LONG-TERM STRATEGIC PLANNING OF PAVEMENT MAINTENANCE IN PRIVATELY FINANCED HIGHWAY NETWORK CONCESSIONS: SLOVENIA CASE STUDY

J. ORTIZ-GARCIA
Asset Management and Pavement Group
WS Atkins Highways and Transportation, Birmingham, United Kingdom
Jose.Ortiz-Garcia@atkinsglobal.com

ABSTRACT

Countries around the world continue to privatise the construction, rehabilitation and maintenance of portions of their highway network. A new trend points towards the move from highway infrastructure concessions on a small portion of the network to privately financed network management contracts covering the majority (or the whole) of a country's road network. Governments preparing this type of long-term contracts need to study carefully the implications of privatisation and ascertain whether they yield good value for money before embarking in such contracts. Similarly, companies interested in bidding for network management contracts need to decide whether the project is affordable, bankable and offers a good return to their investment. This paper addresses these issues, discussing the way in which a highway authority or a private company would estimate the long-term pavement rehabilitation and maintenance expenditure profile for the duration of a concession contract. The discussion is based on experiences obtained during the development of the Slovenia Private Roads Maintenance Project, which encompasses the privatisation of the whole of the country's primary road network to a number of concession companies. The study included the definition of the extent and condition of the road network as a starting point, followed by an analysis of its deterioration and maintenance effects from a number of maintenance strategies, resulting in a preferred long-term rehabilitation and maintenance expenditure profile. Probabilistic deterioration prediction models were used in the study. The lack of information on pavement deterioration resulted in the calibration of such models using a panel of local pavement experts and an innovative methodology for the determination of deterioration probabilities. Such deterioration models were calibrated for a combination of traffic levels and climatic conditions. The maintenance strategies included in the study were aimed at achieving the pre-defined level of service in the whole network, while resulting in good value for money to the Directorate of the Republic of Slovenia for Roads. Competing strategies covered a range of prioritisation rules and generic maintenance treatments, all resulting in a different long-term rehabilitation and maintenance expenditure profile. The selection of the most economically viable and financially attractive profile was based on the overall discounted cost of the concession contracts, the phasing of them and the financial costs attached to the various shapes of the expenditure profile.

KEY WORDS

STRATEGIC PLANNING / MAINTENANCE / DETERIORATION PREDICTION

1. INTRODUCTION

In highway infrastructure concessions, the public authority grants specific rights to a private company to construct, rehabilitate, maintain and operate road infrastructure for a given period. As part of the contract, the public authority charges that company with making the investments needed to create the service at its own cost and operate at its own risk. The price paid to the company comes from the service's users, the public authority or both (Bousquet and Fayard, 2001). In addition, the levels of service at which the road infrastructure should be maintained are defined in the concession contract. The duration and scope of such concessions are variable. They range from operation and maintenance projects with very little or no initial investment, to the operation, maintenance and management of large networks. Nowadays a trend towards privately financed network management contracts covering the majority (or the whole) of a country's road network is emerging.

The estimation of long-term rehabilitation and maintenance requirements is crucial for both a road authority exploring the possibility of letting a portion, or the whole, of their network to a private concessionaire, and a concessionaire assessing whether such a project is bankable, affordable and offers a potential good return to their investment. The long-term, strategic planning becomes more complex commensurate to the size of the network being let to concession. This paper illustrates the process of estimating long-term rehabilitation and maintenance expenditure profiles using the Slovenia Private Roads Maintenance Project (DRSC, 2001) as a case study.

2. HIGHWAY NETWORK CONCESSIONS: SLOVENIA CASE STUDY

Slovenia, like so many of her neighbours in Central Europe, has suffered from under-investment during the years prior to and after national independence in 1991 and consequently the condition of the State Roads Network has deteriorated with time. This deterioration continues despite investment in the rehabilitation of the network. The network is, in effect, deteriorating at a faster rate than the limited resources can reverse.

According to the Slovenian State Road Network Rehabilitation Model (SRNRM), 27% of the road network was in very poor or poor condition in 2001, 25% in fair condition and 48% in good or very good condition. The level of capital requirement needed to rehabilitate the sub-standard portion of the network was prohibitive and Slovenia, like many countries around the world, therefore found itself in the situation of not being able to undertake the necessary major rehabilitation at a quick enough pace to allow the whole of the network to be upgraded to the required standard in the foreseeable future. Therefore, the Slovenian Government approached the European Bank for Reconstruction and Development (EBRD) with the concept of a project to assess the feasibility for, and possibly introduce, a Private Finance element into the rehabilitation of their State Road Network. The overall aim of the feasibility element of this project, the Slovenia Private Roads Maintenance Project, was to ascertain whether undertaking all or some part of the maintenance of the State Road Network would offer better value for money if procured under a series of Public Private Partnership (PPP) concession arrangements as opposed to the current procurement method.

Under such arrangements the concessions would provide the necessary major rehabilitation capital investment required to improve the whole of the State Road Network to a pre-determined standard. These concessions would then operate and maintain the network for a fixed term under a PPP arrangement whereby concessionaires' income would come directly from the Slovenian Government. A major component of the feasibility study was the estimation of long-term rehabilitation and maintenance expenditure profiles for the concessions. The steps followed to produce a strategic plan for pavement maintenance is described in the following sections.

3. STRATEGIC PLANNING OF PAVEMENT MAINTENANCE

Central to the process of planning the long-term maintenance of a network is the definition of the extent of such a network. In the case of the Slovenia Private Roads Maintenance Project, the division of the State Road Network into a number of areas took place at an early stage. A number of criteria were assessed in order to determine the optimum number of areas and their size, including:

- annual financial estimated value of each concession area;
- physical scale (length of carriageway to be maintained);
- homogeneity of region in terms of climate, terrain and natural borders;
- operational and political boundaries and
- financial viability and bankability of each concession area.

The State Road Network was divided into five areas, the size of which may be seen in Table 1

Table 1 – Length of network in each Concession Area

Concession Area	Length of Network
Concession area 1	1,172.69 km
Concession area 2	1,020.11 km
Concession area 3	929.56 km
Concession area 4	848.82 km
Concession area 5	1,146.72 km
Total Concession Area	5,117.90 km

The feasibility study recommended the concessions to be let in phases, as follows: Phase 1 – Concession area 1; Phase 2 – Concession areas 2 and 3 (starting two years after commencement of Phase 1); and Phase 3 – Concession areas 4 and 5 (starting two years after commencement of Phase 2). This phasing was based on concession size, scope and risk, aiming first at the international market, and later at local concession companies and funding institutions.

The estimation of long-term rehabilitation and maintenance expenditure profiles was carried out for each of the concession areas. The process was based on the logic behind the Strategic Planning Model STRAT-2 (Costello and Snaith, 2000), which has been used in a number of Design, Build, Finance and Operate (DBFO) projects in the United Kingdom.

The modelling process, at its simplest, consists of the following:

- Subdividing the road network into homogeneous sub-networks, based on traffic loading and climatic conditions.
- Modelling pavement deterioration using probabilistic transition matrices.
- Modelling maintenance strategies aimed at rehabilitating the whole of the sub-standard network during the first five years of the concession and then maintaining it in good condition for further fifteen years. The maintenance strategies would aim also at achieving the hand-back requirements in terms of pavement residual life and level of service.
- Costing the above strategies.

3.1 Homogeneous sub-networks

Information on section length, carriageway width, climatic zone, pavement condition and traffic loading was available for each of the road sections comprising the network. Each road section was also linked to one of the five concession areas. Within a particular concession area, a homogeneous sub-network was defined for each combination of traffic group and climatic zone, as described below.

3.1.1 Traffic

Roads were categorised into five traffic groups, in terms of the predicted number of 80kN standard axles that will traffic the particular road during a 20-year analysis period, as presented in Table 2.

Table 2 – Traffic classification

Traffic Group	Range: Equivalent Standard Axles of 80kN
1. Very heavy	>7,000,000
2. Heavy	2,000,000 – 7,000,000
3. Medium	700,000 – 2,000,000
4. Light	200,000 – 700,000
5. Very light	<200,000

3.1.2 Climate

Three climatic zones may be found in Slovenia: sub-Mediterranean, moderate continental and mountainous. Pavements in these zones are subject to different ranges of temperature and varying levels of rainfall and snowfall, as shown in Table 3.

Table 3 – Climatic zones definition

Climatic Zone	Average temperature of the coldest month: °C	Average temperature of the warmest month: °C	Average annual precipitation: mm
1. Sub-Mediterranean	0 to 4	20 to 22	1200 to 1700
2. Moderate continental	-3 to 0 $T_{April} < T_{October}$	15 to 20	800 to 2800
3. Mountainous	<-3	~10	1100 to 3500

3.2 Modelling pavement deterioration

3.2.1 Network condition

Condition information was available for each section in the network in terms of Modified Swiss Index (MSI), which is a composite condition index based on the extent and severity of visually collected pavement condition parameters. MSI values were grouped into condition bands as shown in Table 4. It was therefore possible to determine condition distributions for each homogeneous sub-network.

Table 4 – Boundary MSI values according to traffic volume

Traffic volume	Condition Band				
AADT	Very Good (VG)	Good (G)	Fair (F)	Poor (P)	Very poor (VP)
<1,000	<0.9	0.9 – 1.6	1.6 – 2.1	2.1 – 3.3	>3.3
1,000 – 2,000	<0.8	0.8 – 1.5	1.5 – 2.0	2.0 – 3.2	>3.2
2,000 – 5,000	<0.7	0.7 – 1.4	1.4 – 1.9	1.9 – 3.1	>3.1
5,000 – 10,000	<0.6	0.6 – 1.3	1.3 – 1.8	1.8 – 3.0	>3.0
10,000 – 20,000	<0.5	0.5 – 1.2	1.2 – 1.7	1.7 – 2.9	>2.9
>20,000	<0.4	0.4 – 1.1	1.1 – 1.6	1.6 – 2.8	>2.8

3.2.2 Deterioration prediction

Pavement deterioration was modelled for each homogeneous sub-network by means of a probabilistic approach based on transition matrices. A transition matrix specifies, for a homogeneous sub-network, the proportion of that sub-network that deteriorates from one condition band to the following worse every year. An example of such a transition matrix may be seen in Table 5.

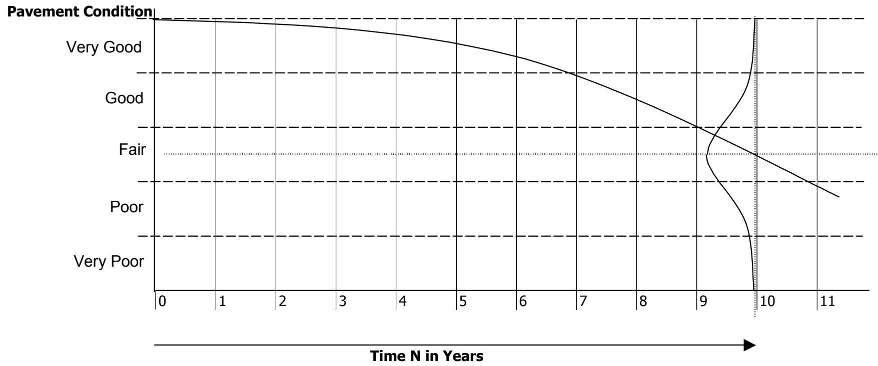
Table 5 – Example of Transition Matrix

From\To	VG	G	F	P	VP
VG	0.60	0.40			
G		0.55	0.45		
F			0.35	0.65	
P				0.20	0.80
VP					100

This matrix indicates, for instance, that 60% of the roads that are in "very good" condition in any one year will remain in "very good" condition the next year and that 40% will deteriorate to condition band "good" (row 1 of the matrix). Similarly, 20% of roads in condition "poor" will remain in that condition next year, while 80% will move to condition band "very poor". Each value in the matrix is known as a transition probability (i.e. transition probability P_{ij} indicates the probability of pavements in condition band "i" to move to condition band "j" in any one year).

It should be noted that the transition matrix defines deterioration as the proportion of the network that moves from one condition band to the next every year. Therefore if the current condition of the network is known (in the form of a condition distribution) then its future condition may be calculated by operating the current condition vector with the transition matrix (Ortiz-García, 2000).

The definition of transition probabilities for each sub-network was achieved by means of an innovative method based on the assumption that when a given road section deteriorates to "fair" condition, 50% of it is above the mid point of the "fair" condition band and the other 50% is below it, following a normal distribution about that mid point. The distribution of condition at this point in time is therefore known. Similarly, the condition distribution of the road section, when it is opened to traffic, is known (i.e. 100% of the road section is in "very good" condition). As a result, if the time in years between opening to traffic and the time when the road section reaches "fair" condition may be estimated, then the transition matrix that reflects that deterioration pattern may be calculated. The concept is illustrated in Figure 1.



TRANSITION MATRIX

	VG	G	F	P	VP
VG	0.720	0.280			
G		0.795	0.205		
F			0.883	0.117	
P				0.940	0.060
VP					1.000

	0	1	2	3	4	5	6	7	8	9	**10**	11
Very Good	1.000	0.720	0.518	0.373	0.268	0.193	0.139	0.100	0.072	0.052	**0.037**	0.027
Good	0.000	0.280	0.425	0.483	0.488	0.464	0.423	0.375	0.326	0.280	**0.237**	0.199
Fair	0.000	0.000	0.057	0.138	0.220	0.295	0.355	0.400	0.430	0.447	**0.451**	0.447
Poor	0.000	0.000	0.000	0.007	0.022	0.047	0.079	0.115	0.155	0.196	**0.237**	0.276
Very Poor	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.009	0.016	0.026	**0.037**	0.051
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**	1.000

Note: The table above contains, for each year of analysis, the proportion of roads in each condition band.
Note that the sum of the proportions is equal to one.

Figure 1 – Logic behind the definition of transition probabilities

In the case study, the time in years that roads in each sub-network take to deteriorate from "very good" to "fair" condition was determined through panel discussions with local pavement engineers. These life spans may be found in Table 6.

Table 6 – Time span between "very good" and "fair" condition: years

Climatic Zone	Traffic Group				
	Very heavy	Heavy	Medium	Light	Very light
1. Sub-Mediterranean	15	15	15	20	20
2. Moderate continental	12	12	15	15	15
3. Mountainous	10	10	12	12	12

The transition probabilities P_{ii} for these matrices were obtained following the methodology described above and may be found in Table 7. These figures indicate the probability of a road length remaining in condition band "i" in any one year. The probabilities of moving from condition band "i" to condition band "j" (next worse) in any one year are calculated as $P_{ij} = 1 - P_{ii}$.

Table 7 – Transition probabilities for various time spans

Time Span: years	$P_{VG\text{-}VG}$	$P_{G\text{-}G}$	$P_{F\text{-}F}$	$P_{P\text{-}P}$
10	0.7197	0.7952	0.8829	0.9401
12	0.7603	0.8288	0.9048	0.9528
14	0.7906	0.8529	0.9197	0.9611
15	0.8031	0.8626	0.9256	0.9642
17	0.8241	0.8785	0.9350	0.9692
20	0.8483	0.8966	0.9454	0.9745
22	0.8611	0.9059	0.9507	0.9771

3.3 Modelling maintenance strategies

Pavement deterioration and maintenance treatments were modelled on a cyclical basis, with cycles of one-year duration. The process is illustrated in Figure 2.

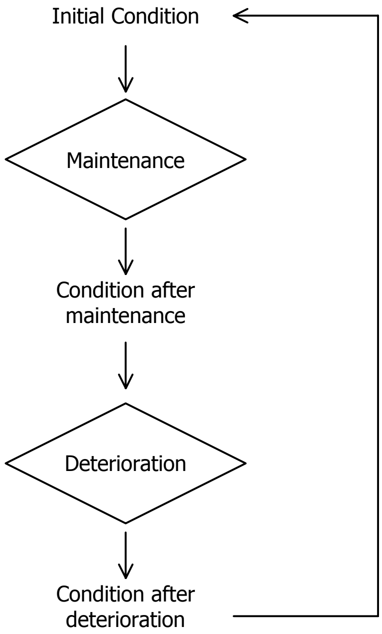


Figure 2 – Modelling Cycle

"Maintenance" in Figure 2 refers to all activities required to bring roads in "very poor", "poor" or "fair" condition to "very good" condition, as the pre-defined standard required roads to be kept above the "fair" condition level. The modelling process assumes that all roads that are at a condition "fair" or below at any one year are treated on that year and brought back to "very good" condition. When modelling surface dressing, which is carried out on "fair" condition roads only, it was assumed that road condition improves from "fair" to "good". The condition distribution of the network after maintenance is then used as an input to the deterioration model. The output of such a model is yet again another condition distribution (after deterioration). The condition distribution at the end of each modelling cycle indicates the performance of the network at that point in time. Of particular importance is the condition distribution at the end of the concession period, which shows the expected condition of the network at hand-back. Table 8 shows an example of such modelling approach as indicated by condition distributions before maintenance (BM), after maintenance (AM) and after deterioration (AD). The proportion of the network receiving maintenance is shown by the maintenance vector (M) (i.e. all roads below "fair" condition).

Table 8 – Example of modelling cycle (2 years)

Condition Band	Year 5				Year 6			
	BM	M	AM	AD	BM	M	AM	AD
VG	36%	0%	53%	43%	43%	0%	49%	39%
G	47%	0%	47%	51%	51%	0%	51%	54%
F	16%	16%	0%	6%	6%	6%	0%	7%
P	1%	1%	0%	0%	0%	0%	0%	0%
VP	0%	0%	0%	0%	0%	0%	0%	0%
	100%	17%	100%	100%	100%	6%	100%	100%

Four maintenance strategies were assessed. The first strategy was aimed at maintaining first those roads in the worst condition. The second was aimed at prioritising maintenance in such a way that the revenue to the concessionaire would be maximised. The third strategy was aimed at maintaining the more important roads first. The last strategy introduced surface dressing as an alternative to rehabilitation, aimed at maintaining the roads just above fair condition.

3.3.1 Strategy A – "Worst first"

In this strategy, road rehabilitation and maintenance was prioritised according to pavement condition, treating all the "very poor" condition roads first, followed by the "poor" condition roads and finally the roads in "fair" condition. This was carried out regardless climatic zone or traffic loading.

3.3.2 Strategy B – "Maximising Internal Rate of Return (IRI)"

This strategy attempted to mirror the thinking of the concessionaire in terms of maximising the IRI to the concession company. It is in the interest of the concessionaire to keep open to traffic and in good condition all roads that would generate a penalty if they were not maintained to the required standard. The concessionaire is therefore interested in maintaining first all the lengths of road that would generate a penalty if they were left to deteriorate. Keeping roads in good condition may therefore be seen as a "saving in penalties". The prioritisation of maintenance works in this case was driven by the potential size of the penalty.

3.3.3 Strategy C – "Road Priority"

This strategy aimed at prioritising maintenance according to the importance of the road, which was assumed to be defined by the traffic group. Consequently in the model, roads carrying "very heavy" traffic were treated first, followed by roads carrying "heavy" traffic and so on.

3.3.4 Strategy D – "Minimum cost"

This strategy was based on strategy C, but introducing surface dressing as a low cost alternative for roads with "medium" or lighter traffic that fall into "fair" condition. As such, the strategy is the same as strategy C for "very heavy" and "heavy" traffic. Strategy D is almost identical to strategy C for "medium", "light" and "very light" traffic. The difference is that during the first ten years of the concession, all roads in these traffic categories that fall into "fair" condition are treated with surface dressing. From year eleven onwards strategy D is identical to strategy C. The return to more comprehensive maintenance practice from year eleven onwards is aimed at strengthening sections that have not received structural maintenance during the initial years of the concession.

3.4 Rehabilitation and maintenance costs

Rehabilitation costs used in the modelling were based on generic activities required to treat a road that has fallen into "very poor", "poor", or "fair" condition, bringing it back to "very good" condition. These costs may be found in Table 9.

Table 9 – Rehabilitation unit costs: €/m^2

Traffic Group	Pavement condition before rehabilitation		
	Very poor	Poor	Fair
1. Very heavy	29.81	16.31	10.77
2. Heavy	19.99	13.93	9.88
3. Medium	14.82	12.56	8.99
4. Light	13.93	10.77	8.99
5. Very light	9.64	9.88	8.99

As expected from the modelling process, each strategy resulted in a different expenditure profile. Strategy A resulted in an unacceptable expenditure profile during the first five years, showing high expenditures in years one, three and five and very low expenditures in years two and four. Clearly, this option would neither be attractive to lending organisations, nor to the concessionaire, who would have to borrow excessively during the first years of the concession. In strategy B, although the major expenditure is delayed to year five, the lending pattern is very erratic, which may not be attractive to lending organisations. In addition, this approach to maintenance may not be acceptable to the Directorate of the Republic of Slovenia for Roads (DRSC) because the principal roads are not always maintained with the highest priority. Strategy C appears to be the most comfortable for all the parties involved: DRSC, the lending organisations and the concessionaires. The expenditure profile obtained with strategy C, which may be found in Figure 3, shows a gradual increment in expenditure during the first five years up to a level of about 40mEuro/year (all concession areas), for five years. Expenditure then reaches a level of about 20mEuro/year for the next eleven years, and then decreases gradually during the last four. In this strategy the most important roads are treated first, which will contribute to a favourable public perception of the concessions scheme. Strategy D is the least expensive one, but is also the one with the highest risk associated to it, in terms of compliance with hand-back requirements.

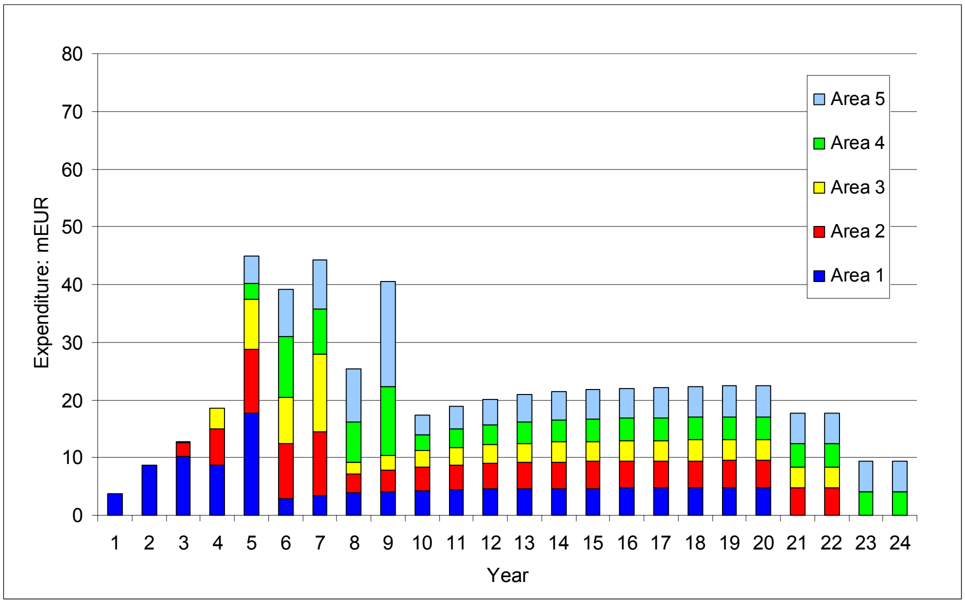


Figure 3 – Preferred Option Concession Spend Profile

If this preferred expenditure profile was adopted by the concessionaire the progression of improvement of the road condition would follow the pattern shown in Figure 4.

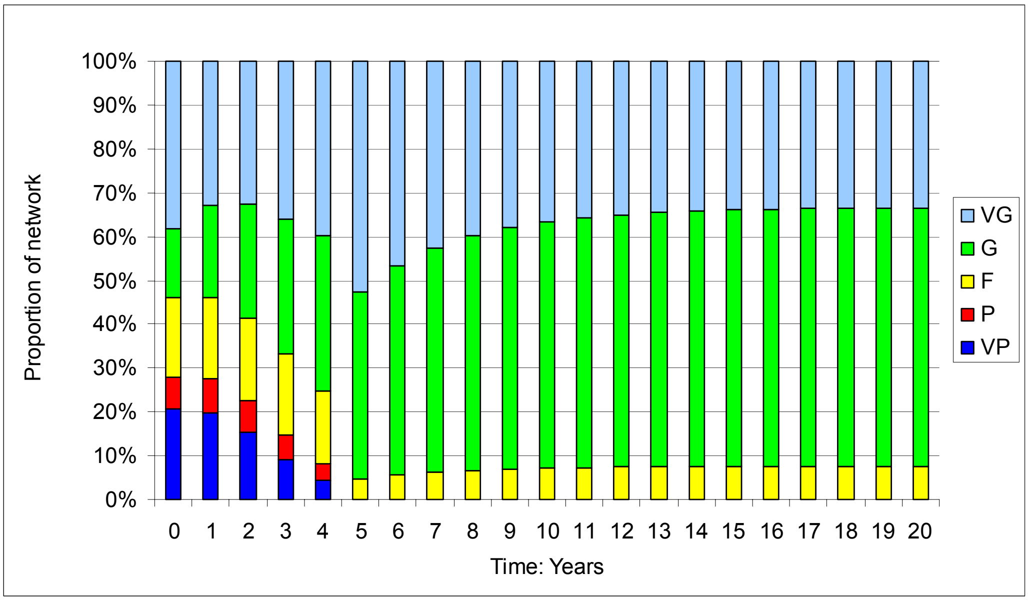


Figure 4 – Progression of Network Condition

4. SUMMARY

The long-term rehabilitation and maintenance expenditure profile for the duration of a concession contract may be estimated through a process that involves the compilation of network dimensions and condition, the calibration of pavement deterioration prediction models, the modelling of a number of alternative rehabilitation and maintenance strategies and the costing of the same. Different strategies lead to a variety of expenditure profiles. The selection of the most economically viable and financially attractive profile is based on the overall discounted cost of the concession contracts and the financial costs attached to the various shapes of the expenditure profile.

REFERENCES

Bousquet, F. and Fayard, A. (2001) Road Infrastructure Concession Practice in Europe, Policy Research Working Paper 2675, The World Bank, Washington.

Costello S.B. and Snaith M.S. (2000) The Development of an Integrated Strategic Planning Tool for Road Maintenance Funding. Proceedings of the 1st European Pavement Management Systems Conference, 24-27 September, Budapest.

DRSC (2001) Slovenia Private Road Maintenance Project: Strategy Report, WS Atkins Consultants Limited, Birmingham.

Ortiz-Garcia, J. (2000) Strategic planning of highway maintenance: condition standards and their assessment, PhD Thesis, School of Civil Engineering, The University of Birmingham, Birmingham.