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The Challenges of Implementing Gravel Road Management System in Sub-Sahara Africa: Tanzania Case Study

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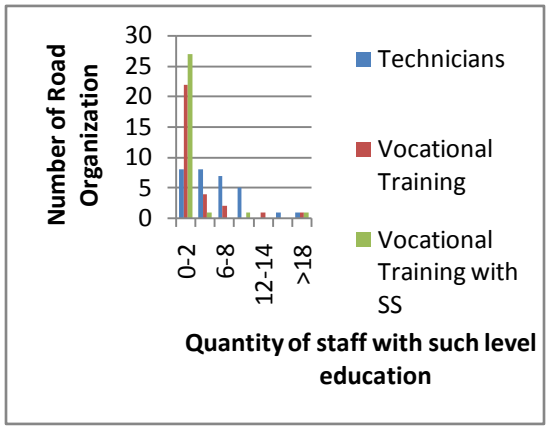
Abstract

The study examined the working environment of road organizations in Tanzania mainland implementing gravel road management system. These road organizations falls into two categories, namely those managing district roads networks and those managing national and regional road networks. The former are managed by building and civil works departments under local government and headed by district council or municipal council engineers under the Prime Minister Office of Regional and Local Government (PRO-RALG). National and regional road networks are managed by road agency known as TANROADS under the umbrella of the Ministry of Works. TANROADS have offices in each regional headquarter and headed by regional manager. A qualitative survey design was used to study the working environment of these organs in managing the gravel roads networks under their judiciary. Data were collected through questionnaire. Randomly selected TANROADS regional offices and district/municipal/city councils engineers' offices were recipient of these questionnaires. All together 30 out of 70, that is 42.86% of the randomly selected road organization offices responded. The study found out these road organizations are shortage of human resources, lack formalized in-service training system, and facilities for effective implementation of gravel road management system (GRMS). Recommendations are thus mainly focused on ways of mitigating these challenges so as to enable these road organizations to run the GRMS effectively.



Keywords: Gravel road performance, Quality control, Construction and maintenance operations, Gravel materials behavior, Road organization, Effective GRMS

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I. INTRODUCTION

There is growing awareness among highway engineers of a need to improve knowledge of inter-relationship between the construction standards, maintenance standards, climate, traffic volume and type, vehicle operating costs and unsealed roads performance (Ellis 1979). To improve such knowledge there is a need of well trained and experienced road organization staffs. The team of these staff should be of adequate size, education and experience. Although lack of adequate staffs do not deny the organization an opportunity of developing such relationship to suit their local condition, but education, experience, and facilities are so important for running effective GRMS that no road organization can do without. Although most sub-Sahara Africa countries are currently deploying a kind of GRMS in running their gravel road network but lack of facilities and experienced and educated staff are upsetting any gain in that direction. The effort is made more complex by the influence the politician have in deciding how far GRMS should go despite, in most cases, lack of knowhow. It is therefore essential for the benefit of road users, road agency, environment, and the sustainability of gravel roads to establish the capacity of road organization in running GRMS effectively. This paper by looking on the challenge being faced by these Tanzania`s local road organizations in implementing GRMS is an attempt in that direction.

II. ATTRIBUTES OF RESPONDENTS AND THEIR RESPONSE RATE

Two groups of respondents were selected for the study to whom questionnaire were sent, namely TANROADS regional offices and district/municipal councils engineers offices. Each one of these two groups uses different package of GRMS for conserving the gravel road network under their judiciary.

TANROADS whom are responsible with managing trunk and regional roads uses Road Maintenance Management Systems (RMMS), while Local Government Authority (LGA) District/Municipal councils engineer`s offices who are responsible with managing district roads uses District Roads Management Systems (DROMAS). Both these system have been developed with experts and financial assistance from foreign countries, with involvement of local experts at ministerial or top managerial levels (Mwaipungu and Allopi 2012). These two groups have mutually exclusive experience on the performance of gravel roads under their judiciary and the extent of the effectiveness of the type of GRMS employed. They are also aware of the strength and weakness of their GRMS.

Although the postal questionnaire were sent to randomly selected TANROADS Regional offices and district/municipal councils engineers offices all over Tanzania mainland, but the targeted areas were those TANROADS regional offices and District and Municipal engineers offices surrounding Iringa region and District and Municipal engineers offices within Iringa region. Iringa region was the study area. The TANROADS regional offices surrounding Iringa region are Mbeya, Morogoro, Dodoma and, Iringa itself, and district and municipal council engineers' offices belonging to the mentioned regions, which will not be listed for brevity.

Table 1 presents the number of questionnaire mailed to each category of respondents, number responded and the response rate percentage. It should be stressed upfront that both categories of populations are homogeneous, and according to Holt (1998:94) the more homogeneous a population is, then the smaller that samples can be drawn from it, and vice-versa. Henrrink, Hutter and Bailey (2011:16) pointed out that qualitative research study population is small and purposely selected.

TABLE I

The number of questionnaire mailed to each category of respondents, and the response rate in percentage

Category of respondents	Number of questionnaire	Number responding	Response rate (%)

	mailed		
TANROADS	15	11	73.3
District/Municipal/ City	55	29	52.73
Total	70	30	42.86

III. DATA ANALYSIS

The questionnaire comprised of five main questions, divided on the following themes; (i) management of gravel roads, (ii) local climatic conditions, (iii) statistical data on gravel road networks, condition survey and uses of road condition data, (iv) management of gravel materials borrow pits and quality control of gravel materials used for surfacing unsealed roads, and (v) construction and maintenance operation of unsealed roads. The analysis of responses follows the order of questions.

The results were analysed using frequency tables. According to Henrrink, Hutter and Bailey (2011:17) qualitative data analysis is interpretive, whereby researchers seek to interpret the meanings of the participant's responses to questions, views and experiences. The following sections present the analysis of the survey results.

IV. MANAGEMENT OF GRAVEL ROADS

Maintenance is essentially a management problem. The improvement of maintenance often involves institutional reform, human resource development and changes to management practices before addressing technical issues. (Mwaipungu and Allopi 2012).

According to Mwaipungu and Allopi (2012) the task of managing a gravel road in an optimal manner still remains a technically complex one, as it involve among other variables, different personnel with different experience. The response obtained on the question of the number of personnel running the gravel road management and their experience on the work varies widely for the road organizations being funded by the same government. Technical personnel range between 2 and 28, with the minimum number belonging to district councils engineer's office. The supporting staff varies between 1 and 71, with the lowest figure belonging to district councils engineer's office and the highest belonging to TANROADS Regional office. This variation, grouped in the range of 2, is indicated in Table II. It can be noted from afore mentioned table, that there is huge variation in the number of technical and supporting staff each road organization have. Such kind of huge variation put those road organizations offices with less staff in a position of being incapable of managing effectively the gravel road network under their judiciary.

TABLE II
The number of technical and supporting staff of each road organization

Range in number of staff	Technical staff	Supporting staff
0-2	2	12
3-5	6	1
6-8	7	2
9-11	5	3
12-14	3	4
15-17	4	2
18-20	1	2
> 20	2	4

It can be noted from Table III that 46.7% of road organizations surveyed have staff possessing experience of more than five years in supervising maintenance operations of gravel roads, while 36.6% of these road organization have staff with experience ranging from <3, 3-5 and >5 years.

It is suffice to conclude that both road organizations are being run by staff with more than 5 years experience. It can be noted from Table III that 70% of road organizations surveyed does not have staff with less than 3 years experience, which implies that they do not recruit new staff.

TABLE III

Experience of road organization in supervising maintenance operations of gravel roads

Range of experience in years	Frequency	Percentage (%)
<3, 3-5, and > 5	6	20
<3 and 3-5	0	0
<3 and > 5	3	10
3-5 and > 5	2	6.6
< 3	0	0
3-5	5	16.7
> 5	14	46.7
Total	30	100

The distribution of staff with less than 3 years, 3-5 years and more than 5 years experience do not display any definite pattern to give room for transfer of knowledge and skills from those with more than 5 years experience to those with less experience.

A. Engineering and technical education

Table IV shows the range of road organization with a number of staff with engineering and technical education, while Figure 1 shown the range of road organization with the number of staff with technical, vocational without secondary education and vocational with secondary education. It can be noted from Table IV that staff with engineering education varies widely, with 13 (43.3%) road organizations having between 1-2 engineers, only 2 (6.7%) organizations having between 9-10 engineers. The same variation is being noted in staff with technical and vocational education. With this type of variation in technical education, it is challenging to organize a formalized system of gravel road management, let alone implementing it effectively.

TABLE IV

Range of road organization with number of staff with engineering and technical education

Range of technical personnel	Engineer		Technician	
	No. of Road agent	Percentage (%)	No. of Road agent	Percentage (%)
1-2	13	43.3	8	26.7
3-4	2	6.7	5	16.7
5-6	11	36.6	7	23.3
7-8	2	6.7	3	10
9-10	2	6.7	3	10
11-12	0	0	2	6.7
> 13	0	0	2	6.7
Total	30	100	30	100

B. The size of technical and supporting staff managing gravel roads

Although the number of regions and districts in Tanzania mainland has increased by almost 2% since the beginning of this research work in 2011, but this is not reflected in technical personnel running gravel road management system.

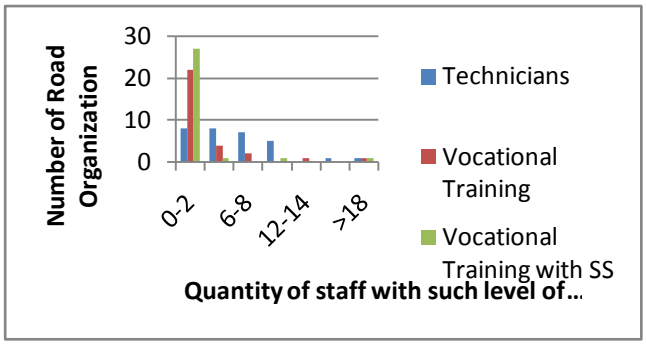

Figure 1: range of road organization with number of staff with technical, vocational, and vocational with secondary school education

C. Training

Education and training is a key feature of any pavement management system for it to be effective and implementable (Kuennen 2009:2). 21 (70%) road organizations surveyed responded positively to the question of if funds are available for training staff, with 9 (30%) declaring that there are no funds for such training. It is alarming that 30% of road organizations surveyed have declared that there is no system in place for providing training to their team of gravel roads maintenance. For sustainable development in the sector of gravel roads management this has to be addressed.

V. LOCAL CLIMATIC CONDITIONS

Those responded to the question of local climatic conditions indicated that their gravel roads fall in one, two or three climatic conditions prevailing in Tanzania, which are wet, dry, and moderate climatic condition as shown in Table V. On the question of if there is an area which receives unique climatic condition different from surrounding areas, 3 (10%) road organizations confirm that they have areas with a unique climatic condition which might necessitate a different deterioration predicting model for gravel roads in those areas.

TABLE V
Tanzania`s local climatic condition in the responded regions

Climate	Frequency	Percentage (%)
Wet	2	6.7
Dry	2	6.7
Moderate	17	56.6
Wet and Dry	3	10
Wet and Moderate	3	10
Dry and Moderate	2	6.7
Wet, Dry and Moderate	1	0.3
Total	30	100

Although such cases as the one reported above are few, but it is a call for road organization to constantly study the environment in which they are working so as to improve further the performance of the gravel road networks under their management within their financial limitations.

VI. STATISTICAL DATA ON GRAVEL ROAD NETWORKS, CONDITION SURVEY, AND USES OF DATA AFTER ANALYSIS

Although the questionnaire included questions requiring knowing the length of earth road and tracks, the paper will discuss only gravel roads which are the centre of this research study and give only a picture of other types of unsealed roads as shown in Figure 2. The length of gravel roads under the judiciary of the road organizations responded vary widely. The extents of variations are from 10 km to 3000 km.

TABLE VI
The frequency of the road organization and the range of gravel road length under their judiciary

Range in km of gravel road length	Frequency of road organization managing such length	Percentage (%)
0-250	11	36.7
250-500	5	16.7
500-750	3	10
750 - 1000	5	16.7
1000 - 1250	1	0.3
1250 - 1500	0	-
1500 - 1750	2	6.7
1750 - 2000	1	0.3
2000-2250	1	0.3
> 2250	1	0.3
Total	30	100

Table VI shows the frequency of road organizations and the length of gravel roads in the range of 250 km under their judiciary.

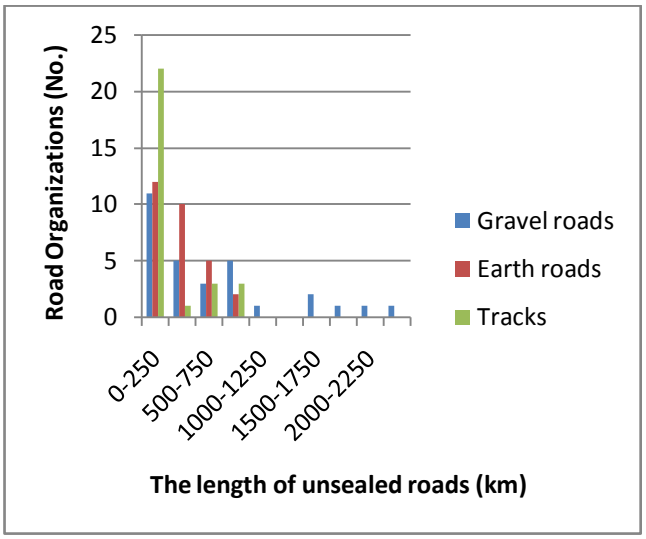

Figure 2: the length of unsealed roads (km) under the judiciary of road organization responded to questionnaire

From the data received on gravel road length, it can be noted that the average length of gravel road under the judiciary of each engineer regardless of the road organization which one is coming from is 160 km. Such kind of length is quite long for one engineer to manage effectively each year, bearing in mind the activities involved in gravel road management. The manageable size recommended in this paper is 50 km per one engineer.

Lazic (2003) supported that the effective decision making in the road organization starts with the gathering of reliable information about the correct condition of the road network under their judiciary. It is no wonder that, all respondents admitted that they do have an inventory of gravel roads network under their management. The frequency in which data on the condition of gravel roads is being collected is mostly once per year, with one district council declaring that it does not collect any data, two are doing it once per two years, one twice per year and the other two have no known schedule for the exercise.

According to Larsen, Hildabrand, and Macdonald (2002:5), traffic is one to the main causes of road pavement deterioration and therefore it is essential to be able to produce accurate traffic forecast. It is no wonder that most road organizations that responded to the question of type of data being collected declared that they do collect traffic volume data and conduct distress survey. Although local climatic condition is said to affect the performance of gravel roads immensely (Paige-Green 1999:163-171), but there is no mentioning of collection of climatic data in terms of rainfall amount specific to each administrative demarcated areas, as Tanzania Meteorological Agency collect rainfall data on very limited locations country wide. None of the road organizations responded conduct time series performance study in terms of longitudinal roughness or gravel loss surveys. According to Ellis (1979) improved time series quantification of the rates of deterioration of gravel roads is necessary in order to assess maintenance needs in economic terms, and to plan cost effective maintenance strategies.

It is evident that for the reliable quantified data to be collected from gravel roads, effort is needed not only to equip road organizations but to give them training on the need of such data. These data are required not only for the purpose of developing gravel road deterioration models but also for understanding the performance of gravel materials used to surface unsealed roads under their management and formulating or improving the specification. This understanding will have a longer effect on the sustainability of gravel roads.

VII. QUALITY CONTROL OF GRAVEL MATERIALS FOR SURFACING UNSEALED ROADS

Each respondent agreed having an active borrow pit for winning gravel materials. On whether these road organizations follow a routine procedure of seeking approval from the Ministry responsible with mining or conduct environmental impact assessment before opening new borrow pit: 21(70%) respondents said that they do not look for approval, among those 21 (70%), 2 (9.5%) do environment impact assessments through contractors who have been awarded construction or maintenance works.

Nine (30%) respondents do seek approval and conduct environments impact assessment. Twelve (40%) respondents out of 30 do not determine the geological nature of these borrow pits due to scarcity of materials laboratory with such capacity. The active laboratories for conducting such test are in Dodoma and Dar es Salaam regions.

Most districts and municipal councils do not own or have materials laboratory within their district, and depends on TANROADS Laboratories which are situated in regional headquarters. Common tests conducted in these TANROADS laboratories with significance to gravel materials are atterberg limits, compaction, sieve analysis, and California bearing ratio (CBR). These tests are sufficient for quality control purposes.

The importance of testing gravel materials before use cannot be over emphasized. If no test is done on construction materials, then one has no right of using them. Paige-Green (1998:19) insist that the properties of the gravel materials should be tested on a regular basis during construction to ensure that they do not differ from accepted specification. Among 30 respondents, 18 (60%) agreed that they do test gravel materials before using them, 3 (10%) district councils uses the test results obtained by TANROADS, and particular those which share the same borrow pits with TANROADS Regional offices. Three (10%) district councils declare that they do not test their gravel materials before use, while 2 (6.7%) district councils declare that there is no funds for such tests, implying that if funds are available they will also perform all necessary tests on gravel materials before using them to surface their unsealed roads.

Variations in materials test results are normally inevitable in gravel road construction or maintenance works. Eleven (36.7%) responded to this question by describing how does variation in test results are addressed during quality control of construction or maintenance works on gravel roads. According to 5 (16.7%) respondents, variations in quality control test results are either addressed jointly by all stakeholders or by referring to standard specification. Four (13.3%) respondents said that they had not encountered variation as the tests are being conducted by the third parties, who settle any variation if encountered within parties involved, with 1 (3.3%) respondent saying that variation encountered is within the acceptable range of ± 5 per cent.

VIII. CONSTRUCTION AND MAINTENANCE OPERATION OF UNSEALED ROADS

The title above cover all categories of unsealed roads, which are gravel roads, earth roads and tracks, although the research mainly concentrates on gravel surfaced unsealed roads.

The questions on construction and maintenance operation of unsealed roads, which were 7 in number, were seeking to know not only the type and availability rate of construction plants, namely graders, excavator, dozer, compaction plants ranging from vibratory, sheep foot, steel roller, pneumatic rollers, plate compactor, and pedestrian roller, but also the quality control measures on construction and maintenance operation of gravel roads. On the availability rate of construction plants, 16 (53.3%) respondents said it is low, 8 (26.7%) said it is medium, while 2 (6.7%) said it is high. By low, it means one plant per seven contractors, medium, one plant per four contractors and high implies one plant per two contractors. Table VII shows the availability rate of construction and maintenance plants.

TABLE VII
Availability rate of construction and maintenance plants

Availability rate	Frequency of respondents	Percentage (%)
Low	16	53.3
Medium	8	26.7
High	2	6.7
No response	4	13.3
Total	30	100

From Table VII it can be noted that the low rate of availability of maintenance plants jeopardizes the timely execution of the construction and maintenance exercise of gravel roads. According to Anastasopoulos, Mannering and Haddock (2009:8) the timely application of the appropriate maintenance treatment preserve the gravel road network and delays future deterioration.

On grading methodology adopted during the grading exercise of gravel roads, Table VIII shows that 26 (86.7%) respondents agreed that they are using self propelled graders, 3 (10%) mentioned that they use both self propelled and dragged equipments, with dragged ones giving unsatisfactory results. Only one (3.3%) respondent indicated that they are using dragged equipments.

TABLE VIII
Types of grading methodology adopted during the grading exercise of gravel roads and its frequency

Type of grading equipment	Frequency of respondents	Percentage (%)
Self propelled	26	86.7
Dragged	1	3.3
Both	3	10
Total	30	100

Labour based gravel road maintenance involves breaking down various component of gravel road maintenance into small and simple activities that are easily carried out by hand such as vegetation control, earth work and gravelling (Tembo and Blokhuis 2004). On labour intensive maintenance method vis-à-vis equipment based method question, 24 (80%) respondents concur that the labour intensive maintenance method is been given low priority, with 6 (20%) respondents giving it medium priority. Table IX indicates how labour intensive maintenance method is being perceived by respondents.

TABLE IX
The level of acceptance of labour intensive maintenance methods

Level of acceptance of labour intensive method	Frequency of respondents	Percentage (%)
Low	24	80
Medium	6	20
Total	30	100.0

In rural areas, the major maintenance methods being employed is the mixed one, that is equipment and labour based, with 24 (80%) respondents voted in favor of that system, while 6 (20%) respondent says that even in the rural areas, equipment based method is being used for maintaining gravel roads.

Most gravel roads require grading to be scheduled at regular interval of time to remove corrugations, to restore the transverse profile, and to bring back into the centre of the road gravel that has been thrown to the sides by the action of traffic (Ellis 1979:5). On the question of when do local road organizations schedule maintenance activity on unsealed road? 25 (83.4%) respondents say that they conduct maintenance immediately after the end of the wet season. Reasons for such decision are as follows:

- To prevent maintenance works to be interfered with the rain, which cannot be programmed,
- It is the source of moisture for compaction in dry areas , and to rectify defects which were developed during the rainy season,
- Intervention to improve road conditions at the end of rainy season yield good results,
- To restore the surface profile and clean drainage structures,
- To rectify distress caused by washout and rain,
- The nature of soil, which is predominantly clay, dictates that

maintenance to be done at the end of the rainy season,

- It is easy to notice defects.
- The soil possesses moisture content which approximately at optimum

One (3.3%) respondent said that they conduct maintenance at the beginning of the wet season, and 4 (13.3%) respondent said that they are doing it twice per year, that is at the end of the dry and wet season. Table X depicts the maintenance schedule of gravel roads on selected routes adopted by respondents.

TABLE X
Season in which maintenance is being scheduled

Season in which maintenance is being scheduled	Frequency of respondents	Percentage (%)
Immediately after the end of wet season	25	83.4
At the beginning of wet season	1	3.3
In both seasons	4	13.3
Total	30	100

From the response to this question, it is evident that the schedule for collecting data on road condition, to be effective, should be set between the period in which no maintenance activities is planned to take place, for the results to be used to determine the intensity of maintenance. Although, from experience, scheduling maintenance activity does not mean that maintenance activity shall be carried out.

The question of whether the compactive effort achieved after compaction exercise is being evaluated, 28 (93.3%) respondents say yes, with 16 (57.1%) among them using performance specification, and 12 (42.9%) using both, performance specification and method specifications. 2 (6.7%) respondents said that the exercise is not being evaluated. Table XI indicates the specification methods preferred during the measurement of compactive effort achieved on gravel wearing course layer.

TABLE XI
Common specification methods used in measuring compaction exercise achieved on gravel wearing course

Specification adopted	Frequency of respondents	Percentage (%)
Performance	16	55.6
Both Performance and Method	12	33.3
None	2	11.1
Total	30	100

It is evident from the response to this question, most road organization do ascertain the quality of road works done themselves, in particular where there is no consultant employed for such work. This is the cause of corruption in road construction industry and shoddy works being accepted.

IX. CONCLUSION AND RECOMMENDATION

In concluding it is suffice to mention that:-

- The capacity of each road organization, in terms of knowledge and skills, should equal the task and working environment in which they are operating GRMS.
- Politicians in the concerned areas have to be constantly informed and create self interest on matters affecting gravel roads performance.

The paper recommends that:-

- The pavement performance predicting models adopted or to be adopted (formulated) for predicting gravel road deterioration should reflect the capacity of a road organization in question to collect data on gravel roads which are relevant to the model in question,

- There is a need to establish materials laboratory for testing road building materials in each district, or to encourage private sector to run one.
- The quality of road works should be ascertained by the third organization, and not by road organization engineers/technicians, to minimize and eventually eradicate corruption practices and shoddy works being accepted in the road construction industry.
- Data on rainfall should be collected district wise, or even at ward level and not at regional level, for them to be very effective in predicting its influence on gravel roads performance in rural areas.
- The road organizations have to constantly study the environment in which they are working so as to improve further the performance of the gravel road networks under their management within their financial limitations.

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