THE DEVELOPMENT OF ANALYTICAL MODELS FOR A PAVEMENT MANAGEMENT SYSTEM IN MOZAMBIQUE:
A Knowledge-Based Expert System Approach

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INTRODUCTION

Background

Mozambique is a large country, of moderate to humid climate, with an area of about 799 390 km^2 and a population of 17.2 million inhabitants. Road transport is the main mode of transport and constitutes the medium of access to other modes (DNEP, 1998). The road network comprises 28 460 km, of which 19 % are paved roads and 81% are unpaved (including earth and gravel engineered roads). The low density of roads (less than 40 m/km^2) is a clear demonstration of the current and future challenges faced to maintain, improve and extend the existing road network.

Problem definition

Roads in poor condition are known to contribute for the increase of vehicle operating costs (VOCs) with consequent increase in the total transport cost (TTC). This impairs the economy of the country as a whole. The nefarious impact of a poor road network in the economy of a country, where the road transport is the dominant mode of transport, has been well demonstrated worldwide by many transport economists. However, limited funds and the scarcity of other resources, call for the rational and efficient use of these resources to try and maximize the benefits, through the use of appropriate pavement management systems (PMSs).

A PMS is a set of procedures of systematically evaluating alternative strategies for the monitoring, maintenance and rehabilitation of roads, normally with the aid of computers, to provide and maintain a road network effectively and to the minimum total transport cost.

PMSs used internationally are not necessarily applicable under the conditions of most developing countries. The relatively high cost involved during data collection for use by these systems, as a result of the type of equipment required, as well as other practical considerations, in most cases limit their implementation. To provide a system that can be applied under circumstances of developing countries, a different approach to pavement management may be required.

Aim of the Paper

The aim of the paper is to evaluate the application of a Knowledge Based Expert System (KBES) for the network level pavement management of bituminous surfaced roads in Mozambique.

Methodology

The traditional pavement management approach is based on sound engineering principles. Pavement conditions are usually surveyed through the use of automated equipment, pavement deterioration over time is assessed using existing models, and the maintenance/rehabilitation needs are determined according to the standards that are predefined. The deterioration models have been developed from studies conducted internationally for this specific objective. Because of the variability of environmental conditions, material types, construction quality and other factors, these models are normally required to be calibrated to suit specific conditions other than those for which the models were originally developed. Furthermore, the use of these models suggests that the same criteria for pavement condition assessment, as originally defined, is followed or else there must be a correlation between them.

The methodology followed in the study on which this paper was based (Camba, 2001), although similar to the above in terms of general principles of pavement management systems, considers a distinct approach to the various phases. Firstly, the method uses visual inspection as the main form of pavement condition assessment and, secondly, it employs the KBES' concept to predict future pavement condition and select technical viable measures to apply to different road segments under specific conditions. Figure 1 gives a basic structure of an expert system, according to Smadi (2000).

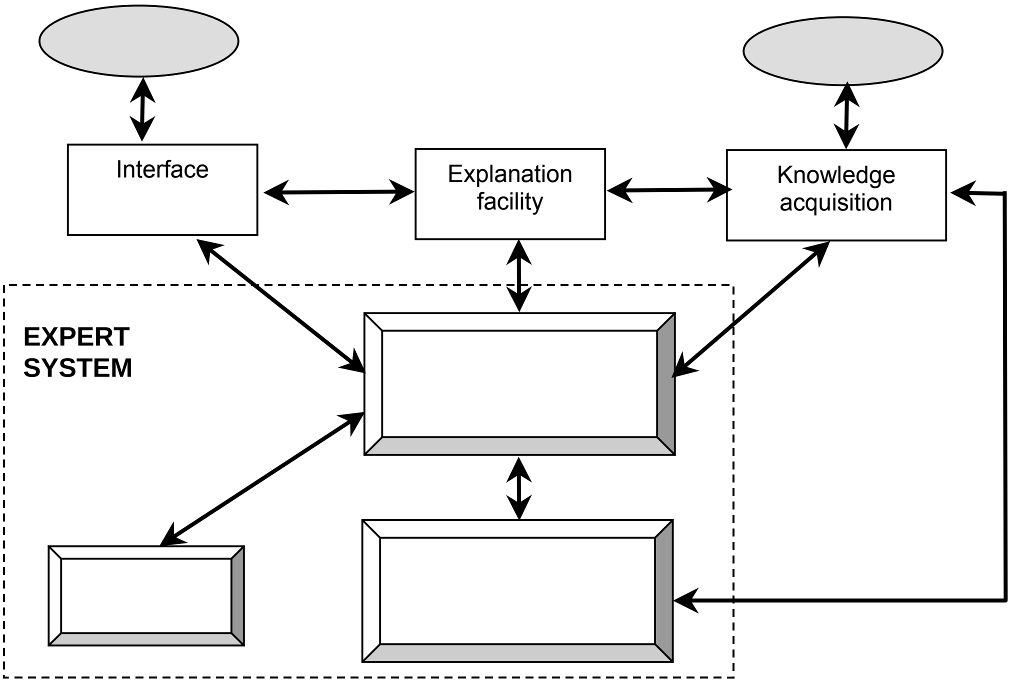

Figure 1. KBES Basic Structure (Smadi, 2000)

The expert system as such, as discussed by Smadi, includes three basic components: The knowledge base, the inference engine and the short-term memory.

The knowledge base is where all the knowledge in terms of “facts” and “rules” acquired from human expertise is stored. Smadi defines "fact" and "rule" as follows: A *fact* is simply an assertion that a relationship for a set of objects is true, while a *rule* is an assertion that some fact(s) is (are) true provided that another set of facts is true.

The inference engine is the problem-solving component of KBES. It uses the knowledge stored in the knowledge base to derive conclusions based on the data provided by the user (i.e., pavement condition, traffic) and accordingly recommends the actions to be taken, using rules based on knowledge and experience (the so-called rule of thumb methods).

The short-term memory is the component of KBES that attempts to fully simulate the capability of the human expert itself. Relatively new facts used to solve previous problem may be retained by the system constituting what is called by short-term memory. This may be used when similar information or a problem is thereafter given to the KBES for solution.

As indicated in Figure 1, there are three additional components, which make the system more interactive and user-friendly, and these are: Interface; knowledge acquisition; and explanation facility. Through these components the user has the facility to access the knowledge from the source and therefore build knowledge, as applied by the system.

The general PMS analytical procedure is shown in Figure 2, which illustrates the function of the three analytical models and how they interact to form a comprehensive PMS. As indicated in the Figure, three relevant questions are regarded to be the departure points setting the role of a PMS, namely:

- How is the road network? (INFORMATION)
- What needs to be done to improve the road network condition? (REQUIRED ACTIONS)
- How much money is available? (RESOURCE CONSTRAINTS)

The answers to these three questions are pertinent and serve as the basis for pavement management, with the view to delivering the needs related to the provision and maintenance of the road network.

The Condition Forecasting Model (CFM), also known as the Pavement Deterioration Model (PDM), is developed knowing pavement characteristics. Historical data of pavement characteristics are important for refining these models, which allow future pavement condition to be estimated for planning purposes. Based on forecasted future pavement condition and applicable maintenance/ rehabilitation policies, the technically viable options can be selected through the Treatment Selection Model (TSM). The selected treatments for each section are then evaluated by the Optimisation and Resource Allocation Model (O&RAM) through an optimisation process, taking into account constraints of funds and others resources, from which, the output will be a list of proposed projects. In this procedure, ES is used to develop PDM and TSM, while the dynamic programming (DP) technique is used to develop the O&RAM.

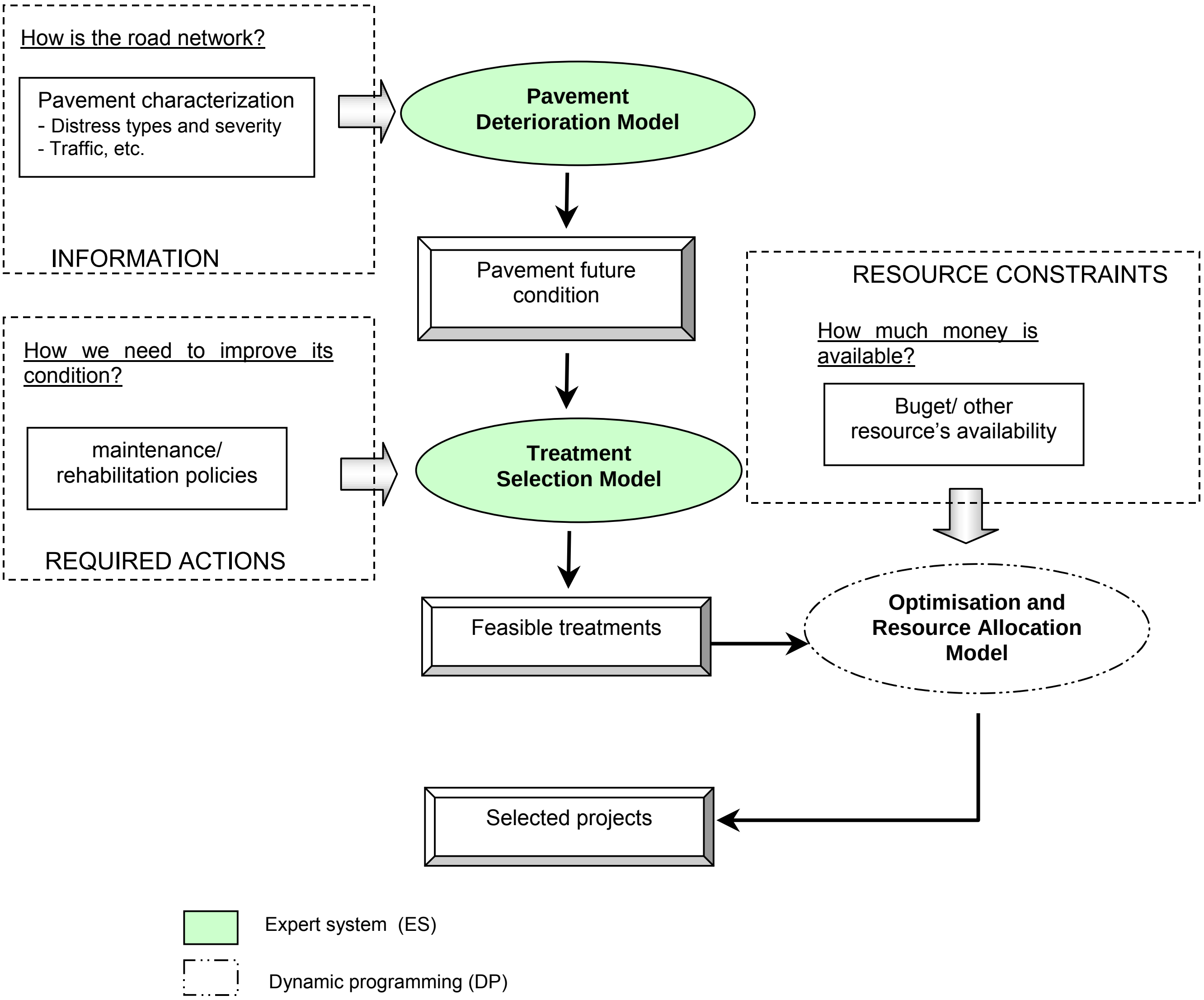

Figure 2. Pavement Management System analytical procedure (*Adapted from* Smadi, 2000)

CONDITION SURVEY AND DATA ANALYSIS

Condition survey

The proposed method employs visual assessment as the main source of the pavement condition survey. Pavement distresses are classified using the *degree* and *extent* classification system, according to TMH9 (1990). The "degree" of a certain distress is a measure of its severity throughout the section of the pavement under investigation, and is indicated by numbers on a *0* to *5* scale (*0* indicating non-visible distress, and *5* - severe condition). The "extent" of distress gives an indication of how widespread the distress is throughout the section of pavement under investigation. Numbers on a *1* to *5* scale are used to define extent, *1* indicating an isolated occurrence, and *5* persistent occurrence of distress.

In Table 1, the pavement distress types included in the analysis are presented.

Table 1. Pavement distress types

Category	**Distress type**
Structural	▪ Cracks (block cracks, crocodile cracking, other cracks) ▪ Deformation (rutting, undulations) ▪ Disintegration (aggregate loss, potholes, patches, edge break)
Functional	▪ Riding quality ▪ Bleeding ▪ Surface drainage ▪ Shoulder condition

The first distress category (structural category) comprises of distresses that are either indicative of structural problems within the pavement or represent a potential for originating these problems, depending upon the degree and manifested characteristics. The functional aspects include, in general, distress types that directly affect the road users, and are comfort and safety related.

The description of degree and extent should be given for each distress, and serves as a guide during the field assessment. The field guide also includes pictures showing the manifestation of different distress types, with an indication of how the condition should be rated in each case.

Data analysis of pavement condition

To process the condition data, the proposed method is based on the modified visual condition index calculation method (TRH22, 1994). Using the visual inspection as the only source of data, the method is applied to determine the Pavement Condition Index (PCI).

The PCI gives the combined effect of various distresses on the general pavement condition. Each distress is assigned a weight factor which represents its influence on the overall pavement condition, and can be adjusted accordingly, depending on the relative importance of distresses as perceived by the user (road authority). Taking into account the individual distress rating (defined by a degree and extent) and the weight factors of each distress, the PCI is calculated. The PCI ranges from *0* to *100*, *0* indicating severely damaged pavements, and *100* pavements in excellent condition. Table 2 shows an example of criteria for pavement classification, based on its condition (Camba, 2001).

Table 2. Pavement condition classification (Camba, 2001)

Condition	Pavement Condition Index (PCI)
Very good	PCI > 90
Good	75 < PCI ≤ 90
Fair	55 < PCI ≤ 75
Poor	35 < PCI ≤ 55
Very poor	PCI ≤ 35

The PCI concept plays an important role. As will be discussed later, the determination of maintenance needs is based on forecasted PCI-values during the analysis period.

ANALYTICAL MODELS

Three basic analytical models are used in the development of pavement management systems. These are the Pavement Deterioration Model (PDM-KBES), Treatment Selection Model (TSM-KBES), and Optimisation and Resource Allocation Model (O&RAM-DP). These models interact to form a comprehensive pavement management system that provides the basis for the systematic and consistent management of the pavement network (Smadi, 2000). This section discusses the development of these models, using the KBES and DP techniques. Whereas the KBES is used to develop both the pavement deterioration and treatment selection models, the DP technique is used to develop the optimisation and resource allocation model.

Pavement Deterioration Model (PDM-KBES)

The rate of deterioration and the nature of changes in the pavement condition need to be predicted so that the timing, type, and the costs of maintenance during the planning period can be estimated. The Pavement Deterioration Model, also termed Condition Forecasting or Pavement Performance Model, is therefore a key component of the analysis supporting decision making in pavement management.

Performance models are generally developed for different pavement behaviour categories based on the pavement types. This requires that comprehensive information on actual pavement structures be available for use in the development and application of the models.

In the absence of data about the structural characteristics of the underlying layers, performance or condition-forecasting models (PCI versus pavement age) were developed based on the surface type, relying upon the KBES concept. It should be noted that to try and get accurate data about pavement composition through testing, in spite of the large investment that would be required, would be of little value in Mozambique. This is because historical data on the performance of the various pavements is also not available. The characterisation of the materials through testing is only justifiable if provision is also made to study the performance of the materials, so that performance models can be developed for different families of materials or pavement types, under local conditions.

In Mozambique, most of the rural roads are made of granular material basecourses (untreated soils) and, in some cases, cement-treated basecourses. The limited range of basecourse materials used in the construction of roads countrywide allows for performance modelling to be developed with no regard to underlying pavement characteristics and surface type can be used as the basis for deriving performance models.

An example of the derivation of deterioration models based on surfacing type is discussed by van Heerden *et al* (1994).

Equation 1 provides the general formula of the PDM-KBES (Camba, 2001).

$$PCI\ (t) = 100 + c^*(1 - a^{\beta t}) \tag{1}$$

Where: PCI (t) – Pavement Condition Index at age “t”
t – Pavement nominal age (in years) associated to pavement condition PCI (t)
a – Constant defined by the surface type and traffic
c – Constant defined by the surface type (controlling the deterioration rate)
β – Adjustment factor for the climatic conditions

The nominal age of a certain pavement section is the age associated with its condition (described by the PCI), and does not necessarily reflect the pavement’s absolute age. This principle, therefore, indirectly takes into account the construction quality inasmuch as this is reflected by pavement condition over time.

The constants of the model were determined for four different surfacing types including Slurry Seal (SLS), Single Surface Treatment (SS), Double Surface Treatment (DS) and Asphalt Concrete (AC). The constants were determined in such a way that surfacing lives predicted by the models, at the different traffic levels, could be compared with typical lives published in the literature, and adjusted as necessary to reflect the Mozambican conditions. In this procedure, pavement life is defined as the period from newly constructed or maintained/rehabilitated pavement until it achieves a PCI of 55. The PCI value of 55 represents the condition at which it is assumed that rehabilitation of the pavement should be one of the options to consider in order to restore the pavement to an acceptable level of service.

Another important consideration, with regard to the condition-forecasting models, refers to the modelling of the response of the pavement to an intervention made on the road. Figure 3, shows the basic concept of the effect of an all-area type of intervention on immediate condition and future performance of the pavement (Camba, 2001). Such interventions include resealing, asphalt overlays and other operations covering the entire carriageway width, and exclude routine maintenance operations, which are localised in nature.

Figure 3 suggests that regardless of the time of intervention (which can be associated with a certain pavement condition described by its PCI-value), the PCI is improved to maximum. This is a reasonable assumption if one takes into account that after an all-area type of intervention (such as reseal, overlay or reconstruction), visible distresses at the surface, if any, will be minimal (assuming no construction faults). Also illustrated in Figure 3, is the impact of the time of intervention on the future pavement performance. From a certain point in the pavement life (defined by a certain condition), the delay in the implementation of a given treatment will impair future pavement performance due to the inability of the treatment at that stage to control the advanced degree of deterioration undergone before the intervention. At this stage, more profound interventions will be required. Through this principle, one can distinguish the impact of the various maintenance strategies on pavement performance, which then allows the trade-off of available options in terms economic viability to be made.

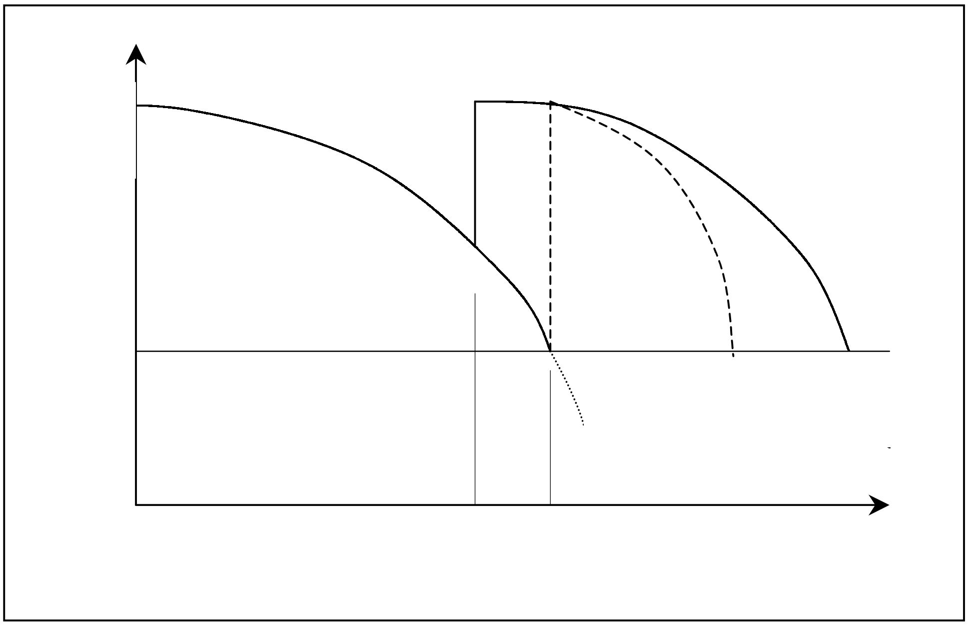

Figure 3. Conceptual effect of an all-area type of intervention on immediate condition and future pavement performance (Camba, 2001)

Pavement deterioration knowledge base and inference engine

The knowledge base stores the facts and rules that relate to the influence of surfacing type, traffic and climatic characteristics on the pavement behaviour. Given a certain problem to solve, the model will apply the facts and rules (IF this fact is true THEN) to derive the solution to the problem, using its inference engine. Generally in a pavement management system a problem to be solved by the condition-forecasting model is what the condition of the various road segments within the network will be after a defined period of time, given their current conditions.

Treatment Selection model (TSM)

The treatment selection model is used in pavement management to select the applicable remedial measures given a certain condition of road segments throughout the network. Such a model is no more than a set of logical predefined criteria to meet performance requirements with regard to road condition.

The TSM uses the ES principle for selecting maintenance strategies based on forecasted PCI throughout the analysis period. Figure 4 shows the definition of trigger limits for identifying sections possibly requiring maintenance, as applied by the TSM (Camba, 2001).

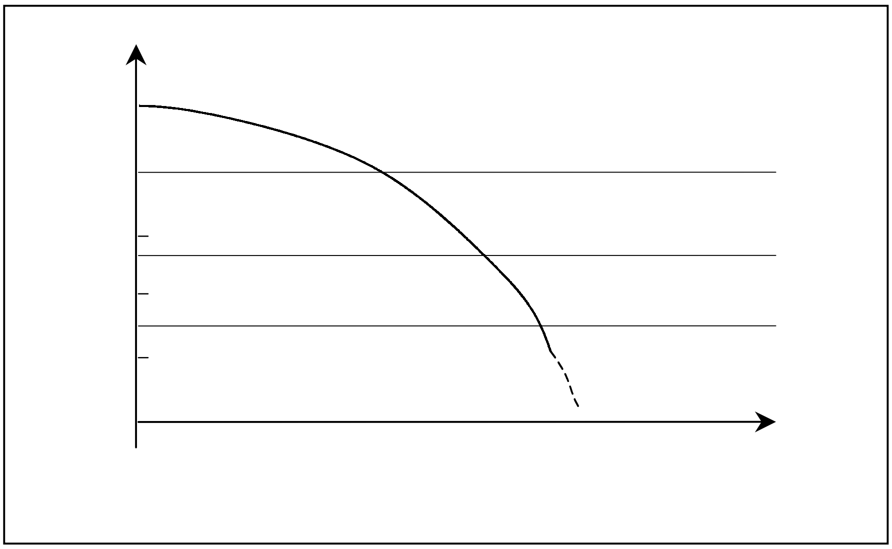

Figure 4. Trigger limits for measure category selection (Camba, 2001)

When the PCI achieves a certain limit, maintenance strategies belonging to the category associated with that limit become potential candidates for implementation. With reference to Figure 4, a pavement with a PCI of 70 will have as options periodic maintenance (resealing works) and "do-nothing", the last taken as base option. Pavements with lower PCI values will be identified as possibly requiring rehabilitation and/or reconstruction, and options of these categories will be evaluated together with periodic maintenance options and the "do-nothing”, where these are still applicable.

The selected treatments serve as input data to the optimisation process discussed later.

Treatment selection knowledge base and inference engine

The knowledge base stores all the facts and rules relating to pavement condition and the applicable maintenance strategies. Besides the selection of treatments to be evaluated through the optimisation process, the TSM will also identify routine maintenance needs for the current year based on individual rating (degree and extent) of the relevant distress(es).

Optimisation and Resource Allocation Model (O&RAM)

The O&RAM considers the treatments selected by the TSM to determine the most economically viable alternative for each section, and finally, to establish priorities for the execution of different projects, taking into account resource constraints.

The definition of “optimum” implies prior establishment of an objective function to serve as the basis for the optimisation process. In pavement management, the objective function defines the investment strategy to be followed by the road authority. Therefore, the objective function is a physical representation of the road authority’s vision with respect to provision and maintenance of the road network and, as such, constitutes the core of the analysis required from the management system.

Worldwide, road authorities have adopted various investment strategies to prioritise road project investments. Such strategies range from those driven just for the sake of introducing changes in management of roads, for instance in order to improve the condition of a deteriorated road network, without necessarily looking at its efficiency in economic terms (e.g., fix the worst roads first), to more elaborate ones aiming at "maximising" economic returns (such as maximisation of benefits, minimisation of total transportation costs, etc.). The implications of pursuing one or another road investment strategy for road management has been well demonstrated elsewhere (Pinard et al, 1998).

The proposed method relies on maximisation of benefits, expressed in monetary terms (the savings in road user costs minus agency costs), throughout the analysis period. To realise the benefit of making trade-offs between the timing of maintenance alternatives, a multi-year analysis using a dynamic programming (DP) technique is adopted. Using the incremental benefit-cost (B/C) ratio method, the most cost-effective path of the dynamic programming decision tree (i.e., the work programme maximising the benefit) is selected for a particular road segment and thereafter the overall work programme is determined for both constrained and unconstrained budget. Whereas with a constrained budget, the budget is pre-limited to meet the availability of funds, in an unconstrained budget situation no such limit is predefined and the optimisation exercise in this case serves to determine the optimum budget level as well as the most cost-effective timing of each project.

The Total Transport Cost (TTC) associated to each maintenance strategy during the analysis period, is given by the sum of the Agency Cost (AC) and the Excess User Cost (EUC), expressed in present terms.

$$TTC = AC + EUC \qquad (2)$$

The AC comprises of the maintenance/rehabilitation costs throughout the analysis period minus the salvage value. The excess user costs are referred to as the extra user costs incurred because of deteriorated pavement beyond a certain level influencing those costs. The model of determining the EUC has been simplified to include only the vehicle types, traffic level and riding quality as variables.

SYSTEM DEVELOPMENT AND APPLICATION

A system based on the principles discussed above was developed using an EXCEL spreadsheet. The following sections outline the fieldwork undertaken to derive the database for the system, and the results obtained by its application.

Fieldwork

The fieldwork consisted of visual inspection of selected roads in Maputo and Gaza provinces, amounting to a total length of approximately 354 km. The main objectives of this study were to evaluate a portion of Mozambique road network to:

- Derive the system database;
- Study the occurrence of relevant distress types to be included in the analysis, and
- Adjust the pavement condition analysis criteria, including weight factors of distresses and PCI ranges for pavement classification.

The assessment form used during the fieldwork is presented as Appendix A.

Traffic data were obtained from the Traffic Information System (TIS) in use at the Mozambique National Roads Department, *Administração Nacional de Estradas* (ANE)

Results

Figure 5 shows the condition statistics of inspected roads, classified after taking into account the PCI discussed earlier.

About 73% of pavements in good condition are part of the National Road EN1. This means that, excluding EN1, the percentage of roads in good condition in the remaining network drops to about 46%, and the percentage of pavements in poor and very poor increases to 30%, and that of pavements in fair condition would be 25%. This result shows some advanced degree of deterioration prevailing on these roads.

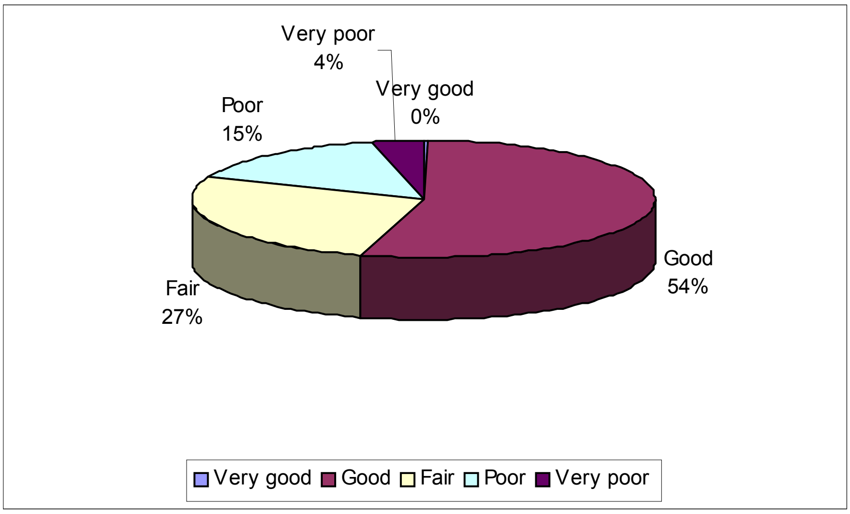

Figure 5. Pavement condition (Sub-network Maputo-Gaza)

Figure 6 presents the distribution of different distress types in warning and severe state. As shown in this Figure, most of the assessed distresses are significant (affect more than 10% of the total length). Shoulder condition is a particularly prominent distress affecting almost the whole length. Low rated riding quality due to undulations/settlement and potholes/failures is also evident.

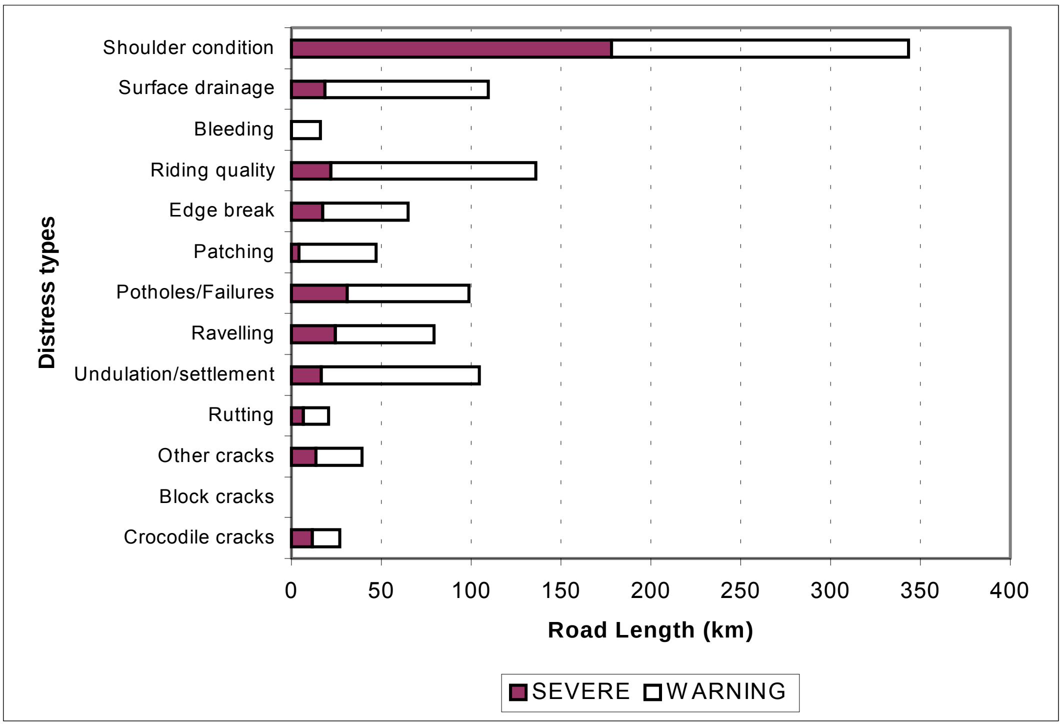

Figure 6. Distribution of significant distresses (Sub-network Maputo-Gaza)

Comparison with HDM-4 results.

The results obtained using the KBES for the sub-network, are compared to those obtained using the Word Bank package HDM-4. Table 3 shows the results obtained by the two systems for a 5–year analysis period. The results presented represent proposed work programmes subject to funds constraints, which for the purpose of this study was fixed at 10 million US dollars. The discount rate was taken as 10% and no inflation was considered.

From the analysis of Table 3, the following observations are derived:

The total amount required to implement the work programme is 9.96 million US dollars according to KBES, against 3.82 million US dollars for HDM-4. KBES uses both a user benefit and a minimum acceptable road condition. The latter may not be an economic criterion, but is essential for a large country where traffic volumes are low and the investment has to be protected. The HDM-4, by using only part of the budget (about 40%), indicates that the user costs has little impact on the total transportation cost compared to the agency costs (AC), particularly for the lightly trafficked roads. In this respect, the KBES result suggests otherwise, favouring road investments to contain the user costs and the total transportation costs. It should be noted, however, that where sections have been triggered for intervention, the remedial measure proposed by the KBES is consistent with that indicated by the HDM-4.

The condition data for input in the HDM-4 model was obtained using approximate relationships. The inaccuracies associated with the use of these relationships may affect the results obtained, and further work may warrant calibrating both pavement performance and vehicle operating cost models.

The road user cost model used in the KBES has not been tested for Mozambique. The cost constants used are based on published values in South Africa, although some adjustment was made in an attempt to reflect the Mozambican conditions. On the other hand, cost parameters of vehicle attributes as required in HDM-4 in order to determine the vehicle operating costs have not been investigated for their use in Mozambique and rough estimates of these were used.

CONCLUSIONS

The results obtained using the KBES and the HDM-4 did not fully match. Contributing to the differences in the results the following factors are identified:

- Condition data input
- Calibration required of the HDM-4 deterioration models
- Road user cost models used by the systems

Despite the discrepancies found, the reasonableness of the results obtained using the KBES shows the applicability of the principles built into the system. The annual cost for maintenance of the roads, according to the KBES, seems to be reasonable and corresponding more closely to the reality in terms of maintenance needs than what is given by the HDM-4 model.

RECOMMENDATIONS

The KBES concept is used internationally for a variety of applications. Mozambique has presently and for the immediate future a great challenge for the maintenance, improvement, and also extension of the road network. The scarcity of resources required to face these challenges calls for the rational and efficient use of available resources to try and maximise the benefits, through the use of appropriate management systems. The application of the KBES concept to develop a PMS can help to overcome the current barriers to the implementation of imported systems, removing the problem of incompatibility of available technologies for their effective use. The KBES is based on human knowledge and experience. More importantly, as more knowledge and experience is gained over time, the system can readily be improved through incorporation of the new knowledge.

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The opinions and conclusions presented in this paper are strictly those of the authors and do not necessarily represent the vision or policies of the Administração Nacional de Estradas (ANE) of Mozambique.

Table 3. Optimised Work Programme (KBES *versus* HDM-4)

		SI							HDM-4			
Road Name	**Section**	**Length (km)**	**AADT**	**PCI***	**B/C**	**Financial Cost**	**Year**	**Work Description**	**B/C**	**Financial Cost**	**Year**	**Work Description**
EN1	Lhang. Cem. - Bridge (EDM)	1.70	28020	73	415.51	0.112	2001	Reseal(DS)	1.386	0.112	2002	Reseal(DS)
EN1	Bridge (EDM)-Inhagoia	0.35	24304	72	931.36	0.009	2001	Reseal(DS)	0.852	0.009	2001	Reseal(DS)
EN1	Inhagoia-Dev. Zimpeto	12.00	15030	49	13.84	1.819	2001	Overlay(AC)	2.016	1.819	2001	Overlay(AC)
EN1	Dev. Zimpeto-Dev. Marracuene	14.00	6665	84	27.90	0.473	2001	Reseal(DS)				
EN1	Maragra+-Incoluane River	51.30	1824	82	1.48	1.431	2003	Reseal(DS)				
EN1	Incoluane River-Macia	18.50	1296	77	20.47	0.098	2002	Reseal(SLS)				
EN2	Dev. Matola Mun.-Matola River	2.70	5723	87	61.00	0.073	2003	Reseal(DS)				
EN2	Matola River - Dev. Umbel/ (Boane)	16.30	5501	65	11.61	1.518	2001	Overlay(AC)				
EN2	Dev. Umbel/ (Boane)-Moamba Junc.	4.70	5252	61	9.72	0.446	2001	Overlay(AC)				
EN2	Moamba Junction -Dev. Peq. Lib.	8.00	505	40	1.28	0.759	2001	Overlay(AC)	1.197	0.263	2001	Reseal(DS)
EN2	Dev. Peq. Lib. - Start EN5 (Impaputo)	10.70	102	61	-	0.055	2002	Reseal(SLS)				
ER565	Dev. Umbel/ (Boane)- Dev. Peq. Lib.	14.70	426	41	-	0.430	2001	Reseal(DS)	1.306	0.430	2001	Reseal(DS)
ER565	Dev. Peq. Lib.-Junction EN203 (Chang/)	14.00	107	36	0.12	1.183	2001	Overlay(AC)	0.007	1.183	2001	Overlay(AC)
ER565	Junction EN203 (Chang/) - Goba+	8.00	33	42	-	0.501	2002	Overlay(AC)				
EN5	Start EN5 (Impaputo) - Namaacha	21.10	2861	69	2.25	0.665	2001	Reseal(DS)				
EN205	Macia - Chokwe	61.00	664	71	6.11	0.244	2003	Reseal(SLS)				
ER408	Macia - Praia do Bilene	37.40	660	82	3.58	0.145	2003	Reseal(SLS)				
					Total	**9.962**			Total	**3.817**		

*Pavement Condition Index (PCI) for the year 2001

Note: All costs shown in the Table are expressed in million US dollars.

Study details:

Network: Maputo- Gaza Subnetwork

Discount rate: 10%
Planning Period 5 years
Base year 2001
Budget $ US 10,000,000.00
Run date: June 2001

APPENDIX A

MOZAMBIQUE PMS PROJECT

CONDITION ASSESSMENT

ROAD NAME		SEGMENT CODE	
LINK NAME		SEGMENT LENGTH	
CHAINAGE	km TO	ROAD WIDTH	
PROVINCE		OBSERVER	
DISTRICT		DATE	______ / ______ / 20______

STRUCTURAL ASSESSMENT

		DEGREE						EXTENT				
		SLIGHT SEVERE						ISOLATED EXTENSIVE				
☐ CRACKS (General)		0	1	2	3	4	5	1	2	3	4	5
Crocodile Cracking (CC)												
Block Cracking (BC)	(N ; M ; L)											
Other Cracking (OC)												
☐ DEFORMATION (General)												
Rutting (R)												
Undulations/settlements (U/S)												
☐ DISINTEGRATION (General)												
Ravelling or stone loss (RA)												
Potholes/ Failures (PH)												
Patches (PA)												
Edge break (EB)												

FUNCTIONAL ASSESSMENT

Riding quality (RQ) NOTE: Assessment of riding quality must be done with the vehicle running at 60 km/h		VERY GOOD	GOOD	FAIR	POOR	VERY POOR

Bleeding (BL) NOTE: Extent must be specified according to general extent classification (1 to 5)	EXTENT	SOUND	WARNING	SEVERE
Surface drainage		ADEQUATE	MODERATE	INADEQUATE
Shoulder condition (Unpaved shoulder/ verge area within 2m of the yellow line)		GOOD	FAIR	POOR

COMMENTS AND OBSERVATIONS

Figure A.1. Condition Assessment Form

THE DEVELOPMENT OF ANALYTICAL MODELS FOR A PAVEMENT MANAGEMENT SYSTEM IN MOZAMBIQUE:
A Knowledge-Based Expert System Approach

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