THE USE OF LONGITUDINAL ROUGHNESS DATA AS A TOOL FOR EFFECTIVE MAINTENANCE MANAGEMENT OF GRAVEL ROADS

RICHARD R. MWAIPUNGU and DR DHIREN ALLOPI*

Durban University of Technology, P O Box 1334, Durban, 4000 Mob: +255 754 292426; Email: rrmwaipungu@gmail.com *Durban University of Technology, P O Box 1334, Durban, 4000 Tel: 031 373-2310; Email: allopid@dut.ac.za

ABSTRACT

This paper attempt to define the use of gravel road longitudinal roughness data as a significant input in Gravel Road Management System (GRMS). The data were collected from three gravel roads constructed using marginal materials in Tanzania. Two of them are in the Kilimanjaro Region and one in the Coastal Region.

The rates of longitudinal roughness progression of these gravel roads were recorded using vehicle mounted bump integrator (VMBI) at 100 metre intervals. These data were later used to locate road sections with roughness at or above IRI 14 m/km for distress survey. Roughness at or above IRI 14 m/km is specified by the literature as the minimum above which the gravel roads will begin to show deep depressions and erosion gulley.

The correlation between longitudinal roughness and traffic volume for each road was good, and the minimum and maximum threshold at which maintenance should be triggered was set. Recommendations are made to use classified traffic volume data together with longitudinal roughness data in prioritising gravel road maintenance.

1 INTRODUCTION

Primarily, roughness from the surfacing layer characterizes the deterioration of gravel roads. The initial roughness of gravel roads will increase through shear, mechanical disintegration and erosion of the surfacing materials caused by traffic and surface water runoff.

The principal operation in maintaining gravel roads is grading, which, depending on traffic level and type of surfacing materials, is carried out once, or twice a year. It is therefore unrealistic to carry out such a maintenance operation in response to defective levels measured during road inspections. A different approach to the maintenance of gravel roads is advocated, whereby intervention should be based on a maximum allowable longitudinal roughness and maintenance carried out at the appropriate time.

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1.1 Problem Statement

Studies of gravel roads operation in Tanzania have noted that apart from very few notable exceptions, there is no strategically planned and optimized GRMS. Gravel roads maintenance decisions are frequently based on judgment and experience of engineers and administrators in different organizational units, as well as on varying and sometimes inconsistent sources of information. Most often superficial or technically inadequate repairs are made. In the worst case, roads are not maintained at all.

Although it has limitations, probably one of the best methods for implementing GRMS aims on gravel roads is by measuring its longitudinal roughness. Quantifying the gravel road longitudinal roughness is the key to correct decision on its repair or renewal. Data of road longitudinal roughness can form the important input in assisting decision makers in locating road sections in dire need of maintenance. And also assist in making decisions on where to spend the limited budget for efficient and effective gravel road maintenance.

1.2 Objectives

To develop:
- i. an affordable system of locating changes in the surface and structural conditions of gravel roads.
- ii. a basis for prioritizing maintenance work.

1.3 Scope of the Study

This study is limited to quantitative and qualitative analysis of data collected for developing GRMS, from Kibiti-Utete, Same-Bangalala-Makanya, and Marangu-Tarakea Gravel Roads.

The data collected were longitudinal roughness, traffic volume, distress survey and indicator tests of subgrade and marginal gravel materials used for surfacing the three gravel roads.

The data were collected for two years, at three months interval from September 1995 to August 1997, and validated in 2009.

In this study an International Road Roughness Index (IRI) has been used. The IRI is a standardized roughness measurement related to those obtained by response-type road roughness measurement systems (RTRRMS), with recommended units in meters per kilometre (m/km).

The study does not attempt to develop or discuss roughness prediction models.

2 LITERATURE REVIEW

2.1 Types and Characteristics of Gravel Roads Condition Data

Surface distress and roughness data are of significant value in developing maintenance and rehabilitation program for gravel surfaced (Clarkson et al, 1982).

2.1.1 Surface Distress

Surface distress is defined as visible manifestation of deterioration of the pavement with respect to either serviceability or the structural capacity (MoW, 1999). Types of distress encountered on gravel roads include but not limited to ruts, corrugation, potholes, dust and loose materials. For each distress type, the corresponding degree and extent are noted. All data are collected subjectively following some form of survey guide (TMH 12, 2000).

2.1.2 Road Surface Roughness

Road surface roughness can be defined as the distortion of the road surface that contributes to an undesirable, unsafe, uneconomical, and uncomfortable ride (Hudson, 1981), or as irregularities on the road surface which adversely affect ride quality (Haas et al, 1994).

2.1.3 Types of Road Surface Roughness

Road surface roughness can be divided into transverse and longitudinal profile components of distortion.

Transverse distortions cause side sway of vehicles, while the longitudinal distortion affects riding quality. Thus, the road roughness evaluation requires measurement of the longitudinal profile of the road in the vehicle wheel path (Haas et al, 1994).

2.1.4 Characteristics of Longitudinal Roughness

Longitudinal roughness, (OECD, 1984), are of limited length. Vertical difference of less than a few millimetres can be considered as relating to the road surface texture, while those ranging over a distance of more than 5 meters are generally not recorded by the roughness measuring instruments. The range of defects lengths studied under the term roughness is thus between 0.1 and 5 m.

2.2 Causes of Gravel Roads Longitudinal Roughness

Gravel roads roughness can be caused by i) Poor levelling control of gravel spreading equipment, ii) Segregation of gravel material during loading at Borrow Pit and dumping at site, and iii) Non-uniform compaction. The initial roughness will increase with development of surface distress.

2.3 The Road Longitudinal Roughness Measurement Methods

There are four generic classes used for measuring road longitudinal roughness based on how directly their measures pertain to the IRI (Sayers et al, 1986), namely Class 1: Precision profiles; Class 2: Profilometric methods other than class 1; Class 3: Estimating IRI methods by correlation equations; and Class 4: Subjective ratings and un-calibrated measures. In this study, class 3 was employed. Class 3 includes RTRRMS and other roughness measuring instruments capable of generating a roughness numeric reasonably correlated to the IRI. MERLIN (simple apparatus to measure road roughness) which was used to calibrate RTRRMS is also classified as class 3.

2.4 Uses of Gravel Road Longitudinal Roughness Data

2.4.1 Prioritising Maintenance Works

Prioritising maintenance works is considered when the budget is insufficient for all the identified work to be carried out. Basis for prioritising should be economic. Studies on road user costs have all shown conclusively that roughness is the main parameter that links road condition with vehicle operating costs. Figure 1 shows the typical changes that can be expected in the vehicles operating cost over the range of roughness values found on gravel roads. For example if the roughness of a road carrying 100 vehicles per day were reduced by an average of 1 m/km, the savings in user cost over a year amount to about US $ 2,000.00 (Robert, 1983).

Longitudinal roughness provides a medium of equitable distribution of funds over the country's road network, by enabling priorities for funds allocation to be determined in a rational way when they are inadequate (Robinson, 1987).

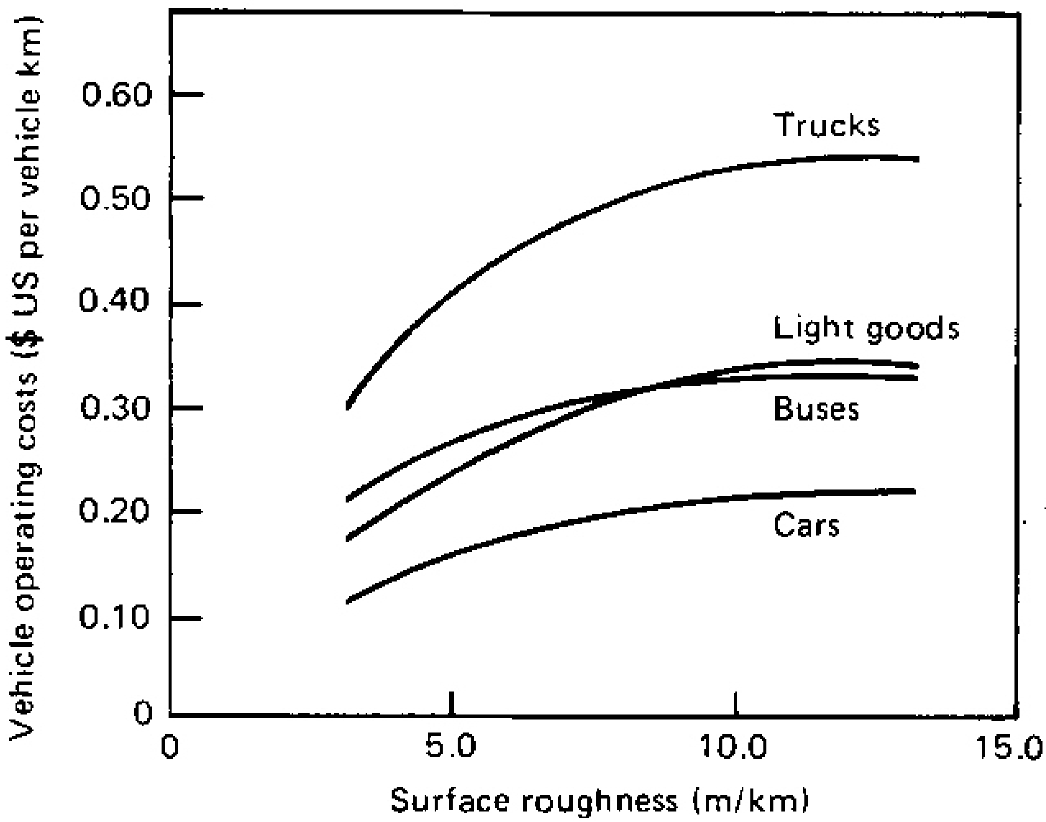

Figure 1: The influence of surface roughness on vehicle operating costs (Jones, 1984)

2.4.2 Monitoring Gravel Roads Deterioration

Gravel road roughness measurements provide a system of monitoring deterioration rate and the efficiency and effectiveness of maintenance works (Robinson, 1987).

2.4.3 Relating it with Level of Serviceability

Gravel roads roughness data can be related to the Level of Serviceability (LoS) of the gravel road in question. Table 1 show the correlation between the LoS and gravel road roughness (TRH 20, 2009), which can used as the basis for setting maintenance intervention.

Table 1: Correlation between the Level of Serviceability and gravel road roughness

Level of Serviceability	Max Roughness IRI (m/km)	Impassability
5	15	Frequently
4	11	< 5 days per year
3	9	Never
2	8	Never
1	6	Never

3 METHODOLOGY

3.1 Experimental Sites

The selection of Kibiti-Utete, Same-Bangalala-Makanya and Marangu-Tarakea Gravels Roads as experimental sites were due to the following reasons:

i) They are one-day journey from Dar es Salaam, which was the research centre,
ii) They were recently regravelled, and
iii) Each road was surfaced with locally available gravel materials, which are marginal

The road sections for calibrating RTRRMS and sampling gravel materials for laboratory testing were selected based on the type of gravel materials used for surfacing. In total there were 15 sections, five sections on each road, of 220 m long. The calibration was done by using MERLIN which is a simple apparatus for measuring road roughness.

3.2 Gravel Road Longitudinal Roughness Measurements

The measurement of gravel road longitudinal roughness was performed in order to:

i) Locate changes in gravel roads surface condition,
ii) Determine the rate of change with time of longitudinal roughness on the entire road ,and
iii) To establish the maximum level of gravel roads roughness on which the maintenance work shall be triggered.

In order to accomplish the objectives of this study the following methodology was adopted:

Measurements of gravel road longitudinal roughness were made at a speed of 32 km/h using the VMBI unit installed on a Land Rover 110. The VMBI was calibrated with the MERLIN. The measurements of gravel road longitudinal roughness were recorded cumulatively in both directions at 100 m increments. The frequencies of measurements were after three months intervals. The measurements were carried out in accordance with the procedure described by Sayers et al (1986).

3.3 Traffic Volumes

The classified counts for vehicles travelling in both directions were taken on each of the three gravel roads at the interval of three months, according to the Transport and Road Research Laboratory (TRRL) report 427 (1972).

3.4 Laboratory Testing of Materials

Samples of gravel and sub-grade materials were tested for classification purposes. Tests in the laboratory consisted of particle size distribution and Atterberg limits carried out in accordance with the procedure described in British Standard (BS) 1377: Part 2: 1990.

3.5 Distress Survey

In determining the distress attributes of the gravel roads under study, visual assessment was conducted according to TMH 12 (2000) outlined procedures. The survey was carried out on road sections with roughness at or above IRI 9 m/km. This is the level of roughness above which the gravel roads impassability begins (TRH 20, 2009).

4 TESTS RESULTS

4.1 Gravel Road Longitudinal Roughness

The results of longitudinal roughness data obtained from the three gravel roads studied showed that, there is good correlation between results from different runs along the same lane.

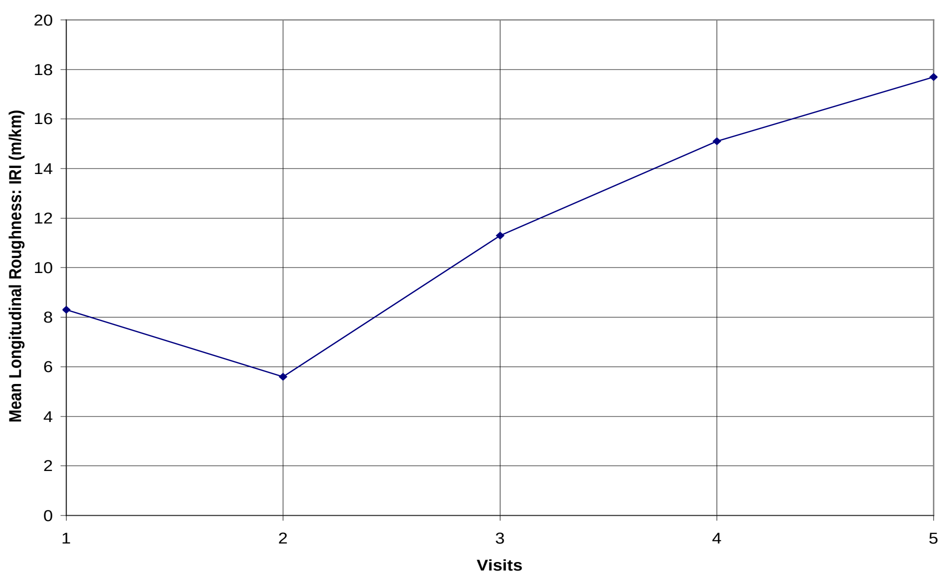

Figure 2: Mean longitudinal roughness on Marangu – Ungwasi section

Figure 2 show the typical summary of longitudinal roughness on Marangu-Ungwasi section along Marangu-Tarakea Trunk Road. The low cumulative roughness observed during the second visit was due to the fact that the section was graded prior to the visit. This shows the effect of grading in reducing road roughness. The increase of roughness of each road also varied according to traffic volume experienced by the particular road.

4.2 Results of Distress Survey

The results of distress survey showed that potholes, corrugation, and stoniness of degree and extent between 3 and 4, contribute significantly to higher roughness values.

4.3 Analysis and Discussion of Results

4.3.1 Subgrade Material

The sub-grade material at Mkongo is typical of Kibiti-Utete Road. The soil is predominantly sand with deficiency in coarse material and soil binder. These soils make suitable subgrades for all types of pavement when confined and damp. AASHTO soil classification put the soil in group A-3.

The sub-grade material at Mbuyuni is typical materials of Same-Bangalala- Makanya Road. The soil is classified as A-5. The soil materials are normally resilient in damp and semi dry conditions. They are subject to erosion and loss of stability if not properly drained.

The sub-grade material at Ungwasi, Mrimbouuwo, Olele, and Urauli is typical material encountered on the entire stretch of Marangu - Tarakea Road. The material is silt –clay. The soil is classified as A-7-5 subgroup, with a group index of 15. The subgroup A-7-5(15) includes those materials with moderate plasticity indexes in relation to liquid limit and which may be highly elastic as well as subject to considerable volume change.

4.3.2 Gravel Wearing Course Materials

The gravel materials used for surfacing the gravel roads under study were marginal materials as explained in the following paragraphs. This implies that they do not comply with the recognised specification as suitable gravel materials for surfacing unsealed roads.

i.Kibiti – Utete District Road

The gravel wearing course materials from Mlima Mwekundu BP is predominantly gravel-sand mixtures with little clay fines. This type of soil may lose stability because of capillary saturation or lack of drainage. The soil is classified as A-2-6.

The soils from Ruhoi BP have high volume change between wet and dry states. The soil consists of sand-clay mixtures, and has high dry strength but lose much of this strength upon absorbing water. The soil is classified as A-6.

ii.Same-Bangalala-Makanya feeder road & Marangu-Tarakea trunk road

Most soil materials used along Same-Bangalala-Makanya road and Marangu-Tarakea road are gravels with fines (A-2-4). These soils need functioning drainage system for satisfactory performance. Exceptions to this are the soils from Sterling BP (A-1-a) used along the first 2 km of Same-Bangalala-Makanya road which consists of well-graded gravel sand, and Mrare BP [A-7-5(3)] along Marangu-Tarakea road which consist of clayey sand.

4.3.4 Traffic Volume

Classified traffic volume data were collected for the purpose of correlating it with roughness progression. Vehicles overloading was observed to be the case in all three roads under study. The road section carrying highest traffic volume was Marangu - Ungwasi (400 Average Daily Traffic (ADT)) and the one carrying the lowest traffic volume was Mkongo - Utete (13 ADT).

4.3.5 Gravel Roads Pavement Longitudinal Roughness

It was noted during the third visit that the longitudinal roughness of the gravel roads under study was between IRI 11.3 and 15.1 m/km. Hence it is concluded that for unsealed roads surfaced with those particular type of marginal materials and the traffic volume between 13 and 400 ADT, the effective grading followed by compaction can be done at the interval of six months. It is expected the roughness by then will be between IRI 9 and 13 m/km.

i.The Correlation between Roughness and Traffic Volume

In the analysis, the longitudinal roughness was plotted as a function of cumulative number of traffic passes. The data was analyzed using simple linear regression equations.

The correlation between longitudinal roughness and traffic for each gravel road was good, with regression coefficients (R^2) between 0.94-0.98.

4.3.6 Distress Analysis

The following distress, corrugation of depth ranging from 50 to 100 mm, and distance between crest in the range of 80 to 100 cm; and potholes of depth more than 50 mm covering an area of 1 m square, were signs of subgrade failure.

Type of gravel surfacing materials used on Kibiti – Utete road contributed to formation of potholes and corrugation as they lack binding material.

On Same – Bangalala – Makanya road, stoniness on the road surface was caused by wind forces blowing off the fine and course sand materials leaving the large stones protruding on the road surface leading to higher rate of roughness progression.

On Marangu – Tarakea Trunk road, the initial roughness was caused by lack of proper control during compaction leading to serious gravel loss caused mainly by traffic, followed by potholes and formation of corrugation. Although there was some grading, on Marangu – Ungwasi section, but its effect on retarding the progress of roughness was short lived, as no compaction followed after the grading operation. On Ungwasi – Tarakea section, the emission of fine particles from the road surfaces started from a loosening and a reduction in cohesion of the gravel layer by the action of traffic and climate. This loss of fine materials increases the permeability of the surface layer and results in the early development of potholes. Furthermore, the stoniness brought about by the removal of the fine fractions causes increase in roughness.

5 RECOMMENDATION AND CONCLUSION

The following recommendation has to be noted for proper maintenance management of gravel roads:

- Due to high volume of traffic on Marangu-Tarakea road, which was associated with high level of roughness and road user costs, as shown in Fig 2, it is economical to upgrade the road surface to surface dressing. Same-Makanya-Bangalala and Kibiti- Utete roads, the grading frequency which is once per year after the rain season can be maintained.
- The location of the wheel paths tends to vary when roughness reaches high levels as vehicles seek to minimize the dynamic impact, hence the measurement of longitudinal roughness must take this self-regulating tendency into account.
- Adequate compaction retards the progress of roughness; hence careful control of moisture content around OMC is normally required for proper compaction of all layers of unsealed roads surfaced with gravel materials.

The paper has demonstrated that:

It is possible to develop a gravel road maintenance management system by having a sound record of gravel road roughness and traffic volume data. Road agencies can implement an efficient and inexpensive method of collecting and reporting roughness data by using VMBI. The MERLIN calibrated VMBI would provide accurate, valid and totally comparable longitudinal roughness data. These data in correlation with ADT and LoS will enable decisions makers to prioritise maintenance work when funds are tight.

In the countries of lesser economy, the threshold of roughness at which gravel road has to be maintained is between IRI 9 -11 m/km. The maximum roughness threshold at which the road should be kept at when the maintenance funds are tight is between IRI 11-13 m/km, above this level regravelling will be needed.

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