Why a PMS Implemented in 1989 is Still a Success and Continuously Used

Jørn R. Kristiansen
Carl Bro Pavement Consultants
Fuglesangsallé 16
6600 Vejen
DENMARK
Tel.: +45 76 34 73 73
Fax.: +45 76 34 73 74
E-mail: cbpc@carlbro.dk
Privalte e-mail : jnk@carlbro.dk

ABSTRACT

A commonly known fact is that after a road authority's first enthusiasm many PM systems are not applied optimally. The reasons are many and varying and cover the fact that some of the systems could not live up to the road authority's expectations, that the service and follow-up offered by the supplier was not as expected or that the road authority could not manage to dispose the required resources for continuing the system. However, the purpose of this paper is neither to describe reasons why nor backgrounds for not always succesfull PMS implementations, as it is assumed that all experienced PMS people are already familiar with these. The purpose of the paper is to describe how an agreement entered into by a Danish road authority and an experienced PMS consultant taking the just mentioned facts into consideration led to an on-going PMS success for the road authority as well as for the PMS consultant.

1. INTRODUCTION

In Denmark and in many other European countries PMS is applied at national, regional and local levels. Today PMS optimises the road maintenance of approx. 75% of the road network in Denmark. The tendency is the same in many other European countries (1). This is not least due to the wide experience gained over the last 20 years of flexible PMS development in Denmark.

Initially the PMS development was not without problems and definitely not in connection with the application of PMS at the regional and local levels. One of the primary reasons for this was the fact that at these levels and especially at the local level no information about the existing road network was available for the implementation of the PMS. Another reason was that at that time as well as today only very few PM systems can handle and evaluate both national, regional and local roads at the same time. This is not only due to technical obstacles but very often also to the political dimension, which inevitably forms part of a well-functioning PMS.

In Denmark the national road network amounts to 2% of the total road network. The regional network amounts to 13% while the local road network (including all towns and cities) amounts to 85% or approx. 65,000 km road administered by 275 municipalities.

This paper describes how a PMS was implemented with a road authority in 1989. A road authority so certain about the value of the computed PMS calculations that they increased the maintenance budget by a factor 12 in the first year. Eighty percent of this amount was financed by external funds.

The paper also gives an account of how the PMS calculated yield and consequences turned out to be more positive in the following years than predicted in the initial calculations. This fact was given a very positive attention.

A description will be given of how the road authority in question has for 10 years been able to keep its roads at a considerably higher service level for a considerably lower investment amount than the rest of the road authorities in Denmark. A fact favoured and still followed very closely by the politicians.

The paper will also describe how a contract was made between the road authority and the PMS supplier in connection with the initial installation of the PM system. The purpose of this was to select a number of test and reference road sections for a parallel test project made in cooperation with the PMS supplier.

Eleven reference road sections were selected as representative of the 10 different conditions into which the road network can be divided. The current deterioration of the pavements of these sections and the influences coming from outside have been followed, recorded and supervised.

The basis on which the mentioned test sections were selected will be mentioned as well as how they were divided into sections of 10x10 metre and how current and comprehensive analyses were made on materials and soil conditions. Photos will be shown of the individual 10-meter sections in connection with the annual condition surveys of the pavement surfaces and bearing capacity measurements. Furthermore, it will be shown how daily measurements and registrations were made of meteorological data, sounding of the groundwater level (which is high for some sections) and how an artificial lowering of the groundwater level had both negative and positive influence on the road deterioration.

Finally, an account will be given of, how the road authority has with great enthusiasm taken part at both the technical and political level resulting in great success for both parties.

2. BACKGROUND

In 1988 a very large part of the road network in Ulfborg-Vemb Municipality had reached a point, which meant that the service level of the 180 km road network was considered one of the worst in Denmark at that time. The consequence for Ulfborg-Vemb Municipality was that any improvement and/or any attempt as a minimum just to stop the rapidly accelerating deterioration of the roads would mean a considerable increase in the local taxes - an impossible requirement due to other just as important tasks in the municipality. Another reason was that at that time the Danish government had introduced penalty upon municipalities using too much money compared to the budget levels already agreed upon. The municipality thus lacked documentation for its claims that it would bee too expensive not to maintain the road network immediately. The funds had in all cases to be found through alternative ways of financing and not by means of further tax collection.

Based on the fact that in 1989 several other Danish municipalities had already implemented the version of RoSy® PMS for municipalities, Ulfborg-Vemb Municipality decided to implement the entire RoSy concept on the road network. Figure 1 indicates where the municipality is located in Denmark.

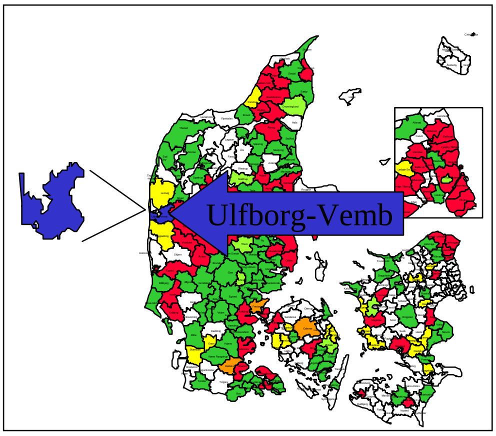


Figure 1

3. DESCRIPTION OF THE INITIAL PMS PROJECT

The purpose of the initial project was to establish, collect and record the data needed in order to allow calculation of maintenance strategies. These strategies were made on the criterion that the future maintenance was to be carried out in the most economic way. Furthermore, solutions and consequences should be calculated on the basis of various constrained budget levels to allow comparison.

Apart from the above the purpose of the calculations was to reveal the economic gain the municipality would obtain if the roads were rehabilitated to an optimum state immediately by means of alternative financing instead of applying the present budget. The PMS structure used for the project appears from figure 2.

It is important to note that the User Cost Model of RoSy has not been applied for this project, as this municipality is not responsible for any national or regional roads. This is due to the fact that user costs would make no sense as regards local and urban roads (-and very often it would be of no political interest). Instead the RoSy modules taking an optimum maintenance of the invested road capital into account (asset management) were applied as an optimisation basis. This has the ear of the local politicians.

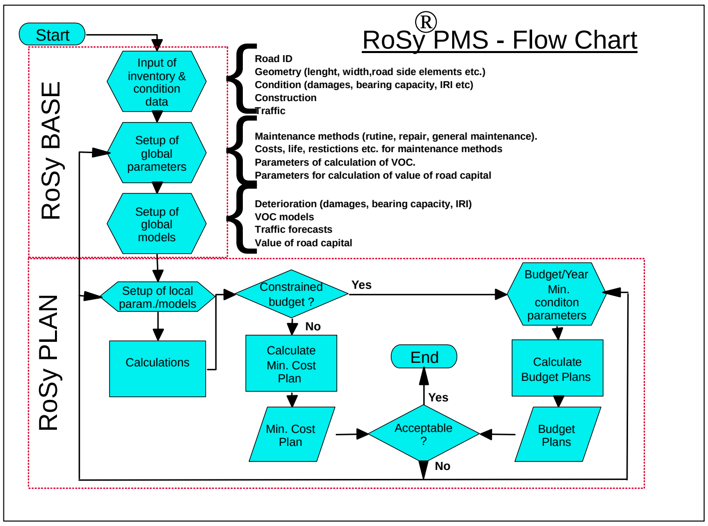


Figure 2. Structure of PMS modules for this project

3.1 Monitoring and condition survey

The following registrations and registration methods were selected:

- Inventory: Geometric data (length, width, shoulders, ditches, kerbs, etc.)
- Condition survey: Visual, max. 10 condition objects were selected.
- Thickness measurements on all sections using ground penetrating radar (GPR)
- Bearing capacity measurements (with FWD)
- Traffic census (AADT, ESAL)

3.1.1 Inventory

The geometric data was originally measured by means of DMI combined with width measuring done with a runner and manually entered to RoSy BASE. Today the plans are to apply the fully electronic CamSurvey method. Figure 3 gives an example of geometric data as this may be presented in the database.

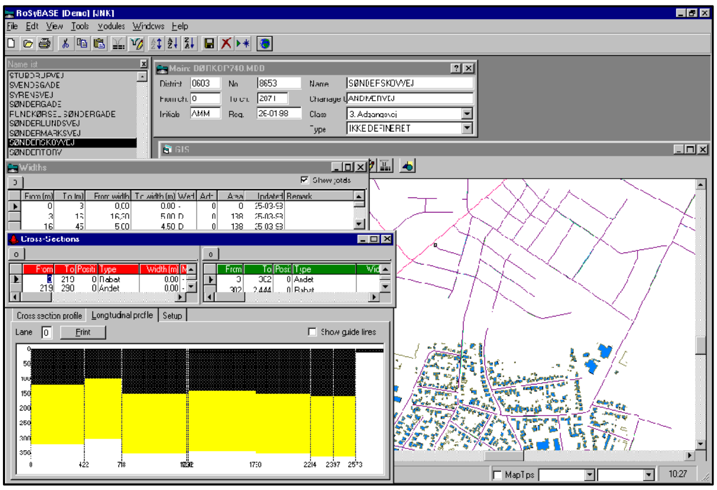


Figure 3. Example of presentation of geometric data in RoSy BASE

3.1.2 Condition survey

For this project a maximum of 10 condition objects were selected as being representative of the functional condition of the road network. From this 9 objects were to form part of the deterioration parameters to be applied for the maintenance calculations. Only some of the objects were to be applied as an expression of the actual and wished service level for the 6 road classes that Ulfborg-Vemb Municipality has chosen to work with. Figure 4 gives an example of a condition window in RoSy BASE.

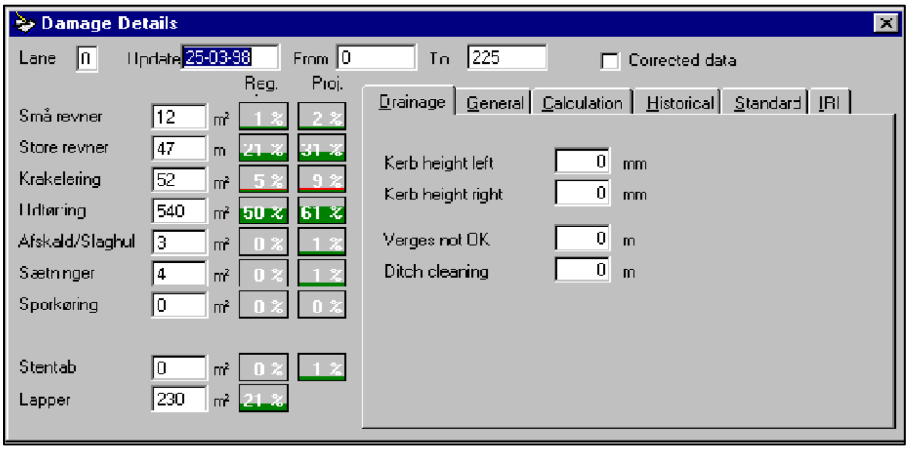


Figure 4. Example of recorded condition data

3.1.3 Thickness measurements (GPR) and bearing capacity measurements (FWD)

All roads were measured by means of GPR and recorded in RoSy BASE and at the same time divided into homogeneous sections with similar pavement structures. Furthermore, the bearing capacity of all road sections was measured by means of FWD twice a year. Applying the data on pavement layer thickness, the expected future traffic load and the measured deflection data, RoSy DESIGN (non-linear elasticity design program for FWD) calculated the present remaining service life and necessary reinforcement. Figure 5 gives an example of the results of the GPR and FWD measurements.

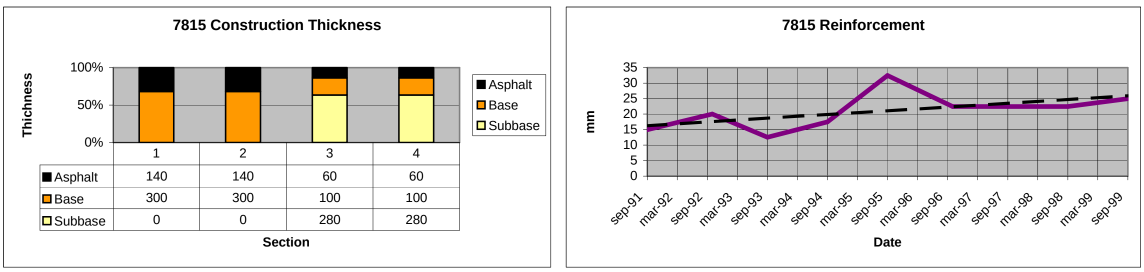
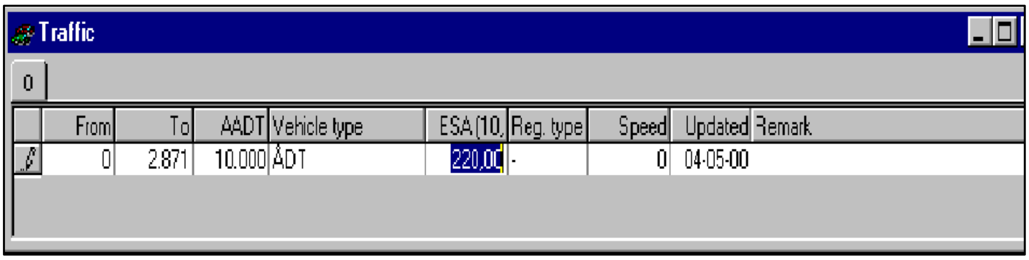


Figure 5. Result of GPR and FWD measurements

3.1.4 Traffic and axle load registration

Traffic census and recording of axle loads were conducted on selected sites. The measurements were conducted as AADT and also the length of the vehicles was measured. On this basis ESAL was calculated in relation to the European Vehicle Classification. Figure 6 gives an example of traffic data recorded in RoSy BASE.


Traffic

0

	From	To	AADT	Vehicle type	ESA(10,	Reg. type	Speed	Updated	Remark
	0	2.871	10.000	ÅDT	220,00	-	0	04-05-00	

Figure 6. Example of traffic data in RoSy BASE

3.1.5 Models, methods and products

A correct setup of the system is essential to allow RoSy® PMS to process the required technical and economic optimisation. In the DOS version of RoSy applied at that time (1989), both models, methods and to some extent the maintenance products and their properties were, contrary to what is the case today, hard-coded in the software and could not be changed by the user as easily as today. However, the system applied at that time had been developed to allow an optimum function under Danish conditions, which should in theory mean that the limitations would not have any negative effect for the municipality. This also turned out to be the fact in the following years.

As mentioned earlier, the application of vehicle operation costs (2) is not an interesting parameter in connection with local and urban roads – particularly not in industrialised countries. This is, however, the case with the value, depreciation and preservation of the invested road capital. Figure 7 gives an example of the model for optimisation by Total Agency Costs.

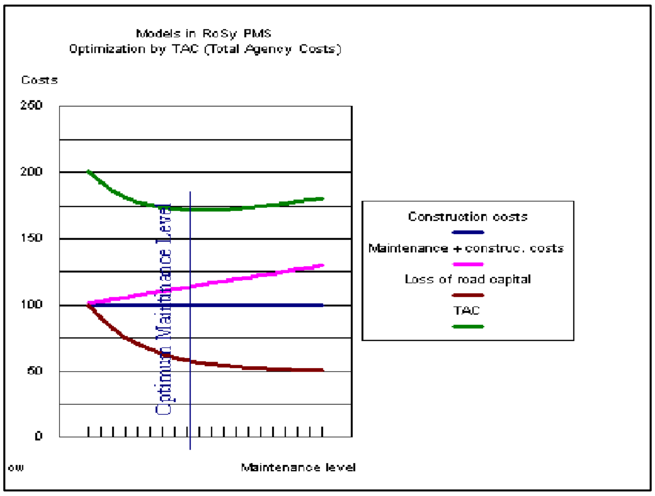


Figure 7. Model for optimisation of Total Agency Costs

3.1.6 Deterioration models

The flexibility of the PM System enables the user to create models for all the condition objects he may wish to work with. Furthermore, it is possible to differentiate the models allowing consideration of both pavement structure type and individual traffic loads.

The calculations processed in 1989 were based on hard-coded (Danish) global data, but the project mentioned under section 4 has meant that realistic historic data at structure level now exists for Ulfborg-Vemb. This data can be applied currently, which results in considerably more accurate life cycle cost calculations. Figure 8 shows an example of a deterioration model for one of the recorded condition objects.

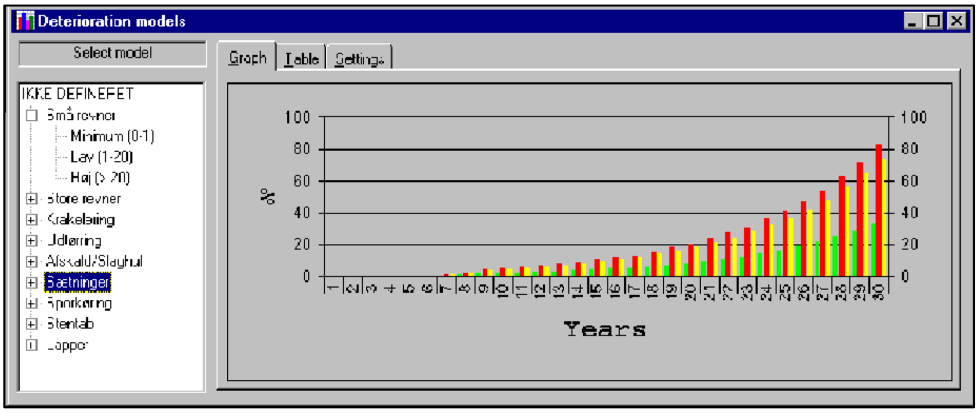


Figure 8. Deterioration model for cracks

3.1.7 Maintenance methods and products

In order to ensure as accurate as possible economic optimisations, information on the methods, products etc. available in Ulfborg-Vemb had to be entered to the PM system. Furthermore, details on which costs and conditions would be connected to the individual method/product were entered to the system. Figure 9 gives examples of information entered to the database.

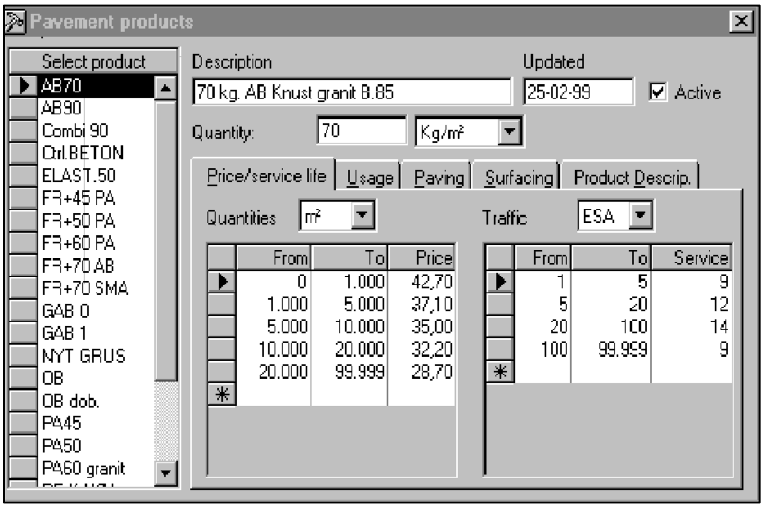


Figure 9. Example of methods and products in a local PMS setup

3.1.8 Calculation and optimisation

Detail description of the calculation and optimisation methodology in RoSy® PMS is not within the scope of this paper. Only it should be mentioned that basically the system uses standard PMS methodology for B/C, NPV, IRR calculation (3). However the methodology is adapted for calculations of local and urban roads etc. in industrialised countries.

Figure 10 gives examples of the “3-D calculation task” being selection of the optimum maintenance solution for each section (4) and illustrates the methodology (incremental benefit/cost) for selecting optimum solutions for a road network based on constrained budgets.

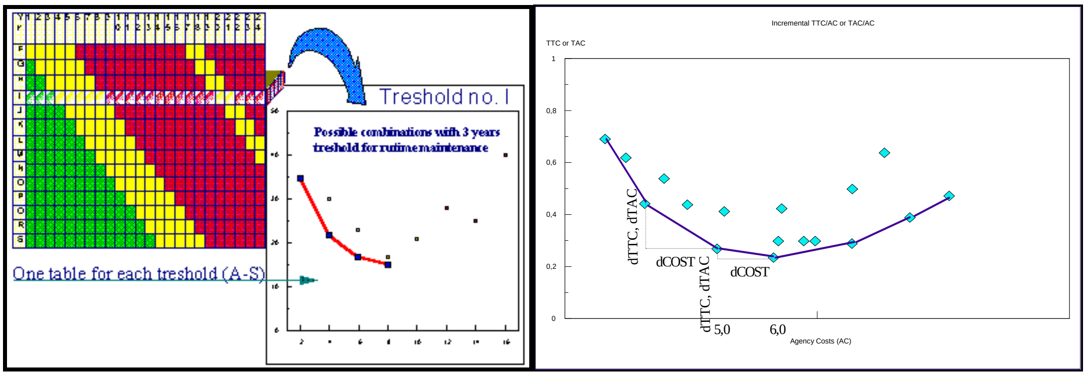


Figure 10. Example illustrating choice of optimum solution and use of incremental B/C for selection of solutions based on a constrained budget

3.2 How the results were applied

The calculations processed in 1989 showed that if the municipality chose to find alternative funds for implementation of the most economic optimal solution instead of applying the originally and totally insufficient road maintenance budget, then the municipality could over a period of 10 years save a total of 15-16 mill. Danish kroner and at the same time obtain an internal cash flow return (IRR) of 18% on the applied funds. Figure 11 illustrates the economic relation between the two maintenance strategies.

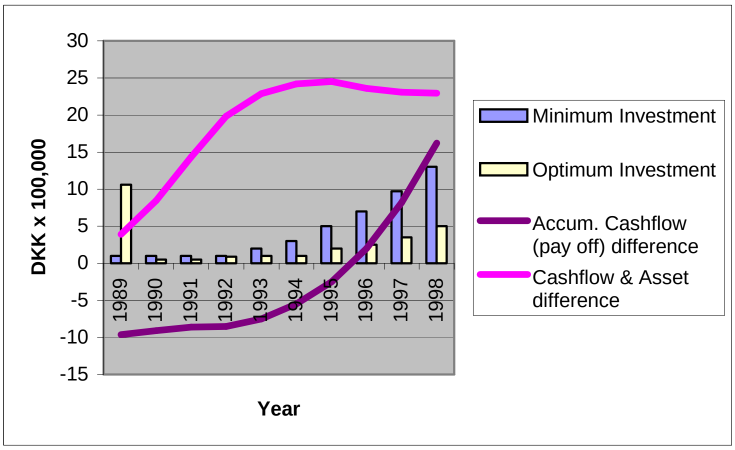


Figure 11. The relation between the two maintenance strategies

The economic facts were obviously very attractive, especially to the political administration of the municipality but at the same time this collided with the cash flow constraints, but also the constraints, which the Danish government had introduced (penalty). However, this did not stop the politicians of the municipality in their efforts to secure that the future maintenance would be conducted as optimally as possible. Having the certified calculations at their disposal, the politicians negotiated with the Danish Ministry of the Interior in two rounds in 1989. The result was that the municipality succeeded in obtaining – without influence of the new law – permission to provide the required funds to exceed already in the first year the original budget for road maintenance not less than 10-12 times.

In 1990 the events became a press sensation in Denmark and both politicians and technicians of the municipality were pleased. The funds were now available and now the next task was to have the work carried out. This turned out to cause some problems. There were no contractors within the area, who were geared to repair and maintain an entire road network from A to Z. Thus, the project took two years to carry through.

The final result was that in 1990/91 Ulfborg-Vemb Municipality had obtained if not the best then one of the best local road networks in Denmark as regards road condition.

The optimum standard on the road network meant that over the next many years only the annual instalments on the non-recurring loan had to be paid and almost no expenses to the annual maintenance. The question was now, whether the prognosis would proof correct in the years to come. Would the deterioration of the roads happen faster or slower than predicted by RoSy PMS? Were there any basic conditions that had not been taken into account?

Among other things, these questions led to the cooperation agreement mentioned under section 4 of this paper. This motivated both the municipality and the PMS supplier to follow the actual development on the road network and currently check up on the quality of the initially processed calculations with the purpose of improving the system currently if this was necessary.

3.3 The actual development

In the years that followed the actual development has till date turned to be more positive than initially calculated both as regards economy and service level. One of the reasons for this was that during the first years after the actual deterioration of the roads turned out to be slower than the initial calculations predicted. However, a general lowering of the ground-water level in an area of the municipality gave rise to some concern as contrary to all expectations it turned out that the bearing capacity of some of the roads had been reduced. However, later the bearing capacity stabilised at an even better level. Another factor was that in the mid-nineties Denmark had a number of mild winters with less frost/thaw than normally.

The parallel test sections (see section 4) confirm both the lowering of the ground-water level and the mild winters. They also demonstrate that the deterioration of a road network seems to be slow over a number of years. Then some pavement structure types can suddenly from one year to another deteriorate heavily. Figure 12 gives an example of such a sudden development in defects on one of the test sections.

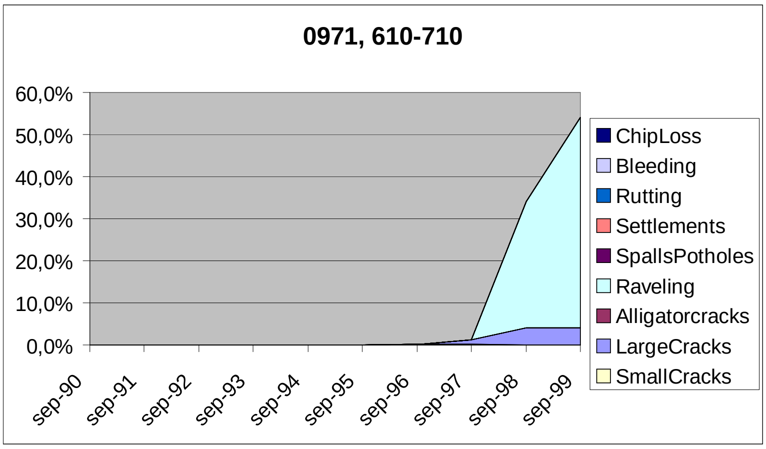


Figure 12. Example of a sudden increase in the amount of defects on one of the parallel test sections

4. THE PARALLEL TEST PROJECT

The purpose of the parallel project to the PMS project in the municipality was to follow the actual deterioration and maintenance needs of the roads in order to compare this data to the needs calculated by the PM system. At the end of 1989 the municipality and the PMS supplier thus entered into a five-year cooperation agreement. This agreement was later extended to 10 years and has recently been extended to 15 years. One of the parameters of the agreement is that the municipality and the PMS supplier are obliged to contribute with 50% each. This has been a very motivating strategy for both parties and has secured the very long life of this project.

The agreement contained the following written goal:

"To form the basis of further development and documentation of RoSy PMS and related products in a cooperation for the benefit of both users and suppliers"

4.1 Project scope

The following project scope was defined:

a. Selection and current monitoring of eleven 100-meter test sections being representative of the entire network.
b. Definition and creation of a calculation model for the functional service life.
c. Selection of repair and maintenance methods and products
d. Test and suggestions as to future software development and definition of needs.

Below criteria were applied for the selection of the eleven test sections:

a. The sections were to be located near local wastewater cleaning plants out of consideration for the daily registration of local climatic conditions.
b. The sections were to be with and without influence from ground-water level.
c. The sections were to be grouped in accordance with four types of traffic loading.

d. A grouping in accordance with various road structure types.
e. A grouping in accordance with the actual condition (structural and functional).
f. A grouping in accordance with the functioning of drainage conditions (ditches/shoulders).
g. The sections could under no circumstances (regardless of future condition) be repaired. This turned out to be a very important contractual condition, as some of the road sections over time grew so poor that complaints were sent to the politicians of the municipality. These were rejected with reference to the agreement.

The individual 100-meter sections were then divided into ten 10-meter sections. On each 100-meter section the below items were investigated and still are:

a. Core taking/excavations and detailed material analyses (once). However, due to the fact that the agreement was extended, further asphalt analysis was conducted.
b. Bearing capacity measurements by means of FWD in the same measuring points twice a year.
c. Daily recording of temperature and precipitation.
d. Recording of traffic density (as required)
e. Visual condition surveys of 10 condition objects once a year
f. Photo (bird's eye view) at 10-meter intervals once a year (In September out of consideration of the light intensity etc.) as a supplement to point e.
g. Insertion of measuring rods and weekly reading of the actual ground water level.

Figure 13 gives an example of 3 selected photos of the same ten meters on one of the test sections. The initial condition in 1989 after 5 years and after ten years.

Figure 13. Example of visual condition of 10 meters of a test section in 1989, 1994 and 1999

4.2 Results

A characteristic factor for all test sections was that the deterioration cycle on the individual sections over the first 5-6 years happened somewhat slower than the PMS calculations predicted. This also appears from the PhD study made at The Danish Technical University carried out over 5 years of the project (5). On the contrary it seems like at the end of the 10-year period something drastic began to happen on more of the sections. Figure 12 gives an example of this development. Other sections have a more regular and logical defect development as illustrated in figure 14.

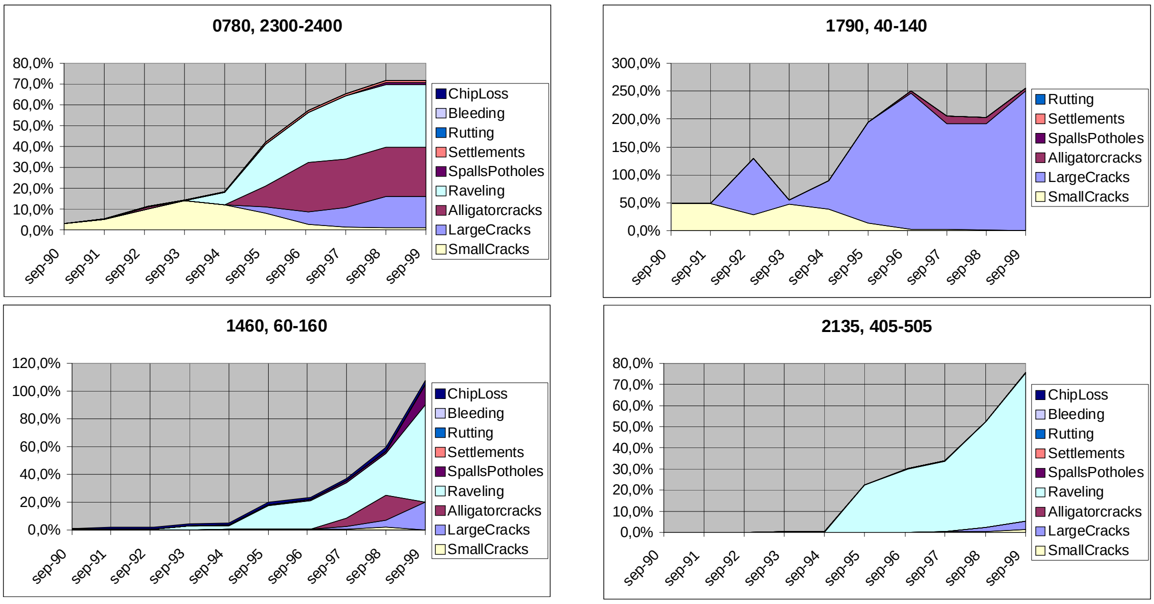


Figure 14. Defect development on selected test sections

As it appears, the functional condition development varies from test section to test section. Also the structural condition development has in some cases differed from the initial expectations.

As mentioned earlier the permanent lowering of the ground-water level in a larger area at first resulted in roads with a poorer bearing capacity in this area (see figure 15). However, the period with mild winters in the nineties also seems to have had an influence on the actual development of the structural bearing capacity. No doubt that in this case it had a positive influence, as in the same period more of the sections suddenly developed a better bearing capacity than earlier. When the normal climate returned to Denmark the tendency seemed to be an immediate deterioration of the bearing capacity. This tendency seems to have stabilised again. See figure 5.

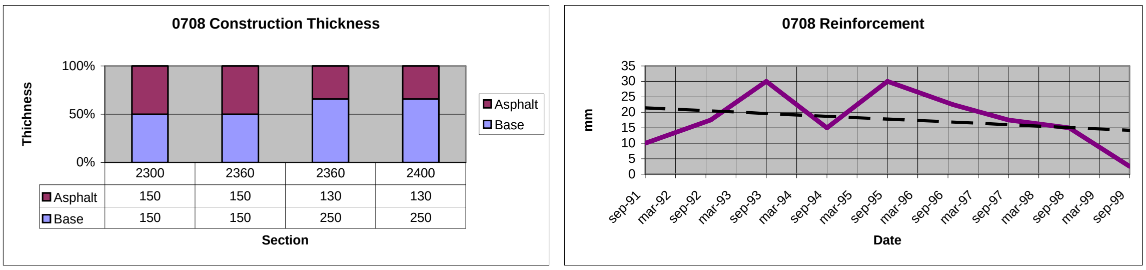


Figure 15. Bearing capacity development on a section with ground-water lowering

An analysis of why both the functional and the structural deterioration developed like they did on the individual test sections is not within the scope of this paper. A new PhD study will analyse these conditions. The very comprehensive and systematically collected data material comprising material tests, climatic data, ground-water level data, traffic conditions etc. and data on the actual functional and structural development on the individual test sections allow us to understand how the various parameters relate to each other.

We can thus already now, as others may have done before us, state that it is very complicated to put nature into equations. It is therefore quite clear to us that if the actual (historic) development on the maintenance sections is not taken into consideration in the PMS deterioration models, which is applied for road networks with a variety of conditions, then the risk that the optimisation calculations will be processed on a totally wrong basis is rather large. Out of consideration of this fact RoSy PMS applies the historic data as a basis for dynamic adjustment of the basic models to actual conditions at section level. In this way the most realistic forecast for the future development will be obtained, not only at construction level but also at maintenance section level.

5. PRESENT AND FUTURE USE OF THE RESULTS

As it appears under section 4, the cooperation agreement was extended with another 5 years to 15 years and will expire at the end of year 2004. Taking the deterioration into consideration that is at the moment on-going on more sections into consideration, the prognoses also shows that it would be right to stop the project at that time. Many sections will then have deteriorated totally. However, for the municipality the result is that it will no longer have to work with theoretical models in RoSy PMS, but will have actual values from 15 years for a number of sections, which are representative of the entire municipal road network. This is very unique.

Regarding the general condition on the rest of the road network, then the initial calculations processed in 1989 showed that after 10 years the municipality would again have to rise the amount required to keep the roads optimally maintained. Now after the 10-12 years this statement seems to be right. At some time during the project it seemed like this could be postponed but the sudden deterioration, which occurred over the latest years, now seems to be reflected on the other road sections in the municipality. The engineers and the politicians of the municipality have therefore started the discussion about the coming financial task. A task, which can in no way be compared to the task the municipality was facing in 1989. This time it is only a question of setting into force a more general strategy so early in the process that the municipality will avoid passing the time, where it will again basically be uneconomical not to have the funds available for the road maintenance. The political interest in the project has been important. This interest has been present during the entire project period, which also appears from the press coverage over the years. An example is an interview, which Mayor Kaj Brink gave to the magazine Asfalt (6) 7 years after project startup. From Figure 16 one of his statements appears:

Mayor Kaj Brink to the magazine Asfalt, 7 years after project startup:

"The project has now been running for 7 years and it turns out that the economic calculations proves right. We have even obtained some very fine asphalt roads.

What happened was that our resources have been used where they gave us the most benefit. The eyes do not always see the truth. Now the computer program has calculated for us where the funds should be used for the paving work and this has given us extremely fine results. We are therefore happy that we decided to join the project 7 years ago.

Over a 10 year period we have saved 15-16 mill. kroner and even had a better result. If all municipalities in this country did the same billions could be saved in spite of the fact that preconditions are not the same everywhere."

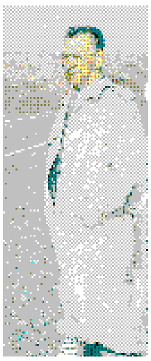


Figure 16. Mayor Kaj Brink's statement after 7 years

For RoSy as a pavement management system, the project was one of the advantageous tools used parallel with the Ulfborg-Vemb project to develop the system so that today it can be used and adapted to a road network anywhere in the world (7), (8), (9). It has also meant that even if a user is not an expert in road deterioration but just takes care that the required data is collected frequently and systematically, then based on the historic data the models in RoSy will automatically and without expert assistance be capable of forecasting a future development tendency for the individual defect types found on the individual maintenance sections.

6. RECOMMENDATIONS

With a sufficient and proper documentation not only local politicians but also government officials can be convinced that it is worth while to maintain the condition of the road network at an economic optimal level.

Working out global/general deterioration models for local and urban roads seems to be impossible if they should be capable of securing a correctly processed optimisation calculation for each individual maintenance section. However in order to secure that the calculation will be correct, a method could be to use progression of historic condition data.

The capacity of a contractor may be a limiting factor if a road authority decides to repair an entire road network all at once.

Implementation of a PMS is a process and cannot be done in one month. It is an obvious advantage for the future success of the project and the implementation of the system as a natural planning tool that the road authority and the PMS supplier/consultant already from the beginning enters into an agreement on sharing the future tasks. One of these is quality control on the output from the system calculations.

For this project it turned out to be a motivating factor for both parties so that each party covered 50% of the cost for the parallel test project.

A general lowering of the ground-water level in an area resulted in a poorer bearing capacity on the roads in the area. The reason may be a rebedding of the materials of the road structure. The condition did not grow permanent.

Mild winters may postpone the structural deterioration of a road structure but may have a negative effect on the functional condition.

7. ACKNOWLEDGEMENT

We would like to thank the politicians, Technical Director S. Faurby and Road Engineer A. Vognbjerg in Ulfborg-Vemb Municipality for their invaluable assistance in connection with this project.

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Key words:

B/C	Benefit/Cost
NPV	Net Product Value
IRR	Interest Rate Return
GPR	Ground Penetrating Radar
FWD	Falling Weight Deflectometer
PMS	Pavement Management System
DMI	Distance Meter Indicator
VOC	Vehicle Operation Costs
RoSy®	Road Systems

Asset Management
Road Capital
Condition Survey
Deterioration
Inventory
Roughness
Traffic