IMPACT OF ROAD CONDITION ON OPERATING COSTS OF BICYCLES

DFID KAR Project Number: R7788

Final report
August, 2003

Ref: 99161/3

Prepared for the

DFID Department for International Development, UK.

By

I.T. Transport Ltd.

Consultants in Transport for Development

CONTENTS

"This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID".

ABBREVIATIONS AND ACRONYMS

RMC	Repair and Maintenance Costs
GBR	Good Bitumen Road
GGR	Good Gravel Road
IMT	Intermediate Means of Transport
PER	Poor Earth Road
NMT	Non-Motorised Transport
HDM	Highway Development Management System
RI_{av}	Average Annual Road Roughness Index
SSA	Sub-Saharan Africa

ACKNOWLEDGEMENTS

I.T. Transport gratefully acknowledges the important inputs to this project by the following local consultants who organized and implemented the monitoring of bicycle-taxi operators and collection of other local data:

Kenya: Mr Geoffrey Maganya – Independent Consultant

Uganda: Mr Achilles Ssesweya – University of Uganda

EXECUTIVE SUMMARY

Bicycles are the most commonly used form of Intermediate Means of Transport (IMT) in Sub-Saharan Africa, greatly increasing personal mobility and load-carrying capacity for rural people. They are increasingly used for providing local transport services, for example bicycle taxis are widely used in Uganda and some parts of Western Kenya. Studies have shown that repair and maintenance costs for bicycles are high due to carrying heavy loads on poor roads and tracks. It is likely that improved infrastructure reduces both operating costs and also trip times, benefiting both personal users and also operators and users of bicycle transport services. However, the economic benefits to bicycle users are rarely included in the appraisal of rural transport projects.

With this in mind the aim of this study was to evaluate the impact of infrastructure quality on bicycle operating costs in order to develop improved tools for including these costs in appraisal of transport projects.

The proposed outputs of the project are summarised as:

1. Studies carried out in 2 countries to show the impact of infrastructure type and condition on bicycle operating costs
2. Development of guidelines on the relationship between infrastructure and operating costs and tools for including bicycle transport in economic appraisal of rural transport projects.

Influencing transport planners to include bicycles in appraisal of rural transport projects should improve the viability of projects focussed on district and village level access. Infrastructure for these vehicles should thereby be improved, leading to reduced operating costs for owners and increased availability and affordability of bicycle transport services for those that cannot afford to own bicycles. Bicycles are the most effective means for improving mobility of the rural poor. Reducing operating costs and service charges will therefore particularly benefit the poor.

Methodology

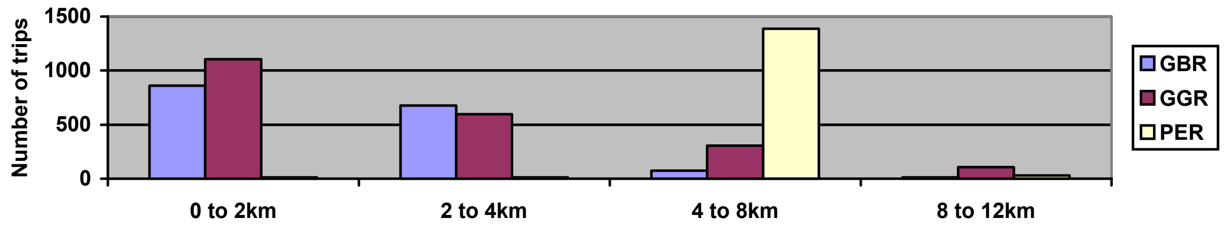
The methodology chosen for the study was to monitor the operations of bicycle taxi operators (persons using bicycles to provide transport services for passengers and goods) in two areas, Uganda and West Kenya. It was observed that these operators worked predominantly along certain routes so it would be possible to identify speeds and operating costs for specific road surfaces. Three roads were chosen in each area with different surfaces – bitumen, gravel and earth. Ten operators were monitored on each road over a period of 12 months to obtain reliable average results and to identify any seasonal effects. Data was entered into spreadsheets to evaluate average values of speeds, fares and repair costs on each type of road. An econometric analysis was also carried out to identify statistically reliable links between various parameters.

The most useful data was obtained from Uganda where about 90% of data could be linked to specific roads. In Kenya some operators did not keep full records of operations and much of the data that was obtained was for operation on a mixture of roads. This data was therefore analysed to identify trends to compare with the findings from Uganda.

Results and findings

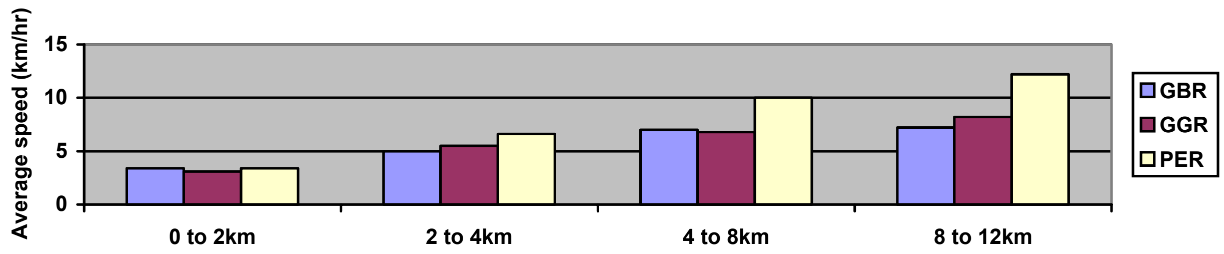
The results from the study are summarised in the following charts where **GBR** = Good Bitumen Road; **GGR** = Good Gravel Road; **PER** = Poor Earth Road.

Figure 1: Frequency of trip lengths on each road



Most trips on the *bitumen* and *gravel* roads were less than 4km because the ready availability of bicycle taxis saved time over waiting for a motorised taxi. For longer trips the overall trip time was shorter in a motorised vehicle because of higher speeds. On the *earth* road there were few motorised vehicles and most trips were between destinations 8km apart.

Figure 2: Average speeds on each type of road



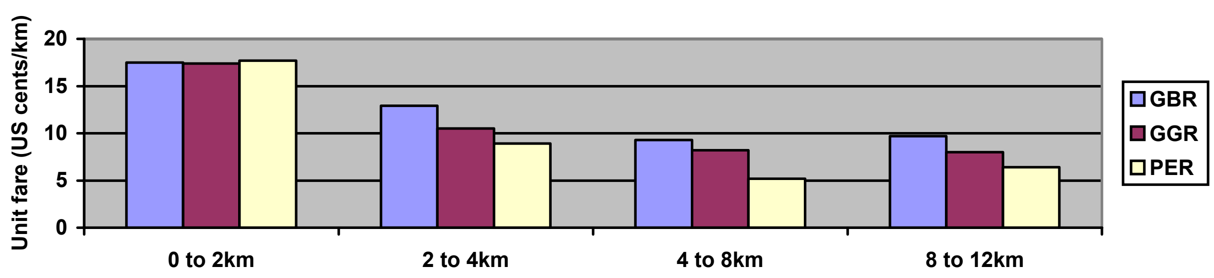
Speeds are influenced by trip length because of inclusion of loading and unloading times. Actual travel speeds are seen to be higher on the *earth* road than on the *bitumen* and *gravel* roads. Two reasons were identified for this through discussions with operators –

(i) The significantly higher levels of motorised traffic on the *bitumen* and *gravel* roads increased safety fears and cyclists often stopped when passed by vehicles, particularly larger vehicles such as trucks and buses. On the *earth* road there was little interference from motorised traffic;

(ii) The operators considered it was easier to cycle on the smooth *earth* surface than on the rougher *bitumen* and *gravel* surfaces

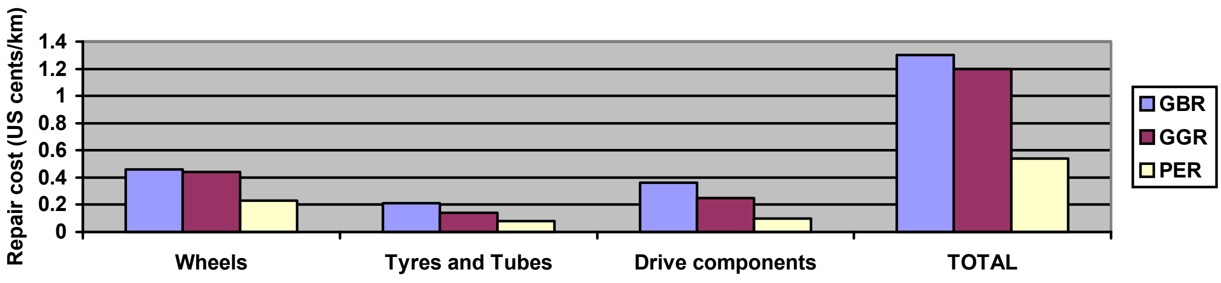
In relation to interference from traffic the bitumen and gravel roads were standard 6m wide. Operators cycled on the road not on the shoulders.

Figure 3: Average unit fares on each type of road



The trend for fares to decrease with increasing trip length is typical of transport services in developing countries as fares become less affordable for longer trips. Fares were highest on the *bitumen* road and lowest on the *earth* road. Operators indicated that fares were set not only by distance but also by demand and what users were prepared to pay. On the *bitumen* road customers were often in a hurry and used bicycle taxis for short trips to save time. They were therefore prepared to pay high fares. Demand was less on the *gravel* and *earth* roads and customers were more inclined to walk if they considered fares too high.

Figure 4: Average unit repair costs on each road type



The above chart compares total unit repair and maintenance costs (RMC) on the three road types and also the main cost components. It is seen that RMC for the *bitumen* and *gravel* surfaces are over double those for the *earth* road. The reasons are indicated by the component costs –

- Wheel costs are from repair of rims and replacement of spokes. It is apparent that these are higher on the harder and rougher (texture) *bitumen* and *gravel* surfaces. Other evidence suggests this is due to a higher level of impact loading on these surfaces
- Tyre and tube costs result mainly from wear of tyres – punctures were not identified as a significant problem. Wear is greater on the harder, rougher *bitumen* and *gravel* surfaces and is probably also increased by more frequent stopping and starting on these surfaces
- Drive components comprise pedals, chain and sprockets. The higher costs on the *bitumen* and *gravel* roads are assumed to result from more frequent stopping and starting on these roads.

The above findings from the results from Uganda were supported by the trends found from the results from Kenya.

Observations

The results obtained are surprising and generally opposite to conventional thinking on the impact of improving roads. The surface that was considered the easiest for cycling, *Bitumen*, in fact has the lowest speed, the highest fares and the highest repair costs; whereas the surface considered the most difficult, *Earth*, has the highest speed and the lowest fares and repair costs. The results for the *Gravel* surface are generally closer to the bitumen surface.

Conventional thinking is that operating speeds and costs are related to the longitudinal bumpiness of the road as measured by the average road roughness index. This has been the basis for appraising the benefits to motorised traffic of improving roads and also is the basis of the recently introduced appraisal method for Non-Motorised Transport (NMT) in HDM-4 (Section 3.6). This approach predicts that upgrading roads from earth to gravel and gravel to bitumen should increase operating speeds and reduce repair and maintenance costs.

The findings from this study indicate that for bicycles the local surface roughness due to the texture of the surface *also* has a significant impact on ease of cycling and on RMC. In fact in this study this factor was dominant so that speeds were lower and repair costs higher on the less bumpy but rougher surfaced bitumen and gravel roads than on the more bumpy but smoother surfaced earth road. It is concluded that cyclists can more easily avoid potholes, ruts, stones etc. than motorised vehicles. However, this may not always be the case, for instance on stony or rocky roads or where there are large ruts on the edge of the road from run-off water. Therefore both surface texture and overall roughness need to be taken into account.

The findings on the influence of surface texture are supported by results from measurement of rolling resistance and level of impact loading on various surfaces (Section 3.5). These showed that a smooth earth path was better for cycling than a rough bitumen road but in wet weather the earth path could be more difficult if there were significant muddy areas. However, this would not affect repair costs.

An econometric model with a high degree of confidence and fit to the data confirmed the impact of the road surface and showed that the following factors have significant impact on RMC:

Loading: carrying additional loads on the bicycle increases repair costs disproportionately i.e. repair costs increase at a higher rate than the increase in loading

Speed: speed has a significant impact on repair and maintenance costs with an elasticity of about 0.8, i.e. an increase in speed of 50% increases RMC by 40%.

Implications of the findings

Although the results of the study are for bicycle taxi operators, the findings on the impact of road surface are relevant for all bicycle users. The average load carried by the operators was 50kg. Domestic users often carry loads up to this level so that unit RMC are likely to be not far below the levels found in the study. The main difference for domestic users will be in the distance travelled per year which will be much lower so that annual RMC will be substantially lower than for the taxi operators.

The condition of the road surface affects the speed, effort needed and repair costs of bicycle users. Speed governs journey times and can be related to costs or savings by the value of time. The need for increased effort in travelling by bicycle is considered a considerable disadvantage by users, whilst an increase in repair costs may result in bicycles being out of service for longer periods because owners cannot afford to repair them. In the case of bicycle taxi operators, both reduced speeds and increased RMC will reduce incomes.

The main implication of the findings for transport planners and designers is that in regard to the impact on bicycle operations three factors need to be considered in the improvement/upgrading of roads – *surface texture, surface roughness and potential increase in motorised traffic.*

Surface texture – an earth road that is rough and bumpy for motorised vehicles may provide reasonably smooth tracks for bicycles that use the edges and can steer round potholes, ruts etc. Regravelling the road will benefit motor vehicles but will dis-benefit cyclists because the gravel surface will be less easy to cycle on and will increase repair costs. The best treatment for cyclists would be to repair the road with earth fill or to leave smooth, firm earth shoulders

Surface roughness – if the road surface is very stony or rocky and/or has substantial ruts along the edges, then regrading and resurfacing are likely to benefit cyclists, but again an earth surface or earth shoulders will be better than a gravel surface

Traffic level – if improving or upgrading a road is likely to increase levels of motorised traffic then it will disadvantage bicycle users in regard to safety, operating speeds and repair costs. If the impact is likely to be significant then serious consideration should be given to providing bicycle paths along the shoulders of the road.

Because new issues are identified by this study, further studies are needed to support the findings before definite guidelines can be prepared for transport planners.

1 INTRODUCTION

Three main issues led to the formulation and implementation of this project:

1. Bicycles are the most commonly used form of Intermediate Mean of Transport (IMT) in Sub-Saharan Africa, greatly increasing personal mobility and load-carrying capacity for rural people. They are increasingly used for providing local transport services, for example bicycle taxis are widely used in Uganda and some parts of Western Kenya. Studies, for instance KAR: R6882, have shown that repair and maintenance costs for bicycles are high, typically $25 to $40 per year for personal use and up to $160 per year when used for transport services. High costs result from carrying heavy loads on poor roads and tracks. It is likely that improved infrastructure reduces both operating costs and also trip times, benefiting both personal users and also operators and users of bicycle transport services. However, the economic benefits to bicycle users are rarely included in the appraisal of rural transport projects.

2. Influencing transport planners to include bicycles in appraisal of rural transport projects should improve the viability of projects focussed on district and village level access. Infrastructure for these vehicles should thereby be improved, leading to reduced operating costs for owners and increased availability and affordability of bicycle transport services for those that cannot afford to own bicycles. Bicycles are the most effective means for improving mobility of the rural poor. Reducing operating costs and service charges will therefore particularly benefit the poor.

3. A further issue is that generally in SSA, bicycles are owned by men and women have limited access to them. This is a constraint which seems to be related to household tradition and may be difficult to break down. However, women widely use bicycle taxis in Kenya and Uganda, substantially improving their mobility and access to markets etc. Improving infrastructure should reduce costs of bicycle taxis and make them more comfortable and safe to use. The latter issues are of especial concern to women so that this project will particularly benefit them. Cost savings for bicycle taxis are likely to be split between increased incomes for operators and reduced fares for users. Both factors will increase the sustainability of services.

DFID commissioned this research in 2000 under their Knowledge and Research Grants (KaR). The overall category was T3. The aim of the research was to evaluate the impact of infrastructure quality on bicycle operating costs in order to develop improved tools for including these costs in appraisal of transport projects.

The specific project purpose was to:

To develop and/or improve tools for including bicycle transport in rural transport appraisal and to reduce bicycle operating costs

The proposed outputs of the project are summarised as:

1. Studies carried out in 2 countries to show the impact of infrastructure type and condition on bicycle operating costs leading to development of guidelines on the relationship between infrastructure and operating costs and tools for including bicycle transport in economic appraisal of rural transport projects.

2. Identification of the main sources of bicycle operating costs and feasible methods, with guidelines, for reducing costs.

It was initially thought that a significant source of repair costs might be structural failure of the bicycle frame or components due to heavy loading and that these repair costs could be reduced by strengthening critical features. However, the results identified the main source of repair costs as replacement of standard components such as wheel and bottom bracket (pedal crank) parts and it was felt that there was little that could be practically done in regard to the design and repair of bicycles to reduce these costs. It was therefore agreed with DFID that this output – *identify feasible methods, with guidelines, for reducing (repair) costs* – could be dropped to allow a more in depth econometrical evaluation of the data from the monitoring of operators. However, it was anticipated that the project would still lead to reduced operating costs through the identification of the most "user friendly" road conditions for bicycles.

The following report describes the methodology as planned and conducted, the main findings and then goes on to discuss the implications of these findings. The layout of the report is as follows:

Chapter 2: Gives details of the methodology, location and organisation of the studies in the two countries.

Chapter 3: Presents the results and findings from the studies and the econometric analysis carried out to check the findings. It also compares the findings with other available data on bicycle operating costs and the impact of road conditions.

Chapter 4: Presents a discussion of, and the conclusions drawn from the findings. It also discusses the implications of the findings to both bicycle users and transport planners.

Annex 1: Is the logical framework for the project showing purpose, outputs and activities.

Annex 2: Shows the data sheets used for collecting data.

Annex 3: Describes participatory research carried out during a visit to the study area in Uganda.

Annex 4: Compares monitoring data with data collected from operator questionnaires.

Exchange rates used in the report are average values over the 12 month period of monitoring:

Uganda, USD $1 = 1,755 Ush; Kenya, USD $1 = 78.5 Ksh

2 DETAILS OF STUDY

2.1 Methodology

It was considered that an effective method for correlating bicycle operating data and repair costs with specific infrastructure types and conditions would be to monitor operations of bicycle-taxi operators (persons who provide a taxi service by carrying a passenger and/or goods on the carrier of their bicycle for a fare) who tend to operate predominantly on one or two routes. Projects were set up in two areas – around Iganga in Uganda and Kisumu in West Kenya – where there are strong bicycle-taxi operations. In each area 3 types of roads were chosen – Bitumen, Gravel and Earth. A local District Engineer was employed to give a brief report on each of the roads. It was found that nine road classifications were necessary to describe the road condition– poor, average and good for each type of road surface. Ten bicycle taxi operators were selected in each area who tended to operate mainly on each one of these road surfaces, bitumen, gravel and earth i.e. 30 operators in each area.

Before the study the operators were surveyed collecting information on their socio-economic situation and taxi-operating characteristics such as 'is the bicycle hired or owned'. During the monitoring programme the operators were paid a fee to fill in monthly log-books giving details of trips, fares and repair costs. The monitoring forms are shown in Annex 2. A local consultant collected the data on a monthly basis, collated it and entered it on a spreadsheet and then forwarded the data sheets to I.T. Transport in the UK. This data was collected over a 12 month period.

The monitoring methodology was developed on the following reasoning:

1. It was considered necessary to monitor 10 operators on each road surface over a period of 12 months in order to obtain reliable and representative data on repair costs. It was also felt that monitoring over 12 months would show up any seasonal effects
2. It was decided that monitoring of operations was also necessary over the whole 12 months in order to relate distance travelled to repair costs but that full-time monitoring would generate excessive data and was not necessary. It was therefore decided to carry out continuous monitoring over 1 month in the dry and wet seasons and the remaining 10 months to monitor on 2 typical days a week. The monthly monitoring was used to establish patterns of operation in order to estimate the total distance travelled from the 2 days of monitoring per week. However, repair costs were recorded continuously

The data was cleaned and analysed using Excel, Access and SPSS[1]. For the comparative analysis, totals and averages were derived for the differing road types. To further validate the data and to evaluate the impact of identified variables, an econometric analysis was conducted.

Following the analysis of the results, a visit was made to the study area in Uganda to discuss the results with the operators to appraise whether the findings were consistent with their experience and to identify factors influencing the results. No similar visit was made to Kenya because of the problems indicated below and because of the need to re-allocate the budget to cover the econometric analysis.

Comments on the Methodology

The methodology worked well in Uganda and reliable data for all operators was returned on a regular basis. Data collection in Kenya proved difficult with varying bicycle taxi operators due to migrant labour (even though every effort was initially made to select a group of relatively long-term operators whom it was felt would remain over the study), the failure of some operators to record all the data needed and the theft of some original data. The work in Kenya therefore yielded reliable data on operations for 15 operators over a 2 month period and for 9 operators

[1] Statistical Package for Social Science SPSS Inc. (1993).

over a 8 to 10 month period, including data on repair costs. However, because the operators in Kenya tended to operate on a mixture of road surfaces, the data gave a good coverage of the different types of roads. The data was analysed to identify trends to compare with the findings from Uganda.

2.2 Study Areas

Uganda

The study was carried out in Iganda District in Eastern Uganda, about 100km to the north east of Kampala. In the south, the district borders on Lake Victoria. Iganda District is reported to have one of the highest levels of bicycle use and of bicycle taxi operations in Uganda.

The District has an area of 11,113 km^2 and a population of 945,783, of whom about 95% are classified as rural. The average population density is 85 persons/km^2.

The average altitude is 1,110 m above sea level and the terrain flat to slightly rolling. The main activity is subsistence farming on average plot sizes of 1 to 2 ha. The main subsistence crop is maize and the main cash crops, coffee, rice and cotton. The average annual agricultural income is estimated as 143,000 Ush (USD 81) per household. A few households own livestock, mainly as a source of income for emergencies. Other minor sources of income include carpentry, weaving, handicraft and charcoal production.

Road selection

The three roads needed for the study were selected with help from the Local Government District Roads Engineer as follows:

Bitumen: *Iganga to Kaliro* - this 6m wide road runs due north from the District centre to the town of Kaliro, a distance of 22 km. The road was classified as GBR (Good Bitumen Road) in both the dry and wet seasons by the District Roads Engineer. The visit of the researcher confirmed this, showing the road was well maintained with shoulders and drains in good condition. The Nabitende bicycle taxi operators association has 20 members and is located about half-way along the road.

Gravel: *Iganga to Kiyunga* – this is a feeder road that runs for 16 km to the north-west of Iganga. It was classified as GGR (Good Gravel Road) in the dry season but as average in the wet season. Side drains were reported as not well maintained and some gullies were formed along the sides of the road by run-off during the wet season. Overall, since the road was improved 3 years ago, it is still in quite good condition with limited potholes and gullies. The bicycle-taxi association on this road has 30 members. The majority of bicycle-taxi trips are on the second half of the road away from Iganga i.e the more rural part.

Earth: *Busesa to Navikumbi* – the road runs from Busesa, about 9 km east of Iganga south to Navikumbi, a distance of 8km. The 4m wide road was classified as average (AER) in the dry season but as poor (PER) in the wet season. Points noted in the inspection were many potholes and gullies, lack of camber, rock outcrops, and towards Navikumbi the shoulders and sides were bushy. In one centre section the community was filling potholes with a clayey gravel, indicating significant problems. The overall classification is therefore PER. The area is rural and herds of cattle were noted moving on the road. The bicycle-taxi association at Navikumbi has 30 members. Trips tend to be over the full length of the road, but may also go off the road to drop people at their homes.

2.3 Kenya

The study was carried out in the peri-urban area to the north of Kisumu, the chief city of Western Kenya. The bicycle taxi operators involved in the study were mainly from Kisumu town or from Kibos, a suburb approximately 12 km from Kisumu centre. There are about 1500 operators in the area. They compete with Matatus (modified pick-ups and light trucks) for business. They offer benefits of providing a more prompt service, Matatus generally wait until they are full, and operating off the bitumen road, often to the customer's house.

Road selection

Bitumen: *Kisumu Bus Station to Kibos* – this is a 12km route. The surface of the first 8 km is classified as GBR (good), but narrow with no segregated footpaths or shoulders and with heavy vehicular traffic. Cycling is considered dangerous on this section. The surface of the final 4 km is classified as PBR (poor), with a badly damaged asphaltic surface likely to damage tyres, potholes and significant pondage in the wet season.

Gravel: *Kibos to Chiga* – this is a 12 km length of feeder road classified as average, AGR. It is poorly maintained and is subject to loss of shape, loss of gravel, extensive wheel ruts and damaged shoulders.

Earth: *Chiga to Ahero* – this is a 16 km length of unclassified road. The surface is classified as good (GER) in the dry season, but poor (PER) in the wet season. Problems in the dry season include grazing animals and heavy pedestrian traffic on market days. Additional problems in the wet season include fallen trees, landslides, slippery surface and considerable ponding.

3 FINDINGS FROM ANALYSIS

The data was initially analysed and compared using spreadsheets to identify trends. Having identified the unexpected results, more in depth econometric testing was carried out using SPSS.

This main analysis of operating characteristics was carried out on the data from Uganda that was for trips that were purely on one type of road (75% of trips) in order to relate findings to a specific road surface. For the purpose of comparing repair costs all trips were considered to give total distances travelled but in all cases it was possible to relate the data to operation predominantly on one type of road. The data from Kenya was less complete and there was much more operation on a mixture of roads. It was possible to identify operating characteristics on each road surface but it was not possible to relate repair costs to a specific surface. The primary use of the data from Kenya was therefore to appraise whether the trends were consistent with the findings from Uganda or not.

In the following sections the discussion of findings is based on the data from Uganda. The findings from the Kenya data are then added as a note at the end of each section.

3.1 Operational Characteristics

3.1.1 Data from Uganda

Table 1 summarises the data obtained from Uganda in relation to trip length, average speeds and average fares on the three road surfaces.

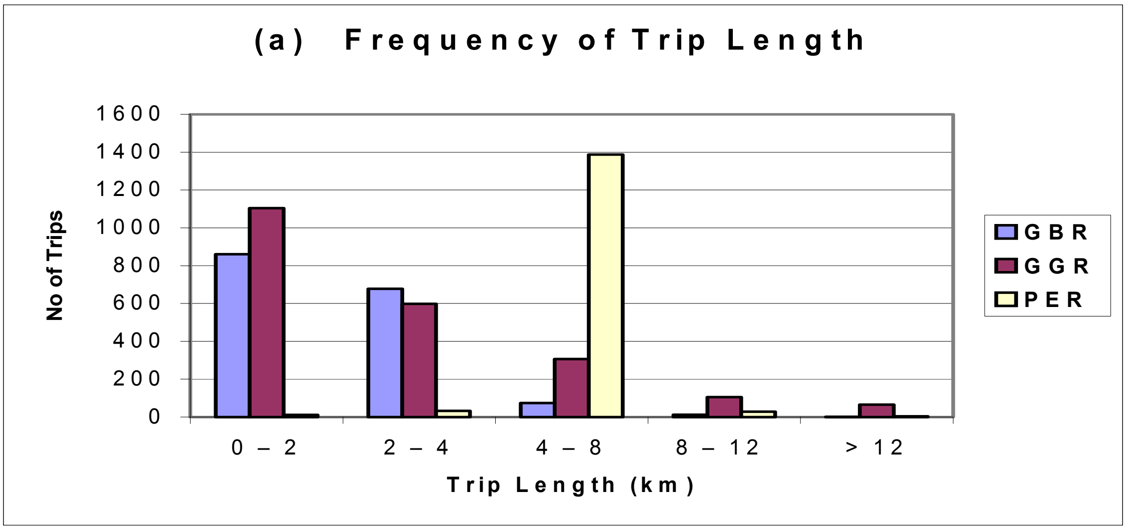
Table1: Characteristics of Bicycle Taxi Operations in Uganda

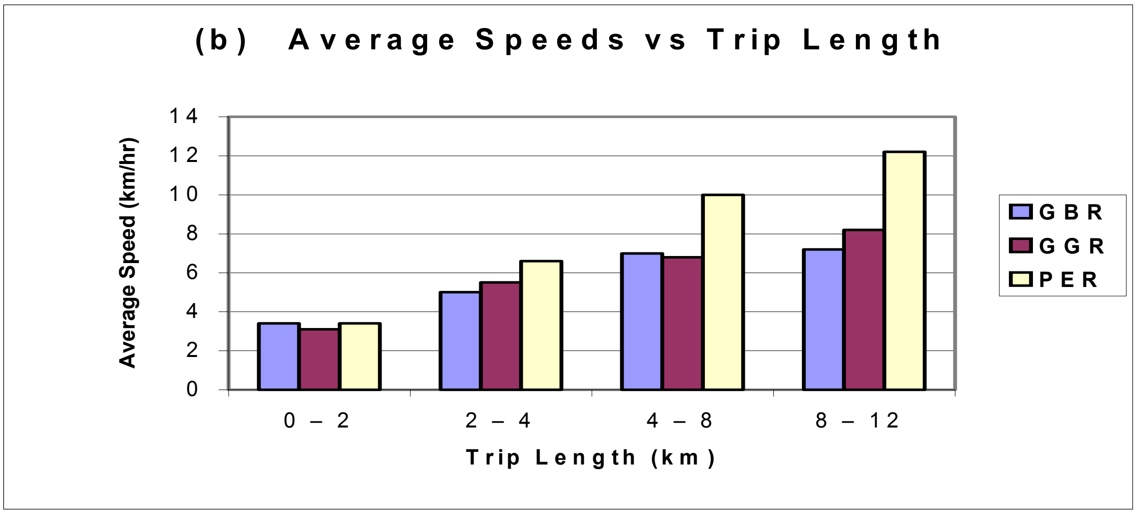
Trip length (km)	Number of trips	Average length (km)	Average Speed (km/hr)	Average Fare/km (Ush) (US cents)
BITUMEN				
0 – 2	861	1.3	3.4	307 (17.5)
2 – 4	678	3.6	5.0	226 (12.9)
4 – 8	74	5.7	7.0	164 (9.3)
8 – 12	13	10.6	7.2	171 (9.7)
> 12	2	18.5	15.3	108 (6.2)
GRAVEL				
0 – 2	1105	1.8	3.1	304 (17.3)
2 – 4	598	3.6	5.5	184 (10.5)
4 – 8	307	5.8	6.8	149 (8.5)
8 – 12	106	10.3	8.2	141 (8.0)
> 12	66	18.1	8.5	104 (5.9)
EARTH				
0 – 2	12	1.8	3.4	310 (17.7)
2 – 4	33	3.7	6.6	130 (8.9)
4 – 8	1388	7.0	10.0	75 (5.2)
8 – 12	29	10.0	12.2	93 (6.4)
> 12	4	16.5	6.2	174 (9.9)

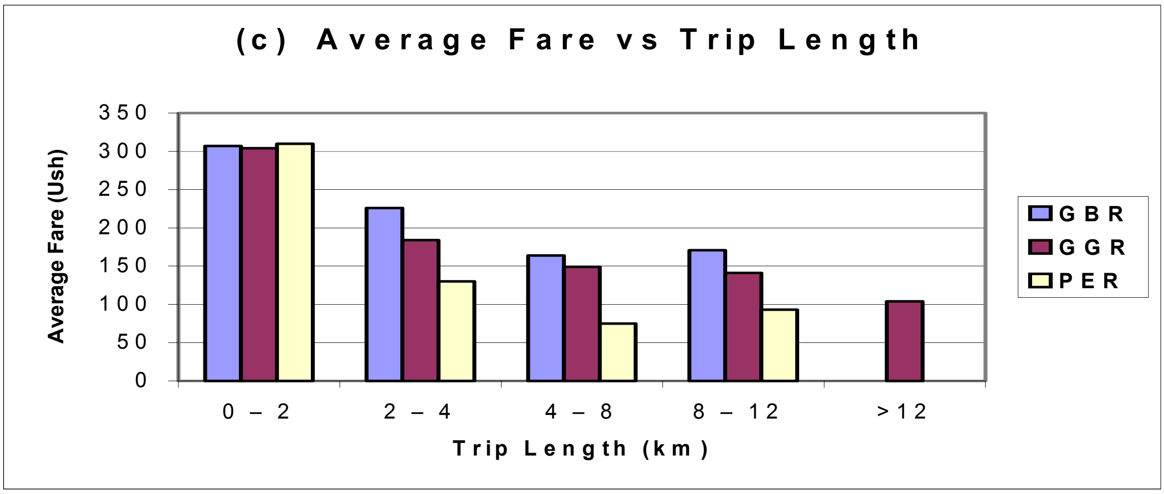
The results for the different road surfaces are compared in Figure 1. It is seen that the comparisons are somewhat surprising in relation to conventional thinking on the effect of road surface. The findings are discussed below.

It should be noted that the number of trips of >12km was only significant on the gravel road and the results for average speeds and fares followed the trends for trips below 12km. The number of trips of >12km on the bitumen and earth roads were too small to show meaningful trends.

Figure 1: Characteristics of Operators





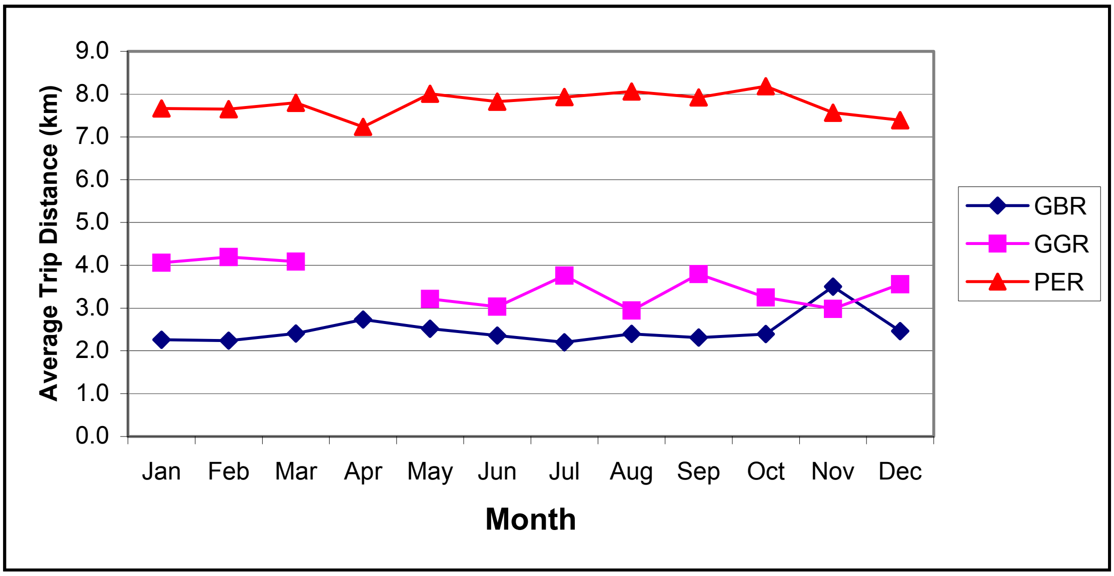


Trip length

The average trip length was greater on PER (7.8 km) than on GBR (2.4 km) and GGR (3.6 km). As can be seen below there was a consistent difference throughout the year. Table 1 and Figure 1(a) show this is due to the much higher number of short trips on the GBR and GGR as compared to the PER. For instance, 95% of trips on the GBR and 80% on the GGR are less than 4 km, compared with only 3 % on the PER. The participatory analysis explained this by the availability of motorised transport services on the GBR and GGR and the attitudes of passengers to choice of mode of transport. For short trips they often use a bicycle taxi because it is quicker than waiting for a motor vehicle. However, for longer trips they choose motor vehicles because their higher speed makes up for the longer waiting time. On the PER there are no motorised services and by far the main trip is between Busesa and Navikumbi, a distance of 8 km. The other factor is that social and economic services on the GBR and GGR are closer which reduces trip distances.

Figure 2 shows that average trip lengths are fairly constant over the whole year.

Figure 2: Average Trip Distances for Each Month on Different Road Surfaces



Average speeds

Figure 1(b) shows a clear pattern of average speeds increasing with trip length. It appears that this is probably due to loading and unloading times being included in trip times and these are a greater proportion of trip time for short trips. As trip lengths increase, the significant factor is that speeds are highest on the earth road, by about 30% below 4 km and by 50 % over 4 km. This is contrary to expectations as it was anticipated that cycling would be easiest on the GBR with its good flat surface. The PER was reported as considerably rutted and potholed with obstructions from heavy pedestrian traffic and cattle on the road and so it was assumed that cycling would be less efficient in avoiding potholes and obstructions. Discussions with and observations of the operators during the participatory study identified the reason for the lower speeds on the gravel and particularly the bitumen road as the influence of motorised traffic. Both discussions and observations showed that the operators often stopped for safety reasons when passed by motor vehicles, particularly heavier types of vehicles.

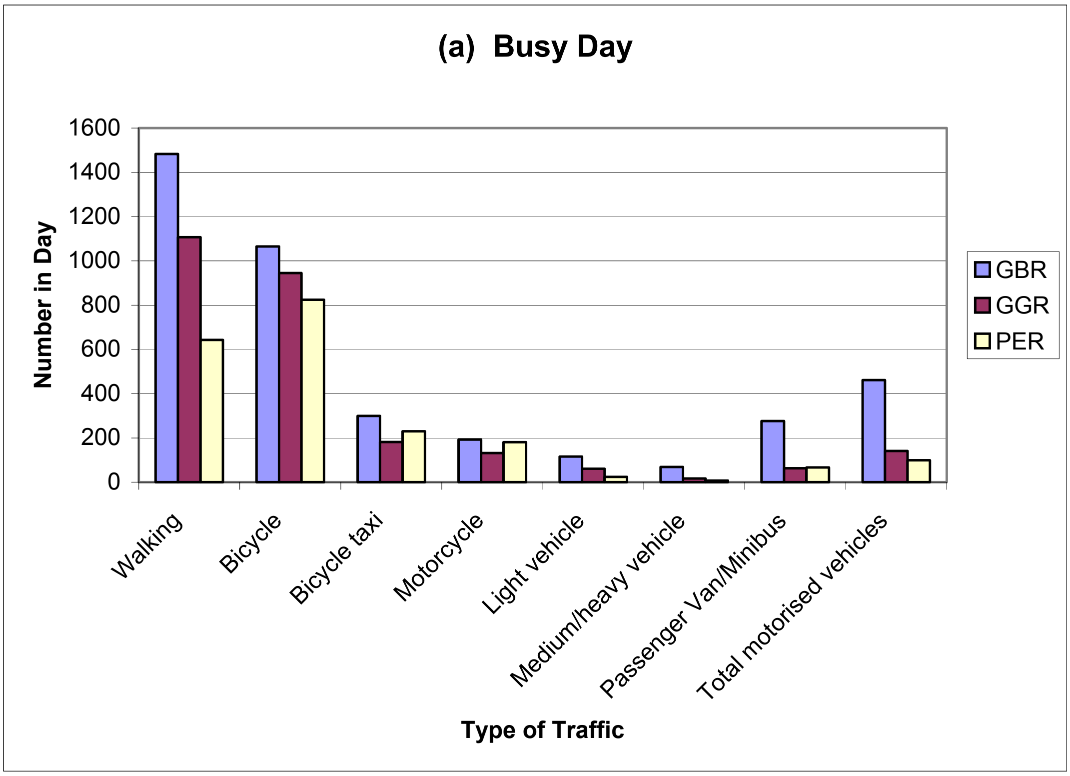
Figure 3 shows traffic counts for the 3 roads on busy and non-busy days of the week. This clearly shows the higher level of motorised traffic on the GBR and GGR compared to the PER, especially on the GBR. The level of medium to large vehicles (passenger vans, minibuses, trucks and buses) is substantially greater on the bitumen road and because of the overall higher level of traffic there will be greater conflict in overtaking bicycles. It is considered that this conflict with motorised vehicles on the GBR, especially larger vehicles, explains the lower average speed on the GBR compared to the PER.

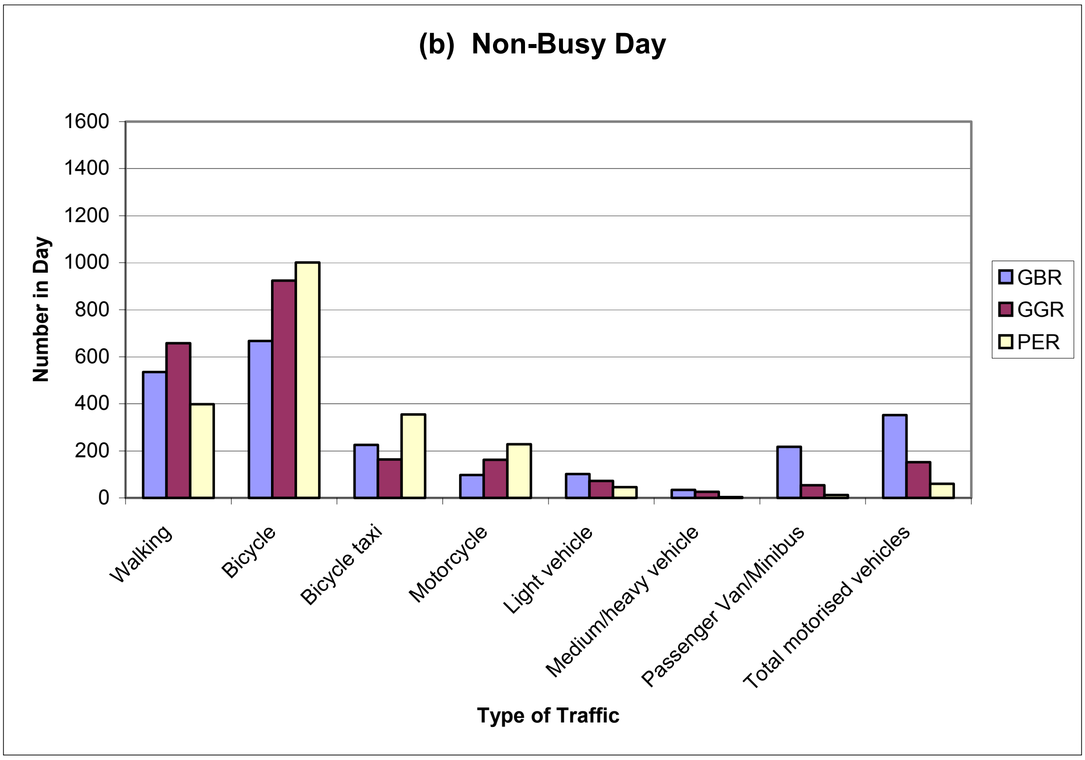
Although relatively flat and free from pot-holes (low roughness index), the surface texture of the bitumen road was quite rough due to the coarse aggregate used. Some operators reported that they found cycling on the smoother (texture) earth road easier. This could also account for lower speeds on the bitumen road.

The level of traffic on the GGR is considerably lower than on the GBR, although still higher than on the PER, but the average speed is not much different than on the GBR. Discussions with the operators suggested that this was due to the greater difficulty of cycling on the rougher gravel surface. They also reported that it was easier to cycle on the smooth earth road surface in spite of the more frequent ruts and potholes. It is therefore considered that there are two factors that explain the lower average speeds on the GGR compared to the PER:

i) The higher level of motorised traffic
ii) The greater effort needed to cycle on the rougher gravel surface

Figure 3: Traffic Counts





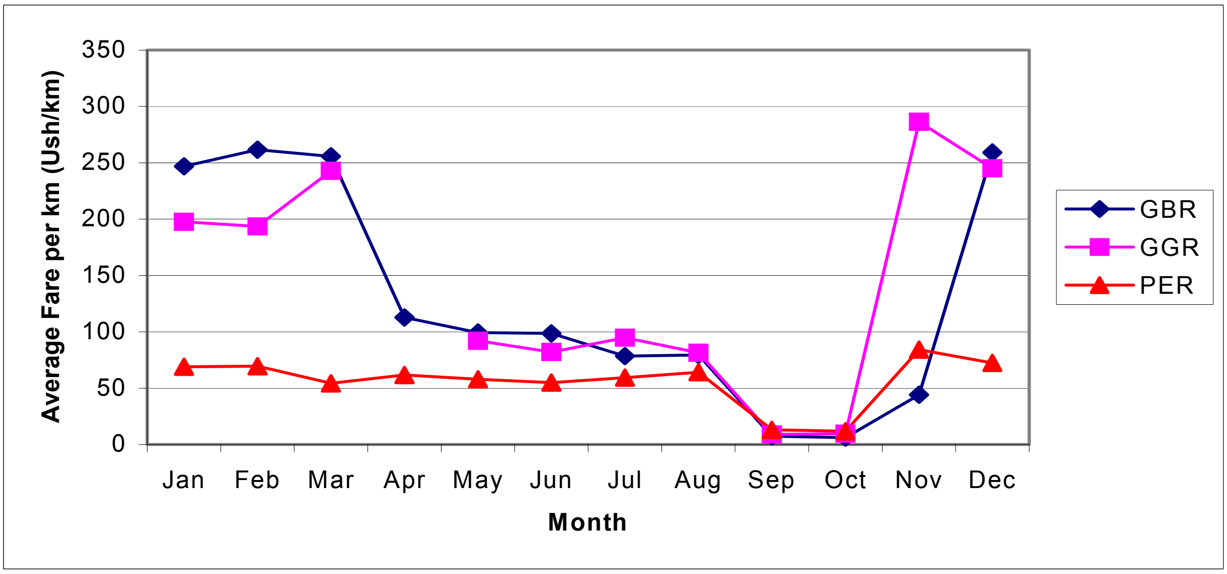
Fares

Figure 1(c) shows that for trips below 2 km there was little difference in the fare/km on the three roads. However, as trip lengths increase there is a substantial difference in fare levels up to 12 km trips. Above 12 km there are few trips on the GBR and PER so that averages are not meaningful – the average for the GGR, where there are a significant number of trips over 12 km, follows the general trend.

The figure shows that up to 12km trips (for trips over 12km there were too few results to draw meaningful conclusions) unit fares are considerably lower on the PER than on the GBR with those on the GGR intermediate but closer to the GBR.

With the improved road surface it was expected that the cost of fares would reduce and passengers would benefit. However, focus group discussions with operators suggested that the factors deciding fare price were predominantly demand and willingness to pay. This negotiation factor was also recorded in the operator questionnaires with 85% of operators saying this was the key factor in fares. This is also seen in the season variations in fare (Figure 4) where in busy times at the end and start of the year, fares are increased. The operators also observed that people on the GBR were often on business and in a hurry so that they were prepared to pay a higher fare rather than walk. On the PER people were less concerned with time saving and if fares were set higher they would choose to walk rather than use a bicycle taxi. This may also explain why unit fares are higher for trips less than 2 km on all roads, since if people are willing to pay for a bicycle taxi rather than walk over these short distances they are probably in a hurry and willing to pay more. Another factor is that unit fares tend to drop as trip lengths increase because of the inability of people to pay high fares for long trips. A further point raised by the operators was that they judged people travelling on the GBR to be more affluent and therefore able to pay higher fares, whereas people on the PER were mainly rural and less well-off.

Figure 4: Average Fare per km for Each Month on Different Road Surfaces



3.1.2 Data from Kenya

Table 2: Data on Operational Characteristics from Kenya

Trip length (km)	Number of trips	Average length (km)	Average Speed (km/hr)	Average Fare/km (Ksh) (US cents)
BITUMEN				
0 – 2	216	1.8	8.4	6.9 (8.8)
2 – 5	171	3.8	11.8	4.6 (5.9)
5 – 10	114	7.6	10.4	4.5 (5.7)
> 10	30	15.3	16.3	4.4 (5.6)
GRAVEL				
0 – 2	144	1.7	8.0	6.9
2 – 5	311	3.9	12.8	4.5
5 – 10	120	9.3	11.7	2.8
> 10	27	16.2	16.8	4.2
EARTH				
0 – 2	44	1.4	7.5	7.9 (10.1)
2 – 5	52	4.6	13.3	3.1 (4.0)
5 – 10	42	7.4	12.0	3.1 (4.0)
> 10	19	19.4	13.9	2.3 (2.9)

Table 2 summarises the average data for 15 operators over a period of 30 Days. Since operators tend to operate far more on a combination of road surfaces, there are considerably less trips on individual road surfaces than in Uganda, particularly for earth roads. The average results for the three surfaces are compared in Figure 5.

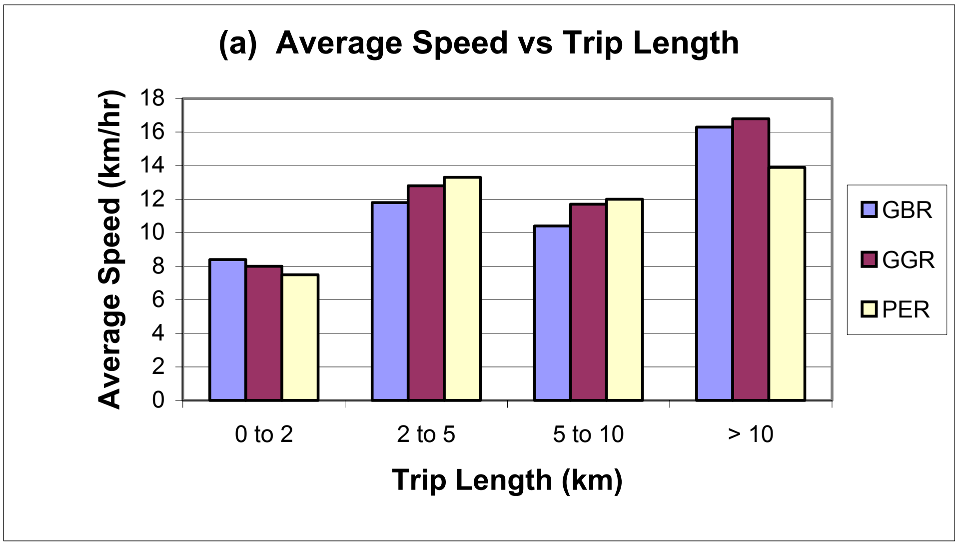
Average speeds

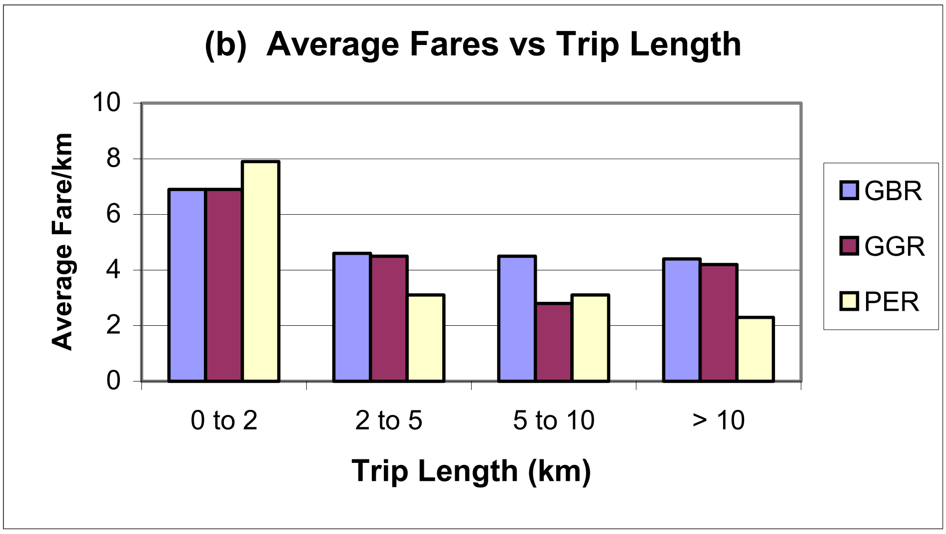
It can be seen in Figure 5 that the results tend to follow the same trend as for Uganda (Figure 1) with speed increasing with distance and average speeds on the earth road being higher than on the bitumen road. However, the speeds are considerably higher, particularly for short trips, and the trends are not so pronounced. The explanation from the local consultant is that bicycle taxis on the bitumen and gravel roads operate for a considerable part of the time on the shoulders of the road rather than on the road surface. The results are therefore for a mixture of operation on the road surface and earth track on the shoulder. This would explain why there is less difference between the average speeds on the 3 surfaces and why the speeds are generally higher than in the Uganda data. Nevertheless, the fact that average speeds are lower on the bitumen road for most of the trips supports the finding from Uganda that higher levels of motorised transport reduce the operating speeds of bicycles.

Fares

The trend in unit fares shown in Figure 5 for Kenya is very similar to that shown for Uganda in Figure 1, with unit fares decreasing with trip length and fares on the earth road being considerably less than on the bitumen road (apart from trips below 2 km). This supports the finding that fares are largely dependent on demand and willingness and ability to pay. Comparison of Figures 1 and 5 shows that for trips up to 10 km, unit fares in Uganda are almost double those in Kenya.

Figure 5: Operational Characteristics – Kenya



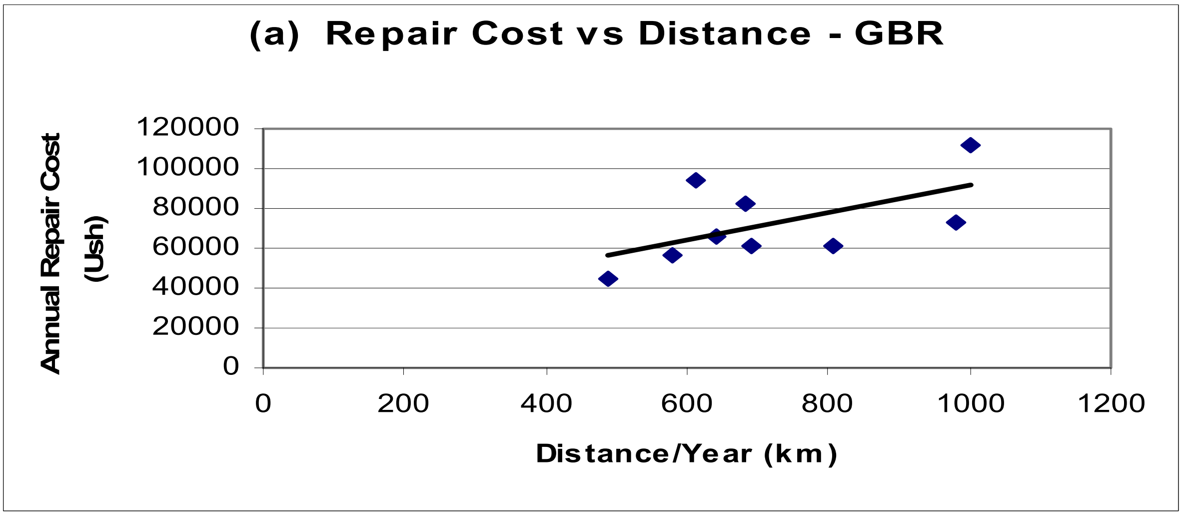


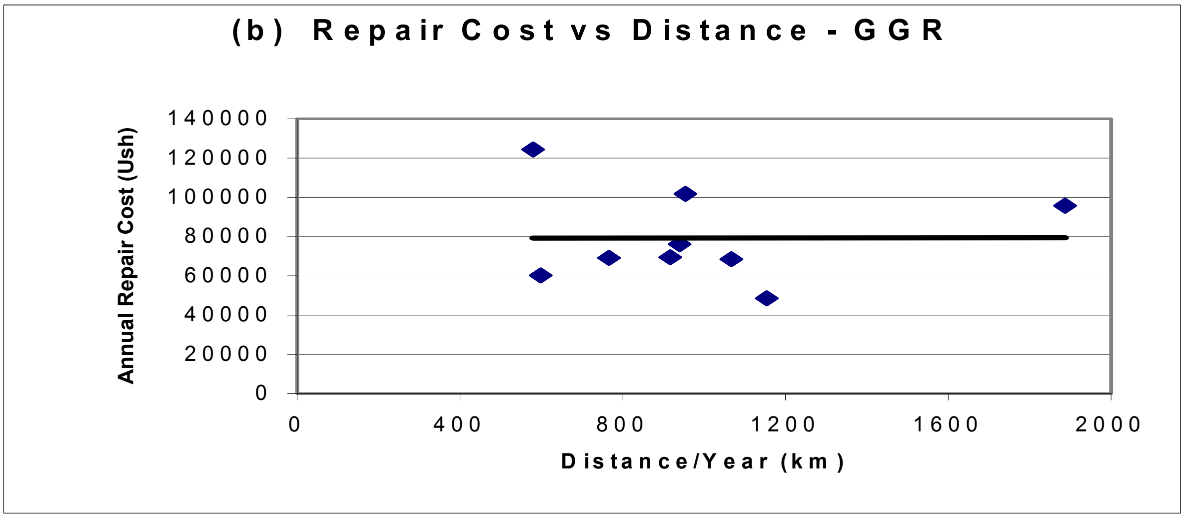
3.2 Repair Costs

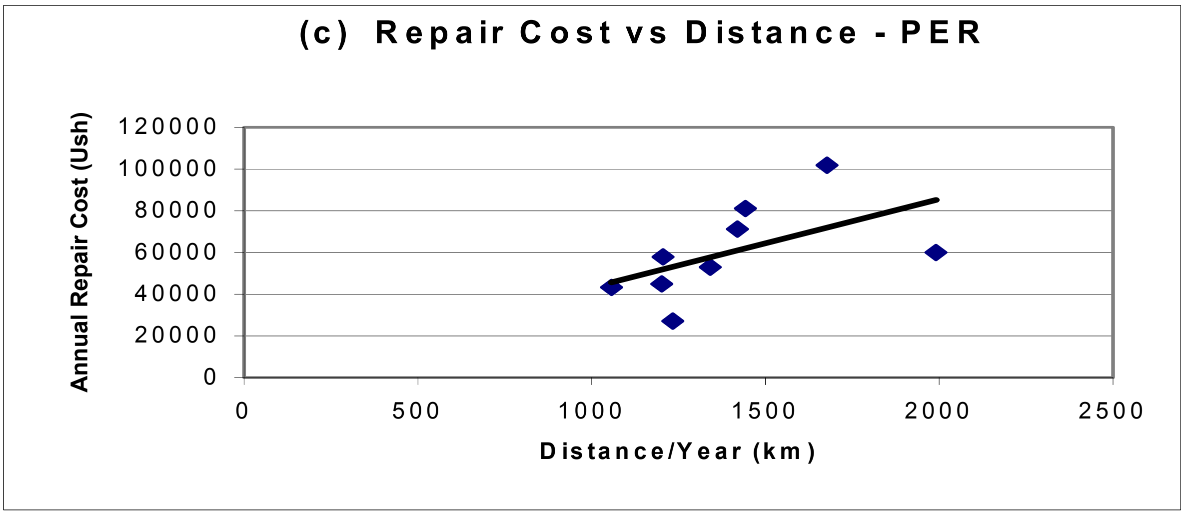
3.2.1 Data from Uganda

Average repair costs were evaluated for each operator over the 12 month monitoring period. It was anticipated that repair costs would be proportional to distance travelled but there would be considerable variations in the results. The relationship between the total repair costs over the 12 months period and the distance travelled is shown for the 3 road surfaces in Figure 6. It can be seen that there is a trend for repair costs to be proportional to distance travelled on the GBR and PER, although with considerable scatter, but on the GGR the scatter is so great there is no trend. Most of the repair costs are due to replacement of standard parts, so scatter would be expected from inherent variation in life and quality of these parts. Also in a few cases there were replacements or repairs of major items such as frames or handlebars that caused considerable jumps in costs.

Figure 6: Repair Cost vs Distance

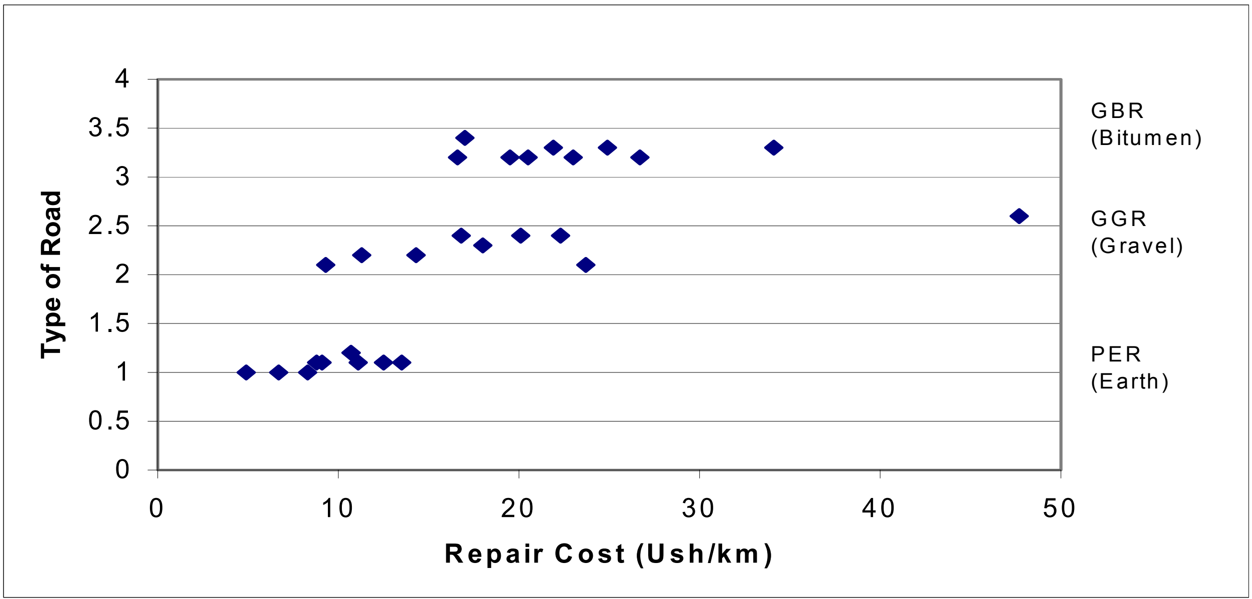






The large variation in unit costs (repair cost/km) is shown in Figure 7. Nevertheless the results show a clear trend that repair costs are highest on the GBR and lowest on the PER, with the GGR between the two.

Figure 7: Impact of Road Type on Repair Costs



Note: Dots indicate individual operators. Dots between lines indicate trips which were on two types of road.

Average values and standard deviations are shown in Table 3.

Table 3: Average Unit Repair Costs

Type of Road	Average Unit repair Cost (US cents/km)	Standard Deviation
Good Bitumen	1.3	0.60
Good Gravel	1.2	0.30
Poor Earth	0.54	0.15

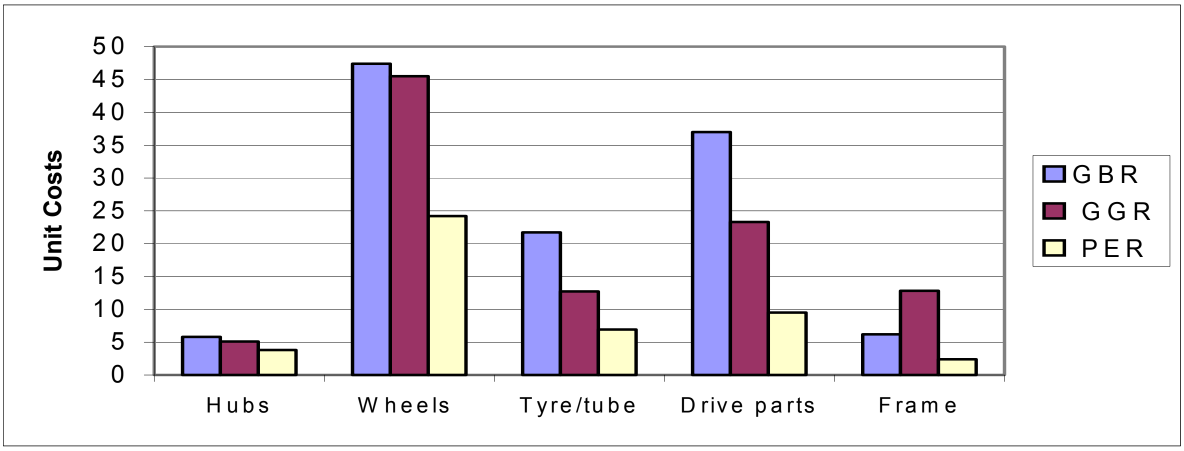
"T" tests showed that the difference in average unit repair costs for the GBR and GGR is not significant but that the difference between these roads and the PER is significant to 99.3%

The most significant finding from the data is that the average unit cost of repairs on the GBR and GGR are double those on the PER. This is contrary to expectations which were that repair costs would be lowest on the bitumen road and highest on the earth road. The fact that speeds were also higher on the earth road increased the expectation of higher repair costs because of the likelihood of greater impacts with potholes and other obstructions.

Further analysis of the repair data revealed that the main cost components for repairs are – wheels (rims, spokes and hubs) 36 to 47% of total cost; tyres and tubes (including punctures) 12 to 17% of total cost; drive components (pedal crank assembly, sprockets and chain) 16 to 28 % of total cost; frame, 4 to 11% of total.

Figure 8 shows a breakdown of the average unit repair costs on the 3 road surfaces. The main findings are:

Figure 8: Breakdown of Repair Costs



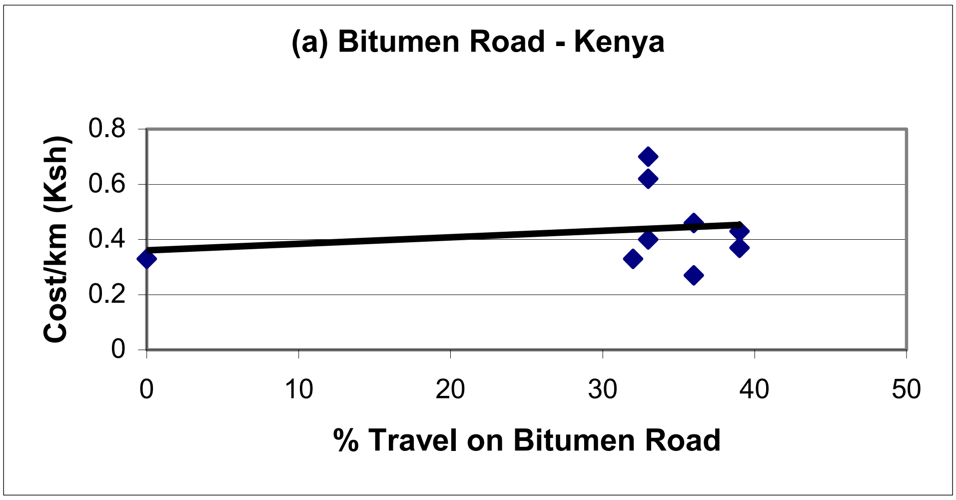
- The wheel and tyre and tube repair costs are higher on the harder bitumen and gravel roads than on the earth road. This indicates that impact loads on the wheels and wear of tyres are both greater on the harder road surfaces. It is also possible that the increased strain from frequent stopping and starting on the GBR and GGR due to short trips and conflict with motor vehicles will increase the wear and tear on these components, particularly on the rear wheel. However, the ratio of the rear wheel costs to total wheel costs – GBR =76%, GGR = 81%, PER =86% - do not show this;
- The drive parts costs are considerably higher for the bitumen and gravel roads, apparently due to the much larger number of short trips on these roads and therefore the greater incidence of starts that put considerable strain on the drive components. The participatory study operators reported that they stopped and started more on a bitumen road not only because of short journeys but more so because of stopping when passed by motor vehicles. Traffic counts have confirmed that there is more traffic on the GBR than PER and significantly more motorised traffic (see Figure 3);
- Apart from spokes, wheel hubs are the most frequently replaced item but due to the low parts cost the proportion of cost is relatively low;
- Frame repairs are relatively infrequent but when they occur the costs are high.

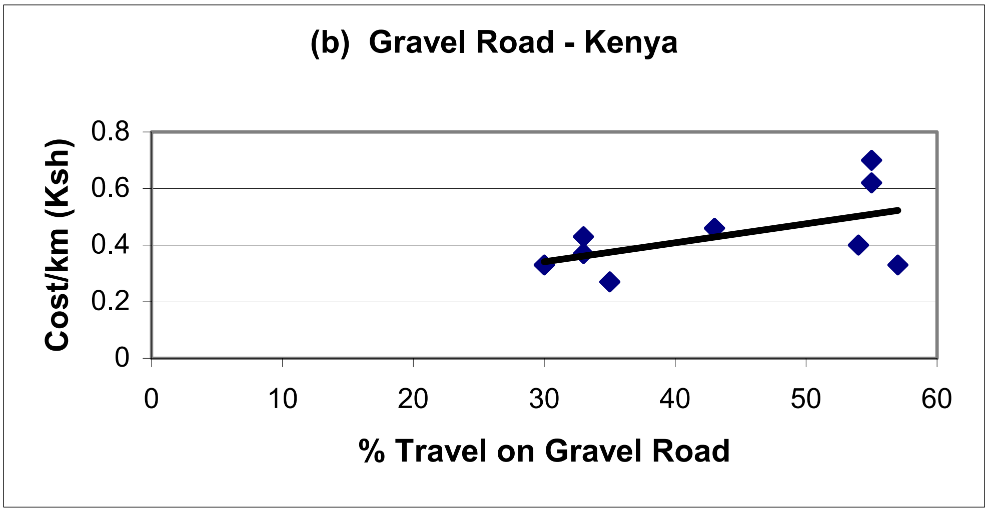
3.2.2 Repair Costs from Kenya

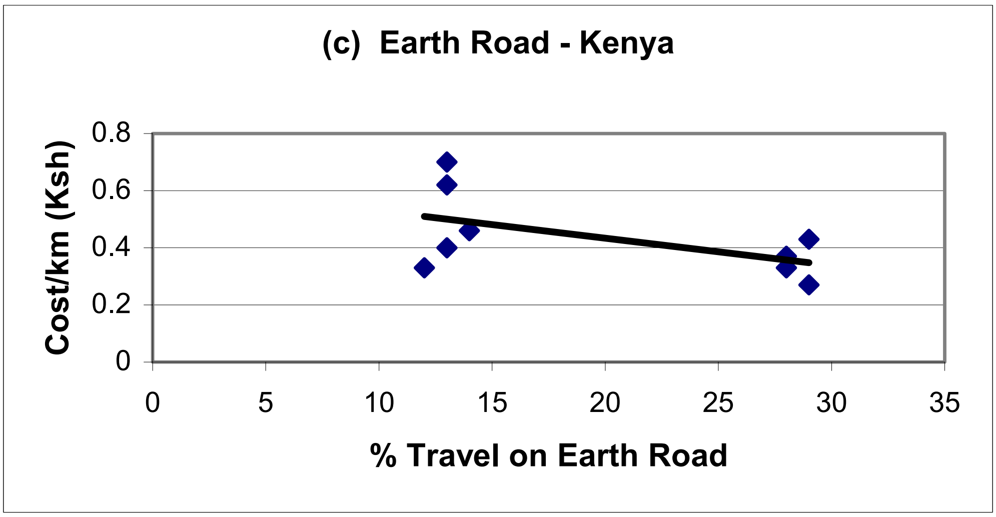
Data on repair costs over a 9 month period is shown in Figure 9. Because all operators worked on a mixture of roads the data is compared in relation to the distance travelled on each type of road. The Figure shows that the data does not provide a definite trend for the bitumen road but for the other road surfaces there are definite trends as follows:

- As the proportion of travel on the gravel road increases (less travel on earth and bitumen roads), the repair cost per km *increases* (see Figure 9(b))*;*
- As the proportion of travel on the earth road increases (less travel on bitumen and gravel roads), the repair cost per km *decreases* (see Figure 9©)*;*

Figure 9: Repair Cost vs Travel







Since the average unit repair cost is made up of the unit repair costs for each type of road and the proportion of travel on each of these roads (Average unit repair cost = $R_{ub}*P_b + R_{ug}*P_g + R_{ue}*P_e$, where R_{ub}, R_{ug} and R_{ue} are the unit repair costs on bitumen, gravel and earth roads respectively and P_b, P_g and P_e are the respective proportions of travel on these roads) then these trends indicate that the unit repair cost on earth roads in Kenya is less than on the other two types of roads. This supports the findings from Uganda as summarised in Table 3.

The trends in the break down of repair costs (Figure 10) also support the findings from Uganda, with wheel and tyre and tube costs increasing with travel on gravel roads and decreasing with increased proportion of travel on earth roads. However, in this case the tyre and tube costs are higher than the wheel repair costs because of a large incidence of punctures.

The unit repair costs from Kenya (see Figure 9) are in the range 0.4 to 0.64 US cents/km which is of the same order but slightly lower than those for Uganda shown in Table 3 above. Because the results are for operation on a mixture of roads it is not possible to give individual unit repair costs for each type of road. However, it is noticeable that the unit repair costs are similar to those on the earth road in Uganda. This is in agreement with the report from Kenya that much of the bicycle operation on bitumen and gravel roads is on earth tracks on the shoulders of the roads so that the average unit cost is biased towards earth roads.

The lower repair costs in Kenya are somewhat surprising when comparing the spare part costs, which are reported as considerably higher in Kenya as shown in Table 4.

Table 4: Comparison of Costs of Spare Parts in Uganda and Kenya

Item	Reported cost in Uganda (USD $)	Reported cost in Kenya (USD $)
Tyre	1.50 to 2.60	3.48
Wheel hub	0.12	0.33
Pedal	0.58	0.95
Chain	1.00	1.66
Pedal crank	0.58	1.04
Rear wheel sprocket	0.86	1.62

In each case the costs are for the parts only. A comparison shows the main difference in costs is for *wheels* (Uganda = $5.10/1,000 km, Kenya = $4.05/1,000km) and *drive components* (Uganda = $3.80/1,000 km, Kenya = $1.25/1,000 km). These comparative costs are again indicative of higher operation on earth surfaces in Kenya.

3.2.3 Comparison with Information from Operator Questionnaires

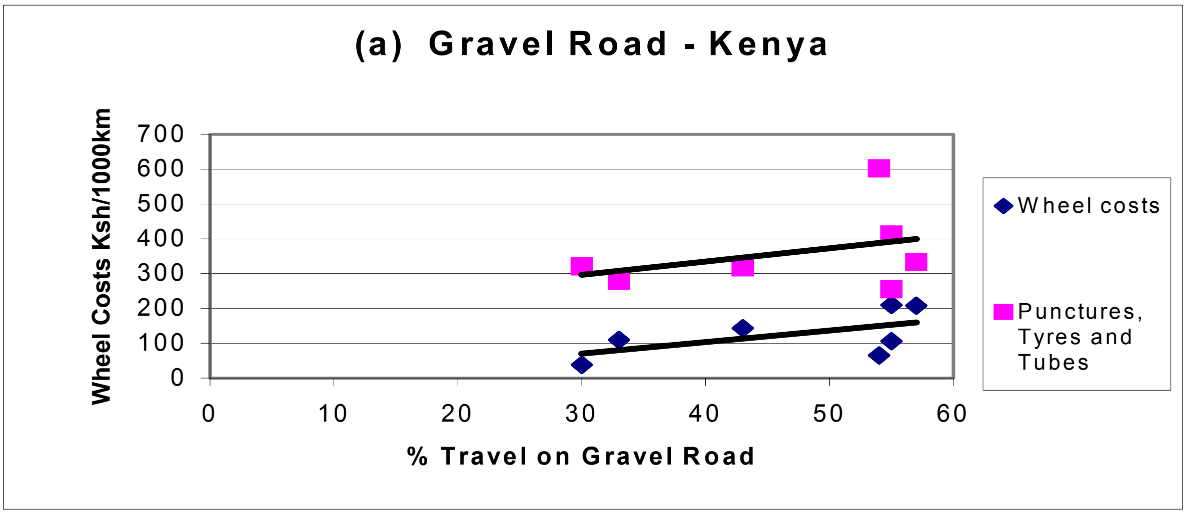
The Operator Profile questionnaires filled out prior to the initiation of monitoring asked operators to state fares charged and to estimate their annual incomes and repair costs. The comparison of the data collected from the questionnaires with the results from monitoring is presented in Annex 4.

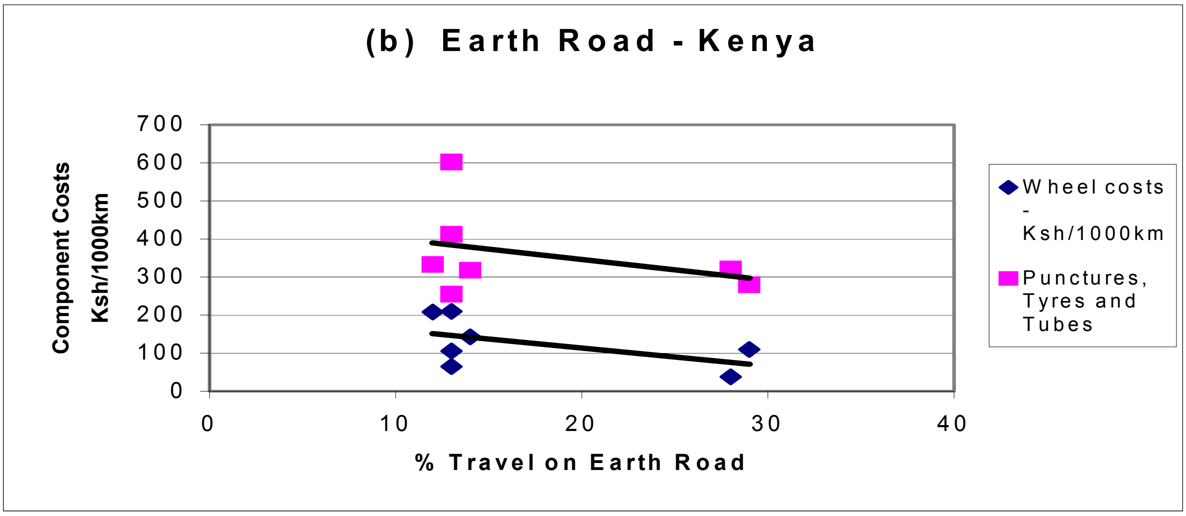
It is seen that there are large differences between the two sets of data but the comparison of the relative values for the three types of roads is very similar for each set of data. The feedback from the operators therefore strongly supports the findings from the monitoring regarding the impact of road condition on incomes and repair costs.

3.2.4 Comparison with Previous Findings

Dennis and Howe1[2] have reviewed published information on operating costs of bicycles. One source is data collected from bicycle taxi operators in Uganda as part of the World Bank Sub-Saharan Africa Transport Programme (SSATP). However, these are overall maintenance costs and there is no breakdown for different road surfaces. Table 5 compares this data with that from the present study:

Figure 10: Component Repair Costs vs Travel





[2] Dennis, R and Howe, J (1993): *The Bicycle in Africa: Luxury or Necessity?* ; VELOCITY Conference "The Civilised City: Responses to New Transport Priorities", November 1993, Nottingham, UK

Table 5: Comparison between 1993 and present study.

Source of Data	Average Cost of Bicycle (USD)	Average Maintenance cost/1000km (USD)	% of Bicycle Cost
1993 study	$112.50	$19.30	17
Present study	$54.00	GBR - $13	24
		GGR - $12	22
		PER - $5.40	10

The most noticeable point is the large drop in the cost of a bicycle since the 1993 study. Taking into account this drop and the likelihood of an accompanying drop in the cost of spare parts, the results of the present study seem consistent with the previous findings.

3.3 Other Operating factors

3.3.1 Operator Incomes

Most of the operators in the Uganda trials owned their bicycle. The average age of the bicycles was 5.7 years and only 10% were older than 10 years, the oldest being 16 years. There was no apparent relationship between bicycle age and repair costs. The average cost of a new bicycle was reported as 95,000Ush (USD 54). Assuming a life of 6 years for the bicycle the average economics of operation are as shown in the following table.

Table 6: Operator Incomes on Different Road Surfaces

Road Surface	Distance per year (km)	Income/km (USD)	Repair cost/km (USD)	Depreciation/km (USD)	Net income/km (USD)	Estimated Annual income (USD)
Bitumen	3,200	0.14	0.013	0.0041	0.123	394
Gravel	4,400	0.11	0.012	0.0030	0.095	418
Earth	6,300	0.05	0.0054	0.0020	0.043	270

All operators in the trials were members of an Operators' Association and have to pay an annual fee out of the income. It is seen that repair costs and depreciation make up only 10 to 12% of income so that time-savings from higher average speeds would be expected to be the main benefit of road improvements. Although speeds were in fact lower on the bitumen and gravel roads the operators still achieved higher incomes due to the high proportion of short trips and corresponding higher unit fares on these roads. In this case demand and willingness of customers to pay have a greater influence on fares and operator incomes than speed and trip times.

3.3.2 Load characteristics

The following table gives the load characteristics for the three types of roads. Interestingly the proportion of women using the bicycle taxis decreases for the lower levels of road surface. This is probably more to do with their isolation from services, the more isolated environment of the roads and cultural conditions than the condition of the road.

Secondly of significant difference is the number of messages/letters that are transported, which is significantly lower on PER, again an indication of the isolation of the population.

Table 7: Details of Loads Carried

Road Type	Male	Female	Male Child	Female Child	Message/ Letter	Bag of produce	Other
GBR	667	574	296	338	201	85	297
GGR	1,080	839	372	436	203	26	19
PER	831	402	372	278	54	56	64

3.4 Econometric Analysis

Because of the surprising and unexpected results identified above the data was further evaluated using econometric analysis. Models were developed to investigate in greater depth the factors influencing both the operational characteristics and repair costs.

3.4.1 Operational Characteristics

An attempt was initially made to develop a model by identifying the factors that were expected to affect the speed of a bike. Unfortunately, no sensible models could be constructed. Faced with these problems, the distances covered by the bicycles were regressed against a host of other dependent variables, including time taken to cover these distances. This helped in finding the factors that significantly influence the speeds of the bikes as the effects of time on distances covered were taken care of within the model. The selected model takes the following form to identify factors that govern the TOTKM travelled by the bicycle in a fixed period of time:

$$\mathbf{Log_e\ TOTKM = b^*Log_e\ (OP\_AGE) + c^*Log_e\ (M\_TRAFFIC) + d\_GBR + d\_GGR}$$

Where,

TOTKM = Total km covered by the bicycle

OP_AGE = Operator's age in years

M_TRAFFIC = average volume of motorised traffic on the particular roads

D_GBR= dummy for good bituminous roads

D_GGR= dummy for good gravel roads

The coefficients were found as follows:

Independent variables	Coefficients	t-value	Significance
Log (OP_AGE)	b = -0.088499	-28.93	0.000
Log (M_TRAFFIC)	c = -0.170057	-15.30	0.000
D_GBR	-0.363062	-16.76	0.000
D_GGR	-0.392067	-28.93	0.000

Overall Statistics of the model:

R Square = 0.94692

Adjusted R Square = 0.94687

Standard Error = 0.35814

F= 19447.7

Significance of F = 0.0000

The overall model statistics, value of the variable coefficients and related statistics can be interpreted in the following manner:

- The goodness of fit of the model and the confidence level of F-statistics is very high. This means that the model is statistically significant. The minimum confidence level of the selected variables is 95%
- Although the operators age is a significant factor in determining the distance covered for a certain amount of time, its elasticity is low – only -0.09. This means that with the increase of operator's age the speed of the bike will slow, but at a highly reduced proportion of the age increase
- The motorised traffic level factor is also inelastic (-0.17). This means that if the level of traffic on a road increases by 100% the distance travelled by the bicycle in a given time (speed) will reduce by 17%
- The distance covered by a bicycle over a fixed amount of time (speed) will be less if the bike operates on a good gravel road or on a good bituminous road rather than an earthen road as the dummy variables explaining the influence of good gravel roads and good bituminous roads are negative. The results may appear counterintuitive, but as confirmed by the participatory study, operators reported that they found it easier to cycle on an earth surface rather than the bitumen or gravel surfaces.
- The insignificant variables that are found to have no influence on the distance travel led for a particular period of time (speed) are: age of the bike, years of operations, weight carried by the bike, dummy for bikes that are purchased new, and dummy for wet season operations.

The econometric analysis therefore supports the main finding of the analysis of operational characteristics (Section 3.1.1) that average bicycle speeds can be negatively affected by the level of motorised traffic on the road and that this factor can override the benefits of a supposedly better road surface. Moreover, the model also indicates that cycling on a smooth earth road may be more efficient than riding on bitumen or gravel roads, a finding suggested by interviews with bicycle taxi operators and supported by the data from Kenya.

3.4.2 Repair Costs

The factors that were expected to significantly contribute to the average monthly maintenance costs were identified with their coefficient values. The analysis constructed different models with a different combination of independent variables. The independent continuous variables used in the models were: distance travelled, average monthly speed, age of bike, level of traffic, average monthly cargo and passenger weight carried by the bicycle, and years of operation. Apart from the aforementioned continuous variables, the models also used some dummy variables (for example, dummy for wet season, dummy for different types of roads surface such as good gravel roads, good bituminous roads, dummy for bikes that are purchased new etc.). The following model was found to be the best model when judged on different criteria (for instance, goodness of fit, sign of the independent variables etc.):

$$\mathbf{Log_e\ MC = a*Log_e\ (A\_SPEED) + b*Log_e\ (TOTKM) + c\ (TOTAL\_WT) + D\_GBR + D\_GGR + D\_WET}$$

Where,

MC = the maintenance costs per month

A_SPEED = the average speed of travel in the month

TOTKM = the total km in a month

TOTAL_WT= the average total load on the bicycle

D_GBR = dummy for good bitumen road

D_GGR= dummy for good gravel road

D_WET= dummy for the wet months

The coefficients found from the model are shown in the following table.

Independent Variables	**Co-efficients**	**T-value**	**Significance**
Log (A_SPEED)	.80664	4.469	.0000
Log (TOTKM)	.34108	3.998	.0001
TOTAL_WT	.04108	9.286	.0000
D_GBR	.86143	6.288	.0000
D_GGR	.69611	5.424	.0000
D_WET	.47261	3.590	.0004

Overall Statistics of the model:

R Square = 0.98712

Adjusted R Square = 0.98682

Standard Error = 0.97239

F= 3282.9

Significance of F = 0.0000

The interpretations of the outputs of the selected model are as follows:

- The model has a very high goodness of fit and the confidence level of the selected model is almost 100%. The confidence levels of all the selected independent variables are over 95%.
- The estimated average speed elasticity is (0.8066) i.e. inelastic. The maintenance costs are estimated to increase by approximately 80% if the average speed of travel doubles. The model therefore estimates that operating speed has a high impact on maintenance costs
- The distance travel elasticity of maintenance costs is 0.3411, i.e. inelastic. The costs of maintenance will increase 34% for 100% increase in distance travelled by the bicycle. However, this finding is for the total data on a monthly basis. If the *annual* repair costs are linked to the specific road surfaces as in Figure 4, the trend lines show the costs to be roughly proportional to distance travelled on the GBR and PER
- It was found that a better model was obtained if Average TOTAL LOAD was put in as a numerical rather than log term. Its coefficient is 0.04108. For the range of data obtained, the model indicates that the extra load carried has a considerable impact on increasing maintenance costs

- The positive coefficients for the dummies for the GBR and GGR indicate that maintenance costs are increased by operation on these roads. For average operating conditions the model estimates that operating costs on the GBR will be approximately double those on the PER. This is in agreement with the analysis of the repair cost data, see Table 2;
- The positive dummy variable for wet season indicates that maintenance costs increase in the wet season. However, this may be due to the fact that operators tend to leave some repairs and maintenance to the wet season when there is less demand for services and they are less busy rather than the impact of wet roads;
- The variables that do not seem to have any significant influence on the maintenance costs of bicycles are: age of the bike, years of operation, dummy for earth road, dummy for bikes that are purchased new.

3.5 Other Information on the Impact of Road Surface on the Operation of Bicycles

No other studies have been found that relate the performance and operating costs of bicycles to types of road surfaces. The only relevant information found is from a study carried out for IT Transport on the performance of bicycle tyres on different surfaces[3]. This investigated two factors:

- The rolling resistance of the tyres on different surfaces – rolling resistance determines the resistance to movement and therefore pedalling effort needed and, indirectly, speed;
- The level of impact loading caused by the roughness of the different surfaces. This indicates the bumpiness of the surface and is one of the main factors affecting the wear and life of bicycle components. The *impact factor* indicates the average peak load on the wheel (load x Impact factor) when the tyre rolls over the surface. It was found to be roughly proportional to speed.

The results are summarised in the following table.

Table 8: Summary of factors measured in tyre performance tests.

Factor measured	Type of surface (1)					
	Smooth Bitumen	Rough Bitumen	Smooth Earth	Rough Earth	Muddy Earth	Soft Earth (sinkage)
Rolling Resistance coefficient	0.009	0.019	0.017	0.020	0.023	0.10
Impact factor @ 10 km/hr	1.13	1.55	1.35	1.60		

(1) Notes on surfaces:

Smooth bitumen – surface worn smooth and polished by traffic

Rough bitumen – coarse aggregate with rough surface texture and loose stones

Smooth earth – smooth walking path

Rough earth – farm track, stony with rutted wheel tracks

Muddy earth – walking track after heavy rain, mud and puddles in places

[3] R.A. Dennis: *Design of Low-cost Wheels*, IT Transport Report No 21, September 1980

Soft earth – wet clayey soil with sparse grass cover; wheel track showed average sinkage of 25mm for 70 kg load

The results show that the roughness of a bitumen surface has a significant effect on both rolling resistance of the tyre and the impact loads on the wheel. A smooth bitumen surface is the best for cycling but a smooth earth surface is better than a rough bitumen surface. The latter conclusion confirms the findings of the present study. A gravel surface is likely to be similar to, or slightly worse than the rough bitumen surface so it is not as good for cycling as a smooth earth surface. The results also show that when earth surfaces get wet they may be more difficult to cycle on than even rough bitumen surfaces. This is supported by the following results from the present study that compare average speeds in wet months with those in dry months. It is seen that speeds are reduced on the gravel and earth roads in the wet months but not on the bitumen road.

Table 9: Average speeds during dry and wet seasons.

Season	Average Speed (km/hr) for different road surfaces		
	GBR (bitumen)	GGR (gravel)	PER (earth)
Dry season months	5.3	6.6	10.7
Wet season months	5.5	6.0	10.1

The most difficult surfaces to cycle on are those that allow sinkage of the tyre, such as soft earth and sand.

The results of the performance of bicycle tyres on different surfaces support the findings from the present study but also indicate that the condition of the particular road surface must also be considered. As might be expected, cycling on a bitumen road with a worn, smooth surface is considerably easier than on a coarse, rough bitumen surface, and gravel and earth surfaces are more difficult for cycling when they become wet and muddy. In particular, the results confirm that a smooth, firm earth surface is better for cycling and will result in lower repair costs than a coarse bitumen or gravel surface.

3.6 Comparison with HDM-4

A method for estimating the operating costs of non-motorised transport (NMT) has been incorporated in the Highway Development Management system (HDM-4), the successor to the Highway Design and Maintenance Standards Model developed by the World Bank[4]. The relevant equation for estimating the unit operating cost is ((27) in reference):

$$RMC = (a\_rmc + b\_rmc * RI_{av}) * CKM * PCHC *10^{-3}$$

Where:

RMC =Repair and maintenance cost per km

a_rmc and b_rmc = Model calibration coefficients

RI_{av} = Annual average road surface roughness (IRI m/km)

CKM = Cumulative km travelled by NMT = 0.5 * AKM0 * LIFE0

Where AKM0 = baseline annual km travelled by NMT; LIFE0 = average life (years) estimated for NMT (Note if annual travel AKMO increases it is assumed that LIFE0 will decrease proportionately)

PCHC = Purchase cost of NMT

The values used for estimating RMC for bicycles on the 3 roads in the project were:

a_rmc = $1.600*10^{-6}$, b_rmc =$0.267*10^{-6}$ (Table 3 in reference – values for bicycles)

Average life (LIFE0) of 10 years at annual travel (AKM0) of 2,500 km (i.e. life of 25,000 km)

Purchase cost (PCHC) = $54 (Local data from study area)

Values of annual average road surface roughness (RI_{av}) were estimated from measurements of average vehicle speeds on the roads [5]. The measured average speeds for cars and pick-up type vehicles and estimated values of RI_{av} and RMC for the three roads are shown in the following table. The values estimated from HDM-4 are also compared with the values measured in this study

Table 10: Comparison of predicted and measured repair and Maintenance costs.

Type of Road	Average speed of vehicles (km/hr)	Estimated value of RI_{av} (m/km)	Predicted Repair and Maintenance Costs ($/ km)	Measured Repair and Maintenance Costs ($/ km)
GBR (Bitumen)	54.5	11	0.0026	0.013
GGR (Gravel)	48.5	12.5	0.0028	0.012
PER (Earth)	29.0	20	0.0039	0.0054

The comparison shows that on the *bitumen* and *gravel* roads the measured repair and maintenance costs (RMC) are 4 to 5 times larger than those predicted by HDM-4, whereas they are of the same order of magnitude on the *earth* road. The actual (measured) trend is therefore completely opposite to the trend predicted by HDM-4. It is considered that this is due partly to

4 J. B. ODOKI and H. R. KERALI: *Modelling Non-motorised Transport Costs and Benefits in the Highway Development and Management System;* Transportation Research Record 1695, Paper No. 99-1129

5 See prediction of correlation between average speed and average roughness in : A Pocket Guide to Feasibility Studies for Low-Volume Roads Government of Zimbabwe, Ministry of Transport and Energy, Department of Roads. Harare, 1998.

increased peak loading on the bicycle from repeated stopping and starting to avoid motorised vehicles but more to the different impact of road roughness.

The surface roughness index used in HDM-4 is a measure of the longitudinal bumpiness of the road which is related to the average speed that a vehicle can be comfortably driven over the road. The results from the study suggest that for bicycles local roughness, or surface texture, is also important to the level of repair and maintenance costs, and in the study was the more dominant factor i.e. RMC were higher on the less bumpy but rougher surfaced bitumen and gravel roads than on the more bumpy but smoother surfaced earth road. Riding a bicycle it is easier to avoid many of the potholes, ruts and rocks than in a vehicle and therefore their effect is reduced.

The findings from the study therefore indicate that HDM-4 may incorrectly predict the benefits to bicycles from improving roads and that the impact may in fact be opposite to that predicted. This is because improvements, for instance regravelling, may reduce bumpiness but increase surface (texture) roughness.

The findings indicate that in designing road improvements to benefit bicycle users both surface texture and surface roughness/ overall bumpiness (RI_{av}) need to be considered.

A further reason for the lower RMC predicted by HDM-4 is that it does not include the effect of bicycle loading. The econometric model developed in this study indicates that the total load on the bicycle has a significant impact on RMC. The model predicts that carrying heavy loads on bicycles significantly increases unit RMC.

4 DISCUSSION AND CONCLUSION

4.1 Discussion of Findings

The purpose of the research was to develop and/or improve tools for including bicycle transport in rural transport appraisal with the aim of increasing benefits and priorities for the large number of rural people who travel by bicycle rather than motorised vehicles. It was anticipated that more clearly identifying the benefits of improved roads to bicycles and including these in appraisal methods for rural infrastructure would increase the priority ranking for low-volume roads that may be heavily used by bicycles and other non-motorised traffic but little by motorised vehicles.

The results obtained are surprising and generally opposite to conventional thinking on the impact of improving roads. The surface that was considered the easiest for cycling, *Bitumen*, in fact has the lowest speed, the highest fares and the highest repair costs; whereas the surface considered the most difficult, *Earth*, has the highest speed and the lowest fares and repair costs. The results for the *Gravel* surface are generally closer to the bitumen surface.

Conventional thinking is that operating speeds and costs are related to the longitudinal bumpiness of the road as measured by the average road roughness index. This has been the basis for appraising the benefits to motorised traffic of improving roads and also is the basis of the recently introduced appraisal method for NMT in HDM-4 (see Section 3.6). This approach predicts that upgrading roads from earth to gravel and gravel to bitumen should increase operating speeds and reduce repair and maintenance costs.

The findings from this study indicate that for bicycles the local surface roughness due to the texture of the surface also has a significant impact on ease of cycling and on RMC. In fact in this study this factor was dominant so that speeds were lower and repair costs higher on the less bumpy but rougher surfaced bitumen and gravel roads than on the more bumpy but smoother surfaced earth road. It is concluded that cyclists can more easily avoid potholes, ruts, stones etc. than motorised vehicles. However, this may not always be the case, for instance on stony or rocky roads or where there are large ruts on the edge of the road from run-off water. Therefore both surface texture and overall roughness need to be taken into account.

The findings on the influence of surface texture are supported by results from measurement of rolling resistance and level of impact loading on various surfaces (Section 3.5). These showed that a smooth earth path was better for cycling than a rough bitumen road but in wet weather the earth path could be more difficult if there were significant muddy areas. However, this would not affect repair costs.

The findings show that the following factors also have a significant impact on bicycle operations:

Traffic: motorised traffic poses a safety threat to bicycles, particularly heavily loaded bicycles that are more difficult to control. Bicycle riders often stop when passed by vehicles, particularly heavier vehicles such as trucks and buses, which reduces average speeds and increases the strain on drive components such as pedals, chain and sprockets, which is greatest when starting from rest. The findings showed that repair costs for these components were significantly higher on the bitumen road which had the highest level of traffic, especially heavy traffic. It is also likely that tyre costs are increased because of greater wear from frequent stopping and starting.

Loading: the econometric model predicts that carrying additional loads on the bicycle increases repair costs disproportionately i.e. repair costs increase at a higher rate than the increase in loading.

Speed: the econometric model also showed that speed has a significant impact on repair and maintenance costs with an elasticity of about 0.8, i.e. an increase in average speed of 50% increases RMC by 40%.

4.2 Impact on Bicycle Users

The condition of the road surface affects the speed, effort needed and repair costs of bicycle users. Speed governs journey times and can be related to costs or savings by the value of time. The need for increased effort in travelling by bicycle is considered a considerable disadvantage by users, whilst an increase in repair costs may result in bicycles being out of service for longer periods because owners cannot afford to repair them. In the case of bicycle taxi operators, both reduced speeds and increased RMC will reduce incomes.

In areas where bicycle taxis operate it was anticipated that improved roads would benefit users of the taxis by leading to reduced fares. However, the study has shown that fares are more dependent on demand for services and what customers are prepared to pay. In the study areas fares were in fact generally higher on the roads that would be considered as "improved".

Implications of the Findings

Although the results of the study are for bicycle taxi operators, the findings on the impact of road surface are relevant for all bicycle users. The average load carried by the operators was 50kg. Domestic users often carry loads up to this level so that their unit RMC are likely to be not far below the levels found in the study. The main difference for domestic users will be in the distance travelled per year which will be much lower so that annual RMC will be substantially lower than for the taxi operators.

The main implication of the findings for transport planners and designers is that in regard to the impact on bicycle operations three factors need to be considered in the improvement/upgrading of roads – *surface texture, surface roughness (bumpiness) and potential increase in motorised traffic.*

Surface texture

an earth road that is rough and bumpy for motorised vehicles may provide reasonably smooth tracks for bicycles that use the edges and can steer round potholes, ruts etc. Regravelling the road will benefit motor vehicles but will dis-benefit cyclists because the gravel surface will be less easy to cycle on and will increase repair costs. The best treatment for cyclists would be to repair the road with earth fill or to leave smooth, firm earth shoulders.

Surface roughness

if the road surface is very stony or rocky and/or has substantial ruts along the edges, then regrading and resurfacing are likely to benefit cyclists, but again an earth surface or earth shoulders will be better than a gravel surface.

Traffic level

if improving or upgrading a road is likely to increase levels of motorised traffic then it will disadvantage bicycle users in regard to safety, operating speeds and repair costs. If the impact is likely to be significant then serious consideration should be given to providing bicycle paths along the shoulders of the road.

Further studies are needed to support the findings of this study before definite guidelines can be prepared for transport planners.

ANNEXES

ANNEX 1: PROJECT LOGICAL FRAMEWORK

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal: Improve the mobility of rural and urban poor for meeting their livelihood needs.	Bicycle operating costs reduced by increased emphasis on improving routes used by bicycle transport.	Evidence from infrastructure improvement and maintenance programmes and from bicycle users.	No Input Required
Purpose: Tools for including bicycle transport in rural transport appraisal are developed or improved and bicycle operating costs are reduced.	Increased inclusion of NMT (especially bicycles) in the appraisal of rural transport projects. Charges for bicycle transport services reduced.	Planning and evaluation procedures of donors and governments. Monitoring charges of bicycle transport services.	(Purpose to Goal) Findings and recommendations are adopted and implemented by donors and governments.
Outputs: 1. Studies in 2 countries showing the impact of infrastructure condition on bicycle operating costs. 2. Guidelines developed on the relationships between type and condition of infrastructure and bicycle operating costs. 3. Tools developed for including bicycle transport in economic appraisal of transport projects. 4. Main sources of bicycle repair costs identified 5. Guidelines produced on methods for reducing repair costs.	1. Study report produced. 2. Guidelines produced. 3. Procedures produced. 4,5 Technical brief and web page produced.	Report and guidelines submitted to DFID, donors and relevant Government departments. Technical brief disseminated to NGOs and others working with bicycle users and operators. Web page on I.T. Transport and other relevant sites.	(Output to Purposes) Findings of study and review show justification for including bicycle transport in planning of infrastructure improvement.
Activities: 1.1 Carry out literature review. 1.2 Plan studies in Kenya and Uganda. 1.3 Brief local consultants, select roads to be included and sample of 10 bicycle service operators on each. 1.4 Set up monitoring programme to monitor trip times and repair costs. 1.5 Collect and collate data at monthly intervals over a 12 month period. 2.1 Analyse data and prepare guidelines on impact of infrastructure type and condition on bicycle operating costs. Prepare guidelines on including bicycle transport in economic appraisal of transport	1. Monitoring programmes set up and operating. 2,3 Guidelines produced on schedule. 4. Report produced. 5. Photographs of innovations under test. Technical brief produced on schedule.	1. Progress report. 2,3 Guidelines submitted to DFID and disseminated to development agencies and Government transport planning departments. 4. Report disseminated. 5. Technical brief distributed and available on I.T. Transport's web site. Article published in Appropriate Technology.	(Activity to Output) 1. Bicycle operators provide reliable and accurate data. 5. Methods of reducing repair costs are found and can be implemented at an affordable cost.

projects. 4.1 Analyse and collate data on bicycle repair costs. Identify possibilities for reducing repair costs. Test possibilities with sample of bicycle operators operating on worst roads. Monitor repair costs over further 6 months and collate data at 3 and 6 months. Analyse data to evaluate reduction in repair costs. Prepare technical brief on methods of reducing repair costs and article for Appropriate Technology.	**BUDGET** **Salaries:** I.T. Transport staff 36,791 Local consultants 8,976 **45,767** **Other Expenses:** Overseas visit 3,200 Monitoring 4,000 Local consultant Costs 5,125 Local workshops 1,000 Communications & Publications 3,200 **TOTAL 16,292** Performance Budget		

ANNEX 2: MONITORING RECORD SHEETS

1 NOTES FOR OPERATORS

1. Details of trips

1.1 Please write **date** at beginning of each new day

Please fill in details of **all** trips

Type of road – please use 3 letters as follows:

Quality - **G** = Good; **A** = Average; **P** = Poor
Road surface – **B** = Bitumen; **G** = Gravel; **E** = Earth
Type of road – **R** = Road; **P** = Path

Example: ABR = Average Bitumen Road; GGR = Good Gravel Road; PEP = Poor Earth Path

If the trip takes place on more than one type of road please give the approximate km on each type. For example – 3ABR + 2GEP would be 3km on average bitumen road + 2km on good earth path

Passenger details - please record as follows: **M =** Man; **W** = Woman; **B** = Boy; **G** = Girl

Boy and Girl are below age of about 15

Goods details – Please state what is carried – Maize, Cassava, Fish, Supplies etc. and estimated weight in Kg

Details of repairs

2.1 Please record details of **all repairs** including punctures, replacement of tyres and tubes and any other parts that wear out or break, on the sheets provided.

2.2 If the frame breaks please mark **accurately** on the sketch provided where the break occurred and the date when it broke

1. LOG BOOK: DETAILS OF TRIPs

Date……………………. Operator Identification ………………………….

Start time	End Time	From (Place)	To (Place)	Distanc e Km	Type of Road	Passeng er Details	Goods Details	Fare

LOG BOOK: DETAILS OF REPAIRS

Date……………………. Operator Identification ………………………….

Date	Details of Repair	Who did Repair	Parts Purchased	Cost of Parts	Total Cost of Repair

ANNEX 3: SUMMARY OF PARTICIPATORY WORK

Brief on Impact on Bicycle of Infrastructure Improvement Study Mission, Uganda, August 2002

The following brief is essentially field notes from the August, 2002 visit for the Impact on bicycles of road infrastructure research. The brief gives an introduction to the week long visit, followed by results and conclusions.

A3.1 Outputs

The outputs of the mission were to have a:

- Clearer understanding of the analysed data.
- Traffic count on the study roads.

A3.2 Activities

Output 1

1. Observation of traffic travelling on the road. Looking for:
    - What part of the road cyclists use – shoulder, main carriage way, etc.
    - What competition for road space there is; and, the condition of the road.

2. Discussions/group sessions with Boda Boda operators on each road. The operators chosen where from the same group that participated in the study. They were always men and included the association chairman. One group discussion was done per road. The discussion was done using participatory methods to build rapport and stimulate discussion. The sequence of discussion topics follows:
    a. The groups were thanked for participating in the study so far.
    b. A discussion of the sphere of travel based on a sketch map drawn by the group.
    c. From the spheres of travel the fares for distances were discussed.
    d. How these fares were made up was asked.
    e. What would be the effect of decreasing or increasing the fares.
    f. How much time do operators spend working per day.
    g. Why are the trips made on earth roads longer in distance?
    h. Why are the journeys on bitumen roads slower?
    i. Why are there high repair costs per kilometre on bitumen roads?
    j. The local bicycle repairer was interviewed asking:
    k. The most common repairs.

Output 2

a. Setting up a traffic count on each of the three roads. Conducting them on the same days that the trip data was collected.
b. Discussion with the District Engineer about the changing traffic on the roads.
c. Discussion with shop keepers on the changing traffic on the roads.

Output 3

Obtain views of local consultant on conduct of study and on the findings from the study.

A3.3 Timetable

Tue - 20-Aug	UK - Leaving at 21:00	BA63 - 21:00. Arrive 07:35
Wed - 21-Aug	Kampala - Nile Hotel	Meetings with Achilles
Thu - 22-Aug	Iganga	Travel to Iganga. Arrange meetings and observe boda boda operation on all roads. Meet District officials. Organise traffic count.
Fri - 23-Aug	Iganga	Meeting with Boda Boda operators and road observation, PER and GGR.
Sat - 24-Aug	Iganga	Meeting with Boda Boda operators and road observation - GBR.
Sun - 25-Aug	Iganga	Assiting with traffic count and, writing of results.
Mon - 26-Aug	Kampala - Nile Hotel	Travel back to Kampala. Analysis of data.
Tue - 27-Aug	Kampala - Nile Hotel	Writing up report and analysis of data.
Wed - 28-Aug	Leave Kampala	BA62 - 09:30. Arrive 16:25

A3.4 Results

A3.4.1 Nakivumbi to Busesa – Poor Earth Road

The Boda-Boda association started in 1954 and were based at the main road in Busesa. In 1967 the association had grown to such an extent that they opened a new branch at Nakivumbi. There are currently 30 bicycles registered with the branch association. Ten of the bicycles are operator owned, the rest are owned by someone who *hires*[6] them to operators. The rural branch association is exclusively for bicycle Boda Boda and the Main branch at the main road is exclusively motorcycle Boda Boda. New operators pay a membership registration fee of 10,000 USh per bicycle and 20,000 per motorcycle. This revenue raised from membership is spent by the association on licence and an association plate. There are no women in the group.

The PER is along one section that was recently improved through regular maintenance by the Local Government. However there are still a number of pot holes. At the time of travelling the drainage structures looked in good condition and adequate. Boda Boda operators take the easiest part of the road to travel on.

Routes

The main route is between Nakivumbi and Busesa. They may drop people off half way or go off the road to drop the passenger to their respective home. There is an advantage for the bicycles as motorcycles can not always travel on difficult terrain.

All the cycle Boda Boda start at Nakivumbi and the motorcyclists start at Busesa. This is mainly because people are more willing to pay for a motorcycle at Busesa and they have alternative routes. If a cycle operator goes to Busesa, he will wait there until he has a load to go back with. Likewise for motorcycle operators.

Fares

The fare for the route for cycle operators varies between 500 to 800 USh. This rate is reportedly decreasing due to decreasing fares of motorcycle operators.

The variation in the fare is done through negotiation and there is no association set price. The main factors are:

[6] The operator will take the bicycle at the start of the day. A share of the daily income is then given to the owner of the bicycle.

a. The operators need for money to meet the daily basic necessities and/or overcome periodic economic shocks. An operator can undercut his colleague, if he needs the money and is willing to go for a lower price. However, if the price is too low the other members of the association will check this. The minimum was considered to be 400 USh.

b. If the operator needs to pay for a repair, he can use this as a bargaining tool.

c. The appearance of the passenger. If they look rich and ignorant of the distance and geography of the area a higher price will be charged. If they are heavy then a higher price will be charged.

d. If they are a new customer they will not know the rates or distances so a higher price is tried.

e. If they are carrying baggage of more than 5kg the fare goes up.

f. There is an over supply of customers (for instance, going for burial or to the market) the fare is raised.

The basis for determining and charging a minimum fare is to earn a bare minimum to meet minor repair cost of the bicycle and remaining with enough for subsistence. For instance, for the average distance the operators would charge a minimum fare of 500Ush, the 200 USh being for any minor repairs, and 300 USh for subsistence. They also said that each time they made a journey there was usually something that needed repairing, although this may just be the tightening of a bolt, rather than a replacement or major repair.

The peak season is during harvest in December, which also coincides with end-of-the year festivities and children having to pay for school uniforms. Fares are higher during this month as there is more demand, greater affordability by passengers and also the operators want to raise school tuition and scholastic material for their children for the new year's school term. In a rural setting, the majority of passengers travel to buy consumables rather than sell crops, as trucks come to the village to buy crops. People also occasionally travel to attend funerals and/or visit relatives.

The low season is during April to June when it is the wet and planting season.

Productive time

The productive time of the operators is between 2 and 3.5 hours a day[7]. They can spend 2 to 3 hours per day waiting for a passenger or load.

Greater speeds on PER

The reasons given included:

- Passengers ask the cyclist to go faster.
- There are few cars to make you dismount and stop.
- If the cyclist is slow may miss the next passenger.
- There is little competition with other modes of transport, so there is more competition between the operators.

Greater distances per trip on PER

The reasons given included:

- In a rural setting, the people would prefer to walk and save the money to spending it on boda-boda fare. However, in more 'urban' area they will not walk as much.
- Affordability in 'urban' areas coupled with need to save time makes people more willing to spend on transport.

[7] 40 mins per trip. 2 per day low time, 5 in peak time.

- Urban people travel for appointments for business, whereas rural people under take longer more planned journeys.

Greater Fares/km on GBR

Reasons given included:

- There is more willingness to pay in 'Urban' areas.
- There is a greater supply of people so the operators can charge more.
- Some passenger tend to pay for speed
- Some passengers like to be transported over the hill and boda-boda would charge more for that trip.

Problems with bicycles

The high number of repairs can be attributed to the quality of the spares. All the spares are from China and India. In general the mechanical parts are better from China and the tyres are better from India. The Indian parts are cheaper. The operators will usually choose the more expensive parts.

The bicycles useable life is on average two years. The oldest bicycle in the fleet of 30 is five years old. The older the bicycle the higher the maintenance cost. When a bicycle is starting to need regular maintenance the owner will start to save money for replacement. The cost of a replacement bicycle is 95,000 Ush (SSD$54).

A3.4.2 Iganga-KiyungaIganga – Good Gravel Road

The Boda Boda association stared in 1974 with five people. The association swelled to 60 people with a mixture of cycle and motorcycle operators. With the improvement of the road 3 years ago the numbers in the association have declined and there are now 30 members. All the members are cyclists. Each member pays annually a 5,000 USh membership fee and 3,000 USh to obtain an association number plate. All the bicycles were operator owned.

The GGR is in a reasonable condition there are some pot holes, but not many. At the time of the visit the drainage structures was in good condition and adequately maintained. Boda Boda operators usually travelled on the sides of the roads, due to motorised traffic taking the middle section.

Routes

The operators predominantly ply routes that are beyond Kiyungain the direction away from Iganga. These include Kyanvuma, Bulopa and Naigamba. The operators offer a transport service for people who want to continue their journey after they are dropped by Iganga-Kiyungaby taxis or minibuses. Two other routes towards Iganga along the improved route are not plied frequently.

Fares

The fares to the destinations beyond Kiyunga are between 700 and 1000 USh. The fares are negotiated with the passenger and there are no set fares. The factors the operators considered in negotiation include:

a. The appearance of the person – rich/poor, old/young. The sex of the person is not usually considered.

b. The costs of spares. If someone has to make a repair they will want to make more money.

c. The trip distance.

d. Amount of luggage.

If the operators increased their fares, the passenger would walk rather than pay more. If they reduced their fare then more people would use boda-boda mode of transport They have to do this at the moment as taxis and minibuses are starting to cut their costs, although the competition is mainly over long distances. There are very few motorcycle Boda Boda as they are under-cut by the minibus and taxi operators.

Productive time

It was very difficult for them to give an estimate of the productive time. Of the six operators they had all gone to the station on the previous day. Two of them had no trips, two had one trip each, one had three and one had four. Of the three and four trips they estimated they waited for five and three hours respectively.

During the peak season in November and December the time waited would be less and they normally make more trips – up to ten a day. The low season is from January to May.

The operators work every day, although, as above this may just involve turning up and not getting a trip. During the wet season operators will work on their farms in the morning and then operate in the afternoon.

Greater speeds on GGR

The reasons given included:

- They thought that you could gain greater traction on gravel roads than bitumen roads.
- They thought that the Boda Boda operators on PER are younger.
- They thought that perhaps the demand from passengers was greater on PER.

Greater distances per trip on GGR

The reasons given included:

- Passengers have to travel with Boda Boda as there is no alternative inland. So they will go further distances. On bitumen roads there is more competition so passengers go shorter distances.

Greater Fares/km on GBR

Reasons given included:

- The operators have greater demands on their income so they charge more in the urban areas.
- Ability of the passenger to pay higher rates

Problems with bicycles

There are many shops for spares and six mechanics in the area. The price of spares is cheaper in Iganga but people rarely go there. In general the poorer quality spares are from India and the better ones are from China. However, Indian mud flaps, saddles, sprockets and tyres are preferred.

The modification of double front forks has been included for many years. The chairman produced a pair that were Raleigh! They are now produced locally in Iganga. They are to support the front forks. The only other modification is the back rack, which is strengthened. These were made locally by the chairman.

The main repair problems were with the frame joints. In general bicycles last for two years. Poorer operator owners will continue to have their bicycle repaired but it is not considered cost effective.

A3.4.3 Kaliroto Iganga – Good Bitumen Road

The Nabitende East and Central Co-operative Society started in 1987 with nine members. They currently have 20 members, all male. The objective of the society was to bring together the skills of the members to assist each other in difficult times. They have only cyclist and there are no women.

The GBR is in a very good condition with signs of regular maintenance. At the time of the visit the drainage structures looked in good condition and adequate. Boda Boda operators usually travelled on the sides of the roads. They will go onto the shoulders if necessary, although this is rare. They will usually stop when large lorries approach.

Routes

They ply a number of routes. The most popular routes are not along the GBR but on a GGR between Itanda and Naibiri. The passengers on the routes are mainly students, patients and general travellers. On the GBR passengers are similar although they are more likely to be in a rush and can't wait for the cheaper taxi's (see below)

Fares

The fares for the GGR are 700 to 1000 USh for Nabitende to Itanda and 300 to 500 USh from Natiende to Naibiri. Trips along the GBR are Nabitende to Kaliro 500 to 700 USh and 300 to 500 USh from Nabitende to Naibiri (an area also on the GBR). The fares are negotiable and depend on:

a. The appearance of the customer – smartness, size, local or non-local.

b. Baggage – if it is over 5Kg they will charge.

c. Regular customer or not.

d. Seasonal fluctuations.

e. The bargaining skill of the potential passenger.

They thought that if they decreased their fares they would get more passengers, but they would not make enough to survive. If they increased then people would walk. (There is little competition on the non-bitumen roads, however the competition on the GBR is high and the taxis charge less than the Boda Boda (300 USh compared to 500 USh). People use the Boda Boda on the bitumen road as the taxis and minibuses come at an irregular interval. Therefore, the Boda Boda are giving a more convenient service.

Productive time

At the moment the operators can have up to 6 hours unproductive time. This decreases to 2-3 hours in the peak time of December, with up to 10 passengers per day.

Out of the ten operators in the study, only three will take a day off a week to attend the mosque or church. This does not change through the year.

Greater speeds on PER compare to GBR

The reason given included:

a. The traction on the GBR is less than that on a PER.

b. The motorised traffic make them stop more frequently.

c. The operators ride on the shoulder of the bitumen only when two vehicles are by-passing or big trucks are passing by. From observation this is not very often.

Greater distances per trip on GGR

The reasons given included:

a. On the GBR the passengers have a choice: to go with the Boda Boda who is more expensive and available; or, wait for the taxi that is cheaper. If the passenger's trip is short and there is no taxi they will go with the Boda Boda. If the trip is long they will wait for the taxi, knowing the total trip time including waiting will be less than if they went with the Boda Boda.

b. On the GGR and PER there is little choice so people will undertake longer distances with Boda Boda.

Greater Fares/km on GBR

Reasons given included:

a. Passengers tend to carry more luggage on the GBR.

b. They offer an express service which costs more.[8]

c. Ability to pay by the urban passenger

Problems with bicycles

There are many shops in the town were they can buy spares, although there is no bargaining. There are also many mechanics who they can bargain with. India tyres, sprockets and free wheels are good, however, they prefer all other spares from China.

The main repair problems are on the connection with the bottom joint and the sprocket.

The strengthening rod of the front fork is made locally and prevents the front wheel from coming out.

Many of the Boda Boda also had addition strengthening rods on the back strut that goes from the rear axle bracket to the seat. They said this aids stability when travelling with a heavy load, reducing the flex in the main frame, these are also made locally. They also mentioned that the saddle covering and springs are poor materials.

The average bicycle will need replacing after 2 years.

A3.5 Participants In Discussion

Nakivumbi to Busesa Road – PER

Group Participants 23/8/02

All male

Name	Designation
Mpyangu John	Association Chairman
Nelson Mudali	Spare part seller
Abdu Muchudu Salongo	Operator
Patrik Kakaire	Operator
Masabala Maganda	Operator
Awali Atalasi	Operator
Mukudhu Hayidali	Operator

8 This does not tally with the above answers.

Iganga to Luyunga Road - GGR

Group Participants 23/8/02

All male

Name	Designation
Matke Isa	Association Chairman
Musana Livingstone	Operator
Almadha Tamwimise	Operator
Mandra John	Operator
Asuman Buyinza	Operator
Godfrey Kyotaite	Operator

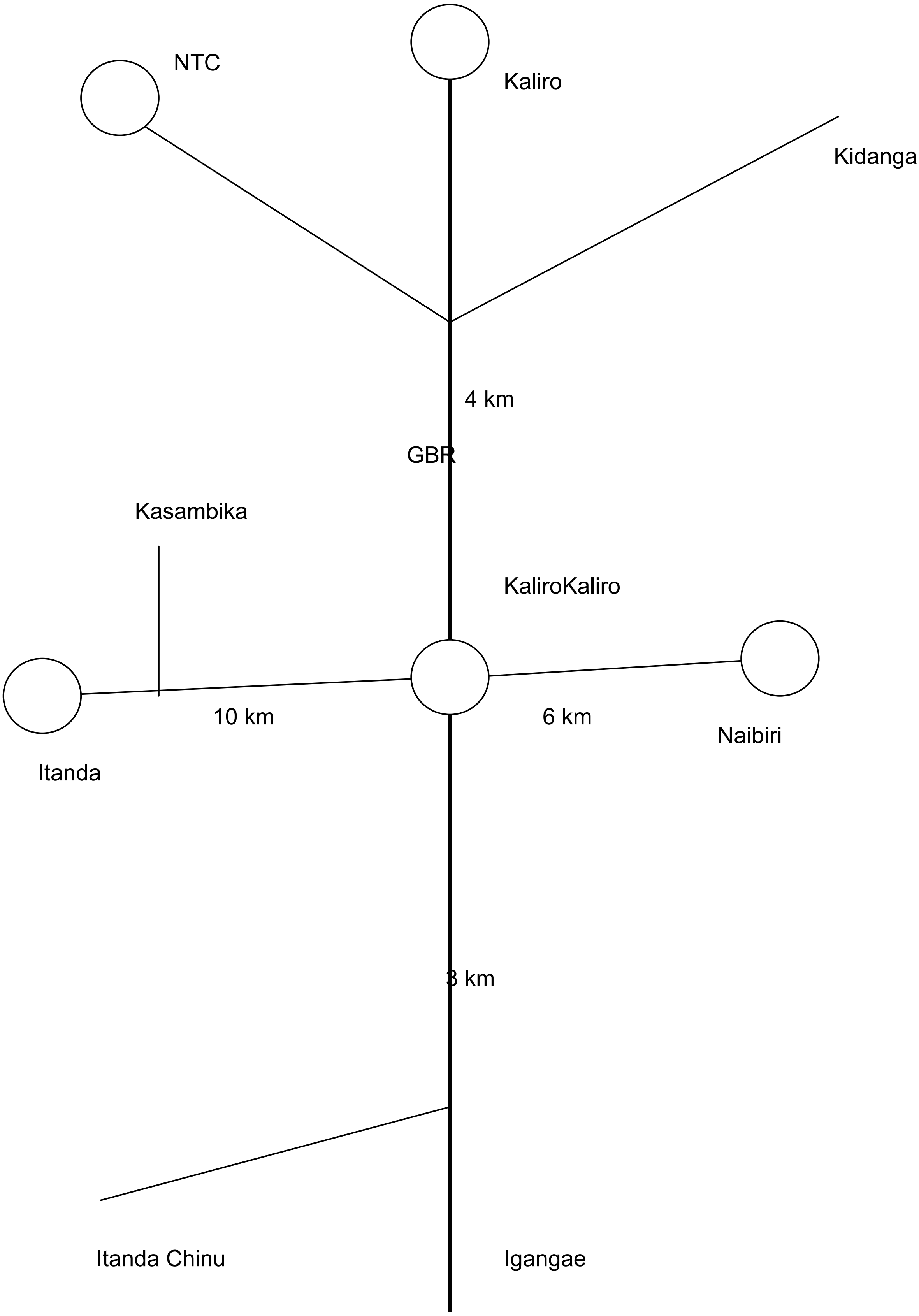
Iganga to Kaliro Road - GBR

Group Participants 23/8/02

All male

Name	Designation
John Bafara	Association Chairman
Isa Marinzi	Operator
Johnson Dadura	Operator
Godfrey Bibita	Operator
Moses Balikowa	Operator
Robert Isabirye	Operator
Sadik Bategre	Operator

ANNEX 2. MAP FOR KALIROKALIRO GROUP



ANNEX 4: COMPARISON OF RESULTS FROM MONITORING WITH DATA OBTAINED FROM OPERATOR QUESTIONNAIRES

UGANDA: COMPARISON OF DATA FROM OPERATOR QUESTIONNAIRES AND MONITORING

Type of Road	Average Unit Charges /Fares for passengers (Ush/km)		Annual income from operator profiles		Annual Income from monitoring	
	Operator profile	Monitoring	Estimate of annual income	Based on estimates of weekly incomes	Average hours of operation per month	Income /year
Bitumen	433	246	126,100	183,400	44	691,000
Gravel	411	193	255,600	198,200	69	733,600
Earth	400	90	126,700	108,300	51	474,000

Notes:

Incomes

1. The average fares found from monitoring are considerably lower than those stated by the operators, especially on earth roads. Ii is assumed this is due to fares/km decreasing on longer trips. Most operators indicated that fares were set by negotiation with customers. Average fares for short trips (<2 km) were about 300Ush on all roads, which is closer to the above values from the operators
2. Despite the lower unit fares the incomes from monitoring data are 3 to 4 times larger than estimated by operators. This *may* be partly due to overestimating the total time of operation over the year. It was assumed that average working days was 18 per month over the year and therefore operating time was 4.5 x monitored time (4 days per month).
3. *The trend* of income for the 3 road surfaces obtained from the operator questionnaires is the same as that obtained from monitoring.

Repair Costs

Road type	Average repair costs per year/ operator (Ush)	
	From operators	From Monitoring
Bitumen	47,900	71,950
Gravel	65,600	79,000
Earth	30,200	59,760

Notes: the comparison is closer than for incomes and the trend is the same for both sets of data, although the differences between the 3 roads is greater from the operator estimates

ANNEX 5: REFERENCES

Dennis, R and Howe, J (1993): *The Bicycle in Africa: Luxury or Necessity?* ; VELOCITY Conference "The Civilised City: Responses to New Transport Priorities", November 1993, Nottingham, UK.

Dennis, R (1980): *Design of Low-cost Wheels*; IT Transport report No.21, September 1980, Ardington, UK.

Odoki, J.B. and Kerali, H.R.(2002): *Modelling Non-motorised Transport Costs and Benefits in the Highway Development and Management System*; Transportation Research Record 1695, Paper No. 99-1129.

Government of Zimbabwe (1998): *A Pocket Guide to Feasibility Studies for Low-volume Roads*; Ministry of Transport and Energy, Department of Roads, Harare, Zimbabwe, 1998.