LONG TERM PAVEMENT MANAGEMENT STRATEGIES IN ROAD REGION SAVO-KARJALA
HOW THE ADVANTAGES OF HDM-4 SOFTWARE WERE EXPLOITED IN FINLAND

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ABSTRACT

Road Region of Savo-Karjala is one of nine regional road districts in Finland. According to region's long term plan pavement management strategies were enhanced as a separate project. The objective of the project was the management of the whole road network (length over 10 000 km) in order to keep up the balance of the available budget and the condition of the roads. Objective was very fruitful to take advantage of the HDM-4 software.

Regional road network model was created as a basis of the study. One of the road feature types for network model was land use classification, which was established in the beginning of the project. Road sections with similar properties were combined to road types. Modelling was done in order to help and clarify the description of road network in the analysis phases performed later during the project. Review on the pavement history condition was run similarly.

Study continued with the definition of different strategies for various pavement types. The base alternative for bituminous roads was to follow the condition criteria given in Finnish PMS. Other alternatives were "lighter version of PMS" (lower criteria), concentration on structure improvements, management with "Do minimum"-alternative and "downgrading" the road (replace the bituminous pavement with gravel). Base strategy for the gravel roads was the present road-keeping and the alternatives were to accept lower condition, upgrading to a sealed road, and frost heave section improvements.

The main objectives for road management were to maintain the present condition on main roads and to improve the condition of less trafficked but otherwise important roads on regional key connections. As the work proceeded "less important" roads had to be moved to lower condition level while with the present budget there are no possibilities to maintain the present condition objectives.

Study included impact assessments for different strategies. HDM-4 program was used to analyse road user costs, road maintenance costs and to forecast road condition (surface and structural condition). Impacts for traffic, environment, inhabitants and routine maintenance were also analysed. All pavement types could be analysed with HDM-4 program equally. HDM-4 models were calibrated similarly according to Finnish PMS-system.

Study revealed that network strategy with present road condition criteria is too expensive for the road district. For less trafficked roads criteria has to be lowered. At the same time money is saved to improve regional key connections. Lower maintenance is acceptable for minor gravel roads in order to move funds to upgrade major gravel roads and to repair frost heave sections.

HDM-4 was found to be a suitable tool for analysing road network in Finland. It could be used for network level analysis of both sealed and unsealed road in freezing conditions. However, a considerable amount of work had to be invested in adaptation and calibration of the model to Finnish circumstances.

KEY WORDS

ROAD MANAGEMENT, PAVEMENT, MANAGEMENT, ROAD FUNDS

1. GENERAL

Road Region Savo-Karjala is one of nine regional road districts in Finland. The population of the region is 425 000 inhabitants and the region covers an area of 35 000 km^2. The length of the public roads managed by Road Region is over 11 000 km. Annual traffic performance on public roads is 2 800 million automobile km, which corresponds with the traffic volume of 700 vehicles/day on each road. Region has two major cities, which both are centres to Finnish provinces - Kuopio with 90 000 inhabitants and Joensuu with 50 000 inhabitants.

Item	Value in Savo-Karjala	Pct/ entire country
Area	34 591 km^2	11,0 %
Population	424 537	8,2 %
Road length	11 177 km	14,1 %
No. of vehicles	198 700 vehicles	7,9 %
Traffic performance	2 750 million vehicle-km	8,5 %
Average Traffic volume	678 v.p.d.	

Figure 1. Location of Road Region Savo-Karjala in Finland

According to region's long term plan pavement management strategies were enhanced as a separate project. The objective of the project was the management of the whole road network in order to keep up the balance of the available budget and the condition of the roads. Region's annual road maintenance budget has been around 35 million euros in the last years. Decreasing condition of road network has changed the emphasis and the attitudes, where basic road management funds are most urgently needed. This study was one component, which helped on the decision to direct more funds to improve the condition of the less trafficked, but otherwise important road network.

Table 1. Used and estimated (*) road maintenance funds in Road Region Savo-Karjala [M€/a].

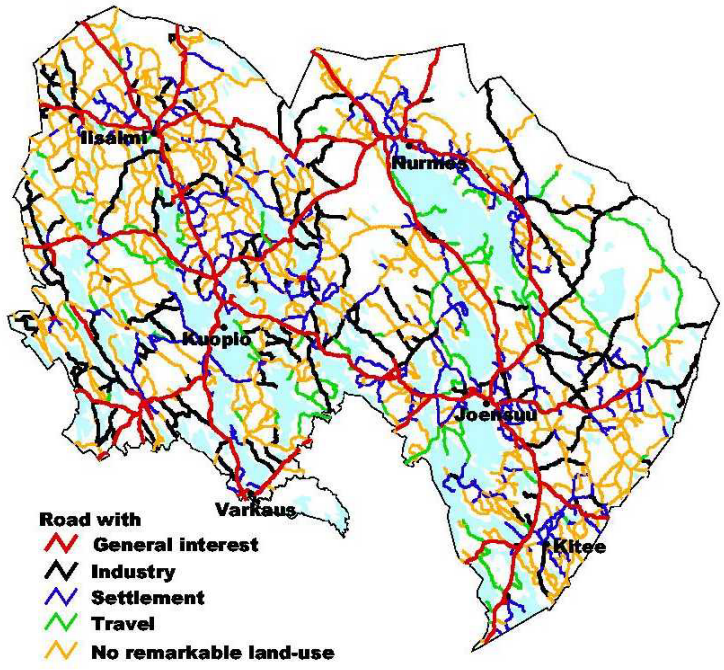
Annual Road Maintenance Funds in Savo-Karjala	**2000**	**2001**	**2002**	**2003 ***	**2004 ***
Routine Maintenance	22,2	23,4	24,4	24,4	24,5
Periodic Maintenance	7,6	7,6	7,3	7,2	8,6
Structural improvements	4,0	4,0	12,5	13,8	13,3
Total	**33,8**	**35,0**	**44,2**	**45,4**	**46,4**

Starting point to this study was to guide the available periodic maintenance funds in the most efficient way. Study forms the target and process frames for periodic maintenance in the Region. Study followed a pre-study performed for one sub-region in Region Savo-Karjala. The pre-study was carried out in order to find out how HDM-4 suits in the Finnish conditions. During the pre-study HDM-4 models were calibrated into Finnish circumstances. Pre-study consisted of the calibration of HDM-4 road user, road deterioration and works effect models. HDM-4 Road User Effect models based to previous road user effect studies in Finland. HDM-4 Road Deterioration and Works Effect models based to the Finnish PMS-models respectively. Using of existing information corresponded the level 2 HDM-4 calibration.

2. ROAD TYPE DEFINITION

Regional Road Network Model was created as a basis of the study. Road sections defined in Finnish Road Register were used to form the Network Model. Network Model was formed by calculating important average characteristics from Finnish Road and Road Condition Data Registers.

One of the road feature types for network model was land use classification, which was established in the beginning of the project. Five different land use classes were set. In road type "General Interest" roads are used widely in general without any specific characteristics. Type "General Interest" roads are mainly highways and other high-traffic-volume roads, also used broadly by heavy traffic. Type "Industry" roads have normally less traffic on than roads with "General Interest" but more heavy traffic than average. Type "Settlement" roads have lot of residents in the range of road's influence. Type has normally trade and villages generating traffic along the road. Unlike in type "Industry" the generated traffic along the road consists of mainly light motor vehicles. Type "Travel" roads have tourism attractions or lot of cottages in the range of road's influence and finally type "No remarkable land-use" has only few residents and no commerce along the road.



Land-use class	Pavement type	Km
General	AC	1372
General	SAC	264
General	ST	107
General	G	34
General	**Total**	**1 776**
Industry	AC	62
Industry	SAC	792
Industry	G	880
Industry	**Total**	**1 372**
Settlement	AC	290
Settlement	SAC	785
Settlement	ST	122
Settlement	G	876
Settlement	**Total**	**2 044**
Travel	AC	60
Travel	SAC	323
Travel	ST	128
Travel	G	394
Travel	**Total**	**906**
N.R.L	AC	122
N.R.L	SAC	1049
N.R.L	ST	262
N.R.L	G	2918
N.R.L	**Total**	**4 351**
All classes	**Total**	**10 811**

Figure 2. Land-use classes and pavements in Road Region Savo-Karjala

N.R.L. = No Remarkable Land-Use, AC = Asphalt Concrete, SAC = Soft Asphalt Concrete ST = Surface Treatment, G = Gravel

The next step was to define a road type for each road section. In addition to land-use classification, also operational function of the road, pavement type, traffic volume were used to form road type definition. On gravel roads ground water information and sensitivity to frost heave were used to form road types. Road sections with similar properties were combined to road types. Modelling was done in order to help and clarify the description of road network in the analysis phases performed later during the project. Noticeable is that all pavements were included in the study.

3. REVIEW ON PAVEMENT HISTORY

Review on the pavement history condition was run similarly. This examination was carried out only to paved road network while accurate data of gravel roads was unavailable. Defects, roughness, ruts and bearing capacity of the road were characteristics studied. The condition of the road network has decreased between the studied years 1994 and 2001. Land-use has not affected to road condition or its development. Deterioration has taken place mainly on lower trafficked roads regardless of different operational or land-use classification. Comparison between different regions show that the development of the road condition has followed the development nation wide. The deterioration situation is better on roads with high traffic volumes. The most serious defect on road network is the roughness. This means that relatively hard and costly operations are required to improve it.

Table 2. Changes in road condition between 1994 and 2001 in Road Region Savo-Karjala.

	Road Region Savo-Karjala		Finland	
	1994	**2000**	**1994**	**2000**
Roughness	2.2	2.3	2.3	2.3
Ruts	3.3	3.7	3.5	4.0
Damage sum	20	27	21	27

4. STRATEGIES ANALYSED

Study continued with the definition of different policies for various pavement types. Different pavements had different policies. Pavements were divided into four different classes – asphalt concrete pavements, soft/light asphalt pavements (Cold mix and soft asphalt), surface treatments as pavement and gravel roads.

The base alternative for bituminous roads was to follow the condition criteria given in Finnish PMS. Other alternatives were “lighter version of PMS” (lower criteria used especially for soft/light asphalt pavements), concentration on structural improvements, management with “Do minimum”-alternative (consisted of only patching as periodic maintenance tool) and “downgrading” the road (replace the bituminous pavement with gravel).

Roads with surface treatments were examined with similar policies as light asphalt pavements.

Base policy for the gravel roads was the present road-keeping and the alternatives were to accept lower condition, upgrading to a sealed road, and frost heave section improvements.

Economical base for study was present budget for road maintenance, approximately 31 million euros. In 2001 budget for periodic maintenance for asphalt pavements was app. 10 million euros. Other maintenance for asphalt pavements cost 10 million euros and gravel road maintenance cost 11 million euros, of which almost 2 million euros are directed to improve frost heave sections.

The main objectives for road management were to maintain the present condition on main roads and to improve the condition of less trafficked but otherwise important roads on regional key connections. As the work proceeded “less important” roads had to be moved to lower condition level while with the present budget there are no possibilities to maintain the present condition objectives.

Study included impact assessments for different policies. HDM-4 program was used to analyse road user costs, road maintenance costs and to forecast road condition (surface and structural condition).

Effects of different policies were examined after evaluating the needed funds and the conditions with program HDM-4 . Impacts for traffic, environment, inhabitants and routine maintenance were also analysed by experts. The results were gathered to excel files (an example in appendix 1). This phase was called multi-criteria analysis. These tables were used to select policies for each strategy and to examine the suitableness of each policy. Effects of different policies were combined to a table for selecting suitable strategy.

For paved roads a strategy according to Finnish PMS-criteria consisted of maximum maintenance. This strategy keeps all the roads in an excellent condition for the whole analysing period. The cost of this strategy is about 18 million euros per annum. Strategy was calculated only for to compare other strategies against it.

Present budget periodic maintenance strategy was the next strategy examined. This strategy keeps the important roads in a perfect condition. Less important roads could be moved to be only patched during the analysis period. The cost of this strategy is 10 million euros.

Present budget periodic maintenance strategy was also the base for other strategies examined. Present budget strategy improving structural condition with cost of 11 million euros and strategy of lightened periodic maintenance with cost of 9 million euros were defined by changing slightly the base strategy.

Further a strategy emphasising periodic maintenance (cost 12 million euros) and strategy emphasising structural condition (cost 14 million euros) were investigated.

Policies were examined in order to form a combined strategy for the whole road network. An example, where different strategies used for paved road network (soft asphalt pavements) are compiled into table and presented in Appendix 2.

Two different combined strategies were examined for gravel roads - A strategy with present maintenance and a lightened maintenance. In both strategies more actions should be directed to important roads. Lightened maintenance could be used on roads with less importance. Land-use classification could be used to select such road sections. If criteria is lighten lightened on less important roads, more funds could be steered to pave important roads and to improve the frost heave problems on more important roads.

Among other pavements some funds should be reserved for periodic maintenance of bicycle and pedestrian ways. These ways need about 0,5 million euros annually for re-pavements.

5. RESULTS

Study revealed that network strategy with present road condition criteria is too expensive for the road district. For less trafficked roads criteria has to be lowered. At the same time money is saved to improve regional key connections. Lower maintenance is acceptable for minor gravel roads in order to move funds to upgrade major gravel roads and to repair frost heave sections.

For paved roads “Present strategy emphasising structural improvements” was selected. Selected strategy could not be used comprehensively. Used road type definition is much too rough for defining actions directly according to selected strategy. Local circumstances i.e. traffic volume and precise importance of the road should always be observed. Selected strategy could be exploited to direct the funds to certain road types. Selected strategy helps deciding on possible savings as well.

On asphalt concrete roads maintenance actions are determined according the technical and economical feasibility. Structural condition is normally adequate. If traffic volumes do not change much only repavements are needed.

On light asphalt pavements lightened PMS-criteria are used. Criteria keep the roads all the time in good condition and funds could be directed to structural improvements of important connections. Less trafficked roads could be “downgraded” into gravel. Downgrading should take place only case-specific and after present pavement is fully utilised.

Roads with surface treatments are kept either by upgrading them into light asphalt pavement roads or by resurfacing them regularly. Less trafficked roads with surface treatment could be maintained by patching until they are fully utilised. After that it has to be decided whether to up- or downgrade the road.

Present road management seems to be adequate for most of the gravel roads. Lowering the criteria for less-trafficked gravel roads funds could be directed to more important gravel roads.

HDM-4 proved to be successful tool for handling strategies also in the Nordic circumstances. As found out already in pre-study HDM-4 cold-climate models need to be developed further. The whole topic from riding on a ice/snow covered roads to frost heave effects needs development. Work and deterioration effects of gravel road models need to be perfected similarly.

6. FURTHER ACTIONS

Land use classification should be sharpened in the future. Classification could be exploited in other operations and projects. Structural improvements could be prioritised by using the method developed similarly to this project. The feasibility of the road pavements downgrading should be analysed properly before performing downgrading actions. The description of lightened pavement policies is needed, especially how the criteria for lightened policies could be defined. Inexpensive overlay methods like surface treatments should be studied as well.

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APPENDIX 1

Soft Asphalt pavements, Regional roads, Industry, AADT<350 Length 126,06 km AADT = 225

Policy Alternative	Development of road condition		Road user costs per vehicle	Annual road user costs and difference to base alternative	Road agency costs (routine and periodic maintenance total)	Effects on traffic	Effects on environment	Effects on maintenance
	Structural condition	Surface condition	c/km average	euros/km/a	euros/km/a			
Policy according to PMS	Improves clearly	IRI stays at 2 mm/m. Rut depth remains low for whole analysis period.	61,7	50 660 **0**	3 513 1 524 **5 037**	Stays at present level.	No notable effects.	No notable effects.
Policy according lightened PMS (Damages used not for criteria)	Stays on present level	IRI decreases from 2 to 4 mm/m. Amount of cracks and patches increase. Rut depth increases to 6 mm.	62,1	50 959 **-299**	1 171 1 750 **2 921**	Cracks and potholes bother the traffic occasionally.	No notable effects.	No notable effects. Light PMS increases patching.
Reconstruction + Policy according to PMS	Stays on present level	IRI stays at 2 mm/m. Rut depth remains low for whole analysis period.	61,0	50 105 **555**	4 108 1 359 **5 467**	Situation improves from the present.	Temporary harm from the reconstruction.	Maintenance becomes easier after reconstruction.
Reconstruction + Policy according to lightened PMS (Damages not used as criteria)	Stays on present level	IRI decreases from 2 to 3. Rut depth stays low. Damages and patches are increasing.	62,0	50 928 **-268**	2 689 1 751 **4 440**	Cracks and potholes bother the traffic occasionally.	Temporary harm from the reconstruction.	Maintenance becomes easier after reconstruction. Light PMS increases patching.
Downgrading present pavement into gravel + gravel road maintenance	Remains in good condition as a gravel road for whole analysis period		71,5	58 742 **-8 082**	865 3 926 **4 791**	Riding quality decreases stringly due to pavement change. Lowers speeds.	Dust and maintenance bothers the traffic. Discharges increase if new pavement bothers the traffic flow.	Increases extremely maintenance in summer.
Patching policy	Stays on present level	IRI decreases from 2 to 7. Expanded cracks. Rut depth grows to 10 mm.	64,6	53 074 **-2 414**	0 2 110 **2 110**	Extremely harmful for the vehicle traffic.	Harmful due to breaking of the road. Discharges increase.	Extremely harmful.

APPENDIX 2

ROAD TYPE	AADT	Length	Strategy according to condition objectives	Strategy emphasising structural condition	Strateghy emphasising periodic maintenance	Present strategy improving structural condition	Present periodic maintenance strategy	Lightened periodic maintenance strategy
	[v.p.d]	[km]	18 M€	14 M€	12 M€	11 M€	10 M€	9 M€
Main Roads, Soft Asphalt Concrete (SAC)	858	213,5	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS
Regional or Connecting Roads, SAC, Roads with General Interest	875	50,0	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS
Regional Roads, SAC, Industry, AADT > 350	647	290,6	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS
Regional Roads, SAC, Industry, AADT < 350	225	126,0	According to PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Industry, AADT > 350	248	128,4	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Industry, AADT = 150...350	248	174,7	According to PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Industry, AADT < 150	89	72,4	According to PMS	Lightened PMS	Lightened PMS	Patching	Lightened PMS	Lightened PMS
Regional Roads, SAC, Settlement	769	260,1	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Settlement, AADT > 350	630	303,2	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Settlement, AADT = 150...350	255	156,4	According to PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Settlement, AADT < 150	85	65,6	According to PMS	Lightened PMS	Patching	Patching	Patching	Patching
Regional Roads, SAC, Travel	668	149,0	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Connecting Roads, SAC, Travel	335	174,5	According to PMS	Reconstr. + lightened PMS	Lightened PMS	Patching	Patching	Patching
Regional Roads, SAC, No Remarkable Land-Use, AADT > 350	670	427,4	According to PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS	Lightened PMS
Regional Roads, SAC, No Remarkable Land-Use, AADT = 150...350	253	183,8	According to PMS	Lightened PMS	Lightened PMS	Patching	Patching	Patching
Regional Roads, SAC, No Remarkable Land-Use, AADT < 150	115	41,3	According to PMS	Lightened PMS	Lightened PMS	Patching	Patching	Patching
Connecting Roads, SAC, No Remarkable Land-Use, AADT > 350	525	122,5	According to PMS	Lightened PMS	Lightened PMS	Lightened PMS	Patching	Patching
Connecting Roads, SAC, No Remarkable Land-Use, AADT = 150...350	221	167,4	According to PMS	Lightened PMS	Lightened PMS	Patching	Patching	Patching
Connecting Roads, SAC, No Remarkable Land-Use, AADT < 150	91	106,1	According to PMS	Lightened PMS	Patching	Patching	Patching	Patching