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Rural road management in Botswana

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This paper discusses the management of rural roads in Chobe in Botswana, which are mainly tertiary and access roads. These roads are low-volume roads and mostly gravelled. It was observed that the maintenance management of these roads was based on engineering judgement through visual inspection all over the country, without having any economic or technical analysis. Therefore, a comprehensive pavement management system for rural roads' maintenance is needed in Chobe and also in all the council areas of Botswana, which would consist of data collection, database, use of the Highway Development and Management Model to undertake efficient decision making project preparation, funding, implementation and feedback. A partial implementation of pavement management system in Chobe has been highlighted in this paper. The present analysis reveals that total demand for the road network in Chobe was 41·29 million pula, the backlog was 34·86 million pula and the first-year backlog demand was 20·63 million pula. Furthermore, the analysis found the long-term periodic maintenance strategy for the network at 6·43 million pula when there is no backlog. This huge backlog indicates that roads are not being maintained appropriately. The paper also estimates current road asset value in Chobe at 55·48 million pula. Finally, the paper recommends several solutions for the efficient preservation of road assets in Botswana.

1. Introduction

Roads are important assets of a country, having a high economic value. Therefore, roads' management is necessary to optimise efficient use of these assets, which has become a major concern all over the world.

However, management of rural roads is almost neglected in Africa and in the South African Development Community (SADC) countries, as high priority has been given to the major roads (Howe, 1999; Pinard, 2008; Zietlow, 2011). Some of these countries do not have a techno-economic model or even an established Pavement Management System (PMS) for prioritisation of roads to manage the assets efficiently.

Botswana may be considered a classic example where roads are being managed based on the traditional approach, namely, by engineering judgement, and political and social factors. Engineering judgement is a simple method of recommending a treatment from one's experiences through visual inspection of roads. This is not a scientific approach to suggest the right treatment at the right time and right place for any road. As mentioned, Botswana does not have any economic model such as the Highway Development and Management model (HDM-4) for road management.

The author's experience in rural roads' management in the Chobe district of Botswana has been highlighted in this paper. The main aim was the introduction of HDM-4 to implement maintenance demand, backlog, asset valuation and maintenance strategy.

2. Road management in Africa

Most African countries are landlocked. As a result, roads have a higher priority over the other modes of transport. About 75% of passengers and freight are being transported by road in sub-Saharan Africa (Zietlow, 2011). A road-condition survey in about 30 countries in East and West Africa revealed that the roads had severely deteriorated due to inadequate maintenance (Howe, 1999). The major emphasis has always been on expansion of the network and upgrading to paved standards, which indicate a lack of interest in road maintenance in the region (Howe, 1999; Pinard, 2008; Zietlow, 2011). Moreover, rehabilitation and reconstruction is wrongly given priority over periodic maintenance (PM) in Africa (Howe, 1999). It has been estimated that the backlog is about US$ 1·2 billion per year in the sub-Saharan region due to lack of maintenance (Zietlow, 2011).

Road maintenance is being done by inadequate numbers of departmental staff in Africa, and only a few countries have planned for the outsourcing of maintenance contracts based on performance, which is commonly known as Performance Based Maintenance (PBM). Some of the countries have introduced Second Generation Road Funding. Pinard and Rohde (2001) have stressed the need to establish a comprehensive PMS with the help of a support tool (HDM-4) to prioritise roads for maintenance in the SADC region.

One of the major reasons for this poor asset management is lack of policies on maintenance – for example, Botswana does not have any maintenance policy nor a maintenance strategy for proper allocation of funds and efficient maintenance.

The studies mentioned above conclude that there is a need to introduce the following in African, particularly SADC, countries

- a comprehensive PMS
- management of roads on business lines, with establishment of a Road Fund through road-user charges, and adequate funding for road maintenance (Pinard and Rohde, 2001)
- Performance Based Maintenance (PBM)
- enhancing institutional capacity for efficient management (Pinard and Rohde, 2001).

3. Current road management in Chobe

This section discusses the current road network and management practices in Chobe.

3.1 Road network in Botswana and Chobe District

There are about 18 327 km of roads in Botswana (RD, 1993), which are divided into four categories based on importance (see Table 1). The Roads Department (National Road Authority, NHA) and Local Councils own about 48% and 52% of roads respectively (RD, 1993). A recent study shows that the asset value of constructed roads is decreasing in Botswana as rural roads are deteriorating at a faster rate due to lack of maintenance (RD, 2007).

The author's experiences in Botswana, especially concerning the management of rural roads in Chobe, are discussed in the current paper. The scenario of rural roads in Chobe is similar all over Botswana. There are about 309·5 km of roads under the Chobe District Council, of which 49% are tertiary and the remainder are access roads. The type of roads can be seen in Figure 1, which indicates that about 89% are unpaved roads. There are about 79% gravel and earth roads in the network. This is consistent with the SADC countries' data where about 80% of roads are unpaved (Pinard, 2008). These inventory and road-condition data are being collected by the in-house staff of the Chobe District Council.

The current condition of the Chobe road network can be seen in Figure 2 which reveals that paved roads are generally good, gravel roads are fair, and earth and sand roads are poor. The classification of the road condition was based on visual assessment. The results are also similar to those of the SADC countries, where about 50% of paved roads are good, but unpaved roads are mainly fair to poor (Pinard and Rohde, 2001). The appendix shows some typical photographs of roads in Chobe.

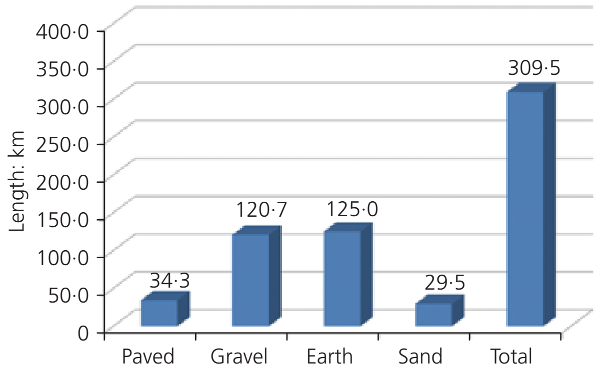

Figure 1. The Chobe road network

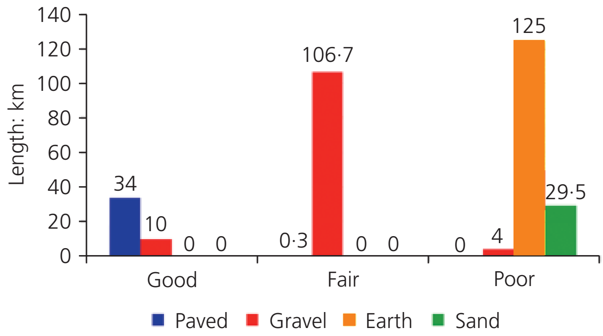

Figure 2. Current road condition at Chobe

3.2 Maintenance funding

A common scenario in developing countries is that new road constructions are encouraged and maintenance is neglected. Similarly, insufficient funds were allocated for maintenance in Chobe. Using the council maintenance-budget data for the current and previous years, it appears that maintenance funding has been reduced (see Table 2), whereas the road network has increased by almost 50% in the last two years. This indicates that maintenance is not getting proper attention.

Type of roads	Description of roads	Responsibility	Total: km (%)
Primary roads	Major national highways	Roads Department (NHA)	3,789 (21%)
Secondary roads	Secondary national highways that connect at least two district headquarters	Roads Department (NHA)	4,882 (27%)
Tertiary roads (rural roads)	Rural roads that connect at least two villages	Local Councils	2,644 (14%)
Access roads (rural roads)	Village internal roads	Local Councils	6,922 (38%)
Total			18,237 (100%)

Table 1. The road network in Botswana (RD, 1993)

Treatment	Year		
	2007–08	2008–09	2009–10
Routine maintenance	0·80	2·10	1·10
Periodic maintenance	8·17	8·28	2·54
Total	8·97	10·38	3·64

Table 2. Road maintenance funding trend in Chobe (funding in million pula; 1 US$ = approx. 7 pula)

It was found that 22%, 16% and 4% of total roads were considered for PM in 2007–08, 2008–09 and 2009–10 respectively. These roads were selected based on visual condition assessment, and social and political factors. As usual, earth and sand roads were not properly addressed. In general, the absence of a maintenance-management policy in Botswana has an impact on this yearly funding.

As mentioned earlier, there is no scientific analysis to determine the timely allocation of funds, which has effects on road preservation. For example, Nata-Kazungula National Highway was destroyed following a lack of timely PM rather only repeated patching was done when structural rehabilitation or reconstruction was necessary for this road (Palapye, 2011). This misuse of public money and applying the wrong maintenance treatments indicate that HDM-4 is necessary for efficient road management.

3.3 Road-maintenance practices

The overall approach in the selection of maintenance treatments is very traditional all over Africa including the Southern African countries, which is mainly based on engineering judgement and social and political pressure. Generally, road maintenance (RM) is done with the help of in-house staff and resources of the local council, and PM is managed through contracting out. The typical maintenance treatments can be seen in Table 3 below.

3.4 Data collection and database

Road-condition data are generally collected through field visits in Chobe. As a result, the system is subjective and needs major improvement. Furthermore, there is no comprehensive database and only the pavement inventory data are being stored. A subjective judgement on road condition is being used to classify a road as good, fair or bad. Details of potholes, cracking, roughness, rutting, deflection and traffic data are needed in future to evaluate the structural and functional condition of roads. Therefore, the training of staff, Road Measuring Data Acquisition System (ROMDAS) for roughness data collection and Benkelman beam deflectometers to obtain deflection data may need to be introduced in Chobe.

3.5 Pavement performance model

As discussed earlier, a road assessment and economic model needs to be introduced for the PMS in Chobe to reach sound decisions. The well-known HDM-4 is suitable for developing countries like Botswana. The road assessment models and necessary calibration studies have been effective in Brazil and South Africa; therefore, the HDM-4 would be very useful for the SADC countries like Botswana (Pinard and Rohde, 2001). It is worth mentioning that the Roads Department has adopted this decision model for analysis of the major roads. However, in reality, use of the HDM-4 model for asset preservation is very limited. The HDM-4 model can predict road deterioration and assess treatment and suggests the optimum maintenance treatments in the life cycle of a road in response to user-specified investment alternatives (Odoki and Kerali, 2000). Appropriate data quality and calibration of the key factors are essential to obtain credible HDM-4 results (Khan, 2007a), which need to be implemented in future.

3.6 Project selection

In Botswana new projects are generally selected through engineering judgement, political pressure, public demand and staff experience. On the other hand, maintenance projects are chosen based on visual assessment and social and political factors. There is no economic analysis to select an appropriate maintenance intervention, which may lead to improper use of public funds. The proposed HDM-4 would be helpful for this purpose.

Treatment types	Type of roads	Works	Resources
RM	Gravel road	Spot gravelling	In-house
		Dry grading	In-house
		Wet grading	In-house
		De-silting and vegetation control	Labour-based
	Paved road	Pothole patching	In-house
		De-silting and vegetation control	Labour-based
PM	Gravel road	Re-gravelling	Contracted out
	Paved road	Resealing	Contracted out

Table 3. Rural road-maintenance practices in Botswana including Chobe

3.7 Asset valuation

Roads have not been evaluated as assets by the authorities; this would help in future business planning and efficient road management. This paper has attempted to assess the roads' asset value.

4. Objectives of the paper

As discussed earlier, rural roads are being managed based on engineering judgement all over Botswana. Therefore, a detailed database, use of the HDM-4 model and the development of maintenance standards and strategy are necessary. It is important to adopt a comprehensive road-management system for future planning, budgeting and prioritisation of upgrading and appropriate road-maintenance interventions. Vincent *et al.* (1994) also emphasised establishing PMS in SADC countries, which comprises database, data collection, HDM model and Geographical Information Systems (GIS) for mapping.

This paper discusses a partial implementation of the PMS in Chobe – for example, improvement of the database, asset valuation, and development of maintenance standards and strategies.

5. Introduction of a PMS in Chobe

To manage the huge road assets efficiently, a comprehensive PMS is necessary in Botswana for major and rural roads' management. Most of the SADC countries do not have a well-established PMS with a decision-making model except for South Africa. In view of this, the author has tried to assess the implementation of a PMS to manage the road network in Chobe, as discussed below.

5.1 Improvement of the road database

Road inventory and traffic data were collected to establish the database. Road condition and roughness data were ascertained through visual assessment and the experience of council staff. Relatively high Motorised Annual Average Daily Traffic (MT AADT) was observed in the developed villages, mainly in the commercial and industrial areas, whereas it was low in other areas. The average MT AADT was 112·5 but the standard deviation was 135·6. On the other hand, the Non-Motorised Annual Average Daily Traffic (NMT AADT) was low in the villages, at 20·63 per day. The high standard deviation for MT AADT was mainly because of the location and importance of villages; remote villages have comparatively low traffic.

Table 4 shows the average roughness using the International Roughness Index (IRI) for paved and gravel roads. Generally, IRI represents the smoothness of a road and is being used in different countries to classify roads. The IRI was ascertained through visual inspection and engineering judgement was applied as there is no roughness survey equipment in Chobe. Table 4 shows that average roughness of the paved roads was 5·75 IRI and the standard deviation was 0·957. The lower the IRI value, the better a road is, and vice versa. The results reveal that paved roads are in good-to-fair condition. On the other hand, average roughness for the unpaved roads was 11·88 IRI and the standard deviation was 1·52, which indicates that the unsealed roads are generally fair-to-poor. Moreover, unsealed roads have gravel losses of about 15 mm. High gravel loss was observed in the areas where maintenance was not frequent.

5.2 Treatment intervention criteria and maintenance standards

Maintenance standards have to be defined to maintain roads efficiently, and this is a requirement for the HDM-4 analysis. Generally, the maintenance standard is a combination of treatments to be used in the life cycle of a road where commonly used RM and PM treatments are chosen. Treatment intervention levels were set based on engineering judgement, experience and local practices. However, the HDM-4 model may be used as a tool in developing optimum treatment intervention criteria for different treatments, which is a scientific approach and has been discussed in Khan (2006) and Khan and Odoki (2010).

The current paper proposes treatment intervention criteria and compound maintenance standards to manage the rural roads in Chobe (see Tables 5 and 6). The common treatments in the country have been chosen for these standards. Table 5 reveals the responsive intervention levels for each treatment. Table 6 shows the compound maintenance standard set for rural roads in Chobe. The proposed treatment thresholds are based on the criteria given in Table 5. For example, the following three types of standards were chosen for bituminous pavement

1. RM + reconstruction, which is the 'base case' as no PM has been considered
2. RM + resealing + reconstruction, which is being generally used but still overlay is missing
3. RM + resealing + overlay + reconstruction, which is the ideal case and may be considered as the maintenance standard.

Data	Average	Standard deviation	Remarks
MT AADT	112·50	135·60	Not well distributed; very low volume in rural areas
NMT AADT	20·63	9·05	Very low volume
Paved road roughness: IRI	5·75	0·96	Good to fair road
Gravel road roughness: IRI	11·88	1·52	Fair to poor road
Gravel loss: mm	15·36	5·60	Reasonable gravel loss

Table 4. Key results of the new road database

Road type	Treatment type	Criteria (valid for any AADT)
Bituminous (paved)	Pothole patching	⩾ 10 No./km Maximum roughness = 12·5 IRI Maximum quantity = 5000 m^2/km/year
	Edge repair	⩾ 10 m^2/km Maximum roughness = 16 IRI Maximum quantity = 5000 m^2/km/year
	Routine	Vegetation control Drain cleaning Road sign
	Resealing (25 mm) (double bituminous surface dressing, DBST)	⩾ 20% total damage area Maximum roughness = 12·5 IRI Minimum interval = 1 year
	Overlay (50 mm)	Roughness range = 6–12 IRI Maximum roughness = 16 IRI Minimum interval = 1 year
	Reconstruction (50 mm surfacing)	⩾ 12 IRI
Gravel (unpaved)	Grading	Maximum roughness = 30 IRI Minimum interval = 180 days
	Spot gravelling/improvement	Annual material loss to replace = 50% Maximum roughness = 30 IRI Maximum quantity = 5000 m^2/km/year
	Routine	Vegetation control Drain cleaning Road sign Reshape of camber
	Re-gravelling	Final gravel thickness = 150 mm ⩽ 50 mm gravel loss Maximum roughness = 30 IRI Minimum interval = 1 year
Earth and sand (unpaved)	Grading	Maximum roughness = 30 IRI Minimum interval = 730 days
	Spot gravelling/improvement	Annual material loss to replace = 60% Maximum roughness = 30 IRI Maximum quantity = 5000 m^2/km/year
	Routine	Vegetation control Drain cleaning
	Re-gravelling	Final gravel thickness = 150 mm ⩽ 50 mm gravel loss Maximum roughness = 30 IRI Minimum interval = 1 year

Table 5. Proposed treatment intervention criteria for Chobe

Similarly, gravel, earth and sand roads have ideal standards (see Table 6) to be utilised in the HDM-4 analysis for road management. In future, strengthening overlay may be used as a rehabilitation option.

5.3 Inputs to the HDM-4 model

HDM-4 model (version 1.3) was introduced in Chobe for the preservation of its road assets. Generally, the following inputs are necessary for a HDM-4 run (Odoki and Kerali, 2000)

(*a*) Updated road condition, inventory and drainage condition data (collected by the council staff)
(*b*) AADT and traffic composition
(*c*) Calibration factors of HDM-4 (default factors were used in the current analysis)
(*d*) Treatment unit costs (see Table 7 for the current analysis)
(*e*) Treatment intervention criteria and set standards (Tables 5 and 6).

Road type	Base case	Maintenance case	Ideal case
Bituminous	RM[a] + reconstruction	RM[a] + resealing (DBST in every 3 years) + reconstruction	RM[a] + resealing + overlay + reconstruction
Gravel	RM[b]	RM[b] + re-gravelling (⩽50 mm, every 3 years)	RM[b] + re-gravelling
Earth and sand	RM[c]	RM[c] + re-gravelling (⩽50 mm, every 5 years)	RM[c] + re-gravelling

[a] Bituminous RM = pothole patching (7 days) + edge repair (2 months) + routine
[b] Gravel RM = Dry grading (2 times/year) + spot gravelling/improvement (⩽50 mm, once a year) + routine
[c] Earth and sand RM = dry grading (once/twice a year) + spot gravelling/improvement (⩽50 mm, once a year) + routine

Table 6. Set of compound maintenance standards

Treatment type	Economic costs:[a] million pula	Financial costs:[a] million pula
Pothole patching	46	58
Edge repair	46	58
Resealing	5·3	6·6
Patching	46	58
Edge repair	46	58
Crack sealing	28	35
Overlay	5·3	6·6
Patching	46	58
Edge repair	46	58
Grading	120	150
Spot improvement	1·2	1·5
Spot re-gravelling	1·2	1·5
Gravel resurfacing	2·5	3
Spot gravelling	1·2	1·5
Gravel surfacing	2·6	3·3
Reconstruction: km	184,600	230,750
Routine: km	5,000	6,230

[a] Generally economic costs do not include tax, VAT etc., whereas financial costs include all

Table 7. Treatment unit costs in Chobe (1 US$ = 7 pula)

5.4 Maintenance demand

A HDM-4 analysis has been done for the whole road network to obtain the maintenance demand for the next 20 years. The above-mentioned inputs (see Section 5.3) were used. Default calibration factors of the Road Deterioration and Work Effects models were used, as no calibration and validation has been recorded for Botswana. However, the original HDM study was conducted in South Africa, which indicates that default factors may be utilised if no calibration were done. The HDM-4 program analysis was used to obtain the total demand, where the optimisation objective was 'NPV (Net Present Value)/cost maximisation'. The result can be seen in Figure 3.

The total maintenance demand obtained was 41·29 million pula for the next 20 years. Therefore, the average demand was about 2·1 million pula per year. The maintenance funding in 2009–10 was 3·64 million pula (see Table 2) which was greater than the average demand. The major allocation was applied to 15 km of gravel roads chosen through social and political factors. Hence, the funding was not appropriately assigned. Therefore, it is recommended to use the HDM-4 model for prioritisation of road projects when resources are constrained.

In future multi-criteria analysis (MCA) may be introduced for managing rural roads in Botswana, which was successfully demonstrated as a case study to prioritise projects using social,

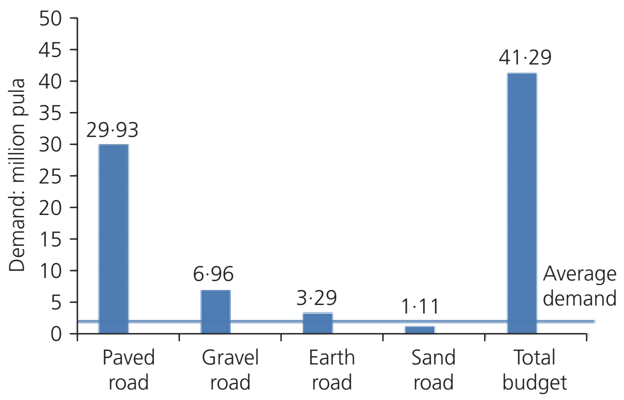

Figure 3. Road preservation demand at Chobe

political, economic, environmental and job-creation factors (Khan, 2007b).

5.5 Asset valuation

The roads' asset value for the Chobe road network was found to be 55·48 million pula (see Table 8). It was estimated that about 20·63 million pula was needed in the first year (in 2009–10) for appropriate road maintenance and to remove backlog, as shown in Table 8. In reality, 3·64 million pula was allocated but not properly used for the whole network – which indicates a huge accumulation of backlog. As described earlier, this is a common scenario in Africa and SADC countries.

5.6 Long-term maintenance strategy

The HDM-4 strategy analysis was utilised to derive a long-term maintenance strategy using the above-mentioned inputs, treatment unit costs, intervention criteria, standards and default calibration factors. The optimisation objective considered in the analysis was 'maximise NPV'.

Generally, roads representative of the network are used as inputs in the strategy analysis. The Chobe road network was therefore grouped into four representative road sections to obtain the long-term maintenance strategy and required budget. These groups were based on pavement type (e.g. paved, gravel, earth and sand) and traffic volume. It has been mentioned earlier that the traffic volume was low on the rural roads in Chobe. To obtain a long-term maintenance strategy, it is usually assumed that there is no maintenance backlog and that road groups are good. Key data of the chosen groups (length-weighted average road sections) can be seen in Table 9, where real and hypothetical road-condition data were utilised to develop these groups.

The result of the long-term maintenance strategy for the Chobe road network can be seen in Table 10. The total PM demand was 6·43 million pula for the next 20 years provided that backlog is removed first. Figure 3 shows that the total maintenance demand was 41·29 million pula. This reveals that the current backlog was about 34·86 (41·29 – 6·43) million pula. Moreover, Table 8 shows that the first-year backlog is 20·63 million pula. The reason for this high backlog was mainly lack of timely and appropriate maintenance. The predicted performance of the paved and unpaved roads in Chobe can be seen in Figure 4. The results show that paved roads can be maintained at good standard (at 4 IRI). However, all the unpaved roads may be maintained at 13 IRI, as they need more attention on maintenance.

6. Conclusion

Rural roads are not managed efficiently in Africa and SADC countries, as they do not have established PMS, and this also applies to Chobe. There is no tool to select projects through economic analysis. Furthermore, the funding trend shows that recent emphasis has been given mainly to road development, and roads are not maintained in a timely manner. To improve the situation, the HDM-4 model has been introduced in Chobe for the first time.

The current paper proposes maintenance standards and treatment intervention levels for Chobe, which have been set based on engineering judgement, experience and maintenance practices.

The present analysis reveals that total demand for the road network in Chobe was 41·29 million pula, backlog was 34·86 million pula and first-year backlog was 20·63 million pula. The long-term PM treatments/strategy have been identified, which will

Road type (1)	Length: km (2)	As new road costs		First-year road-maintenance costs based on HDM analysis: million pula (5)	Current roads' asset value: million pula (6) = (4) – (5)
		Unit rate: million pula (3)	Costs: million pula (4)		
Paved	34·3	1·50	51·45	8·50	42·95
Gravel	120·7	0·15	18·11	8·45	9·66
Earth	125·0	0·05	6·25	3·50	2·75
Sand	29·5	0·01	0·30	0·18	0·12
Total	309·5		76·11	20·63	55·48

Table 8. Current roads' asset value in Chobe

Road group	Description	Length: km	Width: m	Shoulder: m	MT AADT	NMT AADT	Road condition	Drainage condition	Last treatment
PLTG	Paved, low traffic, good	34·3	7·00	2·00	494·3	47·4	Pothole 8·23, cracking 1·6%, ravelling 0·8%, edge break 2, roughness 3·9 IRI	Fair	Resealing (25 mm), 2008
GLTG	Gravel, low traffic, good	120·7	6·94	1·00	137·3	22·6	Roughness 9 IRI, gravel thickness 145 mm	Fair	Re-gravelling, 2008
ELTG	Earth, low traffic, good	125·0	5·35	1·00	31·9	15·0	Roughness 10·5 IRI, gravel thickness 140 mm	Poor	Grading, 2009
SLTG	Sand, low traffic, good	29·5	5·00	1·00	67·4	19·7	Roughness 10·5 IRI, gravel thickness 140 mm	Poor	Grading, 2009

Table 9. Representative road groups for the Chobe road network

Year	Section[a]	Road class	Works needed	NPV/costs	Financial cost: million pula
2010	SLTG	Tertiary	Re-gravelling	25·68	0·08
2010	ELTG	Tertiary	Re-gravelling	12·96	0·36
2011	PLTG	Tertiary	Reseal at 30% surface damage	1·90	1·58
2017	GLTG	Tertiary	Re-gravelling	29·35	0·29
2022	PLTG	Tertiary	Reseal at 30% surface damage	1·90	1·58
2023	SLTG	Tertiary	Re-gravelling	25·68	0·06
2024	GLTG	Tertiary	Re-gravelling	29·35	0·33
2025	ELTG	Tertiary	Re-gravelling	12·96	0·25
2025	PLTG	Tertiary	Overlay at 6–12 IRI	1·90	1·58
2029	GLTG	Tertiary	Re-gravelling	29·35	0·32

[a] For key see Table 9

Table 10. Long-term road-maintenance strategy for Chobe

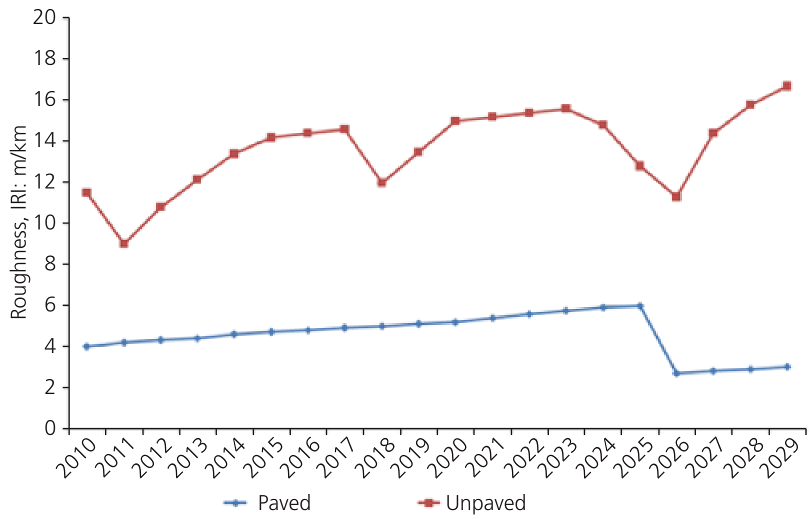

Figure 4. Predicted performance of paved and unpaved roads at Chobe

cost 6·43 million pula (when there is no backlog). This huge backlog indicates that roads are not being maintained appropriately. Furthermore, the paper estimated the current roads' asset value in Chobe, which was 55·48 million pula.

7. Recommendations

The scope of the current project has been to implement a PMS in Chobe. However, the following need to be addressed in future for better road management.

(*a*) A road-maintenance policy and strategy are needed for primary and rural roads in Botswana.
(*b*) A comprehensive PMS is necessary for any road authority, which entails regular data collection, database, use of the HDM-4 model, programming and implementation.
(*c*) Rehabilitation (structural overlay) design needs to be considered along with the current maintenance practices in the country.
(*d*) MCA may be introduced to prioritised rural roads for maintenance after obtaining economic results from HDM-4. The MCA may be based on social, economic, political, environmental and job-creation factors.
(*e*) Adequate and timely road-maintenance funding is essential, therefore, Botswana may consider establishing a Road Fund dedicated for maintenance. Road-user charges are a useful source for ensuring maintenance funding.
(*f*) Outsourcing of road and drainage maintenance using the PBM can be implemented for better road management.
(*g*) Optimum pavement-maintenance standards and strategies using the HDM-4 model need to be set for the whole road network of Botswana.
(*h*) Calibration of HDM-4 is necessary for the country using Long Term Pavement Performance (LTPP) data.

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Appendix

Paved road at district headquarters

Paved road at district headquarters

Intersection of paved and gravel roads

Paved road with defects

Paved road with defects

Bus bay with defects

Figure A.1. Typical photographs of the road network at Chobe

Paved road at district headquarters

Paved road at junction

Paved road with defects

Paved road at junction

Gravel road after rainfall in a village

Earth road after rainfall in a village

Figure A.2. Typical photographs of the road network at Chobe

Gravel road and effect of bad drainage

A major gravel road saturated with moisture

Gravel road with defects

Installation of a temporary culvert during flood

Typical good-quality gravel road

Typical gravel road at district headquarters

Figure A.3. Typical photographs of the road network at Chobe