REQUIREMENTS OF A SUSTAINABLE PAVEMENT MANAGEMENT SYSTEM FOR TANZANIA

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Since the introduction of pavement management concepts in mid-1960s, more than three decades ago, a considerable number of Pavement Management Systems (PMS) have been developed and implemented widely in many parts of the world. These systems differ in scope and sophistication. However, in some cases, pavement management systems have fallen into marginal use, if not into complete disuse, because of a number of reasons. One of the major reasons leading to the marginalisation or abandonment of pavement management systems, is the failure of system developers to recognise specific and unique needs of the agency or authority responsible for road management. In the study presented in this paper, specific characteristics of the PMS implementing agencies in Tanzania were thoroughly investigated. As a result, appropriate and relevant PMS requirements were identified. Furthermore, a method of determining possible sustainability of a pavement management system was developed.

Keywords: *Pavement Management System; Sustainability; Developing Countries; Tanzania; Information Flow.*

INTRODUCTION

The pavement management concept dates back to the mid-1960s as a result of a major research work, which was done in North America. At the beginning, pavement management systems were used for activities such as co-ordinating improvements in design, rehabilitation, maintenance and pavement performance modelling at project level (Hudson and Hudson 1994). About a decade later these concepts had significantly evolved for use at network level in planning, programming and budgeting for entire road network of any size (RTAC 1977). However, as revealed by Hudson and Hudson (1994), these concepts met a lot of resistance in the early stages because they were not widely accepted. In fact, they did not gain any significant acceptance for about a decade after they were conceived. Since then the use of PMS has been accepted worldwide and a steady growth and development has been clearly noted. Consequently, these concepts have expanded and they are now used in other areas such as bridges, buildings, sewerage and other infrastructure management systems.

However, pavement management systems that have been introduced in many developing countries are too complicated and too demanding to be sustained (Robinson and May 1997; Jones 1988). One of the major reasons leading to this problem is the failure of system developers to recognise specific and unique needs and capacity of the implementing agency.

Tanzania is a poor country, which has been identified as having insufficient road restoration and financing capacity (Harral and Faiz 1988). In determining the requirements of a pavement management system for Tanzania, it is necessary to consider the capacity of the Tanzania Roads Agency (TANROADS) and the Ministry of Works (MoW) in terms of financial and human resources required to operate the system.

SUSTAINABILITY

In simple terms, to sustain is to support something and prevent it from collapsing. However, the term sustainability has been used in different ways by various sectors. The term has been used in the agricultural sector, economics, business, engineering, project management, etc. Unless the term sustainability is clearly defined for the context in which it is applied, it can be ambiguous.

If a system is to bring about improved pavement management performances within the organisation, certain basic considerations have to be taken into account during development and implementation. Most importantly, the implementing organisation must be capable of utilising the system in the decision making process about pavements within the scope in which it was intended. As indicated by Robinson and May (1997), this would be possible only if the organisation has necessary financial, technical, managerial capability as well as properly trained and highly motivated human resources. In addition, total top management commitment is a prerequisite for the successful implementation of a pavement management system. Sustainability in the pavement management context therefore means that there is a strong will, commitment and affordability within the organisation to maintain, operate and subsequently improve the pavement management system by using local resources and staff.

Consequently, the development and implementation of a pavement management system should consider:

a. Existing institutional arrangements and any required changes;
b. The relevance and need for management information produced;
c. The capability of the agency to collect the required data and keep them current;
d. Knowledge and computer skills available within the agency (if a computerised system is adopted);
e. Technical knowledge required to operate and subsequently improve the system if and when the need arises; and
f. Staff training programmes in the area of pavement management.

REQUIREMENTS AND SCOPE OF THE SYSTEM

It should be stressed that the first step towards successful implementation of a road management system is to obtain a firm commitment from people empowered within the organisation (TRL, 1998). This can be accomplished by involving them in deciding the objectives, requirements and the scope of the system. To give more confidence, the system developer should be able to show the administration within the road sector that the system can provide them with the information they need.

Consequently, to ensure the sustainability of the proposed PMS in Tanzania, system requirements were determined such that TANROADS/MoW are able to maintain and operate the system using local resources at affordable cost. At the same time, it was recognised that the system should produce realistic and technically feasible solutions within available resources. To meet this goal, the potential users were consulted in order to determine their specific requirements and the outputs expected from a computerised pavement management system.

METHODS USED TO DETERMINE SPECIFIC PMS REQUIREMENTS

During the study it was necessary to first consult the staff in the organisation and establish whether there was a need to introduce a computer based road management system. The study aimed at determining the attitude of individuals towards the implementation of a computer based system and identifying activities, which should be carried out. Talking to individual staff in the form of interviews was the first step towards identifying specific PMS requirements. Individuals working with TANROADS and MoW were met in order to have general views on the concept of introducing a computerised road management system and float an idea of distributing a questionnaire. These interviews were followed by a questionnaire that was distributed to a number of professional staff, including top management, in TANROADS and MoW. Finally, the questionnaire results were supplemented with group discussions. Group discussions involved TANROADS and MoW personnel dealing directly with planning and implementing road maintenance programmes. These discussions aimed at identifying areas that should be given top priority during the development and implementation of a computer based road management system.

During the study, issues were grouped into three different categories as follows:

a. Questions of general nature whose answers did not depend on the views of the individuals in the organisation;
b. Questions seeking views and opinions of individuals in the organisation; and
c. Questions directed to higher authorities in the organisation.

Box 1 elaborates on the types of questions used in the study.

INFORMATION FLOW PATTERN

Apart from having well defined objectives, effective management requires appropriate and up to date information to support management decisions in a co-ordinated and consistent manner so that cost effective solutions are reached. Invariably, communication within the agency is one of the most important aspects for the effective implementation of a Pavement Management System. Appropriate information is required at all levels of highway management from planning, programming, preparation and for day-to-day activities at operational level (Robinson et al 1998). Furthermore, factual information is required to determine the success and failures of these decisions. This feedback cycle provides the means of evaluating previously made decisions and gives the basis for improvement, modification or even rejection of the proposed management scheme (Zaniewski et al 1990).

For instance, the levels at which information regarding maintenance of trunk roads flows in ascending order, include Regional Trunk Road Engineer, Regional Manager, Zonal Director, Director of Maintenance, Chief Executive (TANROADS) and finally the Road Fund Manager and Permanent Secretary (MoW). This upward flow of information involves either raw or processed data as inputs while the reverse (downward) movement includes policies and funds as outputs of the whole process. In essence, this is an ongoing and open-ended maintenance management process, which requires engineering and business management skills (Robinson et al 1998).

The study presented here identified the type of information and its flow pattern within different levels of TANROADS organisational structure. The type of information and its flow pattern from the Regional Maintenance Engineers (TANROADS) to the Road Fund Board and the Permanent Secretary (MoW), as well as the reverse information flow pattern, is presented in Figure 1.

From the questionnaire results, the responses to the three types of questions are as shown in Tables 1, 2 and 3 for type 1, type 2 and type 3 questions respectively.

Furthermore, group discussions focused on setting up priorities during the development and implementation of a computer based road management system. It was recognised during the discussions that staging the implementation of the system would be a better option rather than going for a 'big bang'. It was agreed that questionnaire results should be examined to determine the items that could provide a starting point. Furthermore, it was also recognised during the group discussions that an effective PMS should be able to address the objectives of the organisation. Consequently, the issue of policy objectives of TANROADS, identified in type 1 questions, was used to propose some of the requirements of a PMS.

Box 1 Types of questions used in the study

Type 1 questions

Questions of general nature whose answers did not depend on the views of any individual in the organisation. The responses to these questions were not expected to differ from one person to another. This was the type of questions seeking information on issues such as:

a. Policy objectives of the organisation;
b. Organisational structure of TANROADS and MoW;
c. Information flow pattern within the organisation;
d. Data normally collected by the road organisations in Tanzania, etc

Type 2 questions

Questions depending on views and opinions of the individuals in the organisations. For this type of questions, all 19 respondents were asked to give their personal opinions.

This type of questions included issues such as:

a. The need of having a computerised road management system;
b. Problems of road maintenance in Tanzania,
c. Objectives of a computerised road management system;
d. Outputs one would require from a computerised road management system;
e. Experience of using consultants for data collection;
f. The proposal for sources of funds for system implementation;
g. Adequacy of data normally collected by the organisation.

Type 3 questions

Questions directed to higher authorities in the organisations. These include people in the organisations who could make decisions on the amount of money that can be made available for system implementation. Only 5 out of 19 respondents were in such a position. These respondents include:

a. Chief Executive (TANROADS);
b. Director of Maintenance (TANROADS);
c. Zonal Director (TANROADS);
d. Director of Trunk Roads (MoW); and
e. Director of Rural Roads (MoW).

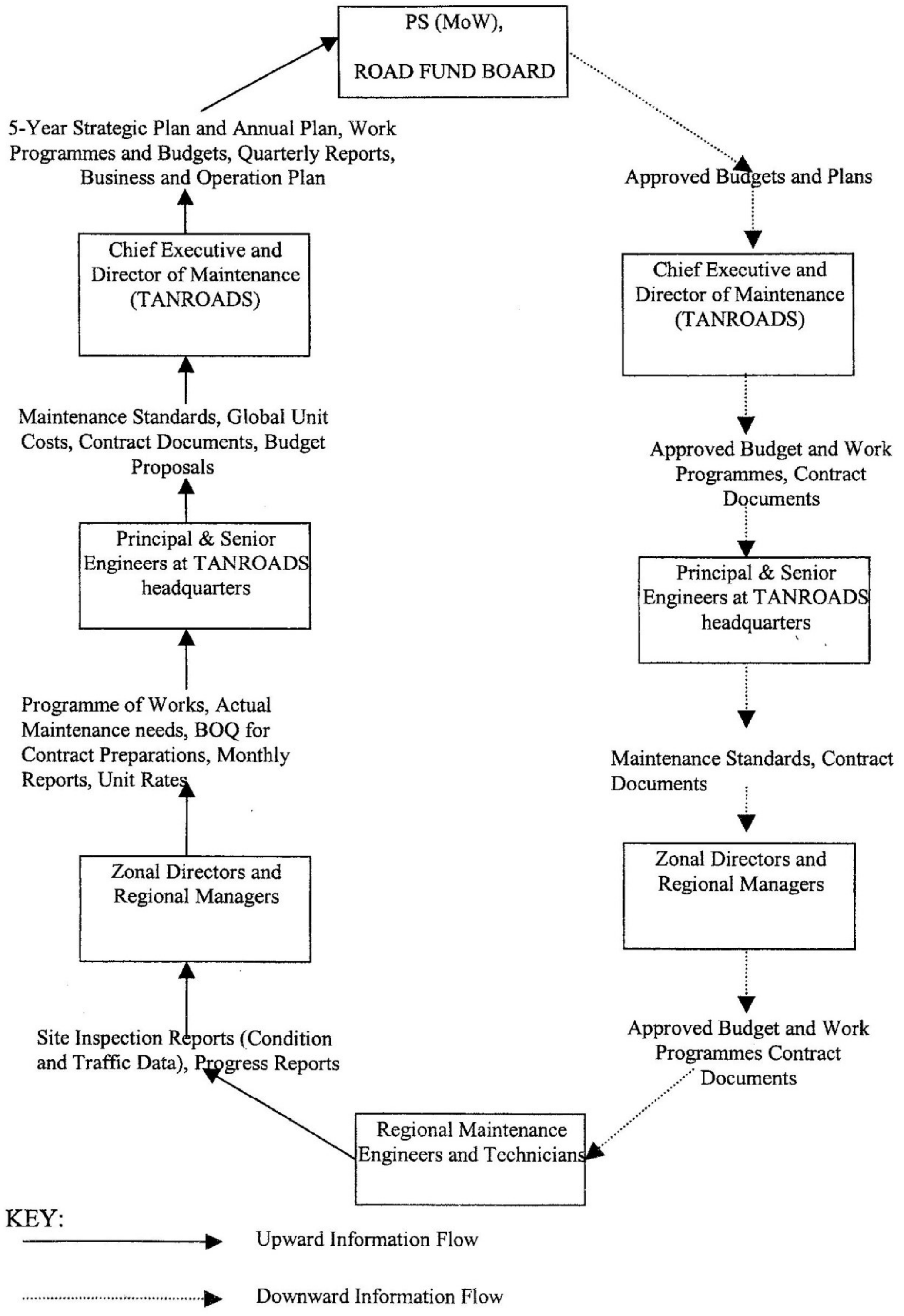

Figure 1. Information Flow Diagram – Trunk Roads Division (MoW/TANROADS)

From the questionnaire results, it is evident that issues identified by most respondents for type 2 questions address programming and planning management functions. Consequently, one of the key outputs from group discussions was the consensus that the organisations' priority need at the moment is a network level road management system. Issues such as preparing bills of quantities and contract documents, design of overlays, pavement and geometric design were identified by only 5.3% of the respondents. Similarly, only 10.5% of the respondents said that the system should deal with keeping and updating bridge condition data.

It was therefore decided that, as a starting point, system requirements should be determined to address issues that were identified by most respondents. For type 2 questions, the issues considered in this study were proposed by between 68.4 and 100% of the respondents. Box 2 presents the PMS requirements as solutions to identified issues/problems.

Table 1. Responses to Type 1 Questions

S/N	Question	Answer
1	What are the policy objectives of your organisation? (TANROADS)	Provide cost-effective and sustainable road maintenance and development of trunk and regional roads totalling about 35,000 km
2	Levels of Management in TANROADS	As presented in Figure 1
3	Information Flow Pattern in the Organisation	As presented in Figure 1
4	Data Normally Collected by the organisation	a. Traffic Counts (annually on selected sections) b. Roughness measurements (occasionally) c. Road condition (occasionally) d. Bridge inventory and condition (occasionally) e. Axle load measurements (occasionally)

Responses to type 3 questions indicated that between 2 and 5% of the annual budget for road maintenance could be made available for the implementation of a road management system. Furthermore, 80% of the respondents proposed that between 4 and 5% of the annual budget could be used for the implementation of the system.

On the other hand, the percentages of the annual budget, which could be made available for data collection, ranged from 1-3. The percentages ranging from 2-3 were proposed by 60% of the respondents.

Apart from the issues presented in Box 2, it was also proposed from the questionnaire that the budget for system implementation should come from the annual budget allocated to road maintenance and rehabilitation. However, it will be noted that the answers to some of the issues did not provide enough information to make any meaningful conclusions. For example, the issue on the use of consultants for data collection in Tanzania does not seem to have received sufficient response.

Table 2. Questionnaire Results for Type 2 Questions

S/N	Question	Answer	No. of Respondents	% of All Respondents
1	In your opinion is a computer-based road management system needed by your organisation?	Yes	18	94.7
		No	1	5.3
2	Problems of road maintenance in Tanzania	a. Inadequate maintenance funds	All	100
		b. Lack of systematic and consistent approach to the preparation of road maintenance programmes	17	89.5
3	Objectives of a computer-based road management system	a. Provide a data bank for road maintenance planning and programming, including the storage of inventory and network condition	15	78.9
		b. Identify maintenance needs of the road network	18	94.7
		c. Provide a rational way of fund allocation	16	84.2
		d. Capable of designing overlays	1	5.3
		e. Prepare bills of quantities	1	5.3
		f. Prepare contract documents	1	5.3
		g. Road pavement and geometric design	1	5.3
		h. Keeping/updating bridge condition data	2	10.5
4	Outputs required from a Road Management System	a. Five year rolling work programme	18	94.7
		b. Long-term budget forecasts and network condition prediction	13	68.4
		c. Overlay thickness	1	5.3
		d. Bills of quantities	1	5.3
		e. Contract documents	1	5.3
		f. Budget allocation by region	15	78.9
5	Experience of using consultants for data collection	a. Lengthy and bureaucratic procurement process	2	10.5
		b. Short execution time	2	10.5
		c. High Cost (magnitude not revealed)	2	10.5
		d. Sometimes inaccurate data	1	5.3
		e. Produce good results	2	10.5
6	Should the cost of implementing a computerised system come from road maintenance budget?	Yes	16	84.2
		No	1	5.3
7	What would be alternative sources of funds for the implementation of a road management system	Donor agencies	1	5.3
8	Is the data collected normally adequate, inadequate or excessive?	Adequate	8	42.1
		Inadequate	9	47.4
		Excessive	2	10.5

Table 3. Responses to Type 3 Questions

S/N	Question	Answer (%)	No of Respondents	% of All respondents*
1	Percentage of road maintenance budget which can be made available for system implementation	2 – 3	1	20
		3 – 4	0	0
		4 – 5	4	80
		> 5	0	0
2	What would be the percentage of road maintenance budget, which can be made available for data collection?	0-1	0	0
		1-2	2	40
		2-3	3	60
		>3	0	0

***The total number of respondents is five (people in higher authority who were in a position to answer the questions).**

Box 2 Relating Identified Issues With PMS Requirements

Attitude of individuals towards a computerised road management system

18 out of 19 respondents agree that there is an urgent need of introducing a proper and effective computerised road management system

The response to this issue indicates that, generally, there is a consensus within the organisation that the development and implementation of a computerised road management system should be in the priority list.

Policy objectives of TANROADS

The main objective of TANROADS was stated as to:
Provide cost-effective and sustainable road maintenance and development of trunk and regional roads totalling about 35,000 km.

To facilitate towards meeting this objective, the system must be designed so that it is capable of identifying cost-effective road maintenance programmes as well as specifying sustainable methods of system implementation. The system should be able to determine work programmes that will give maximum returns for the money spent.

Problems of road maintenance in Tanzania

The following were identified as problems facing the road maintenance agency in Tanzania:

a. *Inadequate maintenance funds for road maintenance;*
b. *Lack of systematic and consistent approach to the preparation of road maintenance programmes,*
c. *Accumulation of backlog maintenance*
d. *Untimely maintenance*

The main problem in road maintenance was due to inadequate funds for maintenance. The problem is exacerbated by the lack of methods of prioritising maintenance activities under budget constraints. This situation results into improper selection of roads to be maintained and, as a result, there is accumulation of backlog maintenance. These problems dictate that a system is needed which will identify the activities that could be carried out under budget constraints.

Box 2 (continued)

Objectives of a road management system

The objectives of implementing a computer-based road management system, as specified by the potential users, are to:

a. *Provide a data bank for road maintenance planning and programming, including the storage of inventory and network condition;*
b. *Identify maintenance needs (budget requirements) of the road network;*
c. *Prepare a rolling work programme;*
d. *Provide a rational way of fund allocation.*

The identified objectives of a computerised road management system show that a network level (programming) system should be implemented in order to:

a. Store pertinent information for all sections of the entire trunk and regional road network. This task requires a comprehensive database management system. The historical data stored in the database provide feedback and documentation of consequences (success or failure) of road management decisions made at various levels. In addition, the historical data provide relevant information for future systematic evaluation and research in the area of road management in the country;
b. Process data and assess pavement condition section by section over a specified period of time. For rolling works programmes, a five year analysis period was selected in line with most development programmes in the country;
c. Identify suitable yearly treatment for each section according to predetermined maintenance standards;
d. Determine the required budget for maintenance and rehabilitation of trunk and regional roads region by region and hence total budget required;
e. Prepare optimised budget that will show budget allocation region by region.

Outputs required from a Road Management System

Respondents proposed that the outputs from the system to be implemented should include:

a. *Five year rolling work programme;*
b. *Long-term budget forecasts and network condition prediction;*
c. *Budget allocation by region.*

The outputs required, as proposed from the questionnaire, are consistent with what have been identified earlier. The only additional item proposed here was that the system should be capable of producing long-term budget forecasts and condition prediction for the entire road network.

It is widely accepted that the use of consultants/contractors, under competitive environment, results into greater efficiency and effectiveness (TRL 1998; Robinson et al 1998). However, the response from the questionnaire respondents clearly indicates that Tanzania lacks experience on the use of consultants/contractor for data collection. The maximum response to this issue was as low as 10.5% of the respondents. As a result, the information obtained from the questionnaire as well as from group discussions was not conclusive. For example, 2 respondents say that the costs of hiring consultants for data collection are very high. However, the magnitude of these costs was not revealed. At the same time, the costs of doing things in-house have not been well documented in Tanzania. In fact, if all cost components are taken into account, for both in-house and contract works, doing things in-house can be slightly costly than contracting the work to external contractors. This fact was revealed from the study done in Kenya, the study that indicated that there was a saving of about 10% when works are contracted out (Robinson et al 1998).

There is a general consensus, within the Ministry of Works and TANROADS, that there is a need for better and more rational methods of programming and budgeting for road works.

The preceding discussion clearly shows that the Ministry of Works and TANROADS urgently need an efficient and effective system of using meagre resources available for pavement maintenance and rehabilitation. Indeed, the major problem currently facing the road management organisations is lack of decision-making tools for short, medium and long term planning, which would result into optimal resource allocation. This calls for an urgent development and implementation of a proper network level pavement management system.

INSTITUTIONAL REQUIREMENTS

Institutional arrangements play a very big role in the success or failure of pavement management system implementation. This fact has been recognised by all key players in the Ministry of Works (MoW). The Management Action Group, a unit which was formed to initiate institutional reforms, was also responsible for co-ordination of development and implementation of management systems in the MoW. These responsibilities have been taken over by TANROADS. Although the Agency has recruited qualified personnel, relevant and open-ended training in the area of road management is necessary. For the sustainability of the system, it is advisable to avoid unnecessary transfers of the staff from TRANROADS. It is hoped that this agency will be responsible for updating and modifying the system as the need arises.

Administratively, the system should restrict user access to avoid unauthorised data manipulation. In addition, for accountability purposes, the system should compare actual work performed against the work planned for the allocated budget.

COMPUTER REQUIREMENTS

Pavement management systems do not necessarily require the use of computer software and hardware. Manual methods could be used especially for small networks. However, the concept of implementing a manual PMS is inconceivable in this era of computer proliferation, especially for large networks (Haas et al 1994). Although manual methods can be implemented, they are not time efficient. The computer is a valuable tool for data storage, processing, analysis and reporting. However, it should be kept in mind that the purpose of computer-based systems is to support individuals involved in the management process and not vice versa (Robinson et al 1998).

Computer Software

One of the important tasks of a PMS is to store pertinent information for all sections of the entire trunk road network in the country. It therefore requires a comprehensive database management system. A system built around PC database software that provides a powerful fourth-generation language capability was selected. Before the decision was made, leading database management systems were considered, these include FoxPro, Paradox, MS Access and Visual Basic.

Out of the above, MS Access database management system was selected. The package is powerful and easy to use and hence most suitable for end users. Less learning is necessary before becoming productive (Whitehorn 1996). Again, this decision was made considering the sustainability of the system, which will be used by non-developers. For programming and development environment, Access contains a full programming language called Access Basic Code. This is very similar to Visual Basic in both feel and syntax, and it is used much in the same way.

Computer Hardware

When planning the development and implementation of a computerised management system, the choice of hardware on which the system will run has to be made. In this case, systems like local area network (LAN) or UNIX are not recommended because of skills required for operation and maintenance of these systems. Instead, a system based on stand-alone microcomputers was considered as a starting point because of the availability of skills for hardware operation and maintenance, in addition to the relatively low initial cost.

DATA ACQUISITION

Data acquisition is one of the most expensive components of Pavement Management System (Smith and Fallaha 1992). The component consumes a lot of resources in terms of time and money. Naturally, funds used to collect data would no longer be available for pavement maintenance. Excessive data collection is one of the problems causing pavement management systems to fail or to be discontinued (Smith and Fallaha 1992). To avoid this particular problem, Mushule (2002) presented a data scheme that was designed in such a way that only the absolute minimum data necessary to provide the required management information is collected for the proposed network level PMS for Tanzania. This allows the PMS to be implemented at a low initial cost. This data scheme was designed on the basis that a good pavement should provide adequate riding comfort to road users, require less maintenance, provide adequate structural support to traffic loading and have adequate skid resistance for safety purposes. Consequently, the scheme included roughness measurements, surface distress assessment, pavement structural evaluation and skid resistance assessment.

SELECTION OF PMS SUPPORT SOFTWARE

Following a review of universally applicable pavement performance models, a major international study was conducted that resulted in the development of the Highway Development and Management tool (HDM-4) (Watanatada et al 1987). This is based on the well-researched HDM-III model developed by the World Bank (Kerali 2000). Both tools comprise pavement performance prediction models and vehicle operating cost models formulated using structured mechanistic-empirical principles. This modelling approach provides significant flexibility for adaptation thereby permitting the tools to be utilised across a wide range of environments with suitable calibration.

The feasibility of using HDM-4 as a decision support system within the PMS for Tanzania was evaluated using the following criteria:

a. The ability of HDM-4 to produce outputs required by MoW/TANROADS;
b. Data requirement by the software;
c. Calibration requirements;
d. Data interchange with the PMS database;
e. Future maintenance and upgrade of the software.

The evaluation based on the above criteria indicated that HDM-4 is an appropriate tool that can be calibrated to provide the pavement management information for the MoW in Tanzania (Mushule 2002).

PAVEMENT MANAGEMENT SYSTEM SUSTAINABILITY ASSESSMENT

As discussed previously, sustainability in the pavement management context means that there is a strong commitment, capacity and affordability within the organisation to maintain, operate and subsequently improve the pavement management system by using local resources and staff. In this study, a method of assessing possible sustainability of a PMS was developed. The main considerations in this method were the key factors that make a PMS sustainable. It was considered that in order for the road agency to continue using the introduced system, the following requirements should be met:

a. The system should be capable of producing management information needed by the agency;
b. The knowledge and skills of operating and maintaining the PMS support software should be readily available to the agency;
c. The knowledge and skills needed to operate and maintain the computer hardware on which the system is run should be available to the agency; and
d. The agency should afford to collect the required data and keep them current.

These aspects should be assessed based on the quality and usefulness of the system outputs, resources needed to collect the required data and the level of expertise required to operate and maintain the system.

Consequently, questions which address these factors were formulated as a checklist. This checklist, presented in Table 4, has been designed to enable practitioners to determine whether a PMS is possibly sustainable or not.
In this method some questions have been assigned subscripts (a) and (b). These parts of a question complement each other. In most cases, with the exception of question 2, parts that address the local sustainability aspect have been assigned subscript (a). Those parts requiring some external inputs have been assigned subscript (b). For such questions, it is assumed that if local resources are not adequate for a specified system aspect, unless the external assistance is guaranteed, it is likely that the system will not be sustainable. More often, long-term external assistance will not be guaranteed and should not therefore be considered reliable.

Practitioners should be able to evaluate a PMS by responding to all the checklist questions. The answer to any question can either be YES, NO or PARTLY. Subsequently, the initial sustainability of the system should be assessed according to the rules presented in Table 5.

Table 4. Pavement Management System Sustainability Assessment

SYSTEM ASPECT	CHECK LIST QUESTIONS OF KEY SUSTAINABILITY FACTORS	YES	PARTLY	NO
MANAGEMENT INFORMATION	**Does the system:**			
	1. Provide all of the management information required by the road agency?	√		
	2a. Produce reports relevant to the user requirements?		√	
	2b. Produce sufficient output information to give reports required by different levels of management?	√		
INFORMATION UTILISATION	**3** Can the information produced by the system be fully utilised in the decision making process	√		
DATA ACQUISITION	**Equipment**			
	4a. Is the required equipment available?	√		
	4b. Is the cost of new equipment affordable?	N/A		
	5. Is the expertise required to operate the equipment locally available or easily attainable?	√		
	6a. Can the maintenance of the equipment be done locally?	√		
	6b. Can the required foreign expertise be affordable?	N/A		
	Data Collection			
	7. Is the cost of collecting the required data (and keeping them current) within the means of the agency?	√		
	8. Are all of the data collected used to obtain management information?	√		
	9. Is the intensity of data collection appropriate for the required Information Quality Level (IQL)?	√		
	Human Resources			
	10. Can the agency afford the human resources required to collect the data within the specified time frame?	√		
PMS SUPPORT SOFTWARE	**11**. Is the acquisition cost within means of the implementing agency?	√		
	12. Are operational skills locally available or easily attainable?	√		
	13a. Can maintenance of the software be done locally?		√	
	13b. Can any required external technical support be easily procured?	√		
COMPUTER HARDWARE	**14**. Is the acquisition cost affordable by the agency?	√		
	15. Are maintenance skills locally available or easily attainable?	√		
Comments:	**The system passes the initial sustainability test in all aspects. Based on this, the system is possibly sustainable. Therefore, no revisions required.**			

Table 5. Rules for PMS Initial Sustainability Assessment

Rule No	Descriptions
1	If the answer to part (a) is YES then part (b) of the same question would not be applicable.
2	If the answer to part (a) is NO or PARTLY and that to part (b) of the same question is YES then the system passes that particular aspect.
3	If the answer to part (a) is NO or PARTLY and that to part (b) of the same question is NO or PARTLY then the system fails that particular aspect.
4	If the answer to any other question is NO or PARTLY then the system fails that particular aspect.
5	Failure of the system in any one aspect means that the system is not recommended for implementation.
6	If a system passes the initial sustainability test in all aspects, then it should be considered for implementation.

It is important to mention that after the assessment of the system, if a PMS fails the sustainability test, recommendations on whether the system can be revised, in order to make it implementable, should be given. These rules have been used to assess the proposed PMS for Tanzania as presented in Table 4 (Mushule 2002).

DISCUSSION AND CONCLUSIONS

There are several options of introducing a pavement management system in a road agency. These are (Haas 1998; Robinson et al 1998):

- Importing a commercially available system developed elsewhere and using it as it is (off-the-shelf solutions);
- Modifying a system developed elsewhere in order to suit specific and unique agency requirements (local customisation);
- Developing a new system specifically for the agency in question (bespoke development).

As noted earlier, a system imported from elsewhere and used without modification is likely to be unsuccessful (Robinson and Thagesen 1996). It therefore follows that the first option of using a ready-made system without modification is not recommended. On the other hand, developing a new system that will include all required aspects from a condition evaluation to a condition prediction and optimisation sub systems requires a substantial amount of time and resources. This means, yet again, a third option of developing entirely a new system, with new underlying relationships is not economical.

Consequently, this research preferred a second option. In this study, already developed road management software was selected as support software for the proposed PMS. However, as discussed in previous sections, the introduction of any PMS should consider unique agency characteristics.

There are two different approaches of selecting a model for use in a PMS (Robinson and May 1997). The first approach is to start by selecting a model which will, in turn, dictate the requirements for the PMS. By contrast, a second approach is to identify user needs and specify the requirements before the selection of the model is made. In this approach the model that nearly fits into the identified user needs and specified requirements is selected.

Experience has shown that a system introduced using the first approach is not sustainable.

Consequently, for the sustainability of the system, this study has adopted a second approach.

In this study, specific characteristics of the MoW and TANROADS were thoroughly investigated. As a result, appropriate PMS requirements relevant to the road sector were identified. These include the recommendation of the appropriate and affordable data collection scheme. This will enable the MoW/TANROADS to obtain required outputs from the PMS at a reasonable cost. On the basis of these requirements the choice of the model to be used in the proposed PMS has been made.

Furthermore, the study recommends full involvement of potential users during the development and implementation of the system. This will ensure that the system evolves within the ministry. As noted earlier, a system evolved within an agency is more likely to succeed rather than a system introduced from elsewhere (Robinson and Thagesen 1996).

Finally, it is beneficial to adopt a very simple approach when introducing a pavement management system for the first time. Once these methods have been accepted and fully institutionalised, the benefits that accrue from using a PMS will be recognised. As a result, all key players in the road sector in Tanzania will gain confidence in the use of a pavement management system for making road management decisions. Subsequently, after this significant acceptance of the system, advanced but affordable methods can be gradually incorporated into the system.

In conclusion, the requirements of a computerised road management system in Tanzania have been determined after consultation with relevant personnel in TANROADS and MoW. To accomplish this goal, interviews, questionnaires and group discussions with people in these organisations were used. The information collected and the identified objectives and tasks to be performed by the system clearly indicate that an appropriate planning and programming system (network level PMS) is urgently required. This would aim at assisting TANROADS and MoW to achieve their organisational objectives as well as provide a basis for alleviating some of road management problems. The users of the system are top personnel and professional staff in these organisations. The output from the system would help TANROADS to prepare 5-year rolling work programmes as well as budget estimates which must be submitted to the Road Fund Board and to the MoW budget committee (through the Permanent Secretary, Ministry of Works). Also, the potential users proposed that the system should be able to prioritise annual road maintenance works within the available budget. Additionally, the questionnaire results show that most respondents proposed that a computerised road management system should be capable of producing long-term budget forecasts and road network performance predictions.

However, it should be pointed out that the decision to implement a pavement management system should be justified by the assessment of costs and benefits involved. However, most benefits are very difficult to quantify since they are subjective in nature.

Generally, the benefits are realised because of the resulting improvement in asset management as well as contract and cost control. In addition, the implementation of a pavement management system provides better management information.

Specifically, benefits that are expected to result from the introduction of a network level PMS in Tanzania include:

Better design of maintenance works

- Treatment selected on the basis of measured condition;
- Treatments selected in a consistent manner by using standard rules;

- Incorporation of historical data into the design process;
- Projection of pavement condition can be used t select treatments to be suitable for the time that they are applied, rather than being based on existing conditions.

Allocation of funds

- Priorities for funding can be based on highest economic return on investment in different maintenance options within a constrained budget;
- Funds can be distributed equitably to activities and administrative areas using pre-defined rules.

Monitoring

- Records of deterioration, treatments and unit costs can be kept to feed back into the policy and planning process.

However, it is recommended that, in the long run, the actual effectiveness of a PMS should be measured from the ultimate savings in real highway expenditures. Invariably, initial pavement investment along with related costs should be compared to the savings in real highway expenditures plus user cost savings.

NOMENCLATURE AND ACRONYMS

HDM-III	Highway Design and Maintenance Standards Model
HDM-4	Highway Development and Management Tool
IQL	Information Quality Level
MoW	Ministry of Works
N/A	Not Applicable
PC	Personal Computer
PMS	Pavement Management System
RTAC	Road and Transport Association of Canada
TANROADS	Tanzania Roads Agency
TRL	Transport Research Laboratory
S/N	Serial Number

REFERENCES

1. Haas, R. *Pavement Management: A Great Past But What About the Future,* Keynote Address, Fourth International Conference on Managing Pavements, Proceedings, Volume 1: Opening and Basic Tools and System Outputs, Durban, South Africa, pp. 1 – 38, 1998.
2. Haas, R., W.R. Hudson, and J. Zaniewski, *Modern Pavement Management*, Kriegler Publishing Company, Malabar, Florida, 1994.
3. Harral, C., and A. Faiz, *Road Deterioration in Developing Countries: Causes and Remedies*, A World Bank Policy Study, The World Bank, Washington, D.C., 1988.
4. Hudson, W.R. and S.W. Hudson, *Pavement Management Systems Lead the Way for Infrastructure Management Systems*, Third International Conference on Managing Pavements, San Antonio, Texas, Conference Proceedings, Volume 2, pp. 99-112, 1994.
5. Jones, T.E. *Optimum maintenance strategies for Unpaved Roads in Kenya,* PhD Thesis, University of Birmingham, United Kingdom, 1988.
6. Kerali, H.R. *Overview of HDM-4, Volume 1 of the Highway and Management Series,* International Study of Highway Development and Management (ISOHDM), World Roads Association, PIARC, Paris, 2000.
7. Mushule, N.K.M. *Development of a Sustainable Network Level PMS for Tanzania: Concepts, Methods and Specifications,* PhD Thesis, University of Dar es Salaam, Tanzania, 2002.
8. Robinson, R., and B. Thagesen, *Maintenance Management*, In Thagesen, B., Ed; Highway and Traffic Engineering in Developing Countries, E & N Spon: An Imprint of Chapman & Hall, London, pp. 385 – 408, 1996.
9. Robinson, R. and P.H. May, *Road Management Systems: Guidelines for Their Specifications and Selection,*

Proceedings, Institution of Civil Engineers, Transp; 123, pp. 9 – 16, 1997.

10. Robinson R., U. Danielson, and M. Snaith. *Road Maintenance Management - Concepts and Systems*, Macmillan Press Ltd, London, 1998.
11. RTAC (Road and Transport Association of Canada), *Pavement Management Guide*, Ministry of Transport, Ottawa, Canada, 1977.
12. Smith, R.E., and K.M. Fallaha, *Developing an Interface between Network and Project Level Pavement Management System for Local Agencies,* In Transportation Research Record No. 1344, TRB, National Research Council, Washington, D.C., pp. 14-121, 1992.
13. TRL, *Guidelines for the Design and Operation, of Road management Sys*tems, ORN 15, Overseas Centre, Transport Research Laboratory, Crowthorne, Berkshire, UK, 1998.
14. Watanatada, T., C. Harral, W.D.O.Paterson, A.M. Dhareshwar, A.Bhandari and K. Tsunokawa, *The Highway Design and Maintenance Standards Model, Vol. 1: Description of the HDM-III Model*, John Hopkins University Press, Baltimore, 1987.
15. Whitehorn, M., *Easier Database Creation for Developers and Users*, In PC User, 21 Feb. - 5 March Issue, pp. 27-30, 1996.
16. Zaniewski, J. P., R.H. Perera, and M.S. Mamlouk, *Feedback of Pavement Management Performance Data for Pavement Design*, In Transportation Research Record No. 1272, TRB, National Research Council, Washington D.C., pp. 74-79, 1990.