APPROACH TO IMPLEMENTING SUSTAINABLE ROAD MANAGEMENT SYSTEMS IN DEVELOPING COUNTRIES: A CASE STUDY OF TANZANIA

by

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ABSTRACT

A number of pavement management systems (PMS) have been implemented in developing countries without taking into account the needs, requirements and capacity of the implementing agencies. These systems have tended to specify requirements aimed at high-tech solutions that are often not sustainable in developing countries. As a result, many such systems have largely been marginalised. A research project was carried out to develop a framework and specifications for a sustainable network level PMS for Tanzania.

The study started by identifying the potential users and then defining the needs and capabilities of the implementing agency (Ministry of Works). Based on this, a sustainable data acquisition scheme was designed and tested. It was recognised during the study that the PMS must provide management information that is practical and utilised on a day-to-day basis. Furthermore, the procedure and algorithms used to produce this information must be well understood by technical staff within the organisation. A decision support system built around the Highway Development and Management tool (HDM-4) was recommended and tested in a trial implementation. The research concluded that, for the sustainability of a PMS, simple but technically sound methods should be used during the development and implementation.

Keywords: pavement management system, sustainability, developing countries.

1. INTRODUCTION

Tanzania is a large country with a substantial length of paved and unpaved road network. A very important feature is Dar es Salaam harbour on the Indian Ocean which serves as a gateway to the rest of the country and for the landlocked neighbouring countries such as Malawi, Zambia, Burundi, Rwanda and Uganda. Most heavy goods transit vehicles to these countries use the Tanzania road network. Unfortunately, funds available for maintenance and rehabilitation of the road network are very limited.

The condition of the road network in Tanzania has been poor for more than a decade. This has been attributed to lack of maintenance and rehabilitation. Consequently, there is an evident need, for planned programmes of maintenance of pavements, so that maximum benefits are obtained from the limited funds available.

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The problem of managing roads has been shown to be a very big issue in both developed and developing countries at varying scales (*Gichaga and Parker, 1988*). Tanzania, like many other developing countries, has had inadequate maintenance of her road network due to various reasons mainly administrative, technical and financial problems.

The road network is managed by the Ministry of Works (MoW) in Tanzania which should ensure that any model to be used in the decision making process should be studied carefully and should be well understood by local staff. This will help to identify the strengths, weaknesses and limitations of the system before it is used so that it can be gradually modified and adapted to fit local conditions. As pointed out by Robinson and Thagesen (*1996*), a system evolved within a road agency stands a better chance to succeed than a system copied from elsewhere.

This paper describes the results of a pilot implementation of a Pavement Management System in one region of Tanzania as part of a larger research project.

2. SUSTAINABILITY

In simple terms, to sustain is to support something and prevent it from collapse. However, the term sustainability has been used in different ways by various sectors. For example, USAID (*1988*) considers a development programme sustainable if it can still provide required benefits to the local community for a considerable duration after all external assistance has been withdrawn. Faini and Melo (*1990*) state that, in agricultural development, an output growth can never be considered sustainable unless it exceeds the population growth.

2.1 Sustainability in the Pavement Management Context

The components of a PMS are well defined and their methods of operation are well understood (*Haas, 1998*). Most importantly, organisations must be capable of utilising the PMS in the decision making process about pavements. Sustainability in the pavement management context therefore means that there is strong will, commitment and resources within the organisation to maintain, operate and subsequently improve the PMS by using local resources and staff.

Consequently, the implementation of a sustainable PMS should consider:

- existing institutional arrangements and any required changes;
- the relevance and need for management information produced;
- the capability of the agency to collect the required data and keep them current;
- technical knowledge required to operate and subsequently improve the system if and when the need arises;
- knowledge and computer skills available within the agency (if a computerised system is adopted);
- staff training programmes in the area of pavement management.

2.2 Sustainability of a PMS in the Tanzanian Context

Pavement management systems that have been introduced in many developing countries are often too complicated and too demanding to be sustainable (*Robinson and May, 1997;*

Jones, *1988*). In determining the requirements of a PMS for Tanzania it was necessary to consider the capacity of the MoW in terms of financial and human resources required to operate the system. Consequently, to ensure sustainability, each component of the PMS had to be designed such that the MoW is able to maintain and operate the system using local resources at minimum cost. At the same time, the system should produce realistic and technically feasible management information within available resources.

3. REQUIREMENTS AND SCOPE OF THE SYSTEM

According to the OECD (*1994*), a sustainable road management system should include:

- Data collection methods that are affordable, appropriate and provide relevant information;
- Road information system (or database management system) that is flexible and capable of producing both standard and ad hoc reports;
- A decision support system that can be used to investigate the consequences of various management decisions and strategies; and
- Adequate management information that are practical and pertinent to the needs of road organisations.

It was found necessary to use a decision support system capable of producing medium to long-term plans for the entire road network as well as multi-year, or rolling work programmes, for short periods typically less than 5 years. It is intended that this will assist road managers in the analysis of maintenance and rehabilitation options, production of estimates for road works, determination of expenditure requirements and prediction of network performance under various budget scenarios.

Decision-support systems are classified according to the management functions that they perform within the highway management process (*Robinson and May, 1997)*. These functions include planning, programming, preparation and operation. Planning and programming decision support systems are the most relevant to the above specific requirements. These functions are normally carried out at network level.

3.1 General Requirements

The PMS is required to perform budgeting and works programming for the trunk roads in Tanzania. By implication, the system should be capable of managing both paved and unpaved roads in excess of 10,000 km. Consequently, the general requirements that were considered in developing the PMS include:

- making the system agency specific with the framework, engineering parameters, models, data acquisition and processing, tailored to the unique conditions and road management practice in Tanzania with minor modifications where found necessary;
- clearly addressing the needs of the MoW by providing the required management information.

3.2 Institutional Requirements

Institutional arrangements play a significant role in the success or failure of PMS implementation. At the time of this study, the MoW was in the process of implementing institutional reform. Consequently, the PMS specifications had to take into account the proposed restructuring involving the creation of a new road agency in Tanzania (TANROADS).

4. USE OF HDM-4 AS A DECISION SUPPORT SYSTEM

Most developed countries have derived pavement performance models that are suited to local conditions by setting up long term pavement performance studies. This approach requires extensive investment in time, expertise and money to study the long term behaviour of pavements in response to different pavement materials, traffic loading, climatic effects and local maintenance strategies. Few developing countries have the resources required to set up similar large-scale field experiments.

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) (*Kerali 2000; Odoki and Kerali, 2000*). This is based on the well-researched HDM-III model developed by the World Bank *(Watanatada et al, 1987)*. 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:

- the ability of HDM-4 to produce outputs required by MoW from the PMS;
- data requirement by the software;
- calibration requirements;
- data interchange with the PMS database;
- 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, 2000)*. In addition, the HDM model is often specified as the standard tool for conducting economic appraisal of road projects in Tanzania.

5. DATA ACQUISITION

Data acquisition is one of the most expensive components of a PMS (*Smith and Fallaha, 1992*). To avoid excessive data collection, the data design for the PMS was made in such a way that only the absolute minimum data necessary to provide the required management information should be collected. This allows a PMS to be implemented at a low initial cost.

5.1 Network Referencing

One of the first steps in the development and implementation of a PMS is the establishment of a referencing system. The referencing systems that are commonly used in

road management include; road or route name, node-link, route and chainage, branch-section and co-ordinate system (*Haas et al, 1994*).
The node - link referencing was found to be the most suited to needs of the network level PMS (*Mushule, 2000*) for Tanzania. This is in line with the current practice in the MoW where a well-established referencing system already exists.

5.2 Inventory Data

For the PMS, it was decided that information about highway features that remain reasonably constant over time should be gathered from existing MoW records. These consist of records of items such as road length, carriageway width, shoulders, pavement details, footpaths, details of drainage design and construction history.

6. CONDITION EVALUATION FOR PAVED ROADS

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 (*Haas et al, 1994)*. Consequently, the minimum data required for effective management of paved roads in Tanzania were judged to be roughness, surface distress, structural adequacy and surface friction.

6.1 Roughness Measurements

There are several methods and types of equipment used for roughness measurements. Out of these, the TRL vehicle mounted bump integrator was selected for the reasons that: a) the equipment is available in Tanzania and it has been in use for sometime; b) the rate and accuracy of measurement is adequate; and c) it is easy to use.

Roughness measurements were carried out using a bump integrator mounted on a 4-wheel drive vehicle. Pavement roughness, which relates to serviceability or ride quality, was measured in IRI m/km using a vehicle travelling at about 32 km/hr. At this speed, trained assessors were also able to visually rate the pavement surface condition (*Eaton et al, 1987*).

6.2 Pavement Distress Measurements

Pavement surface defects include permanent deformations, cracking, patching, potholes and edge break. Various methods are used around the world for surface distress assessment ranging from visual surveys, to detailed manual measurements and use of automated systems. Whilst it may be argued that manual methods are subjective, unsafe, involve high personnel costs and have low repeatability (*Kalikiri et al, 1994*), the initial costs of acquiring automated systems coupled with the technology required to operate and maintain them can be prohibitive for most developing countries. Furthermore, Weaver (*Weaver, 1979*) found that if panel ratings are properly devised, conducted and analysed, they can measure serviceability with adequate precision and reproducibility. Weavers method was successfully used by the New York State Department of Transportation, and in Indiana for subjective rating of unpaved roads (*Riverson et al, 1987*).

For the PMS, it was decided that individual defect ratings should be used instead of condition indices. This is because firstly, composite indices loose some information at each level of aggregation, and secondly, it may take several years to develop and validate indices that are specific for Tanzanian road conditions. Consequently, all types of surface distress were assessed by trained technicians on a scale of 1 to 5, in which 1 represents perfect condition and 5 represents extremely poor condition as defined in Table 1. Samples of the assessment forms are shown in Tables 2 and 3 for paved and unpaved roads, respectively.

Table 1. Definition of Usual Rating Scale

RATING	DESCRIPTION	CONDITION RATING
1	No defects seen	GOOD
2	Slight defects occasionally seen	
3	Slight defects frequently seen	FAIR
4	Moderate defects seen	
5	Severe defects seen	POOR

6.3 Pavement Structural Evaluation

Methods used in pavement structural evaluation are classified as destructive or non-destructive. Destructive methods include digging of test pits so that existing pavement materials and layer thickness can be obtained. Non-destructive devices for pavement evaluation include deflection measurements using devices such as the Benkelman beam, Dynaflect, Road rater and Falling Weight Deflectometer (FWD).

The Benkelman beam has been extensively used in most developing countries because of its simplicity and low cost. However, the device is very slow compared to other types of non-destructive measurement devices.

The Dynamic Cone Penetrometer (DCP) provides an alternative method for determining in-situ structural properties of existing road pavements. This has been used in many parts of the world (*Livneh et al, 1995*). The device is cheaper than the Benkelman beam and requires less resources to operate; a DCP test requires only three operators, whilst a Benkelman beam requires two operators, a loaded truck and a driver.

Consequently, it was decided that DCP measurements should be conducted on road sections that show signs of structural weakness. These are sections rated as poor for roughness and/or surface condition. For road sections rated to be in good or fair condition construction data gathered during the inventory phase should be used. It should be noted that the above decision reduces the annual number of road sections that should be tested using the DCP to a sustainable level.

For the evaluation of the structural adequacy of existing pavements, it was decided that pavement design methods used in Tanzania should be used as the basis for determining the required structural strength. Consequently, the TRL Road Note 31 was used (*1993*).

Adjusted structural numbers were calculated to correspond with the following pavement designs that are most commonly used Tanzania:

- granular road base with surface dressing, for low traffic;
- granular road base with semi-structural surface, for medium traffic;
- granular road base with structural surface, for high traffic.

Table 2. Road Condition Visual Assessment Form for Paved Roads

ROAD CONDITION VISUAL ASSESSMENT	**REGION:**	Morogoro	**SECTION No:**	T0030605
	DISTRICT:	Morogoro (Rural)	**SECTION NAME:**	Msanvu - Sokoine
	ROAD:	Morogoro - Gairo	**SURFACE TYPE:**	SD
	TOPOGRAPHY:	Rolling	**DATE:**	05/03/99
INSPECTOR: Mushule				

	CARRIAGEWAY DEFECTS																													
	RUTTING					CRACKING					POTHOLES					RAVELLING					PATCHING					EDGE BREAK				
CHAINAGE (KM)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Km 0.0 ~ 3.5			√			√					√					√					√					√				
Km 3.5 ~ 7.4				√			√				√					√					√					√				
Km 7.4 ~ 15.8			√				√					√				√						√				√				
Km 15.8 ~ 22.4			√				√					√				√					√					√				
Km 22.4 ~ 35.0			√			√						√				√						√				√				
	SEVERITY					NONE = 1					V. SLIGHT = 2					SLIGHT = 3					SIGNIFICANT = 4					SEVERE = 5				

Table 3. Road Condition Visual Assessment Form for Unpaved Roads

ROAD CONDITION VISUAL ASSESSMENT INSPECTOR: Mushule	**REGION:** Morogoro **DISTRICT:** Ifakara **ROAD:** Ifakara-Mahenge **TERRAIN:** Rolling					**SECTION :** T0160110 **NAME:** Kivukoni-Lupiro **SURFACE:** Gravel **DATE:** 12/03/99				
	SURFACE DISTRESS					IMPASSABILITY				
CHAINAGE (KM)	1	2	3	4	5	1	2	3	4	5
Km 0.0 ~ 12.5			√			√				
Km 12.5 ~ 18.5				√		√				
Km 18.5 ~ 23.3				√			√			
SEVERITY	None = 1		V. Slight = 2		Slight = 3		Significant = 4		Severe = 5	

Considering the entire range of subgrade strength for the three traffic levels, the following required structural numbers were obtained:

Traffic Level	**Required Structural Number**		
	Minimum	**Maximum**	**Average**
Low	2.03	3.15	2.59
Medium	3.09	4.30	3.69
High	4.44	5.57	4.98

An alternative design method, the Southern African Transport and Communication Commission (SATCC) design guide (*Kristiansen, 1996*), was used for comparison. This method incorporates environmental effect by including a regional factor term. The method recommends a minimum subgrade CBR of 8% and suggests that subgrade materials below that value should be improved prior to construction. The method gave the following required structural numbers:

Traffic Level	**Required Structural Number**		
	Minimum	**Maximum**	**Average**
Low	2.44	3.10	2.78
Medium	3.42	4.03	3.74
High	4.32	4.66	4.50

By comparing the two methods, it was concluded that a structural number of 2.0 is critical for low traffic, 3.0 for medium traffic and 4.0 for high traffic.

Adjusted structural numbers were calculated for road sections in poor condition from the DCP test results, and from construction history or design records for road sections in good or fair condition. Thereafter, depending on the level of traffic, the pavement structural adequacy for each section was evaluated as either adequate, critical or inadequate.

6.4 Skid Resistance Evaluation

The relevant methods and equipment for measuring skid resistance considered for Tanzania include a calibrated locked-wheel skid trailer as specified by ASTM E274 *(Haas and Hudson, 1996)*, a Sideways-Force Coefficient Routine Investigating Machine (SCRIM) *(Hosking et al, 1976)*, and a Pendulum Tester *(Croney and Croney, 1991)*. The locked-wheel skid trailer is mostly used in North America. It determines skid resistance in terms of a Skid Number (SN).

The SCRIM is extensively used in the United Kingdom and is capable of measuring wet skidding resistance in terms of the Sideways Force Coefficient (SFC). However, the cost of the equipment is very high.

The simplest equipment considered for measuring the skid resistance is the Pendulum Tester. This measures wet skid resistance in terms of a skid resistance value (SRV) which corresponds to the skidding value of a patterned tyre travelling at 50 km/hr. Apart from its simplicity, the equipment is also cheap and easily portable. However, the equipment is very slow in measuring the surface friction of the pavement surface.

For the network level PMS for Tanzania, it was decided that accident data should be used to identify black spots. These spots would then be evaluated for skid resistance using a pendulum tester. The equipment has been selected because of its simplicity, portability and low cost. However, skid resistance values measured by this equipment represent the values at a speed of about 50 km/hr and may not give a proper representation of the values at much higher speeds. For high-speed roads, TRRL (*1969*) recommend measuring the texture depth as an additional criterion for evaluating the adequacy of pavement surface friction. A minimum Skid Resistance Value of 55 (SRV) for trunk roads along with a minimum texture depth of 0.65mm as determined by sand patch method as recommended by TRL.

These minimum requirements were expressed in terms of the International Friction Index (IFI) using the procedure presented by Wambold et al *(1995)*. From this, the minimum skid resistance requirements for Tanzania were determined as IFI(24.62, 0.242).

7. CONDITION EVALUATION OF UNPAVED ROADS

In Tanzania, more than 60% of the trunk road network consists of unpaved roads. Consequently, for the PMS to be complete, it must properly address issues pertaining to the maintenance management of unpaved roads in the country. The rate of deterioration of unsurfaced roads is mainly influenced by weathering, traffic, road geometry, material properties and maintenance practices. The main modes of deterioration considered are riding quality (roughness) and gravel layer thickness.

7.1 Road Roughness

This mode of deterioration has a great impact on road user costs and it has been shown that maintenance and rehabilitation intervals are very sensitive to the rate of roughness progression (*Watanatada et al, 1987; Kerali 1992*).

The study found that it was not practical to use a vehicle mounted bump integrator for measuring roughness on very rough unpaved roads. It was therefore decided to establish a method for estimating roughness from average travel speeds. This was done by correlating average travel speeds attained by a four-wheel vehicle with the roughness measured using a vehicle mounted bump integrator.

This method should be used where roughness is the only factor considered to affect the travel speed. However, the above does not consider the effect of terrain. Consequently, it was decided to establish the roughness level beyond which the effect of terrain on average travel speed is insignificant. HDM-4 was used to predict speeds for different terrain. It was found that at roughness of around 16 m/km, the average speed prediction for a four-wheel drive vehicle for all the terrain classifications converge to around 40 km/hr. This is illustrated in Figure 4.

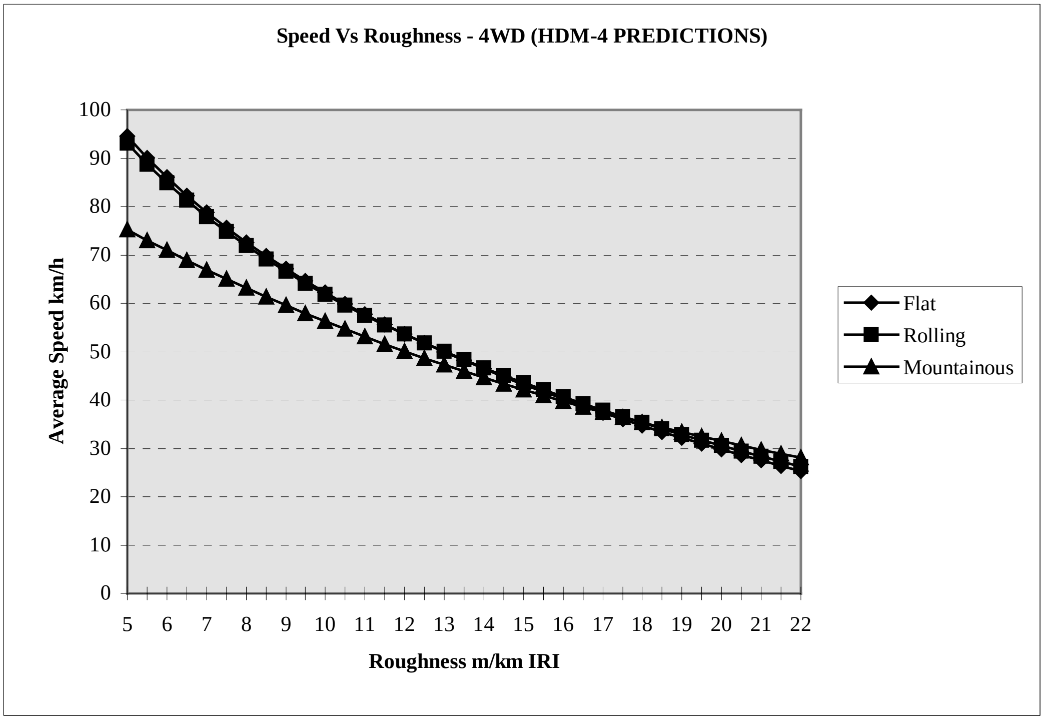

Figure 1. Average Speed as a Function of Roughness for Different Terrain

Consequently, the regression model used for correlating average speeds with roughness on unpaved roads was *(Mushule 2000)*;

For speeds less than 40 km/h: $IRI = -7.9832 \ln(S) + 45.365$ $R^2 = 0.9373$

Where: S = average speed of a four-wheel vehicle (km/h)

7.2 Adequacy of the Gravel Layer

Jones (*1988)* revealed that, in most developing countries, the design thickness of the gravel layer is around 150 mm. Consequently, it was decided that the adequacy of gravel layers should be evaluated in terms of surface distresses related to inadequate bearing capacity of unsealed roads. Minor surface rutting indicates the presence of dislodgement of gravel whilst severe rutting indicates inadequate gravel layer thickness. Similarly, isolated potholes indicate isolated weak conditions, whilst extensive potholes indicate that the gravel layer is not adequate. A rating scale of 1 to 5, similar to the one formulated for paved roads, was therefore used.

It was further decided that the surface layer thickness and strength for each surface condition rating should be determined by using DCP measurements on sample sections.

7.3 Passability

A major problem facing highway engineers is to keep unpaved roads open to traffic at all times and in all weather. The impassability of unpaved roads is an indication of inadequate surface material. It was therefore decided that passability should be assessed on a 5 point scale in a similar manner as surface distress for paved roads. In this case, 1 means a road section in perfect condition, whilst 5 represents an almost impassable road section. A sample of visual assessment form for unpaved roads is presented in Table 3.

It should be noted that the surface distress of the unpaved roads (rutting and potholes) are assessed in order to determined the adequacy of the gravel layer, as explained previously.

8. PILOT IMPLEMENTATION OF THE PROPOSED SYSTEM

A pilot trial of the proposed methods presented in this paper was carried out in Morogoro region. The objective of the pilot implementation was to demonstrate the practicality of the proposed methods of data collection. In addition, the trial implementation permitted the identification of the elements that required modifications in order to meet the needs of the Ministry of Works. Furthermore, the trial implementation was also used for training various potential users of the proposed PMS. Summaries of the collected data are shown in Tables 4 and 5 for paved and unpaved roads respectively.

Table 4. Summary of the Collected Data for Paved Roads

Section No.	Section Name	Length (km)	AADT	IRI m/km	Surface	Edge	Topo-graphy	Structural Adequacy	Surface Type
T0010105	Ngerengere-Lubungo	16.4	1167	3.82	Good	Good	Hilly	Adequate	AC
T0010110	Lubungo – Msanvu	31.5	1167	3.50	Good	Good	Rolling	Adequate	AC
T0010115	Msanvu – Sangasanga	15.7	3948	3.59	Good	Good	Rolling	Adequate	AC
T0010120	Sangasanga-Melela	13.7	3897	3.10	Good	Good	Rolling	Adequate	AC
T0010125	Melela – Mikumi	90.1	480	2.26	Good	Good	Rolling	Adequate	AC
T0010130	Mikumi – Iyovi	33.0	352	1.64	Good	Good	Hilly	Adequate	AC
T0010135	Iyovi – Ruaha Iringa brdr	40.3	352	2.68	Poor	Fair	Hilly	Adequate	AC
T0030605	Msanvu – Sokoine	35.0	510	3.18	Fair	Fair	Rolling	Critical	SD
T0030610	Sokoine - Dar Brew	15.0	510	3.06	Poor	Fair	Rolling	Adequate	SD
T0030611	DarBrew – Magole	13.5	510	7.6	Poor	Poor	Rolling	Inadequate	SD
T0030612	Magole – Dumila	2.0	492	3.91	Poor	Poor	Rolling	Adequate	SD
T0030615	Dumila – Gairo	68.9	276	4.06	Poor	Fair	Hilly	Critical	SD
T0160100	Mikumi – Kidatu	36	206	1.59	Good	Good	Rolling	Adequate	AC

Table 5. Summary of the Collected Data for Unpaved Roads

Section No.	Section Name	Length (km)	AADT	IRI m/km	Surface	Passa-bility	Topo-graphy	Surface Layer Strength	Surface Type
T0160105	Kidatu – Kibaoni	69.3	143	12.57	Poor	Good	Rolling	Low	Gravel
T0160106	Kibaoni – Ifakara	5.92	554	24.22	Poor	Good	Rolling	High	Gravel
T0160107	Ifakara – Kivukoni	6.0	117	17.74	Poor	Fair	Rolling	Low	Gravel
T0160110	Kivukoni – Lupiro	23.3	112	14.66	Poor	Fair	Rolling	Low	Gravel
T0160115	Lupiro – Mahenge	41.7	55	18.12	Poor	Fair	Hilly	Low	Gravel

Using the pilot trial data, the work programme for the trunk roads in Morogoro region was produced using HDM-4. A summary of this is shown in Table 6.

Table 6. Summary of the Work Programme

Region	Section No.	Section Name	Length (km)	Age (Years)		Surf. Type	Yearly Capital Treatment				
				Cons	Surf		2000	2001	2002	2003	2004
Moro-Goro	T0010105	Ngerengere- Lubungo	16.4	26	10	SD			RS		
	T0010110	Lubungo – Msanvu	31.5	26	10	SD			RS		
	T0010115	Msanvu – Sangasanga	15.7	26	10	AC				RS	
	T0010120	Sangasanga – Melela	13.7	26	7	AC				RS	
	T0010125	Melela – Mikumi	90.1	26	7	AC					
	T0010130	Mikumi – Iyovi	33.0	26	5	AC					
	T0010135	Iyovi – Ruaha Mbuyuni	40.3	26	-	AC	RS				
	T0160100	Mikumi – Kidatu	36.0	3	-	SD				RS	
	T0030605	Msanvu – Sokoine	35.0	16	-	SD	RS				
	T0030610	Sokoine – Dar Brew	15.0	16	-	SD	RS				
	T0030611	Dar Brew – Magole	13.5	16	-	SD	OL				
	T0030612	Magole – Dumila	2.0	16	-	SD	RS				
	T0030615	Dumila – Gairo	68.9	16	-	SD	RS				
	T0160105	Kidatu – Kibaoni	69.3			G	RG				
	T0160106	Kibaoni – Ifakara	5.9			G			RG		
	T0160107	Ifakara – Kivukoni	6.0			G	RG				
	T0160110	Kivukoni – Lupiro	23.3			G	RG				
	T0160115	Lupiro – Mahenge	41.7			G	RG				
Yearly Expenditure (‘000,000 TAS)							7294	0.00	838	1306	0.00

AC - Asphalt Concrete; SD - Surface Dressing OL - Overlay ; RS – Resealing;
RG - Regravelling

The main management information requirements of the MoW from the PMS are maintenance and rehabilitation options, production of estimates for road works and determination of expenditure requirements (*Mushule 2000*). Consequently, the results presented in Table 6 provide the main source of management information to engineers and road managers in the MoW.

9. DISCUSSION AND CONCLUSIONS

The research presented in this paper developed a framework and specifications for a network level PMS for trunk roads in Tanzania. The potential users of the system are top management and professional staff within the Ministry of Works.

However, the main concern in this study was the sustainability of the specified system. This refers to the long-term ability of the Ministry of Works to operate and subsequently improve the system using local staff and resources.

The research evaluated the resources required to develop and implement the system. It assessed the capability of the Ministry of Works to provide adequate resources for:

- the proposed data collection scheme;
- procurement of the required hardware and software;
- necessary training of key staff responsible for operating the system;
- acquisition of computer knowledge and skills required to maintain and upgrade the system.

It was found that the required resources for the aforementioned items are available to the Ministry of Works if genuine commitment exists. This includes, amongst other things, the provision of proper staff retention schemes in terms of job satisfaction so that the trained staff are retained as long as possible.

This research found that the most critical parameters are human resource constraint and time required to collect the data. Underestimate of the time required to collect, input and validate the data into the PMS is a common hindrance to sustainability of a PMS.

In general, the research concluded that, for the sustainability of a PMS, simple but technically compatible methods should be used in the development and implementation of the system. These methods are particularly suitable for developing countries, such as Tanzania, which cannot afford high-tech instrumentation.

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