

MOZAMBIQUE ROAD FUND (FE)

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Development of an Index for Monitoring the Condition of Low-Traffic Unpaved Roads



Indices Review Brief

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1 BACKGROUND

Mozambique's road network consists of slightly over 29 000 kilometres of which 24 318 kilometres are unpaved, constituting over 80% of the network.

The condition of the unpaved roads is currently monitored through bi-annual visual condition surveys and associated speed surveys that are largely subjective in nature.

The condition of the roads is reported in terms of average speeds achieved, these are categorised into the following bands:

<u>Condition</u>	<u>Average Travel Speed</u>
Very Good	> 80 kph
Good	60 – 80 kph
Fair	40 – 60 kph
Poor	20 – 40 kph
Very Poor	< 30 kph

A study undertaken in 2006 revealed that 52% of the unpaved network was in fair or better condition using the above-mentioned criteria.

The shortcomings of the method in current use were identified as lack of objectivity, non-automation and absence of linkage to Threshold/Desirable or Design Speed for each class of road.

The Mozambique Road Fund (FE) is concerned with the overall network condition monitoring and wish to represent the condition of the entire network using an alternative indicator of the level of service or performance that is relatively easy to derive whilst being robust.

The FE contends that speed of travel can be used as useful proxy indicator for road condition on low volume unpaved roads where other indicators such as roughness cannot be easily measured due to technical and economical reasons.

In June 2009 a project was instituted whose objective was to develop a practical, affordable, reliable and objective method of monitoring condition and level-of-service of unpaved road networks in Mozambique using speed data collected using simple GPS technology.

Simple recreational GPS receivers were used to collect speed data under a testing regime that examined the following variables: sampling method (time or distance), sampling frequency, driving regime (fast, normal, slow), road class, reported road condition and GPS receiver type. Extensive 'second-by-second' data was collected in a relatively cheap way and prepared for further analysis using simple methods.

Indices were developed that report on the 'speed deficiency' characteristics at road segment, link and network levels. Use was made of plots of speed and acceleration versus time to capture the speed variation profiles over the journeys. Indices were then calculated off these profiles.

Annexure I gives a typical plot of *speed versus time* as found during the project surveys.

The same annexure also contains a plot of *acceleration vs time* as derived from the velocity logs.

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‘Speed deficiency’ was measured against datums defined by Threshold/Desirable Speeds assumed as the Design Speeds set by ANE for vicinal, tertiary and secondary roads. Where speeds achieved were above Threshold/Desirable Speeds this was taken as indicative of good road conditions.

In summary the indices identified the length of roads and extent of network where speeds below Threshold/Desirable Speeds were experienced, compared the time it took to traverse those sections to the time it would take travelling at Threshold/Desirable and finally attempted to quantify the lowering of travel speed below Threshold/Desirable Speed.

The mentioned indices, which were calculated at segment (5kms), link and network level were:

- SEI – Speed Efficiency Index
- SSI – Sub-Speed Index
- SSDI – Sub-Speed Distance Index
- SSTI – Sub-Speed Time Index
- TTI – Travel Time Index

The indices definitions are given in detail in subsequent sections of this brief.

Following conclusion of the field trials and data analysis it was found necessary to review and rationalise the proposed indices to decide on the most practical to adopt.

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2 RATIONALE FOR SPEED DERIVED INDICES

In planning and monitoring the performance of road infrastructure well established ways of evaluating level of service include determining traffic speed, volumes, density and travel time.

Several research projects and the Highway Capacity Manual (HCM) have suggested that a good service measure should encompass various aspects of service quality such as travel time and speed, freedom to manoeuvre, traffic interruptions, comfort and convenience (Joonho Ko, 2006).

As mentioned in a prior section Mozambique uses *average speed* over road links as an indicator of condition.

The use of average speed on its own has been found to give unreliable and/or inadequate information about a journey and thus cannot be a useful indicator in monitoring the performance of a network.

To illustrate the above, as shown in *Figure 1* below, two vehicles driving over the same distance can return the same average speed although the speed profiles will be totally different. Vehicle A maintained a relatively controlled driving regime over the road stretch whilst Vehicle B had two distinct regimes of speeding up and one of slowing down.

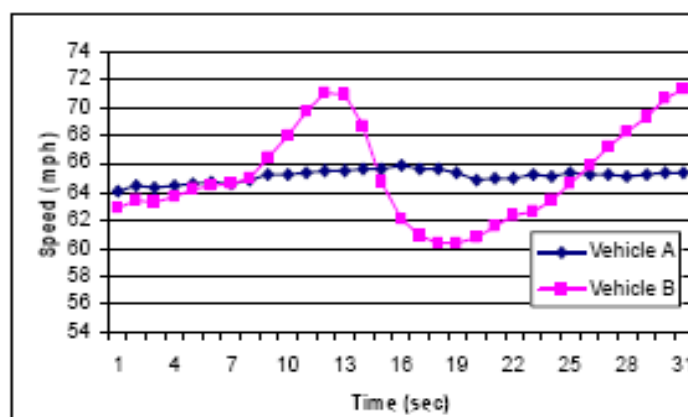


Figure 1: Speed Profiles with Same Average Speed

Source: Joonho Ko, 2006

Under ideal conditions the expectation is that drivers maintain uniform speed without accelerations or decelerations.

This does not happen in practice as drivers are induced into reducing or increasing speed in response to:

- Traffic interactions,
- Road alignment,
- Road side developments, and
- Road surface condition.

It has been found that even in conditions approaching the ideal, drivers cannot maintain constant speeds as sensory perceptions come into play. As a result there will always be some acceleration and decelerations.

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To correctly depict the experience of a vehicle on a journey, it has been shown that the use of *speed variation* seems to have merit because it includes additional elements of service quality perceived by drivers and can be modelled to suit road administrators' performance management systems.

The degree of speed variation is directly or indirectly related to road condition, driver satisfaction, safety, traffic conditions etc as diagrammatically represented in *Figure 2* below.

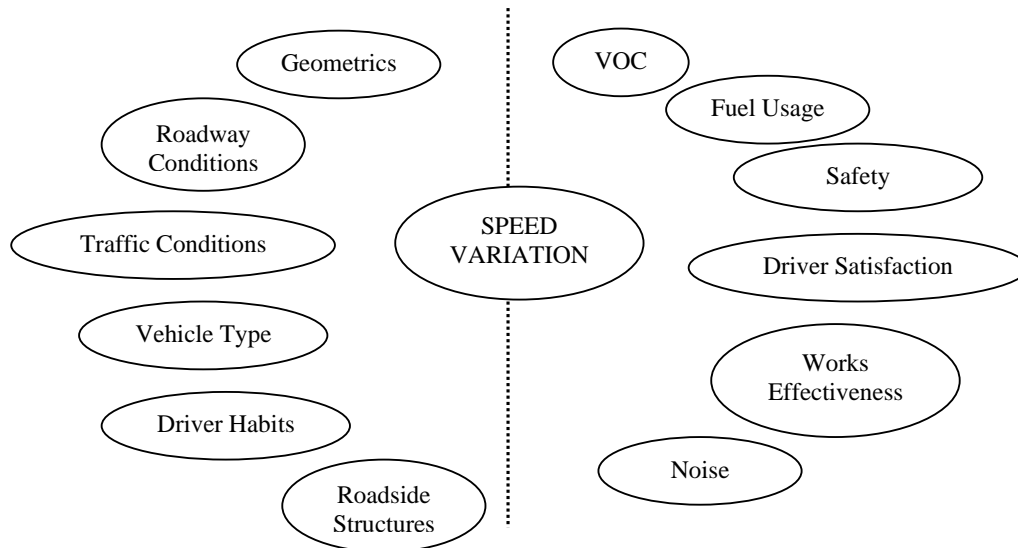


Figure 2: Schematic Representation of Speed Variation Factors

Speed variation in response to the road and traffic environment has been successfully modelled in the development of investment analysis packages such as HDM-4.

Extensive research has been undertaken to relate vehicle operating costs, fuel usage, noise, driver comfort etc to speed variation under different conditions.

3 SPEED DATA LOGGING USING GPS RECEIVERS

The main problem faced over the years has been the difficulty in capturing speed data due to practical and economic reasons. Vehicles required sophisticated instrumentation to accurately log speed data continuously.

Advancement in Global Positioning System (GPS) technology has now made it possible to collect very accurate data using simple and cheap instruments. The technology has enabled measurement of second by second vehicle speeds using simple and relatively cheap receivers.

The GPS consists of 24 satellites (21 navigational satellites and 3 active spares) that orbit the earth in 12-hour orbits. This configuration provides the user with at least five satellites visible at any point on earth at any one time.

GPS satellites find the position of the receiver via “triangulation”, which means that three satellites are required to obtain a fix on the position. The satellites use an algorithm to send a unique time-varying message. The receiver, having the same message generation algorithm installed, continually tries to match its message with received messages. Since there is a time lag between when the message is sent from the GPS and when the receiver receives the message, the distance can be calculated by determining the time lag and assuming that the signal travels at the speed of light [Soon-Aik Gan et al, 2002].

Modern hand-held GPS receivers are capable of receiving signals from a large number of satellites simultaneously (typically 12 for low-cost receivers), and at short intervals, typically 1 or 2 seconds. Stated accuracy for commercially available receivers ranges from +/-15 m without differential correction and can be sub-meter with differential correction. GPS equipment has the ability to save a log of the position and time readings, which is available for later download and processing [Bellis G., 2004].

Further improvement in the technology has yielded receivers that also process, display and log velocity data. This data has been reported as more accurate than that obtained by post-processing of position data. Velocity is obtained by calculating the Doppler-Shift in the satellite signal carrier waves which are detected separately from the coordinate data stream and the system error in speed is rarely more than 0.1km/hr [Clark, 1998].

Computer software is also now readily available on the market to aid GPS/GIS data collection and maintenance.

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4 REVIEW OF ORIGINAL PROPOSED INDICES

4.1 Definition of Threshold/Desirable Speeds

ANE's Design standards (ANE, 2004) were used to define Threshold/Desirable Speeds for the three classes of unpaved roads under consideration: secondary, tertiary and vicinal.

The Threshold/Desirable Speeds were taken as:

- Secondary – 60 km/hr
- Tertiary – 50 km/hr

As ANE standards do not specify the speed for vicinal roads a speed of 40 km/hr was adopted for the project.

4.2 Road Segment Level Ratings

The following ratings were proposed for testing the method at road segment level, a segment being 5 kilometres in length:

Speed Efficiency Rating – compares actual overall Average Speed achieved over each segment to the Threshold/Desirable Speed. The Threshold/Desirable Speed may alternatively be referred to as Design Speed. A vehicle travelling at a uniform speed equivalent to the Threshold/Desirable Speed over the duration of the entire journey will have a rating equal to 1.0.

Review: The rating can be viewed as traditional, giving the overall perspective of the driver's ability to match the Threshold/Desirable speed. On the whole the rating does not give information on the speed variation over the segment.

Sub-Speed Time Rating – the cumulative total time travelled at speeds below Threshold/Desirable Speed within the segment is expressed as a ratio of calculated time it would take to traverse the same distance travelling at the Threshold/Desirable Speed. A road in poor condition returns a rating above 1.0 whilst that in good condition will have a rating approaching 1.0.

Review: Use of such a rating requires a well developed concept of the value of time. This might not be applicable to an environment where this is missing. As such the rating may not be easily understood by users. Concept of time varies significantly amongst populace.

Sub-Speed Distance Rating - a ratio of the total distance travelled at speeds below Threshold/Desirable Speed to the length of a road segment. A length of road in good condition will have a rating approaching zero.

Review: Rating will most likely be found favourable as it has a more physical reality than time. Users will be able to easily relate to length of road where sub-speeds are achieved. Generally the road user is more aware of location than of time durations. It is likely that road users will find it more appealing when the sub-speed distance is aggregated and are informed of the extent/proportion of the road over which travel is sub-standard.

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Sub-Speed Rating – the calculated average of speeds below Threshold/Desirable Speed for a segment, reduced by the standard deviation of speeds over the segment, and then taken as ratio of the defined Threshold/Desirable Speed. The reduction with the standard deviation gives greater weighting to the speeds below Threshold/Desirable Speed. All segments with average speeds above Threshold/Desirable Speed are assigned a Sub-Speed Rating of 1.0.

Sub-Speed Rating varies from 0 to 1, where a rating closer to 1.0 indicates travel closer to Threshold/Desirable Speed and thus a road in good condition.

Review: This rating may be difficult to understand and weighting with standard deviation not easy to justify. The index may not be easily understood as speed of travel varies significantly with class of vehicle. As the indices are meant to be understood by lay-men, the question will arise as to the type of vehicle used.

4.3 Road Link Level

Link Speed Efficiency Index – weighted average of segment Speed Efficiency Ratings, weighted by standard deviation of acceleration of each segment.

Standard deviation of acceleration gives a good indication of the ‘start and go’ nature of a journey. Previous studies (FHWA, 2004) have demonstrated how acceleration is so linked and the Highway Capacity Manual includes guidelines using the same to estimate acceleration noise and fuel consumption in an urban setting.

Review: This index is derived from the Speed Efficiency Rating outlined in Sub-section 4.3. Basically it compares achieved average speed to Threshold/Desirable Speed. It does not indicate the journey experience vis a vis variation of speed.

Link Sub-Speed Time Index – the average of segment Sub-Speed Time Ratings.

Refer Sub-Speed Time Rating review above.

Link Sub-Speed Distance Index – the average of segment Sub-Speed Distance Ratings.

Refer to Sub-Speed Distance Rating review.

Link Sub-Speed Index (L-SSI) – The average of segment Sub-Speed Ratings.

Refer to Sub-Speed Rating review.

Link Travel Time Index – ratio of actual travel time taken traversing the road link to calculated time it would take travelling at the Threshold/Desirable Speed. A value above 1.0 indicates poor road condition leading to extended travel time.

Review: As with Sub-Speed Time Rating reviewed above, the index may not easily be acceptable given the likely variation in travel times due to the much varied vehicle classes.

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4.4 Network Level

Network Speed Efficiency Index – weighted average of link Overall Speed Efficiency Indices, weighted by length of links and Threshold/Desirable Speed.

Network Sub-Speed Time Index – the weighted average of Link Sub-Speed Time Indices weighted by length of links and Threshold/Desirable Speed.

Network Sub-Speed Distance Index – the average of Link Sub-Speed Distance Indices weighted by length of links and Threshold/Desirable Speed.

Network Sub-Speed Index – the average of Link Sub-Speed Indices weighted by length of links and Threshold/Desirable Speed.

Network Travel Time Index – weighted average Link Travel Time Indices weighted by length of links and Threshold/Desirable Speed.

*Review: The concept of projecting the Link Indices to the network level involved applying a weighting by **Link Length** and the set **Threshold/Desirable Speed** for each link. This weighting gave prominence to longer roads and higher classification. Higher classification depicts greater importance.*

Network Sub-Speed Index (N-SSI) – the average of Link Sub-Speed Indices, weighted by Sub-Speed Distance Index and Sub-Speed Time Index.

The **N-SSI** is the ultimate index that defines the ‘speed deficiency’ of the network and varies from 0 to 1.

A road network with an **N-SSI** index approaching 1.0 is judged to be in good condition and vehicles will generally achieve speeds close to Threshold/Desirable Speed.

Review: The Network Sub-Speed Index weightings resulted in those links with ‘condition’ deficiencies contributing more to the derivation of the Index. Weighting with Sub-Speed Distance and Sub-Speed Time may be viewed as difficult to justify.

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5 REVISED AND RATIONALISED INDICES

5.1 Objective

Following discussions with Mozambique FE, it was agreed to focus on indices that capture the extent and intensity of *speed variation*.

The following sub-sections outline how the originally derived indices were rationalised and revised to take the above mentioned objective into account.

Annexure II gives a summary table of the re-calculated indices using data collected for all roads surveyed during the project.

5.2 Road Segment Level Indices

As the Mozambique Road Fund (FE) is concerned with the overall network condition, the revised indices are proposed to be calculated only for the link and network levels.

5.3 Road Link Level Indices

Only three indices are recommended for consideration to indicate the condition of unpaved roads and these are briefly outlined below.

Average Sub-Speed Index (ASSI)

ASSI compares average of speeds below the Threshold/Desirable Speed over the journey to the Threshold/Desirable Speed, as a percentage.

This index is largely similar to that in use currently by ANE, the difference is that it is be calculated for each road link in detail using more objective data and only for speeds below Threshold/Desirable Speed.

A vehicle travelling at a uniform speed equivalent to or above the Threshold/Desirable Speed over the duration of the entire journey will have an Index equal to or higher than 100 percent.

On the other hand a vehicle travelling at slow speeds will have an index approaching zero percent.

In layman's terms, an index of 100% percent means the road is in good condition.

For each road link the index will be calculated as follows:

$$\text{ASSI} = \frac{\text{Link Average Sub-Speed}}{\text{Threshold/Desirable Speed}} \times 100\%$$

Speed Variation Index (SVI)

It is recommended that a measure be adopted which compares the speed variation on a link to a standard calibration sections adopted for a class of road.

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The calibration sections must cater for the expected ends of the spectrum, that is the Very Good and Very Poor conditions. The sections can be selected using detailed visual condition methods in use by ANE and should also have geometrics that are representative of the class of road.

Standard Deviation of Acceleration, also known as **Acceleration Noise** in Traffic Flow Theory, is recommended for adoption as a measure of speed variation and is derived in a standard manner using the formula:

$$\text{Standard Deviation (STDEV)} = \left[\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^2 \right]^{\frac{1}{2}}$$

Where
 n = number of acceleration measurements
 X_i = acceleration measurement i
 \bar{X} = mean acceleration

The calibration suggested above will yield maximum CALIB_STDEV_{max} and minimum standard deviation CALIB_STDEV_{min} values to which the maximum is assigned a value an SVI_{max} of 100% and the minimum an SVI_{min} value of 0%.

For each road, the measured link standard deviation, say LSTDEV, will be used to determine the SVI by interpolation using the following equation:

$$\text{SVI} = \frac{(\text{LSTDEV} - \text{CALIB_STDEV}_{\min})}{(\text{CALIB_STDEV}_{\max} - \text{CALIB_STDEV}_{\min})} \times 100\%$$

For this project the following maxima and minima values have been adopted based on HDM4 default values:

$$\begin{aligned} \text{CALIB_STDEV}_{\max} &= 1.8 \\ \text{CALIB_STDEV}_{\min} &= 0.2 \end{aligned}$$

Sub-Speed Distance Index (SSDI)

The previously considered approach to determine the proportion of the total distance travelled at speeds below the Threshold/Desirable Speed is recommended.

This distance would be termed Sub-Speed Distance.

The Sub-Speed Distance is then taken as proportion of the length of the link. As the concept of percent is relatively easy to understand the index can be expressed as such.

A link in good condition will have an SSDI approaching zero percent.

For each link of road the index will be calculated from the formula:

$$\text{SSDI} = \frac{\text{Sub-Speed Distance}}{\text{Total Journey Distance}} \times 100\%$$

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5.4 Network Level

Network Average Sub-Speed Index (N-ASSI)

The network N-ASSI is calculated as the average of road link ASSI values weighted by link length and Threshold/Desirable speed.

Network Speed Uniformity Index (N-SVI)

In a similar way to the above the average of road link SVI values weighted by length of links and Threshold/Desirable Speeds will give the network level N-SVI.

Network Sub-Speed Distance Index (N-SSDI)

Following on the calculation of SSDI at road link level, the network level N-SSDI will be taken as the average of the link SSDI's weighted by length of links and Threshold/Desirable Speeds.

5.5 Acceleration Noise as Indicator of Speed Variation

As mentioned elsewhere, as a vehicle traverses a road section there are speed variations in response to traffic congestion, road alignment, pavement surface condition, presence of non-motorised traffic and other road side activities or presence of livestock.

Of the above factors, traffic congestion is not a major factor on Mozambican rural roads as traffic volumes are low.

It has been established through research that the *Standard Deviation of Acceleration* otherwise known as *Acceleration Noise*, gives a good indication of severity of speed changes. Low levels of acceleration noise indicate minor speed changes whilst large values indicate major changes (Bester, 1981).

The total acceleration noise for a vehicle consists of two components: natural acceleration noise and traffic induced acceleration noise. Traffic induced acceleration noise is not applicable to this project as volumes are low (NDLI, 1995).

Natural acceleration noise applies to the project and is a function of:

- Noise due to driver personal characteristics and that which will arise even when conditions are ideal,
- Noise due to road alignment,
- Noise due to road side developments, NMT, livestock etc,
- Noise due to road roughness.

Natural acceleration noise has been modelled in HDM-4 where the total natural noise is given as:

$$\sigma_{an} = \sqrt{\max((\sigma_{adr}^2 + \sigma_{aal}^2), \sigma_{asf}^2, \sigma_{anmt}^2, \sigma_{airi}^2)}$$

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where σ_{adr}	is the noise due to natural variations in the driver's speed in m/s^2
σ_{aal}	is the noise due to the road alignment in m/s^2
σ_{asf}	is the noise due to roadside friction in m/s^2
σ_{anmt}	is the noise due to speed limits in m/s^2
σ_{airi}	is the noise due to roughness in m/s^2

Noise due to driver variations and road alignment is combined as it was found that it was difficult to differentiate between the two (Bennett C.R et al).

The values of the other components are modelled as:

$$\sigma_{asf} = 2.5 (1 - XFRI) \sigma_{xfrimax}$$

$$\sigma_{anmt} = 2.5 (1 - XNMT) \sigma_{xnmtmax}$$

$$\sigma_{airi} = \min \left(\sigma_{irimax}, \sigma_{irimax} \frac{RI}{AMAXRI} \right)$$

where $\sigma_{xfrimax}$	is the maximum acceleration noise due to side friction (default = $0.20 m/s^2$)
$\sigma_{xnmtmax}$	is the maximum acceleration noise due to non-motorised transport (default = $0.40 m/s^2$)
σ_{irimax}	is the maximum acceleration noise due to roughness (default = $0.30 m/s^2$)
AMAXRI	is the roughness at which the maximum acceleration noise arises (default = 20 IRI m/km)
XFRI	is the road side friction factor
XNMT	is the road non-motorised traffic factor.

Research has been undertaken to quantify acceleration noise model parameters for HDM-4 for different classes of road ranging from 2-lane undivided to 6-lane motorways.

Information on modelling for rural roads, especially unpaved roads, is not readily available.

It should be noted that effects of NMT and road side friction during logging of speed data for this project were minimal as there was sparse settlements along the test roads.

Therefore, it has been assumed that the acceleration noise calculated from the data was due to the physical condition of the road geometrics and driver characteristics.

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6 DATA RE-ANALYSIS RESULTS

6.1 Sampling Frequency and Method

GPS receivers can be set to log speed data in three basic modes: time, distance and automatic. The amount of data collected depends of the frequencies selected. The question that arose during the project was whether sampling method and frequency would have any effect on the results.

As included in results table in *Annexure II*, a testing regime was set where a 10 kilometre stretch of a vicinal road in poor condition was traversed under a normal driving regime with the GPS receiver set to record at 1, 2, 4 and 8 seconds and 10, 20, 40 and 80m intervals for time and distance options respectively.

Considering two of the new proposed indices, that is *Average Sub-Speed Index* and *Sub-Speed Distance Index*, it was found that there was a general decrease in the indices as the sampling time or distance interval increased.

Figures 3-6 below show the trend in the two indices with sampling time and distance intervals.

It can therefore be concluded that when the method is eventually applied in the field it will be necessary to adopt one sampling method and frequency.

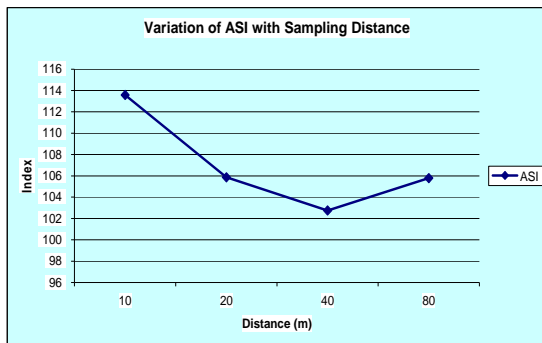


Figure 3: Variation of ASSI with Sampling Distance Interval

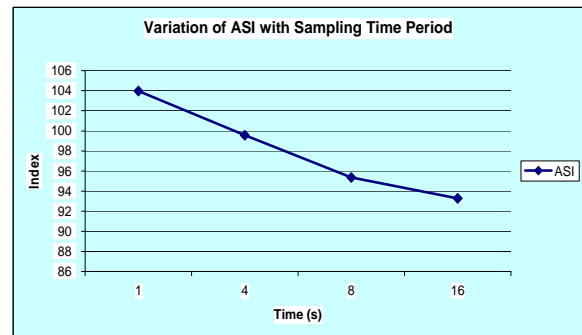


Figure 4: Variation of ASSI with Sampling Time Period

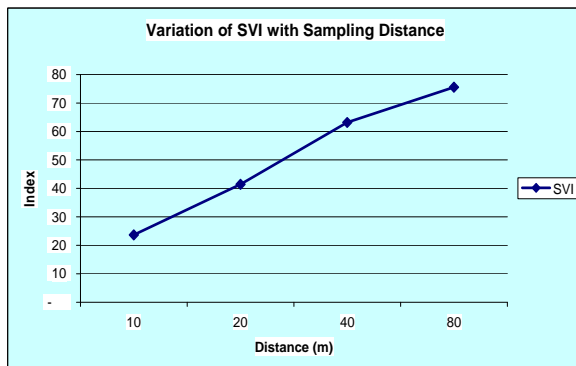


Figure 5: Variation of SVI with Sampling Distance Interval

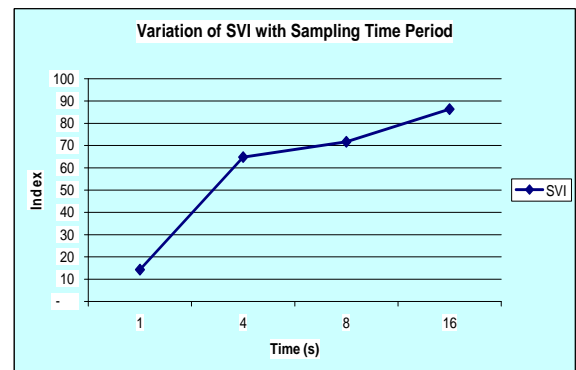


Figure 6: Variation of SVI with Sampling Time Period

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To compare the two methods of sampling, time and distance, a *t*-test was performed to determine whether the results of the two methods were likely to have come from the same two underlying populations that have the same mean.

A P value of 0.192 was returned for **SSDI** indicating that there was no significant difference between the two methods. It should be pointed out, however, that the sample size was small.

6.2 Threshold/Desirable Speed Variation

One aspect the Mozambique FE wishes to investigate is the effect of varying Threshold/Desirable Speed on the indices.

Three representative roads (vicinal, tertiary and secondary) were selected from the survey sample to investigate the effects.

For the following two of the revised indices values were calculated for Threshold/Desirable Speeds varying from 30-105 km/hr:

- ASSI : Average Sub-Speed Index
- SSDI : Sub-Speed Distance Index

The remaining index, that is the **SVI** (Speed Variation Index) does not vary with Threshold/Desirable Speed.

Graphical representations of the effect of varying Threshold/Desirable Speed are shown overleaf on *Figures 7 -12* for the representative three roads.

It can be seen from the plots overleaf that there is a clear relationship between ASSI and Threshold/Desirable Speed since this is simple ratio calculation. Average Speed on a particular road does not change with Threshold/Desirable Speed.

On the other hand, SSDI is a function of Threshold/Desirable Speed and displays a polynomial relationship with lower and upper bounds of 0 and 100 respectively.

SSDI is more sensitive to variation on Threshold/Desirable Speed for the vicinal road than tertiary or secondary roads. A 10km/hr change in Threshold/Desirable Speed for the vicinal road can result in 50 percentage points change in the index.

Setting lower Threshold/Desirable speeds will result in ASSI and SSDI indices that reflect a good condition network in most instances. In comparison, this is where the SVI would be more appropriate as it is independent of Threshold/Desirable Speed.

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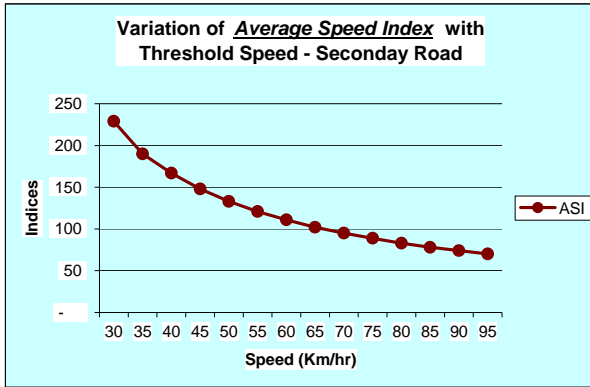


Figure 7: Variation of ASI with Threshold Speed Secondary Road

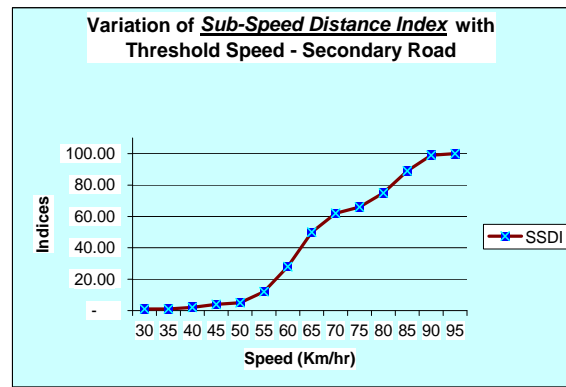


Figure 8: Variation of SSDI with Threshold Speed Secondary Road

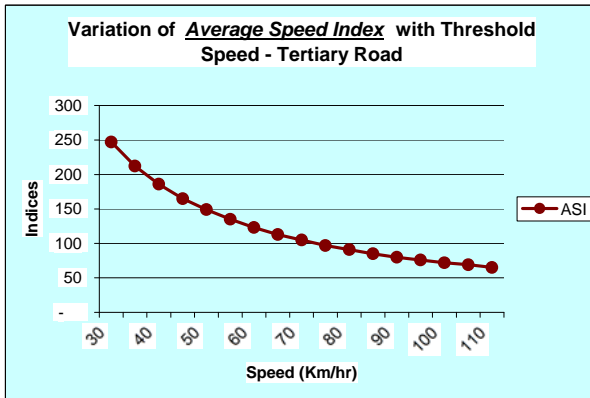


Figure 9: Variation of ASSI with Threshold Speed Tertiary Road

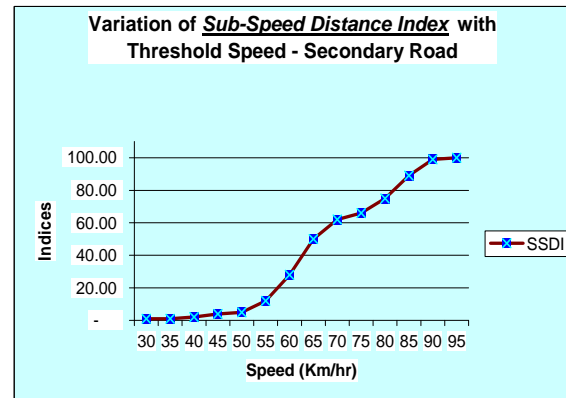


Figure 10: Variation of SSDI with Threshold Speed Tertiary Road

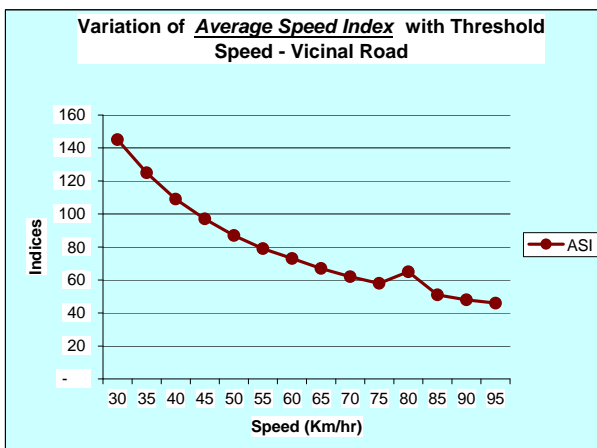


Figure 11: Variation of ASSI with Threshold Speed Vicinal Road

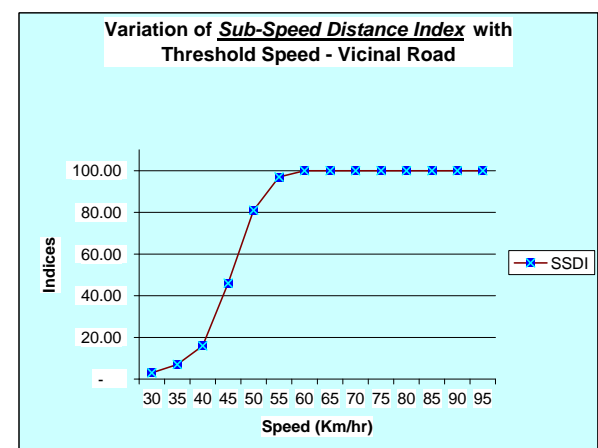


Figure 12: Variation of SSDI with Threshold Speed Vicinal Road

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6.3 Repeatability

As given in the project final report, repeatability test runs were undertaken on two vicinal roads, one in reportedly good condition and the other in fair condition.

The purpose was to determine the reliability of data collected from using one driver.

Figures 13 and 14 below show the relative variation of ASSI and SVI for a number of re-runs made on one of the above mentioned vicinal roads.

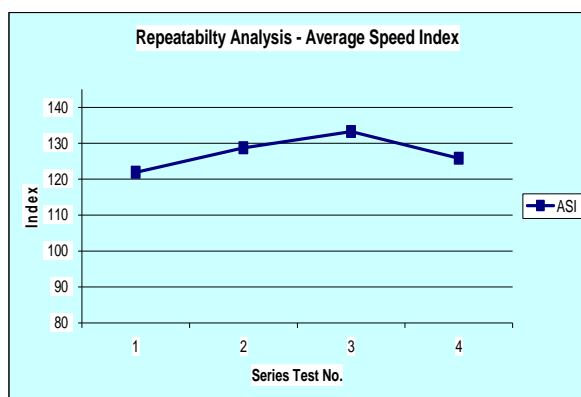


Figure 13: Repeatability Variation of ASSI

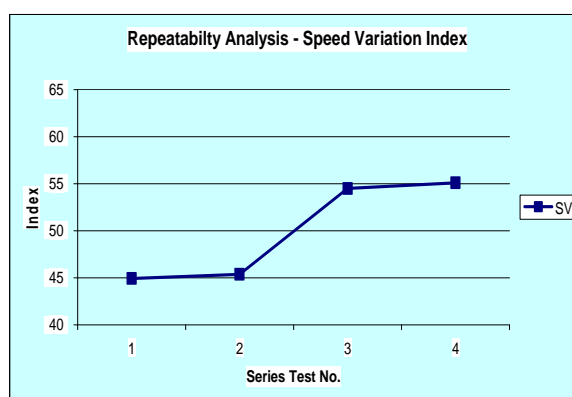


Figure 14: Repeatability Variation of SVI

The ASSI plot shows indices some uniformity over the four test runs whilst the SVI plot result is inconclusive.

To understand the trend statistically, the coefficient of variation was used to measure variability of the indices calculation results and enable judgement to be made on the repeatability.

The results showed that the order of magnitude of the variations was insignificant and this was confirmed by coefficients of variation of almost nil for both indices.

The method will therefore potentially yield repeatable results although further trial need to be undertaken to cater for different conditions.

6.4 Reproducibility

Measurement of reproducibility quantifies the variability that can result from use of two or more drivers.

No tests were undertaken on this aspect.

6.5 Level of Service Definition

It is proposed that the **Average Sub-Speed Index (ASSI)** be adopted as the primary indicator of condition of the unpaved road network.

Indices Review Brief

Speed Variation Index (SVI) and **Sub-Speed Distance Index (SSDI)** can be used as secondary supporting indices.

There will be need to develop and establish Level of Service criteria bands for the primary indicator that may be structured as indicated in Table 1 below.

Table 1: Proposed Level of Service Bands for Average Sub-Speed Index (ASSI)

Level of Service	Average Sub-Speed Index (ASSI)	Road Condition
A	0 – 20	Very Poor
B	20 – 40	Poor
C	40 – 60	Fair
D	60 – 80	Good
E	80 – 100	Very Good

Indices Review Brief

7 BIBLIOGRAPHY

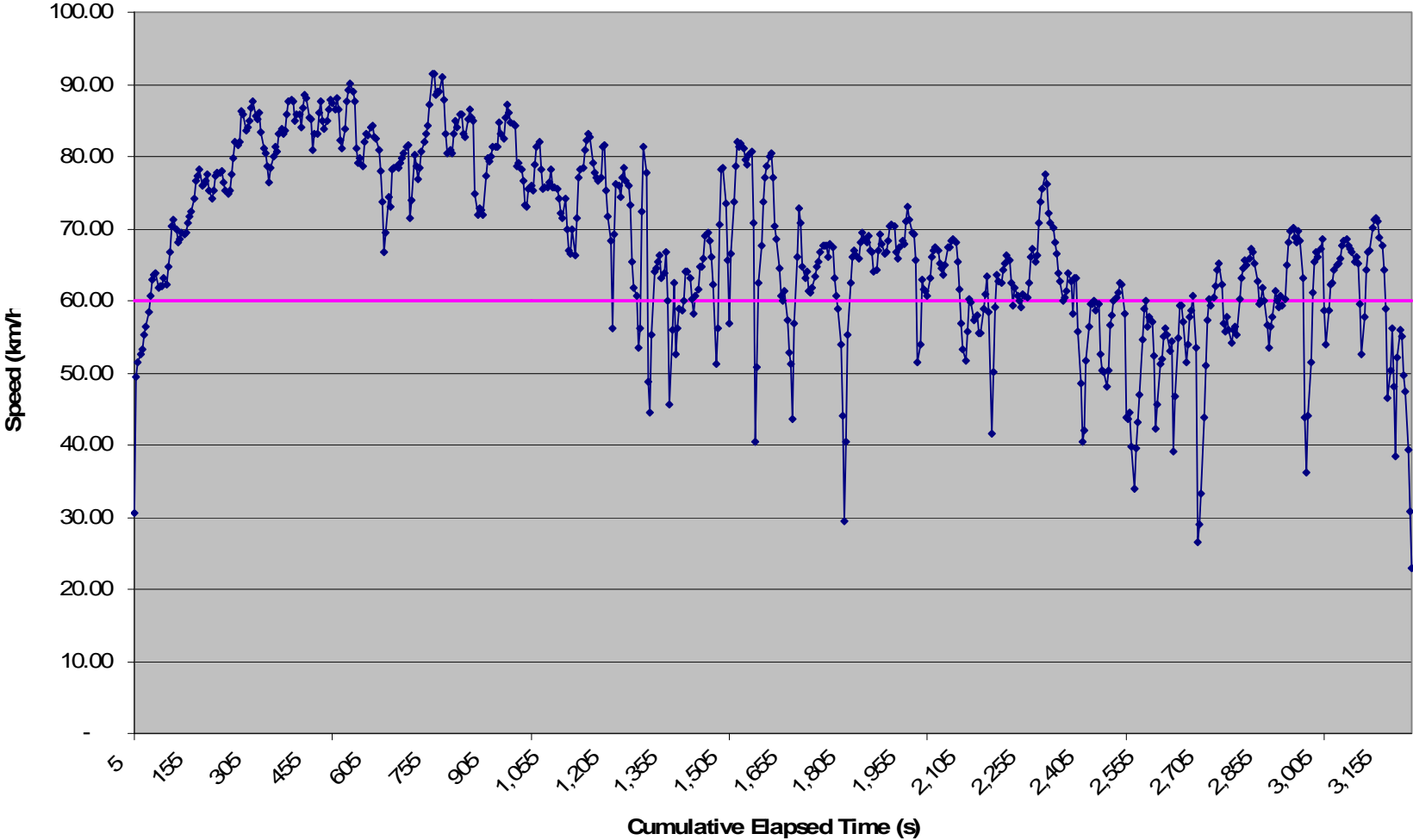
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ANNEXURE I

Typical Speed/Time and Acceleration/Time Profiles

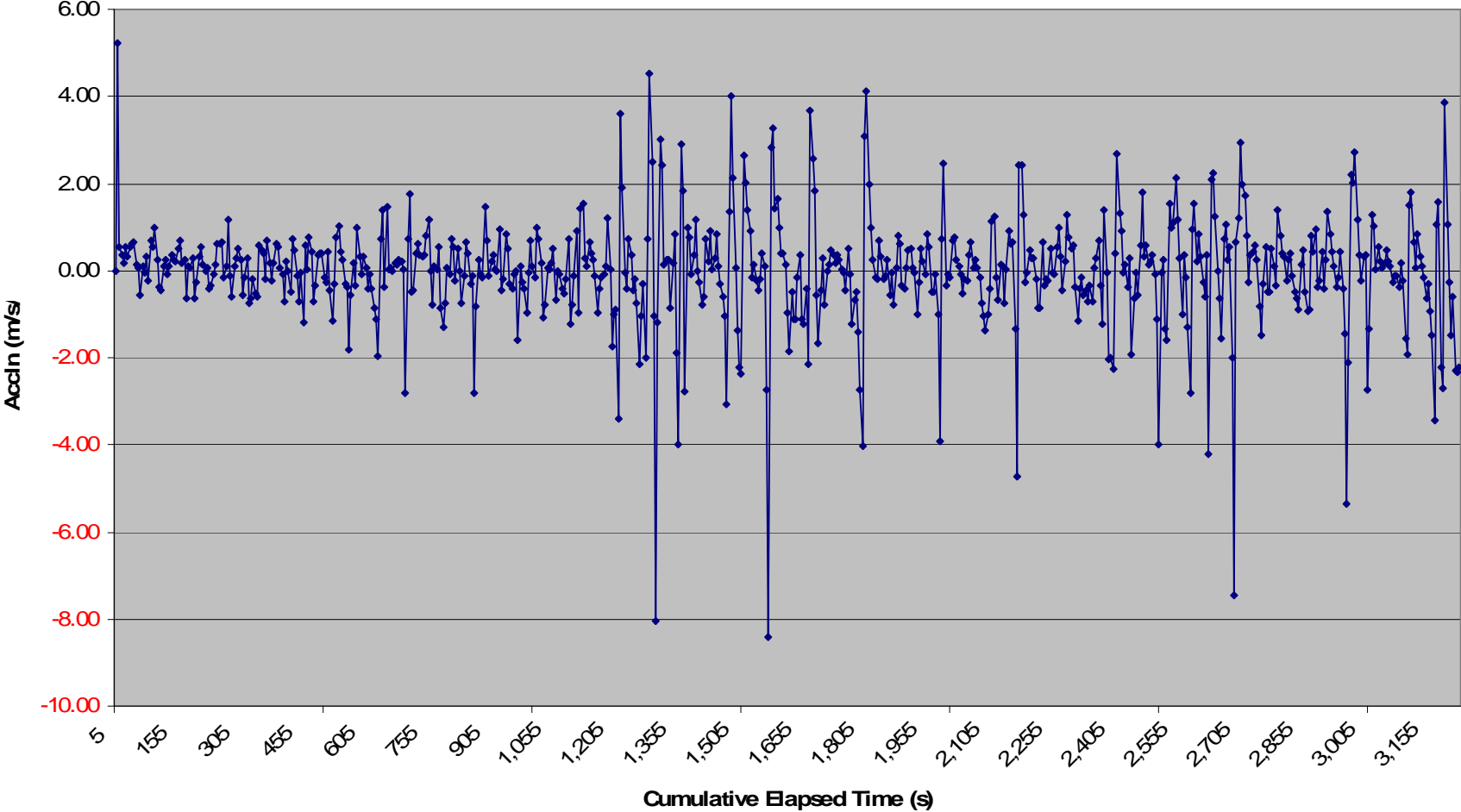
ANNEXURE I: TYPICAL SPEED vs TIME PROFILE

Speed/Time Profile



ANNEXURE I: TYPICAL ACCELERATION vs TIME PROFILE

Acceleration/Time Profile



ANNEXURE II

Revised Indices Calculation Results

MOCAMBIQUE ROAD FUND
DEVELOPMENT OF UNPAVED ROAD CONDITION INDICES

REVISED INDICES CALCULATION RESULTS

Series No.	Road Details				Survey Length (km)	Observed Road Condition		Desirable Speed (Km/hr)			Driving Regime			GPS Receiver		Sampling Method		Sampling Frequency	Road Link Statistics										Road Link Indices		
											Fast	Normal	Slow	Garmin 1	Garmin 2	Time	Dist		Cum Travel Time (Hr)	MEAN Running Speed (Km/hr)	Overall MEAN Speed (Km/hr)	Speed STDEV	Speed Coeff VAR	Accn MEAN	Decln MEAN	Decln Events/ Km	Accn & Decln STDEV	Average Sub-Speed Index (ASSI)	Sub-Speed Distance Index (SSDI)	Speed Variation Index (SVI)	
	Province	Route No	Class	From - To				Fast	Normal	Slow	Garmin 1	Garmin 2	Time	Dist	Cum Travel Time (Hr)	MEAN Running Speed (Km/hr)	Overall MEAN Speed (Km/hr)		Speed STDEV	Speed Coeff VAR	Accn MEAN	Decln MEAN	Decln Events/ Km	Accn & Decln STDEV	Average Sub-Speed Index (ASSI)	Sub-Speed Distance Index (SSDI)	Speed Variation Index (SVI)				
1	MAPUTO	N200	Secondary	Boane - Bela Vista	60.7	Poor	60		x				x				5s	0.90	67.71	67.71	12.28	0.18	0.75	-0.87	5	1.27	111	28	59		
2-1	GAZA	N221	Secondary	Macarante-Mabalane	69.6	Good	60	x				x		x			5s	0.81	86.40	86.40	15.01	0.17	0.52	-0.61	10	0.85	140	8	36		
2-2	GAZA	N221	Secondary	Macarante-Mabalane	70.2	Good	60		x					x			5s	0.98	72.04	72.04	13.19	0.18	0.68	-0.77	5	1.20	121	17	56		
3	GAZA	R453	Secondary	Mabalane-Combomune	46.7	Fair	60		x			x		x			5s	0.64	73.48	73.48	16.34	0.22	0.95	-1.12	5	1.72	117	12	84		
4	MAPUTO	R408	Tertiary	Catuane - R407	61.9	Good	50		x			x		x			5s	0.81	76.58	76.46	17.77	0.23	1.21	-1.36	5	1.99	149	4	99		
5-1	MAPUTO	R403	Tertiary	Catembe - Bela Vista	41.9	Fair	50	x				x		x			5s	0.54	78.16	77.78	18.17	0.23	1.51	-1.64	5	2.29	156	4	116		
5-2	MAPUTO	R403	Tertiary	Catembe - Bela Vista	41.9	Fair	50		x			x		x			5s	0.75	56.28	55.98	11.19	0.20	0.83	-0.96	6	1.40	110	15	66		
5-3	MAPUTO	R403	Tertiary	Catembe - Bela Vista	41.3	Fair	50			x		x		x			5s	1.10	38.56	37.53	9.09	0.24	0.55	-0.59	10	0.85	75	98	36		
6A	MAPUTO	R406	Tertiary	N200 - Catuane	70.2	Poor	50		x			x		x			5s	1.31	53.73	53.73	15.99	0.30	1.15	-1.36	7	1.84	109	27	91		
6B	MAPUTO	R406	Tertiary	N200 - Catuane	35.7	Poor	50		x			x					5s	0.58	61.11	61.11	14.50	0.24	1.11	-1.39	6	1.88	120	15	93		
7	MAPUTO	R406	Tertiary	N200 - Catuane	34.7	Poor	50		x			x			x		2s	0.59	58.71	58.71	11.33	0.19	0.47	-0.52	15	0.81	115	15	34		
8	MAPUTO	R406	Tertiary	N200 - Catuane	34.6	Poor	50		x			x			x		50m	0.58	61.58	59.31	12.04	0.20	0.72	-0.82	8	1.33	120	15	63		
9	MAPUTO	R406	Tertiary	N200 - Catuane	34.5	Poor	50		x			x			x		100m	0.56	64.57	62.11	12.39	0.19	1.16	-1.14	5	1.90	124	12	94		
10-1	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.6	Poor	40		x			x		x			10m	0.25	44.53	41.92	10.49	0.24	0.39	-0.47	32	0.62	114	36	24		
10-2	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.2	Poor	40		x			x			x		20m	0.25	42.21	41.02	7.84	0.19	0.62	-0.69	19	0.95	106	41	41		
10-3	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.1	Poor	40		x			x			x		40m	0.26	40.62	38.80	8.56	0.21	0.95	-0.97	11	1.34	103	46	63		
10-4	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.0	Poor	40		x			x			x		80m	0.25	41.42	40.08	7.98	0.19	1.12	-1.07	6	1.56	106	49	76		
10-5	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.2	Poor	40		x			x		x		1s	0.25	40.22	40.22	8.73	0.22	0.29	-0.35	41	0.46	104	43	14			
10-6	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.2	Poor	40		x			x			x		4s	0.26	38.95	38.95	8.63	0.22	0.89	-1.14	11	1.37	100	47	65		
10-7	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.1	Poor	40		x			x			x		8s	0.27	37.60	37.60	7.00	0.19	1.10	-1.13	6	1.49	95	56	72		
10-8	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.1	Poor	40		x			x			x		16s	0.27	37.16	37.16	7.96	0.21	1.41	-1.38	3	1.75	93	68	86		
10-9	MAPUTO	R453	Vicinal	Rio Matola - Boane	10.1	Poor	40		x			x		x	Auto		Auto	0.25	38.38	40.20	7.88	0.21	1.27	-1.21	6	1.68	101	43	82		
11-1	GAZA	R852	Vicinal	Changane - Nalazi	20.2	Good	40	x						x			5s	0.30	67.49	67.49	11.30	0.17	1.89	-2.15	5	2.58	165	2	132		
11-2A	GAZA	R852	Vicinal	Changane - Nalazi	20.2	Good	40		x					x			5s	0.40	51.06	51.06	6.41	0.13	0.77	-0.85	7	1.15	126	6	53		
11-2B	GAZA	R852	Vicinal	Changane - Nalazi	20.3	Good	40		x					x			5s	0.39	52.08	52.08	7.02	0.13	0.83	-1.21	6	1.33	128	4	63		
11-2C	GAZA	R852	Vicinal	Changane - Nalazi	20.3	Good	40		x					x			5s	0.39	54.44	51.92	7.49	0.14	0.99	-1.16	7	1.42	131	5	68		
11-3	GAZA	R852	Vicinal	Changane - Nalazi	19.9	Good	40			x		x		x			5s	0.50	39.65	39.65	5.46	0.14	0.57	-0.67	9	0.94	99	44	41		
12-1	GAZA	R856	Vicinal	Chokwe - Fr Maputo	21.5	Fair	40		x			x		x			5s	0.44	48.26	48.26	7.07	0.15	0.82	-0.82	8	1.16	121	7	45		
12-2	GAZA	R856	Vicinal	Chokwe - Fr Maputo	21.4	Fair	40		x			x		x			5s	0.43	50.92	49.76	6.77	0.13	0.78	-0.82	7	1.02	128	9	45		
12-3	GAZA	R856	Vicinal	Chokwe - Fr Maputo	21.5	Fair	40		x			x		x			5s	0.41	52.00	52.00	11.09	0.21	0.91	-1.00	7	1.30	126	3	55		
12-4	GAZA	R856	Vicinal	Chokwe - Fr Maputo	21.5	Fair	40		x			x		x			5s	0.43	49.69	49.69	8.23	0.17	0.92	-0.97	8	1.34	124	7	55		
13	MAPUTO	R403	Tertiary	Catembe - Bela Vista	41.9	Fair	50		x			x		x	Auto		Auto	0.63	61.97	66.37	18.15	0.29	1.45	-1.60	3	2.32	125	5	118		
14	GAZA	R442	Tertiary	Chibuto - Changane	51.2	Fair	50		x			x		x			5s	0.92	55.72	55.55	12.93	0.23	0.99	-1.12	7	1.65	111	18	80		
15	GAZA	R441	Tertiary	Nalazi - Chokwe	96.4	Poor	50		x			x		x	Auto		Auto	1.97	48.07	48.89	15.08	0.31	1.38	-1.65	6	2.19	99	33	110		
16-1	GAZA	R453	Vicinal	Combomune - Macandze	50.0	Poor	40		x			x		x			5s	1.12	44.79	44.79	6.93	0.15	0.72	-0.80	8	1.13	109	16	52		
16-2	GAZA	R453	Vicinal	Combomune - Macandze	49.9	Poor	40		x			x		x			2s	0.98	50.91	50.91	9.09	0.18	0.58	-0.65	17	0.88	130	4	38		

Total Kms Surveyed 1,211.5

Network Level Indices
Weighted by Length of Road Surveyed and Desirable Speed

Network Indices		
N-ASSI	S-SSDI	N-SVI
119	72	20