-mentioned are from Roadscanners Oy, Finland. Kent Middleton checked the language. Mika Pyhähuhta of Laboratorio Uleåborg designed the report layout. Authors would like to thank ROADDEX IV steering Committee for its encouragement and valuable guidance in this work.

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1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organizations across northern Europe that aims to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finland Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX IV from 2009 to 2013.



Figure 1. The Northern Periphery Area and ROADEX IV partners.

The Partners in ROADEX IV “Implementing Accessibility” comprised public road administrations and forestry organizations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and Comhairle Nan Eilean Siar from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency, The Centre of Economic Development, Transport and the Environment of Finland, The Government of Greenland, The Icelandic Road Administration, and The National Roads Authority and The Department of Transport of Ireland.

The aim of the Project was to implement the road technologies developed by ROADEX on to the Partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland.

A main part of the Project was a programme of 23 demonstration projects showcasing the ROADEX methods in the Local Partner areas supported by a new pan-regional “ROADEX Consultancy Service” and “Knowledge Centre”. Three research tasks were pursued as part of the

project: “Climate change and its consequences on the maintenance of low volume roads”, “Road Widening” and “Vibration in vehicles and humans due to road condition”.

All ROADEX reports are available on the ROADEX website at www.ROADEX.org.

1.2 THE DEMONSTRATION PROJECTS

Twenty three demonstration projects were planned within the ROADEX IV project. Their goal was to take selected technologies developed by ROADEX out on to the local road networks to have them physically used in practice to show what they could achieve. The projects were funded locally by the local Partners, designed and supervised by local staff, and supported by experts from the ROADEX consultancy.

The demonstrations were managed in 6 groups by a nominated lead manager from ROADEX:

- D1 - “Drainage Maintenance Guidelines”
- D2 - “Road friendly vehicles and Tyre Pressure Control”
- D3 - “Forest Road policies”
- D4 - “Rutting, from theory to practice”
- D5 - “Roads on Peat”
- D6 - “Health and Vibration”

This demonstration project is part of the D1 “*Drainage Maintenance Guidelines*” group. The report describes the results of drainage analysis in Umeå area in Northern-Sweden. The report also describes the results of seasonal tests and test results on tools for improving the outlet ditch inventory.

2. ROADS SURVEYED

A drainage survey was carried out in the Umeå Södra area in Northern Sweden in 2010 (Figure 2). The distances covered by this survey consisted of 416.9km of paved roads and 100.3km of gravel roads (total 517.2km).



Figure 2. The surveyed roads located in the Northern Sweden.

The roads surveyed for the seasonal tests were selected from the same roads to be a representative sample of typical roads in the area. These roads were the same roads surveyed for the laser scanner and thermal camera tests. The surveyed roads were as follows; 353, 363, 500, 501, 504, 505, 506, 506_01, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 528, 530, 532, 533, 536, 538, 539, 540, 552, 553, 554, 555, 568, 570, 573, 573_1, 574, 574_01, 575, 632, 691, 693, Y1085 and Y1092. The traffic volumes of the roads varied; some had a very low amount of traffic and some were busier. The landscape and terrain varied from level fields to rocky side sloping ground.

3. DATA COLLECTION, FIELD SURVEYS

The data collection was mainly carried out in May 2010. The autumn measurements on the selected roads for seasonal tests were performed in November 2009. The weather was good during the autumn measurements. A light snow sheet caused a minor problem. In some sections the snow had melted. During spring measurements the weather was sunny all the time. The sunny weather created shadows and in some cases made the ditch bottom observation from the video quite difficult. Figure 3 shows an example of autumn and spring data from the same place.



Figure 3. Example of autumn (left) and spring (right) data from Road 353, chainage 10600m.

Field measurements were carried out on one road section at a time and both sides of the road were analysed separately. The vehicle used in the surveys is shown in Figure 4. During the data collection the driving speed was about 30 km/h. The vehicle was driven close to the pavement edge to give the cameras the best possible view of the ditch and side slope. A CamLink video-logging system by Roadscanners Oy was attached to the roof of the van. The GPS device, used to receive the position data, was an INCA2. All the data was linked to GPS coordinates using Road Doctor™ CamLink software. Preliminary classifications were done during the survey using the pc keyboard. Audio comments in the vehicle were also recorded to assist data interpretation in the office. These audio comments were mainly about road cross section profile, soil type, presence of ditches and their condition, and to correct any mistakes in classifications made with the keyboard.



Figure 4. The survey van used in the survey project. The orange CamLink box contains the digital video cameras sheltered against the rain and other adverse weather conditions.

Earlier drainage analysis had had problems in reliably evaluating the position and condition of the outlet ditches, and to improve this a third digital video camera was added to the survey configuration to test if it could provide additional useful information. The third camera was pointed at angle of 90° from the road towards the ditch (Figure 5). The other two cameras were pointed as usual towards the road and the ditch.

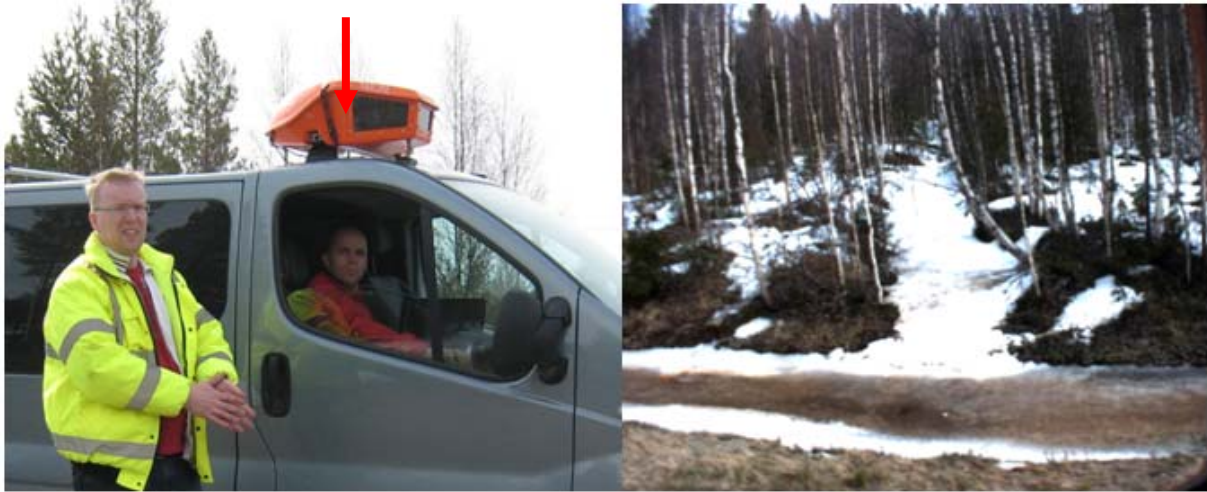


Figure 5. The third digital video camera was pointed towards the side at the angle of 90° (marked with red arrow on the photo in left side). The photograph on the right hand side shows an example of a still image taken by the third camera.

4. DRAINAGE ANALYSIS

4.1. TYPICAL DRAINAGE PROBLEMS

The most important finding of the drainage analysis on the roads in the Umeå Södra area was that the condition of the culverts beneath the access roads had a major impact on the functionality of the road performance. In most cases on the roads surveyed the access road culverts were missing or clogged. Quite often house properties in the villages came right up to the road edge. This caused drainage problems as there were no ditches beside the road. Other places that were seen to pose drainage problems were side-sloping ground and flat field areas. The typical drainage problems for Umeå Södra area are discussed in detail in the following.

4.1.1. House properties close to the road

There were several villages along the roads surveyed. Typical in these villages the private land of the houses came extremely close to the road. Where this happened the ditches between the road and the house property were usually missing resulting in the local drainage being very poor. In these circumstances it will be impossible to improve the roadside drainage without destroying the vegetation within the private land. These sections were noted in the analysis, but were left out of the identification of special maintenance sections. Examples of house properties close to the road are shown in Figure 6.



Figure 6. Examples of road sections with private land or trees close to the road.

4.1.2. Access road culverts

Another typical feature on the roads in the Umeå Södra area was that of the access road culverts. Typically these culverts were missing with the result that water had built up next to the junction as it had no possibility to flow freely through the junction. Another issue with these culverts was that they were clogged with soil or vegetation that blocked the water flow. Figure 7 shows an example of a culvert, set so high that water could not flow freely through it. Figure 8 shows examples of access roads where the culverts were missing.



Figure 7. An example of an access road culvert which had been set too high. The culvert is marked with a red arrow.



Figure 8. Examples of missing access road culverts.

4.1.3. Outlet ditches

The outlet ditches surveyed were found to have problems in flat and even areas. A number of outlet ditches were clogged. In flat areas there was often not enough gradient to assure that the water flowed away from the road area. A few examples of outlet ditches in poor condition are shown in Figure 9. The survey of outlet ditches is covered in chapters 6 and 7.



Figure 9. Examples of outlet ditches, which are in poor condition.

4.1.4. Road profile related problems

A number of drainage problems were noted on the surveyed roads which could be clearly related to the road profile. This was particularly the case on the sections located on side sloping ground where the ditch on the upper, road cut, side was regularly filled in. Figure 10 shows examples of typical problems related to side sloping ground.

A further drainage issue concerned those roads near the coast where the topography was generally level and flat. Clogged ditches were typical in this topography. The main problem was that it was almost impossible to make a gradient in the ditch. The result was that water could not freely flow and instead lay in pools in the ditches. Figure 11 shows some photographs of typical problems related to flat and level areas.



Figure 10. Examples of problems related to side sloping ground.



Figure 11. Examples of problems related to flat and level areas.

4.1.5. Other problems

During the analysis it was observed that some road sections had been repaved but that the ditches had not been cleaned out at the same time. Examples of such sections could be found on Road 508 (Figure 12). Based on earlier research in ROADDEX, it can be expected that these sections will start to show damage quite quickly. For this reason ROADDEX recommends that when a road is repaved the drainage should be improved at the same time as this will increase the pavement lifetime.



Figure 12. Example photograph from road 508, at point 43285m. The road has been repaved, but the ditch has not been cleaned out.

4.2. DRAINAGE CLASSIFICATION

The drainage classifications carried out in the project followed the general ROADDEX principles which are briefly summarised in this chapter, together with photographs of typical roads sections in the Umeå area. The complete description of the ROADDEX drainage analysis method is given in the ROADDEX report “*Drainage Survey Method Description*” written by Timo Saarenketo. The principles can be applied to both paved and gravel roads.

4.2.1. Class 1; Drainage in Good Condition

Description: The drainage condition in Class 1 is flawless. The cross-section of the road has preserved its form well and water flows from the pavement into the ditch unrestricted. Water also has a clear passage in the ditches.



Figure 13. Examples of road sections which have been classified into drainage Class 1.

4.2.2. Drainage Class 2; Drainage in Adequate Condition

Description: There are minor deformations in the road profile. Along the edge there are minor ridges or dense vegetation can be seen, which prevents water from flowing freely into the side ditch. Vegetation in the ditch slows down the water flow and creates dams. Soil can be sliding from the slopes into the ditch, which raises the bottom level of the ditch and impedes water flow.



Figure 14. Examples of road sections which have been classified into drainage Class 2.

4.2.3. Drainage class 3; Drainage in Poor Condition

Description: There are local deformations and distresses in the road cross section. There are ridges and/or dense vegetation between the road shoulder and the inner slope, causing ponds to form in the carriageway or shoulder. Vegetation prevents water from flowing into the ditch. The outer slope or both slopes are unstable and have slid into the bottom of the ditch preventing water flow. A blocked outlet ditch or culvert prevents water flow in the ditch.



Figure 15. Examples of road sections which have been classified into drainage Class 3.

5. DRAINAGE ANALYSIS RESULTS

Drainage condition was divided into three different classes: Class 1 “Good condition”, Class 2 “Adequate condition” and Class 3 “Poor condition”. When carrying out the sectioning and drainage analysis, the side of the road with the poorer drainage condition class was used to define the average condition of the drainage. The verges were not classified, but their existence was marked in the analysis if it had an effect on the condition of the road drainage system. If a verge was noted it was recommended that the verge should be removed. In addition to the drainage classification special drainage maintenance classes, i.e. sections needing special measures, were identified on the roads.

The status of “*special drainage maintenance class*” was given to those road sections of drainage condition Class 2 or 3 and included factors that are described below.

- Those sections where the rate of increase in rut depth was more than 1 mm/year when traffic flow <3000 vehicles/day, and more than 1.2mm/year when traffic flow >3000/day.
- Depth of ruts were clearly (>5%) bigger than average rut depth in those road sections where the drainage condition was Class 1.
- IRI-values were substantially higher than the values in those sections where the drainage condition was Class 1.
- There were edge settlements, edge deformation, longitudinal edge cracking and alligator cracking.

Gravel roads were not surveyed for RUT or IRI values. Instead, the factors that triggered a designation as a special maintenance class were a) differential frost heave problems, b) the road profile and c) subgrade soil type. A special maintenance class was identified when the road was located on side sloping and wet ground and the subgrade soil was moist moraine or silt and the upper side ditch was critical. If the road was located in a road cut and the soil was either moraine and/or silt then it was also designated as a special maintenance target. Another feature which triggered a special designation was when the subgrade was wet silt and the road had been widened and material from the inner or outer slopes had flowed into the side ditches.

When selecting the sections for a special maintenance class care was taken to ensure that they were homogenous and continuous sections that started and ended at reasonable locations, such as an outlet ditch. Special drainage maintenance sections were defined independently for both sides of the road.

The results of the drainage statistical analysis are presented in Figure 16. The drainage of Road 540 in the North-East seemed to be in the poorest condition (mainly Class 2 and 3) and roads in the North-West area (363, 632 and 691) were in the best condition (mainly Class 1). These roads were located mainly on sandy subgrades.

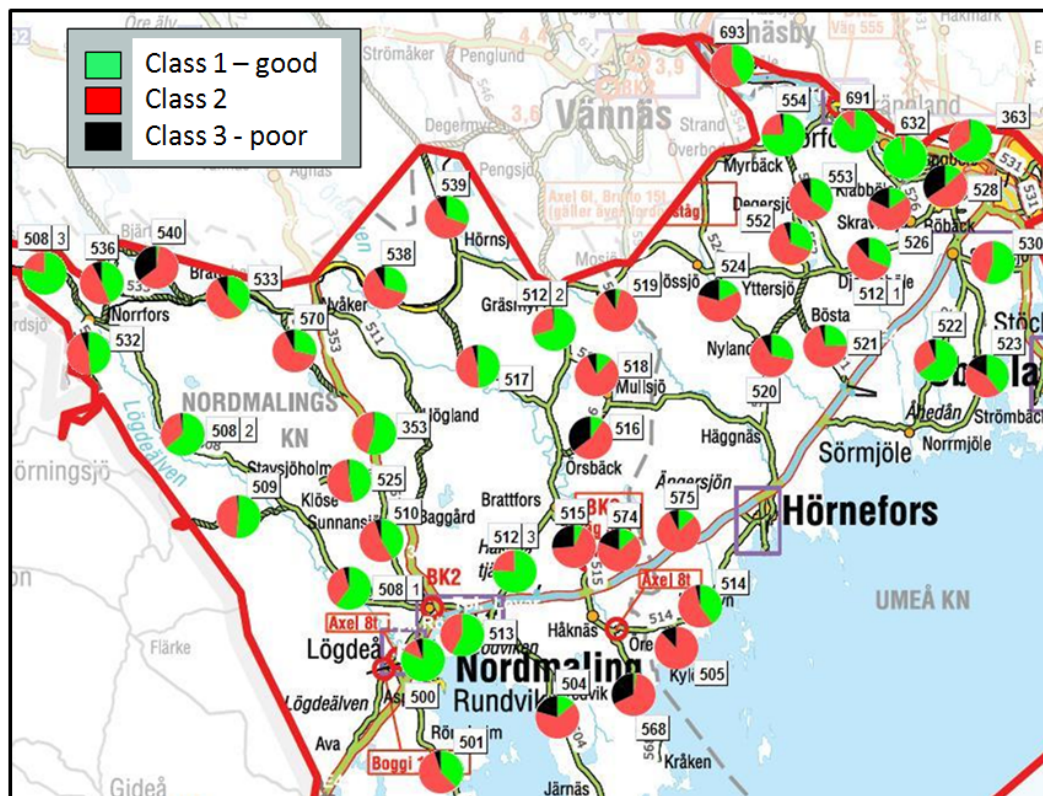


Figure 16. The distribution of drainage classes on the roads surveyed.

5.1. DRAINAGE AND ROAD PERFORMANCE

The effect of drainage was compared to roughness and rutting values. A statistical analysis was carried out for those roads that had rutting and roughness information from past years. These statistical calculations were divided into two groups. Road 353 was treated as a separate road because it was clearly a busier road than the others, while roads 500, 501, 504, 505, 508, 510, 511, 512, 513, 514, 517, 518, 520, 522, 523, 524, 525, 528, 538 and 552 were considered as an average. In the statistics the average of these roads is called “Other roads”. The average roughness values compared to the drainage classes is presented in Figure 52_1. According to these graphs, the roughness value correlates quite well with the drainage class. The poorer the drainage class, the higher the average of IRI-value.

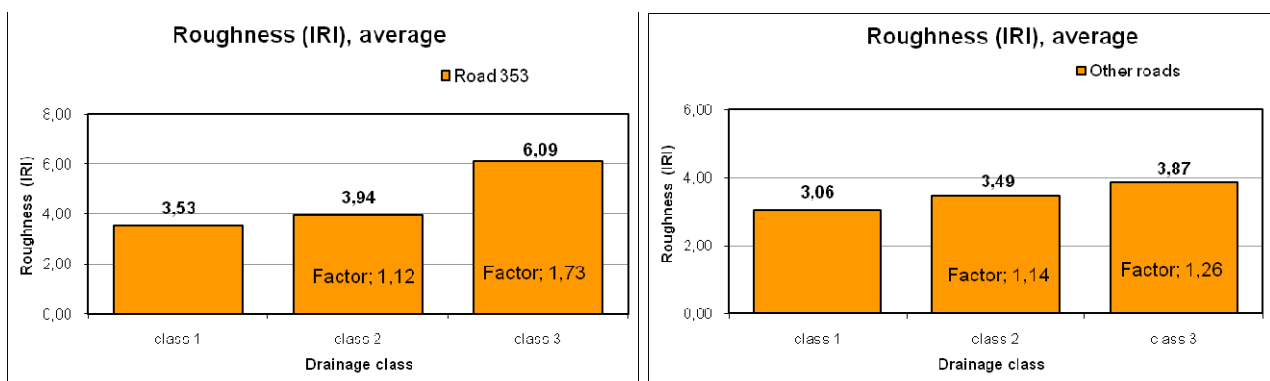


Figure 17. The average roughness value compared to the drainage class of Road 353 (left) and of the other surveyed roads (right). The value on the top of the column shows the average IRI-value

in each drainage class. The factor shows how many times bigger the value is compared to the value of Class 1.

Average rut depths for each drainage classes are presented in Figure 18. These rut depths do not correlate so well with the drainage classes as did the roughness values. The average of rut depth seemed to be at the same level in all three drainage classes. A reason for this could be explained by the fact that a great part of the roads were located in side sloping ground and the rutting and roughness values were measured on the embankment side, not the road cut side. Similar results were found in the ROADDEX drainage analysis carried out on roads in the Western Isles, Scotland. Another reason for the relatively poor correlation was that some of the roads had been recently repaved.

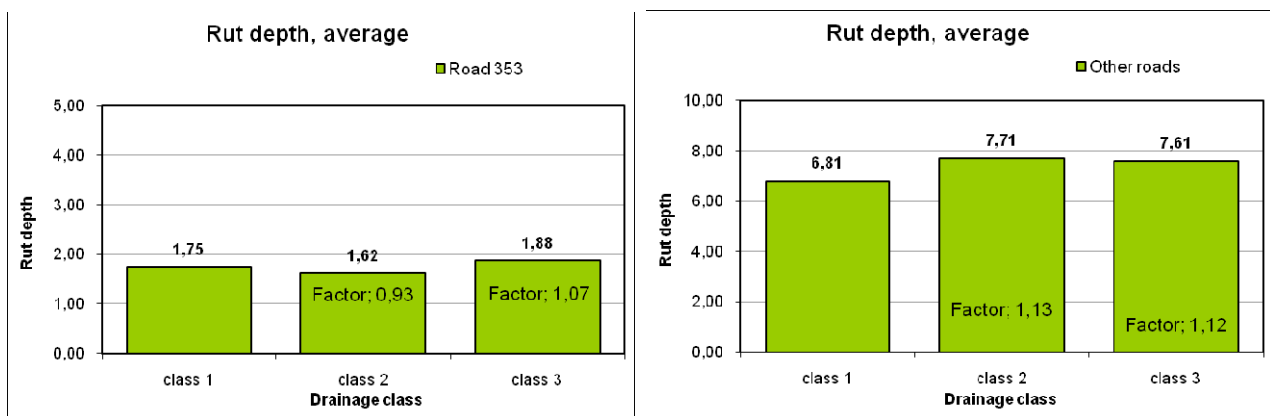


Figure 18. The average rut depth value compared to drainage class of Road 353 (left) and of the other roads surveyed (right). The value on the top of the column shows the average rut depth value in each drainage class. The factor shows how many times bigger the value is compared to the value of Class 1.

5.2. DRAINAGE AND ROAD PROFILE

Drainage classes, rut depths and roughness values were also compared with the road profile (Figure 19). On Road 353 the drainage seemed to be in the best condition in sections which were on 0-level (the average drainage class was 1.09), and surprisingly in road cuts (1.03). The drainage condition was in the worst condition, according to the statistics, on the side sloping ground. On the other roads surveyed the best drainage values were in the road cuts, and the worst values on the 0-level and side sloping ground.

On Road 353, the poorest drainage condition was identified in sections on side sloping ground and the best drainage condition, again quite surprisingly, was on the road cut sections. On the other hand Figure 20 shows that the highest average roughness and rutting values were measured in road cuts, which tells that visual drainage evaluation might not always give reliable results on such sections and new techniques, such as GPR and laser scanners, could have a use in future surveys for drainage analysis.

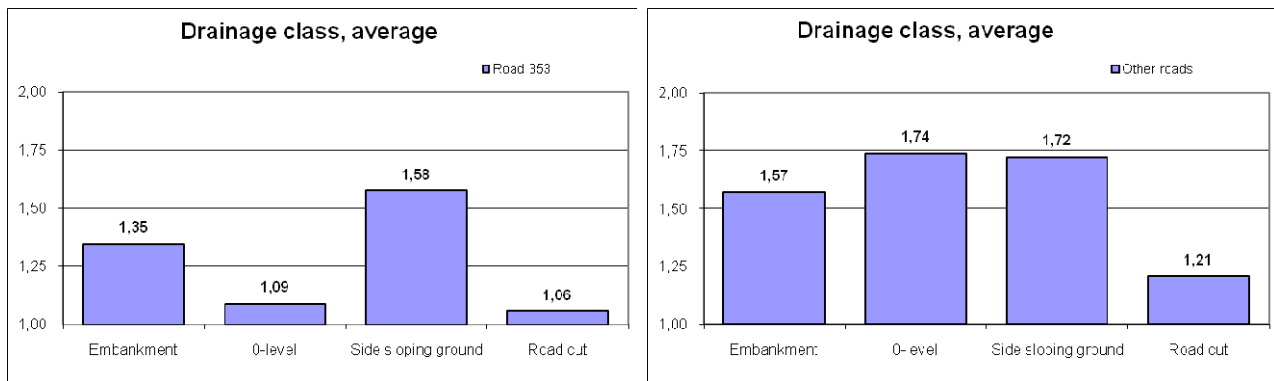


Figure 19. The average drainage classes from each road profile, Road 353 (left) and the other roads surveyed (right).

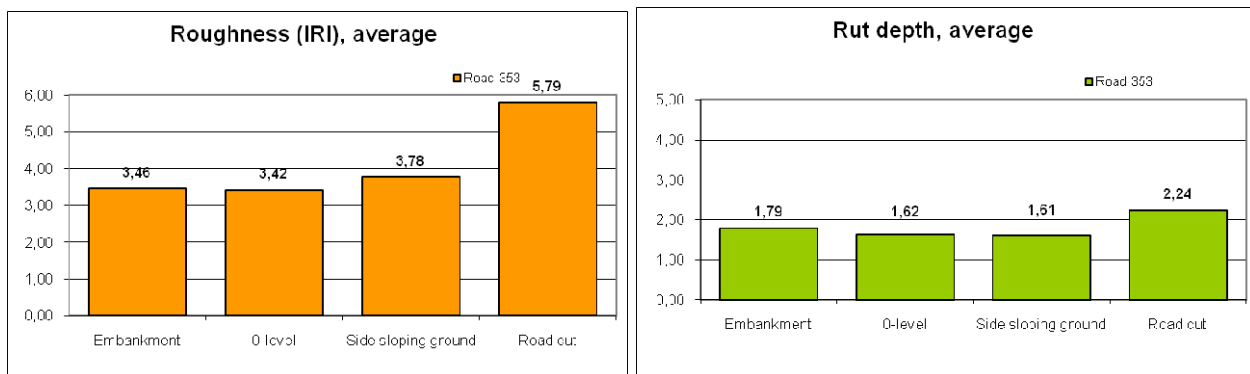


Figure 20. The average IRI-value and average rut depth from each road profile, Road 353.

On the other roads surveyed, the average rut depths and roughness values were approximately on the same level (Figure 21). The IRI value was, on average, at the same level on all road profiles. The lowest (2.79) IRI value was on the side sloping ground, the highest IRI value was on embankments (3.58). The rut depth was lowest on the side sloping ground (5.30) which supports the argument that the rut depths were measured on the “wrong side” of the road.

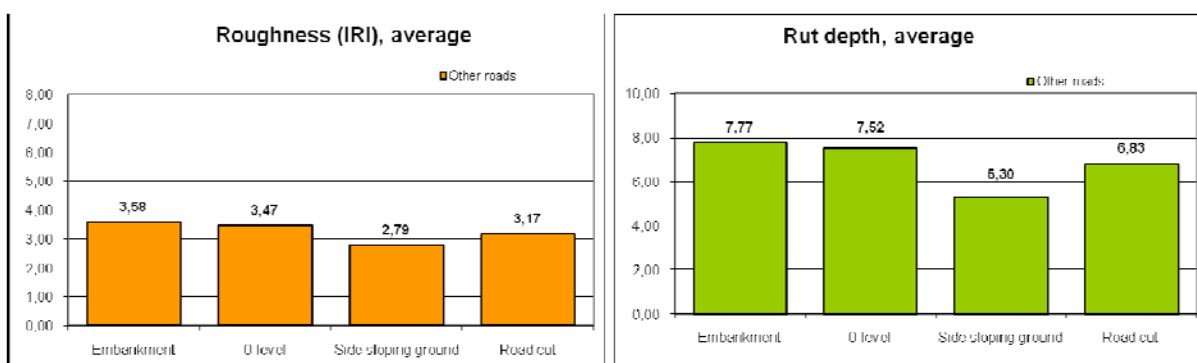


Figure 21. Average IRI-value and average rut depth from each road profile for the other roads.

6. DRAINAGE AND PAVEMENT LIFETIME

The lifetime of a road section is determined by its worst 10 % sub-sections. The results of the drainage analysis from other ROADEX partner countries have shown that improving the drainage condition in critical sections, and maintaining it in good condition, will increase the pavement lifetime by 1.5 - 2.0 times. The conclusion was that if drainage maintenance and rehabilitation can be carried out in an economic fashion, it can lead to major savings in the annual paved road network costs.

A map of the calculated lifetime factors on the surveyed roads of the Umeå Södra area is given in Figure 22. A great part of pavement lifetime factors were less than 1.05 but there were some roads where the life time factor was higher than 1.5 and in these road drainage improvement could be very economical. The reason for the low life time factors is most likely the previously mentioned fact that profilometer surveys were carried out on the embankment side of the road. On the other hand in most of the roads with low life time factor the drainage was in good condition. The only roads that had relatively poor drainage and low life time factor were roads 518, 520 and 553.

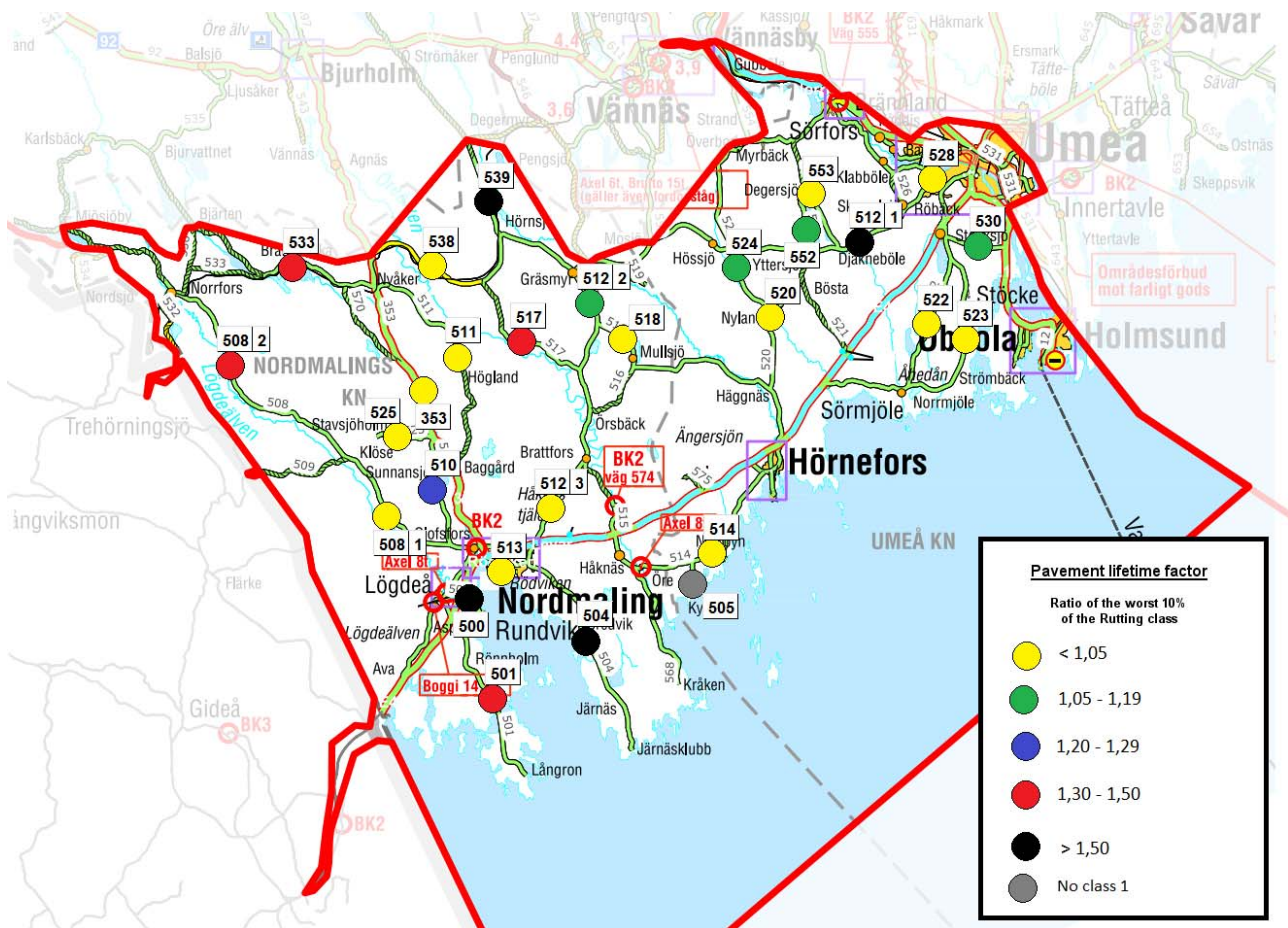


Figure 22. Pavement lifetime factors in the Umeå Södra area.

7. SEASONAL TESTS

Seasonal tests on the survey data were carried out by comparing the drainage analysis results made from spring and autumn data. The roads were classified into different classes based on the difference between the seasonal results, i.e. was the drainage class better or worse in spring than in autumn, or the same in both seasons.

According to the results of these seasonal tests the majority (69.8%) of the drainage were classified into the same class both times, and only a small proportion of the drainage classes were significantly different (Figure 23). Only 0.1% of ditches were classified to be significantly better in spring and 0.% significantly worse in spring.

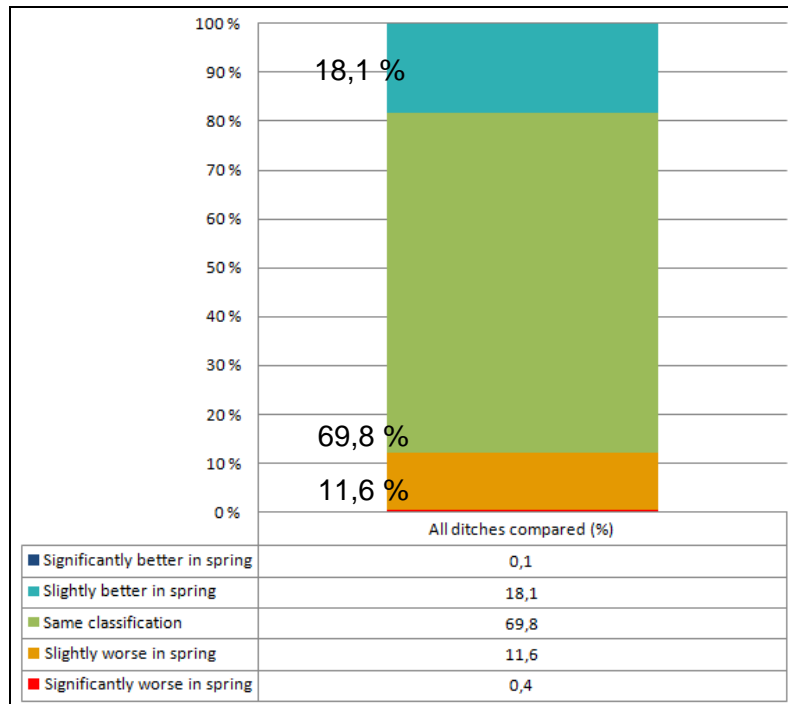


Figure 23. The distribution of comparison classes.

The reasons for the differences in the drainage classifications were also investigated. The road sections with the biggest differences in the two analyses were those with water permeable subgrade soils (35%) and sections with water standing in the ditch (27%). Other reasons for differences were: vegetation, verges, snow, and flowing water. Some of the cases (6%) could also be classified borderline cases where the drainage classes could have reasonably been classified differently.

The sections that were classified as Class 3 in the analysis in either spring or autumn were evaluated more closely. The main reason for differences in these classifications was water in the ditch, which was the reason for the difference in about 64% of the cases. A permeable subgrade was the reason in 25% of cases. The majority (95%) of sections with permeable subgrade soil were classified as being slightly better in spring. There were no sections which would have been significantly worse in spring. If the reason for the difference was water in the ditch, the majority (93%) were classified as being slightly worse in spring. There were no sections which would have been significantly better in spring.

8. TOOLS FOR OUTLET DITCH INVENTORY

8.1. GENERAL

A common difficulty in the drainage analysis projects carried out so far in ROADDEX has been the location and evaluation of the outlet ditches. To address this, a third digital video camera, aimed at a 90° angle from the road, was tested in the project.

Test results of the outlet ditch camera showed that the quality of video data was surprisingly good. The presence of the outlet ditch, and its condition and functionality, was easily observed from the 90 degree video. The data from this third camera was not routinely checked during the analysis but was referred to in those cases where there were problems in locating the ditch or evaluating its condition. Examples of still images from the “outlet ditch” camera are shown in Figure 24.



Figure 24. Outlet ditches can be observed easily from the 90 degree camera.

8.2. LOCATION AND CONDITION

As part of the seasonal tests of the drainage surveys, the “observation hits” of the outlet ditches were also compared seasonally. The analysis of the outlet ditches from the autumn data was done without the aid of the third “outlet ditch” camera. This was not available during the survey. The third camera was however included in the spring survey, but the analysis was carried out without its data. Later the third camera video of the outlet ditches was analysed carefully for the location of

outlet ditches and their condition. This was then compared with the autumn and spring analysis results. These comparisons showed that only about half (45%) of the outlet ditches had been observed both times, and that one in four (23%) of the outlet ditches had not been observed at all. The majority of these unobserved outlet ditches were not working and were critical to drainage performance. The statistics of the outlet ditch observations are summarised in Figure 25.

The results of these comparisons clearly show that a third video camera can make the outlet ditch inventory more reliable. It is not easy to observe outlet ditches from a moving car, and even if it is observed the assessment of its condition can still be unreliable.

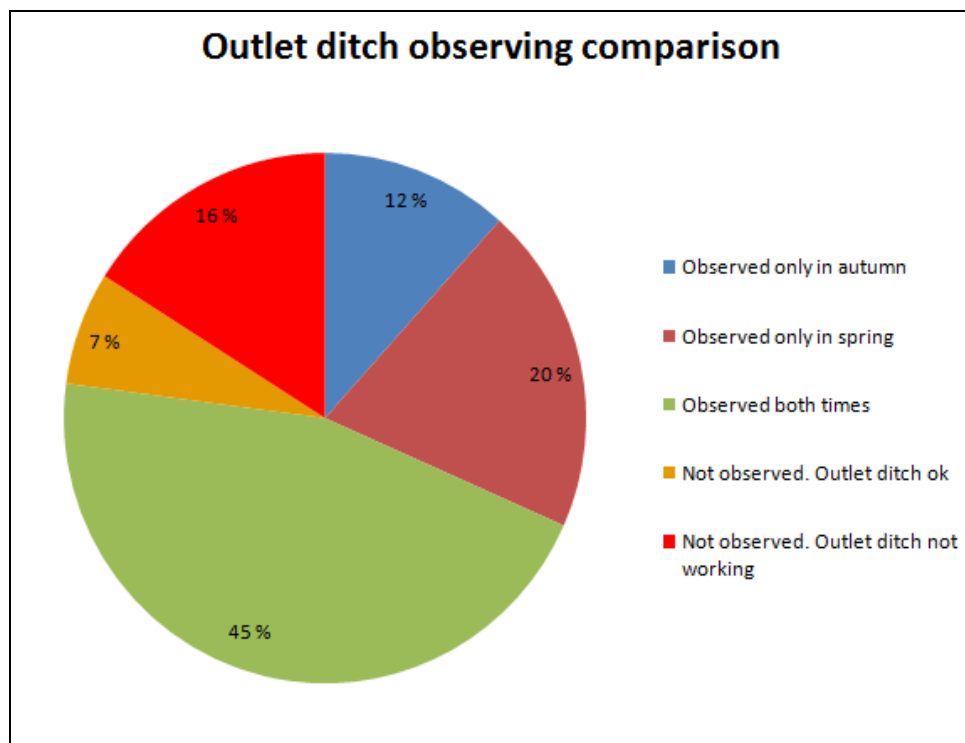


Figure 25. Statistical summary of the outlet ditch comparison.

9. DRAINAGE IMPROVEMENT DESIGN

The ROADEX project has noted that drainage, and drainage improvement, has a low priority in many ROADEX countries despite research proving that it is important that road drainage is kept in good condition. At present a number of issues have to be addressed when planning drainage work. What is the best way to organise it? Should the work be the responsibility of the maintenance or pavement contractor, etc?

In sustainable road condition management it is not just enough that the problematic drainage sections should be improved, it is also vital that the improved sections should be kept in good condition. To achieve this constant monitoring and maintenance of the improved drainage must be carried out to ensure that good drainage work remains effective.

When drainage improvement works are executed the work should be done carefully. It is more important pay attention to the longitudinal gradient of the ditch and the removal of obstacles blocking the water flow (big stones, flowing soil, etc.), than to dig the ditch deeper. Ditches that are dug too deep increase the risk of side slope erosion. It is recommended that the bottom of the ditch should be 20-30cm deeper than the bottom of the road structure and that the longitudinal gradient of the side ditch should be at least 4 ‰ (4 mm/m).

If the ditch has steep side slopes, it is better to carry out the improvement work in the early summer so that the local vegetation has enough time to grow back before winter, thereby reducing the risk of erosion.

The ROADEX project has proposed new structural solutions to strengthen slopes that are sensitive to erosion. Slopes can be supported by rocks or ballast to prevent soil flowing to the bottom of the ditch. Figure 26 shows an example of a typical structure. The photograph was taken at the ROADEX test site in Jämsä, Finland.



Figure 26. The example of supported slopes adjacent to a ditch. Photograph from the ROADEx test site, Jämsä, Finland.

The most important feature of the surveyed roads in the Umeå Södra area was clogged access road culverts. Opening and renewal of these access road culverts should be included in the improvement design process.

10. CONCLUSIONS

This demonstration project was conducted on 53 test roads in the Umeå Södra maintenance area of Northern Sweden. The lengths of roads varied from a short few hundred metres to dozens of kilometres and both gravel roads and paved roads were surveyed. The surveys were carried out mainly in spring 2010, but a few were performed in autumn 2009 in order to conduct seasonal tests.

The condition of the surveyed ditches varied from flawless to extremely poor. Ditches in road cuts and the upper ditches in side-sloping ground sections were especially poor. The IRI and RUT values correlated well with poor drainage problems on Road 353 but analysis of other roads did not show such good correlation. One reason for this is these roads were located mainly on side sloping ground and that the rutting and roughness values were generally measured on the embankment side, not on road cut side. Also some of the roads had been recently repaved. Flat and even areas seemed to be problematic, since water was standing in the ditches. The outlet ditches in flat field areas did not have any gradient and, as such, the water did not flow away from the road area.

Other typical features of these roads were problematic access road culverts, which were missing or clogged. The private house properties close to the road also created difficulties as there was no space for ditches or any drainage improvement.

Seasonal comparisons showed that the drainage analysis method can be equally performed in spring and autumn with only minor differences in the drainage classes of the compared roads. The main reasons for differences were permeable subgrade (the drainage class was slightly better in spring) and water in the ditch (the drainage class was slightly worse in spring). Autumn surveys may be more difficult to carry out as the working hours are likely to be shorter, with the sun setting earlier and twilight hours making it more difficult to capture good quality video.

A new potential method for analysing outlet ditches was tested. A third camera was pointed at angle of 90° from the roads towards the side in addition to the main two cameras pointed towards the road and the ditch. This third camera technique was found to be an excellent tool for checking the position and condition of the outlet ditches and it is recommended that it be used in future drainage analysis surveys.

Some of the surveyed roads In the Umeå tests were also surveyed by laser scanner. This can help detect the road cross-section and edge verges more easily. According to common experience in the Nordic countries road drainage generally works well if the ditch is 20-30cm deeper than the bottom of the road structure. The results of the laser scanning surveys indicate that the condition of the ditches has the greatest significance on road condition when the road structure thickness range is 0.6-1.0m. The analysis of the scanner data also showed that in visual drainage analysis it is not possible to observe all of the factors that affect the condition of the drainage system. The results from laser scanner and thermal camera tests are presented in detail in the ROADEX report "*New survey techniques in drainage evaluation; laser scanner and thermal camera*".



ROADEX PROJECT REPORTS (1998–2012)

This report is one of a suite of reports and case studies on the management of low volume roads produced by the ROADEX project over the period 1998-2012. These reports cover a wide range of topics as below.

- Climate change adaptation
- Cost savings and benefits accruing to ROADEX technologies
- Dealing with bearing capacity problems on low volume roads constructed on peat
- Design and repair of roads suffering from spring thaw weakening
- Drainage guidelines
- Environmental guidelines & checklist
- Forest road policies
- Generation of 'snow smoke' behind heavy vehicles
- Health issues raised by poorly maintained road networks
- Managing drainage on low volume roads
- Managing peat related problems on low volume roads
- Managing permanent deformation in low volume roads
- Managing spring thaw weakening on low volume roads
- Monitoring low volume roads
- New survey techniques in drainage evaluation
- Permanent deformation, from theory to practice
- Risk analyses on low volume roads
- Road condition management of low volume roads
- Road friendly vehicles & tyre pressure control
- Road widening guidelines
- Socio-economic impacts of road conditions on low volume roads
- Structural innovations for low volume roads
- Treatment of moisture susceptible materials
- Tyre pressure control on timber haulage vehicles
- Understanding low volume pavement response to heavy traffic loading
- User perspectives on the road service level in ROADEX areas
- Vehicle and human vibration due to road condition
- Winter maintenance practice in the Northern Periphery

All of these reports, and others, are available for download free of charge from the ROADEX website at www.ROADEX.org.

