Measuring Road Condition of the First Mile

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Abstract

The efficiency of rural transport is important for improving financial and time costs in the delivery of produce and for reducing post-harvest losses. Many crops lose value as they are transported over rough roads and suffer time delays in getting to the market. The pattern of transport varies between seasons with many roads becoming impassable, which results in slower transport and increased costs. There is growing recognition that rural infrastructure needs to be planned together with transport services to minimise transport costs, reduce crop wastage and gain the maximum advantage for farmers.

TRL is undertaking research in Tanzania and Kenya on moving harvest along the primary transport segment, or 'First Mile', from farm to established road access. This project is concerned with the cost-beneficial improvement of access, by assessing the condition of these primary road segments to determine the effect on crop damage and wastage. The condition assessment is being carried out using a variety of high-tech methods, in addition to traditional visual surveys being assessed from DashCam videos of the road. A quantitative assessment of road roughness was measured using three methods, maximum comfortable achievable vehicle speed, smartphone apps and accelerometers. Accelerometers were placed in both passenger and goods vehicles; in amongst the produce when vehicles are loaded. The accelerometer data was analysed, along with socioeconomic data, to gain a greater understanding of First Mile access problems that will result in recommendations for improvement.

Keywords—First Mile; road condition; accelerometer; access

I. INTRODUCTION

The issue of the relationship between crop damage and road condition is a largely under-researched area, although some previous studies have been undertaken on the topic 0, [2], [3]. IFRTD also carried out two pilot studies covering the transport and marketing of onions in Kenya [4] and tomatoes in Tanzania [5]. This work considered the potential exploitable benefits of smallholder farming productivity, and the impact that improved access to rural markets can have for local smallscale economies in Kenya, Tanzania and across Sub-Saharan Africa.

The current 'First Mile' research project under the UKAid funded Research for Community Access Partnership (ReCAP) intends to extend the evidence base for the benefits associated with access improvements to small-scale farmers, and the potential impact that those benefits have on food security and poverty reduction on a much wider scale.

The efficiency of rural transport is important for improving financial and time costs in the delivery of produce and for reducing post-harvest losses. Many crops lose value as they are transported over rough roads and suffer time delays in getting to the market. The pattern of transport varies between seasons with many roads becoming impassable, which results in slower transport and increased costs. Farmers normally bear the brunt of these losses. There is growing recognition that rural infrastructure needs to be planned together with transport services to minimise transport costs, reduce crop wastage and gain the maximum advantage for farmers.

The project team worked with counterparts from the Ministries, Departments and Agencies (MDAs) in both countries to select sites, within the context of their own investigations from previous projects conducted in Kenya and Tanzania. Two sites were selected each in Kenya and Tanzania where farmers, local transporters and local infrastructure specialists were consulted. The condition of farm access roads was also measured, so the effect of the road condition on the transport of produce and subsequent damage could be estimated.

The focus of this paper is the measurement of road condition and the monitoring of crop damage as a result of this condition. A number of different methods were employed to achieve this, as discussed later in the paper. At present the results are still being finalized, but will be incorporated into the final paper before the conference date.

II. BACKGROUND

Steyn and Pretorius 0 note that vibrations generated by Vehicle-Pavement Interaction (V-PI) are one of the major factors that cause damage to crops. The objective of their paper was to quantify the vibrations a truck and the produce it carries have to endure due to different road conditions when travelling from farm to collection point or market distributors in main cities. The vibrations were measured using accelerometers placed at different places within the truck cargo, and one of the conclusions was that accelerations were higher at the rear of the truck regardless of the cargo or the suspension type. Measurements were taken on unpaved and paved roads, with the unpaved roads being deemed to cause more damage. This is not surprising, but it is nevertheless an important finding, although the measurement of road condition on paved and unpaved roads was not directly compared. This is of course difficult to do as the nature and features of the deterioration are quite different.

The study was limited to damage caused by transportation, and did not consider damage that resulted from postharvest handling or the temperature and maturity of the fruit. It is however a useful reference to help understand the mechanism of physical damage to crops during transit. The paper focuses on the measurement of vibrations at different positions on the

truck and different vertical positions within the palletised container. Different road conditions were also considered.

A study on the analysis of road conditions [2] identified three major frequencies:

- to 5 Hz. This range represents the body bounce of the truck;
- 5 to 20 Hz. This range represents the axle hop response, and
- 20 Hz. This is the response from the structure, road roughness and drive train.

Not surprisingly, the study concluded that the most damage to cargo, especially fresh produce, would occur on unsurfaced roads at high speeds. Some of the main conclusions were that:

- 2-ton trucks produced lower vibration levels and damage as compared to 6-ton trucks.
- The severity of vibration levels increased with vehicle speed
- The laterite road conditions were the most severe vibration-producing surfaces, followed by concrete and asphalt roads.
- The damage to fruit was highest when travelling on unpaved roads, as compared to concrete highways, and asphalt roads produced the lowest vibration damage.

A study on road and rail in Belgium [3] also found that asphalt roads produced the least vibration, whilst cobblestones were worst. This research is the least relevant to the 'First Mile' project, but there are still interesting aspects of this research that can inform the 'First Mile'.

III. RESEARCH

The research TRL is currently undertaking in Tanzania and Kenya is focused on moving harvest along the primary transport segment, or 'First Mile', from farm to established road access. This project is concerned with the cost-beneficial improvement of access, by assessing the condition of these primary road segments to determine the effect on crop damage and wastage. There were four areas of interest, two in each country. They are summarised below:

A. Kenya:

1) Meru:

Main crop, French Beans. French Beans are largely an export crop so quality is paramount. Beans need to be transported as quickly as possible to collection centres, where they can be refrigerated and transported on for export. The main modes of transport from farm to collection centre in Meru are headloading and backloading. This is because the available access roads have washed out and are no longer accessible to vehicles. Two of the roads are possible for motorcycles and animal carts to pass, but the cost of transportation on these two roads is very high, so the farmers persevere with manual transport. In this case Meru was not the best example for road condition monitoring.

2) Machakos:

Main crop, French Beans. Again, most of the crop from Machakos is for export. The access roads from the farms to the collection points are generally in reasonable condition, with some variation, depending on the season. A combination of animal carts, motorcycles/bicycles, small trucks, pickups, wheelbarrows and headloading are used for transporting the crops, so road condition is a significant factor in the quality of the crop when it is assessed by the buyers at the collection point.

B. Tanzania:

1) Matola:

The main crop is potatoes, which suit the high altitude and cooler conditions. The collection system in this area of Tanzania is not so well developed as that in Kenya. There are no formal collection points, the farmers generally tend to take their crop to the roadside and wait for a transporter/buyer to collect. All farmers in Matola used headloading to transport their crop to the collection point.

2) Madeke:

The main crop here is pineapples, which grow at slightly lower altitudes. The situation in Madeke is similar to Matola in that there are no formal collection points and the farmers bring their produce to the main road for collection. Some farmers have started to construct their own shelters, but they are very basic and just enough to keep the sun off the produce. In Madeke the farmers use a combination of Ox cart, motorcycle, animal cart and headloading to transport their pineapples to the collection points along the road.

Focus group discussions, household surveys of farmers and interviews with transport operators and local experts were the main source of information to determine the agricultural situation and identify the problems present on the 'First Mile' in all four locations.

IV. OVERALL ROAD CONDITION

Roads and the associated water crossing structures are an expensive asset to construct. Although most farm roads are rural and carry few vehicles per day, and may not warrant the application of bituminous pavements in the short term, they can be a significant cost to local road organisations. Nevertheless, infrastructure from farm to market or first collection point needs adequate strength and serviceability required for the purpose. To make this link cost effective in providing year-round access it is important to consider the philosophy of using construction materials that are "fit for purpose". This means making the best use of materials that are locally available. It can be a fine balance to use materials in a way that they are neither sub-standard nor wasteful in excess of the standards demanded by their engineering task. Therefore the normal philosophy for constructing such roads is to construct them with earth or gravel; apply spot improvements in sections likely to encounter seasonal problems; use simple tools and equipment and use methods that can be easily implemented and maintained by the community.

Hindson [6] defines two main classifications of earth roads; village roads and market roads. A village road is the smallest, cheapest road or track, which may run from one small village to another or to a farm, a small settlement, a school or a dispensary. A market road on the other hand would run to a market, a food-buying depot, a rural development scheme or other important rural centre where traffic might amount to ten or twenty vehicles a day.

He acknowledges that at this level, it may be expensive to gravel the whole road, and thus proposes using earth for such roads and only spot gravelling areas where water may pond and soften the surface. The author discusses at great length various approaches to keeping water off the road, including elevating the carriageway at least 30 cm above the surrounding land or the side drain. This ensures that the road is mostly dry all season, thus facilitating all-season truck access. As a country develops, village roads may turn into market roads, so village roads should therefore not be located on steep gradients (gradients more than 1 in 12) where loaded trucks going to the market may not be able to climb in wet and slippery conditions.

Water crossings are a potential weak point in rural roads. They are vulnerable to washout during periods of heavy rain, especially if they become blocked with debris, and are subject to erosion even in times of light rainfall. Due to their nature water crossings are invariably at the low point of the road, so water tends to collect on the surface if it is not maintained at the recommended camber and the water is not able to flow freely from the surface. In addition, in tropical areas especially, vegetation tends to grow more and higher close to the water source, increasing shade on the road surface and preventing it from drying out. These factors will soften the surface over time and cause deterioration near the water crossing.

Given the conditions in the study area, where the majority of farmers in both countries use manual labour to carry their crop to the collection points, the condition of the road can have more effect on the time taken to transport the crop, rather than damage to the crop through the roughness of the road. Delays incurred between picking and packaging at the collection point can have a significant effect on the quality of crops, especially those that are vulnerable to temperature. In Meru, for example, if the access roads had been constructed properly then a vehicle could transport crops from farm to collection point in about 10 minutes, but at present the average time taken by manual labour is two to three hours.

A. Road condition assessment

For the purposes of measuring road condition and how it affects crop damage, the districts of Madeke in Tanzania and Machakos in Kenya were used as examples. These districts have a variety of vehicles using the access roads from farm to collection point. The travel from collection point to market was also considered, as these roads tend to take larger trucks but are still susceptible to poor road condition, which can cause crop damage. In Machakos the main road is paved and in good condition, but in Madeke it is a gravel surface that is vulnerable to damage in the wet season.

The condition assessment was carried out using a variety of means:

- Traditional visual surveys using a drive-through methodology, with the engineer and a technician in a 4WD vehicle. The vehicle will stop at structures such as culverts to allow the engineer to exit the vehicle and inspect them. A representative sample of roads was assessed using this methodology, as it is generally deemed to be the most accurate after a walk-through survey, which are seldom undertaken on existing roads due to the excessive time taken and consequent high costs.

- DashCam videos of the roads, taken by the enumerators and assessed in the office by the engineer. This was used to assess all roads, as well as to clarify any issues and audit any conditions that were disputed. The limitations of this method include the accurate assessment of structures, for example to determine the condition of a culvert it is necessary to inspect the inside of the culvert to see if it is obstructed or damaged. The underneath or inside of structures are not visible from these videos, although major damage can be noticed.

- Road roughness is usually measured in terms of the International Roughness Index (IRI). IRI is a standardised roughness measurement related to those obtained by response-type road roughness measurement systems, with recommended units: metres per kilometre (m/km). It is a ratio of accumulated suspension motion of a vehicle (inches, mm, etc.) divided by the distance travelled by the vehicle during the test (miles, km, etc.) [7]. It therefore follows that roads with high IRI will have a high detrimental effect on vehicle suspensions and the goods they carry.

New methods of measuring road condition and roughness are being developed all the time. In 2006 some research was carried out using the internal diagnostic tools in mine haulage trucks to determine the condition of the gravel roads that lead to mines in South Africa [8]. In 2011 some research was carried out in the Philippines [9] using artificial neural networks to provide condition ratings of roads with only traffic and inventory data. Research in 2018 in Poland [10] used three-dimensional analysis of liner accelerations of vehicles to measure road conditions.

A quantitative assessment of road roughness in the study areas was measured using three methods:

- Maximum comfortable achievable vehicle speed. The World Bank scale for speed against condition was used for this assessment [7]. The DashCams recorded speed on all roads, with the maximum and average speed recorded for each video, as well as continuous speed display throughout the videos.
- Smartphone app (RoadLab) developed by the World Bank to measure IRI using the accelerometer and gyroscope within the
- smartphone [11]. Other apps have been developed for the same purpose, but the World Bank app was used because it is freely available to download. The results from some of these apps are variable as they depend greatly on the vehicle speed, how and where the vehicle is driven and the vehicle details (weight, suspension, tyre pressures, etc.), so the RoadLab results were used as a double-check only.
- Individual accelerometers were placed in goods vehicles; in amongst the produce when the vehicles were loaded. These are switched on when they are placed, then retrieved and switched off when the vehicle reaches its destination.

The subject of this research is unpaved roads, most of which in the study area are earth, with the main access roads being gravel in Tanzania and paved in Kenya. The measurements with the accelerometers were predominantly taken on earth roads that linked farms to collection points. Some were taken on main gravel access roads, but readings were not taken on paved roads.

Readings were taken in May 2018, immediately following the wet season. This is when most of the roads were in a poor condition as they had been damaged during the rains and had not yet received any maintenance. This situation was similar in both Kenya and Tanzania.

B. Type of transport

Following the first round of data collection it was found that the majority of farms were using manual labour to transport goods to the first collection point. There were a number of reasons for this:

- In some cases the access roads that had been constructed with the purpose of facilitating the transport of produce to the collection point or market, were either completely washed out or were in such bad condition that access by vehicles was not possible. This includes vehicles such as motorcycles and animal carts. The worst examples were in Meru where the roads were constructed at too steep a gradient in very erodible soil, leading to rapid deterioration. The roads were clearly not designed to specification and suffered as a result.
- In some cases the vehicular transport was simply too expensive, and the most cost effective solution was to transport the produce manually. This is even the case in places where the vehicular transport takes approximately 15 minutes, and the manual labour takes 2 to 3 hours. Farmers made the decision to use manual labour here, even though they appreciated that the crop (beans) suffers from a prolonged time unrefrigerated. It is assumed that the additional cost through damage by delayed refrigeration is less than the additional cost of paying for motorised transport.
- There was in some cases a cash flow problem for the farmers, which meant that they did not have available cash to pay for vehicular transport. This is exacerbated by the fact that payment often arrives two or three weeks after the crop has been delivered to the collection

point and the payment has been agreed. Linked to this is the fact that at the Meru site, the farmers were often paid less than the agreed price, with the buyers claiming that when the crop reaches the market or the holding depot it is downgraded in quality and the price is consequentially reduced. The knowledge that this is probably going to happen means that farmers are reluctant to spend more on transport than they need to.

The main problem associated with manually carrying crops to the collection point are mainly the time it takes and the additional exposure to the sun. In the case of crops that are vulnerable to high temperatures or exposure to weather, such as French Beans, the extra time in the sun whilst being transported manually can increase the rate of deterioration of the crop. Typically, French beans are cooled at the collection point and transported quickly to their final destination to maintainquality.

In Meru there is a regular problem of late delivery to the collection point due to the unreliable transport service provision. The transporter's vehicle is usually scheduled to leave at 6pm, so if deliveries to the collection point are late, it can delay the transport, or the transport leaves without them. Either way there is additional damage to the crop.

V. RESULTS

The aim of the road condition measurement is to differentiate between access roads in terms of road condition, to see if it has a bearing on crop deterioration and if so, by what magnitude. Other factors also have to be considered, such as the road length, with access roads varying between 100 m and 7 km in length. If a crop is transported on a 7 km road of poor condition, it is likely to suffer considerably more damage than on a road of 100 m. In this context the measurement could be considered in terms of accessibility, which would take into account both the surface condition and the length of the road.

From focus group discussions it was learned that communities would be willing to participate in road maintenance in order to keep roads open and facilitate the passage of goods to collection points. They were unwilling to do this without some instruction in the technical aspects of road maintenance, but would happily attend on-site training to learn about the basics of how a road can be maintained.

A. Results

The traditional visual condition surveys were used to calibrate the surveys from DashCam videos. This was used to form a baseline against which the accelerometer readings can be compared.

It is accepted that unpaved roads will give variable and unpredictable results of roughness using equipment, apps and even visual surveys. Therefore some reference readings were taken using the accelerometer on very good and good condition bituminous surfaced roads (IRI was determined with visual surveys and the RoadLab app). The results of this survey can be seen in Table 1.

Table 1: Surveys on paved roads

IRI m/km	Measurement		
	Vert. Acceleration m/s2	*Vehicle speed Km/hr*	*Road surface condition*
1.0	0.13	30	Very Good, new asphalt overlay
1.0	0.16	80	
3.0	0.22	8	Good, bituminous surfaced road
3.0	0.28	17	
3.0	0.34	30	
3.0	0.43	80	

These results are very consistent and show a steady increase of vertical acceleration with an increase in speed. It should be noted that the IRI was derived from a combination of visual assessment and RoadLab, and was estimated to the nearest whole integer. This shows that roughness readings using an accelerometer must be compensated for speed.
Measurements were taken on the unpaved access roads in Machakos, Table 2. The surface condition of the road was determined using visual condition surveys from visual surveys and DashCam videos, with the result indicated on a scale of 1 to 4, derived from the following scale:

- 1 = Good: IRI 5 – 10
- 2 = Fair: IRI 10 – 15
- 3 = Poor: IRI 15 – 20
- 4 = Bad: IRI > 20

The visual reports noted that there were little differences between the access roads, all were given a poor condition, except for No. 5 which was classed as fair and was the only road with no bottlenecks.

However, the vertical acceleration did not show any difference to the other roads. Access road 4 did have a higher number of bottlenecks, and a significantly higher maximum vertical acceleration. The three main roads showed similar results, although main road 3 showed the lowest acceleration and facilitated the highest speed, suggesting it was in better condition. Overall these results are inconclusive, but it should be noted that speeds were very low.

Table 2: Machakos roads

Machakos Roads	Factors			Vertical acceleration	
	Surface condition	*Mean speed*	*Bottle- necks*	*Mean*	*Max*
Access 1	3	15	1	0.9	5.5
Access 2	3	15	1	0.7	5.5
Access 3	3	15	1	0.7	6.5
Access 4	3	20	3	0.8	9.7
Access 5	2	20	0	0.7	6.6
Main rd. 1	2	15	1	0.8	6.9
Main rd. 2	2	15	2	0.8	6.5
Main rd. 3	2	25	3	0.6	6.7

Table 3: Madeke roads

Madeke Roads	Factors			Vertical acceleration	
	Surface condition	*Mean speed*	*Bottle-necks*	*Mean*	*Max*
Access 1	3	<15	6	0.8	5.8
Access 2	3	<15	5	0.9	7.2
Access 3	3	<15	2	0.7	3.6
Access 4	3	<15	2	1.2	6.4
Access 5	3	<15	2	0.7	5.7
Access 6	3	<15	2	1.0	7.9
Access 7	3	<15	0	0.7	3.4
Access 8	3	<15	5	1.0	9.1
Main rd	2	50	0	0.5	3.9

Similar measurements were taken on roads in Madeke, in Tanzania, Table 3. The achievable speed was lower at consistently less than 15 k.p.h. Quite a wide range was experienced in vertical acceleration, given that the roads were all rated as 'poor'. Again the visual surveys all rated the roads as in similar condition. The number of bottlenecks seems to make little difference to the overall vertical acceleration, although it is noted that the road with no bottlenecks did have the lowest maximum vertical acceleration, which is not surprising as it would be logical for the bottleneck areas to produce high maximum vertical accelerations. For the access roads the results were similar to Machakos in Kenya.

The one main road surveyed was classed as in good condition, and had an unusually high achievable speed of 50

k.p.h. Unsurprisingly the vertical acceleration was low and there were no bottlenecks, although the maximum reading was 3.9, which is similar to the best condition access road. It can therefore be assumed that the higher speed can produce a high vertical acceleration, even over relatively modest bumps. Again this highlights the need for calibration of the vertical acceleration readings with respect to speed.

Measurements were also taken in Machakos on loaded and unloaded vehicles, Table 4, with the accelerometer placed within the crops being transported in loaded vehicles. This was in order to try and determine the vertical acceleration of the actual crop while it is being transported.

Table 4: Machakos loaded and unloaded vehicle measurements

Machakos Vehicle / Route / Loading	Surface type	Vertical acceleration	
		Mean	*Max*
Car: Canal rd. – Loaded	Gravel/Earth	0.7	8.8
Car: Canal rd. – Not Loaded	Gravel/Earth	0.7	6.6
Motorcycle: Canal rd. – Loaded	Gravel/Earth	1.7	14.8
Truck: To Kithimani – Loaded	Gravel/Earth	1.6	11.6
Truck: To Nairobi – Loaded	Bituminous	0.6	6.9
Car: To Nairobi – Not Loaded	Bituminous	0.7	3.6

These results showed that the loaded motorcycle transport exhibits the highest vertical acceleration, closely followed by a loaded truck. Cars seem to show less acceleration on unpaved roads. One surprising result is that the loaded car showed a higher maximum vertical acceleration than the unloaded car, whereas logic would suggest that the loaded vehicle would move or 'bounce' less when going over a bump. The unloaded car on a bituminous surface showed even less vertical acceleration, which would be expected. Also the loaded truck shows significantly less vertical acceleration on the surfaced road.

A similar exercise was carried out on roads in Madeke in Tanzania, Table 5, where pineapples are the main crop. This data shows that the vertical acceleration on the earth road was higher than on the gravel road for unloaded cars. However, the loaded trucks showed little difference.

The sample sizes of these tests are too small to draw any conclusions. They do however highlight the need for further research into the ability of loaded and unloaded vehicles travelling on poor roads to transport crops without damage.

Table 5: Madeke loaded and unloaded vehicle measurements

Madeke Vehicle / Route / Loading	Surface type	Vertical acceleration	
		Mean	Max
Car: Main road – Not Loaded	Gravel	0.5	3.9
Car: Access road – Not Loaded	Earth	0.9	6.1
Truck: Access road – Loaded	Earth	0.6	5.4
Truck: Main road – Loaded	Gravel	0.6	6.9
Truck: Main road – Loaded	Gravel	0.7	13.1
Car: Main road – Loaded	Gravel	0.7	8.0

Some other interesting results were found from the household surveys and other investigations carried out as part of the research. For example, it was clear that the farmers had a very different perception of the road maintenance issues than the transporters, Table 6. The transporters' view of the problems is very much focused on issues with the road surface, such as mud, slipperiness and water crossings; issues that would affect vehicle movement. Vegetation, gradient and narrowness did not seem to be concerns at all. However, the farmers considered steep gradient to be the major problem, with narrow tracks and slippery surface close behind.

This perhaps shows a lack of knowledge or understanding of the vehicles used and their capabilities by the farmers. It could also reflect a high usage of human and animal transport, which are much more common for farmers, but which are not usually provided by transporters. For example gradient would be difficult for headloading or backloading, but assuming it is not more than about 12% it should be no problem for a motorised vehicle. For the issue of narrow tracks, it is presumed that transporters simply do not use narrow tracks, so they do not see them as a problem, whereas farmers would like the narrow tracks to be widened so that the transporters could use them.

Table 6: Perception of road access problems

Bottleneck/maintenance issue	Farmers		Transporters	
	No. of responses	% of responses	No. of responses	% of responses
Vegetation too dense	14	4%	0	0%
Thick mud when wet	43	13%	23	29%
Slippery surface	68	21%	27	34%
Gradient too steep	99	30%	0	0%
Difficult waterway crossing	21	6%	30	38%
Path/track too narrow	82	25%	0	0%

Another interesting finding is that almost all farmer respondents perceived the road condition as having had, at some point, negatively affected the condition or value of their produce, Table 7.

Table 7: Effect of road condition on produce value

Question	Yes		No	
	No. of responses	*% of responses*	*No. of responses*	*% of responses*
Has the road/track condition ever negatively affected the condition or value of the produce?	113	97%	3	3%

The research was also able to take readings before and after the rainy season to monitor any potential changes in condition on the main access roads, which are further to the access roads which make up the First Mile, Table 8.

The first table is from Machakos in Kenya. Using vertical acceleration it shows a significant deterioration of the road condition from before the rainy season to after the rainy season. Although there are only two examples, the results do seem to be quite consistent. They highlight how much the condition of gravel roads can change in a short time.

Table 8: Condition before and after the rains

Machakos Gravel Main Road Access	Before rains		After rains	
	Mean	*Max*	*Mean*	*Max*
Main access from Sofia	0.8	6.9	1.2	8.7
Main access from Sofia	0.8	4.9	1.3	11.1

A similar exercise was carried out in Matola in Tanzania, which measured a main gravel road three times; three months before grading and compaction, immediately afterwards and some weeks following, Table 9. Again these results seem to be quite consistent, and seem to show a regular cycle of deterioration and rehabilitation throughout the year.

Table 9: Matola access through the seasons

Matola Road access	3 months before grading and compaction		Immediately after grading and compaction		6 – 8 weeks after grading and compaction	
	Mean	*Max*	*Mean*	*Max*	*Mean*	*Max*
Main gravel road, Njombe to Matola	0.7	9.1	0.4	3.4	0.5	6.1

These results show firstly that it is difficult to obtain reliable roughness values on unpaved roads that are in poor and bad condition, mainly because the speed for measurement is too slow. It is likely to be as effective to carry out visual assessments where speeds of only 20 k.p.h. or less are possible. Accelerometers were used as it was recognised that many roads would not allow speeds more than the threshold for RoadLab smartphone IRI to record measurements, i.e. 25 k.p.h. However, the accelerometer results were not clear enough to be able to work out an IRI equivalent, especially for the worst condition earth roads.

Accelerometers placed in loaded and unloaded vehicles showed accelerations to be higher on unpaved roads, and particularly with loaded vehicles. Motorcycles showed particularly high accelerations, which is a concern as they are regularly used for the transport of crops, especially when the roads are too poor for four-wheeled vehicles. This would leave crops that are particularly vulnerable to bruising as risk when being transported by motorbike.

There is also a clear mismatch between the farmer's perception of road access problems and that of the transporter. To some extent this can be explained by different levels of knowledge of the capability of vehicles and a focus on the current modes of transport in use in the study areas. This seems to suggest a gap in knowledge and a potential to gain from awareness-raising in this area. Regardless of the access issues, it seems that all parties are convinced that road conditions do have an effect on the quality and price of the produce being transported. Where access roads are poorly constructed and maintenance is neglected, the conditions can change rapidly through the seasons. It is unlikely that remote farm access roads will receive the level of maintenance they require, so alternative solutions need to be considered that involve the community, transporters and local road engineering experts together for a sustainable solution.

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ROBIN WORKMAN

A Senior International Consultant, Robin has twenty seven years post graduate experience in engineering, much of it in road maintenance management, transportation, capacity building and research in low-income countries. Institutional development of roads organisations has been a common theme in his career, in all aspects of roads. He has specialised in labour-based, environmentally friendly road construction and maintenance in Asia and Africa.

Most recently he has managed high-tech projects for TRL to establish a road network and asset management system in Kampala using flown LIDAR surveys, plus a research project to investigate the feasibility of assessing road condition through satellite imagery in Nigeria.

He has also worked on projects in Kenya, Nigeria, Uganda and Zambia including to establish road research centres in Zambia, Mozambique, South Sudan, Ethiopia