Development of a New Approach to the Characterisation and Evaluation of Earth Road Degradation Parameters

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ABSTRACT

This article suggests the characterization of earth roads degradations using various parameters. The considered parameters are planned to be used later on as a basis for futher assessment of earth road degradations. Six (6) degradations were listed like most frequent degradations encountered on earth roads in Cameroon recurring. These are namely : corrugations, ruts, potholes, gullies, loss of materials and loss of camber. Considering the complexity of measurement of two last degradations, they will not be studied in this work but will be taken into account for the final evaluation.

Compared to the assessment methods used by the Organisation for Economic Co-operation and Development (OCDE) and Laboratoire Centrale des Ponts et Chaussées (LCPC), our approach covers a wider spectrum of measurable parameters. This enable us to describe these degradations. Each one of them has been described through the following measurable parameters: length, width, depth, number and size.

This approach makes use of simple tools (landmarks, tape lines, graduated wooden rules, etc) and reveals the importance of parameters not taken into consideration in the above-mentioned methods. Survey findings have enabled us to improve the OCDE method of degradation assessment used so far.

Keywords: Earth roads, degradation, assessment, measurable parameter, road maintenance, programming, Cameroon.

1. INTRODUCTION

Transportation in many developing countries is substantially done by road (Mijinyawa and Adetunji, 2005). Cameroon’s road network measures about 51,257 km, of which 4,918 km are paved and 46,339 km (90,4%) unpaved (MINTP, 2004). An overview map of Cameroon’s road network is shown in Figure 1. Valued at about 6,000 billion CFAF (9,15 billion euro or US$ 10 billion), it constitutes a major national asset worthy of being preserved through appropriate maintenance culture. Poor maintenance of a road increases the cost of repair by 200% - 300% after every rainy season, and that of a vehicle by more than 50% for paved roads if not much more for gravel and earth roads (Mijinyawa and Adetunji, 2005).

Earth roads ensure the transportation of 80% of persons and goods in Africa (Heggie, 1995). Consequently, they are the most subject to heavy traffic (transportation of logs, transit traffic towards Chad, CAR, Congo and Gabon) and are generally in a poor condition (MINTP, 1996). The main difficulty of maintaining these roads stems from a number of dysfunctions like the incompetence of those in charge of giving out contracts, the dishonesty of those who are awarded contracts , corruption, and disrespect of texts (Madjadoumbaye, 2000)

Indeed, the programming of road maintenance in Cameroon is based on a two-prong visual network inspection : a broad inspection and a detailed visual survey. Conducted regularly, the visual inspection enables actual visualisation of all the degradations on the network, but the detailed inspection which ought to permit the accurate measurement thereof in order to establish the exact quantities of works to be executed, is flawed by the absence of reliable measuring instruments and lack of professionalism on the part of consulting firms to whom the state entrusts project management. This results in an approximative characterisation of the condition of the earth road network and thus, leads to wrong quantification of works.

It is in an attempt to provide a solution to this problem that a new approach to the characterisation and assessment of earth road degradations using readily available and affordable instruments is being proposed.

This study comprises four parts:

In the first part, earth road degradations are characterized ; this is done by using some valuable parameters;

The second part presents the two evaluation methods most used in Cameroon; a comparison of both is made and the most complete of them is chosen;

In the third part, the chosen method is improved through the setting-up of a new approach;

Results and discussions are presented in the last part.

Figure 1. Map of Cameroon’s road network Source: MINTP, 2004

2. CHARACTERISATION OF DEGRADATIONS

This characterisation involved degradations most recurrent on earth roads, namely corrugation, rutting, potholes, gullies.

2.1 Corrugation

These are permanent ondulatory and regular deformations perpendicular to the road centre line (Azam et al., 1996). They are due to the drive of material of surface by the action of the moving traffic, the low cohesion of material, the fine loss or Materials with weak index (Fenzy, 1974). They were characterised by their amplitude h, period d_c and length L (Figure 2). This defect results in discomfort and highly undermines the state of the vehicle. The vibration is specifically critical to the health of vehicle drivers, who are regularly exposed to vibration (Dhingra *et al.*, 2003). It is one of the main causes of user-cost increase.

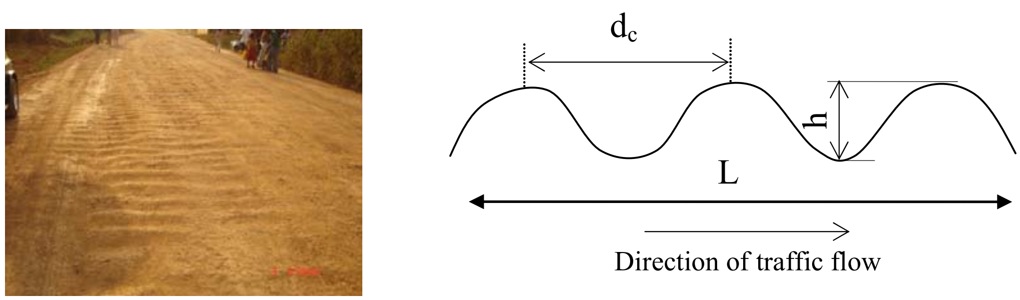

Figure 2. Corrugation

2.2 Rutting

These are permanent longitudinal depressions affecting the wearing course (Azam et al., 1996). They are caused by the actions of vehicles wheels, the side displacement of materials, the material creep of surface, the loss of stability of the pavement or the ground support (OCDE, 1990). Deformation depth may extend right to the base course causing the latter to lose its initial resistance by increasing its water content. They are characterised by their amplitude h, length L and width l (Figure 3).

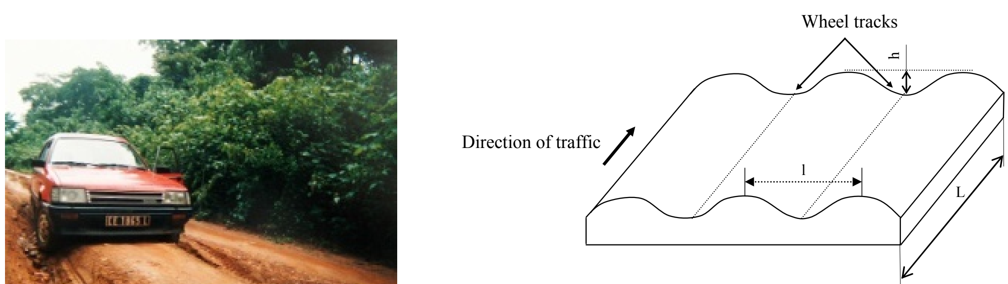

Figure 3. Rutting

2.3 Potholes

Potholes are small cavities of various shapes created on the road surface by localised dislodgement of materials (Azam et al., 1996). They are caused by lack of flatness of the platform or other preexistent degradations (corrugated iron, ruts, gullies, etc.); of a stagnation of water on the roadway or a irregularity and bad compaction of materials of surface of the road (OCDE, 1990). Owing to heavy traffic, they grow and spread in a chain over the entire carriageway surface. During the wet season, water fills and transforms them into mud pools. Potholes are characterised by their average depth p, average area s and number n per 100 m section (Figure 4).

Figure 4. Potholes

2.4 Gullies

These are deep, extended depressions dug out by flowing surface water (OCDE, 1990). They are caused by the erosion of the riding surface by surface waters or materials badly compacted and sensitive to water ((OCDE, 1990). They may be longitudinal (steep inclination) or transverse (steep superelevation). They are characterised by their depth p, length L and width l (Figure 5).

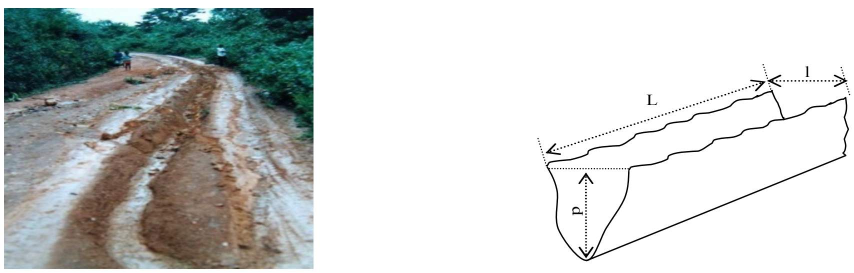

Figure 5. Gullies

3. USUAL METHODS OF SURVEYING EARTH ROAD DEGRADATIONS

There are two main methods of surveying degradations on earth roads used in Cameroon (Madjadoumbaye, 2002 ; Madjadoumbaye *et al.,* 2007) :

- the OCDE assessment method ;
- the VIZIRET method.

3.1 The OCDE Assessment Method

Degradations concerned are : corrugation, rutting, potholes, gullies, loss of materials, loss of camber and clay (OCDE, 1990).

The assessment of degradations comprise two procedures : the Summary Inspection (SI) and the Detailed Visual Inspection (DVI). The DVI is carried out only on the sections which were retained on the basis of result of the SI as being in a doubtful state. The SI aims to collect and process data on the general state of the road network while the DVI raises the type, the extent and the gravity of degradations.

This assessment is done in three groups as indicated in table 1 with regard to the road.

Table 1. Elements taken into account for evaluation

Group	Comments

Roadway	This parameter gives a total evaluation of the characteristics of surface road. It is represented by a figure providing the impression of the users as for the comfort of bearing and the visual aspect of the wearing course. The number of level of notation is 5.
Side elements	Their inspection is significant because it helps to preserve the roadway and the structure itself under acceptable operating conditions. They are the ditches (Silting, erosion), verges (deformation, erosion), roadside (vegetation, remains, sand, obstacles etc). The number of level of notation is 3.
Panels, equipment	They are the elements which milked with safety and which belong to the accessories of roadway such as safety fences. It is evaluated in term of damage, of salissement, of absence/disappearance. The number of level of notation is 3.

Source : OCDE, 1990

The method comprises two basic aspects : measuring the level of gravity and the extent of degradation. "Level or gravity" refers to the depth and "extent" to the size of the damaged area. Each aspect is awarded marks ranging from 1 to 3, depending on the condition of the carriageway as indicated in Table 2.

Table 2. Assessment of extent and gravity aspects

Value	Extent	Gravity	General condition
1	Non-existent	Nil	Very good
2	Frequent	Average	Fairly good
3	Generalised	Serious	Poor

Source: OCDE, 1990

Taking both extent and gravity into consideration gives rise to a matrix the overall score of which ranges from 1 to 5, based on the condition of the carriageway as shown in Table 3 below (OCDE, 1990).

Table 3. Condition of the carriageway overall score

Rating	Condition of the carriageway
1	Excellent, no visible deffect
2	Good
3	Fairly good
4	Critical
5	Very Poor

Source: OCDE, 1990

3.2 The VIZIRET Method
It's a method developped by LCPC, it's based on the characterisation of four main types of degradation which affect earth roads, namely deformations, potholes, corrugation, and gullies (Autret and Brousse, 1998).

The degradations are awarded marks per level (1, 2 and 3 with 'no damage' indicated as level 0) as shown in the table 4 below (LCPC, 1998).

Table 4. LCPC method overall score for carriageway condition

Defect	1st mark	2nd mark	3rd mark
Deformation	< 5cm	5cm < deformation < 10 cm	Deformation > 10 cm
Potholes	Few and small in size	Numerous and large in size	Number & size requiring reconstruction
Corrugation	Deflection < 2 cm	2 cm < deflection < 5 cm	Deflection > 5 cm
Gullies	Depth < 5 cm	5 cm < depth < 10 cm	Depth > 10 cm

Source: LCPC, 1998

These degradations lead to an overall score comprising four levels as seen in table 5 below (LCPC, 1998).

Table 5. Correspondence between assessment and level of degradation

Level	Appraisal	Comments
0	Absence of degradation	Road in good condition
1	Slight degradation, hardly felt by the user	Road at onset of degradation
2	Considerable degradation, felt by the user	Deteriorated but passable road
3	Advanced degradation	Highly deteriorated, impassible road

Source: LCPC, 1998

After the two methods are summarily presented, some comparative data are introduced in table 6 below.

Table 6. Summary comparison of the two methods used

	Method		Comments
	OECD	VIZIRET	
Degradations not considered	None	Loss of material	Significant to take into account but influences enormously on the bearing pressure of the roadway
Gravity	Considered	Considered	-
Extension	Considered	Only the potholes are taken into account but in a no quantifiable way	The knowledge of the extent makes it possible to control the width in term of damaged surface
Side elements, panels, equipment	Considered	not considered	Significant elements but makes it possible to preserve the state of road etc.

The above comparaison reveals that the OECD method is more simple and takes more elements into account than the VIZIRET method like side elements (ditches, verges, roadside), panels and equipment (Table 6).

Although OECD has enough elements taken into account, the characterization of various degradations shows that a number of relevant parameters is not considered

4. NEW APPROACH TO THE CHARACTERISATION OF EARTH ROAD DEGRADATIONS

The new method of characterization and evaluation of the parameters will consist to initially arise the parameters not taken into account by the OCDE method and to evaluate them thereafter while taking as a starting point the methodology of notation by OCDE. (OCDE, 1990).

These parameters are : d_c (distance between two successive ridges of corrugation) ; l (width of the gullies and rutting) ; s (area of the potholes).

The importance of these parameters is presented below :

- d_c : the distance between corrugation ridges greatly affects the level of comfort and vehicle maintenance cost. Comfort is dependent on speed owing to the fact that at high speed, inter-ridge distances become shorter and less discomfort is felt. It is important, therefore, to take this parameter into consideration.

- l : Gully width greatly affects traffic because if it is wider than the wheels, the latter would jump into holes which may considerably undermine safety. But then, if the width is below the wheel dimension, traffic will flow without much problems. Moreover, it is an important factor for the determination of the volume of works to be executed.

- s: whatever the value of the other parameters, area of potholes is a very important element with regards both to comfort and safety. The larger the area, the more one is constantly in danger during driving. It helps to determine the volume of materials required to fill the holes. The road user is the prime beneficiary of road maintenance given its impact on vehicle operating cost and on traffic safety and comfort.

- l : for a single vehicle, the width of ruts is a negligible parameter because the driver can decide to place his vehicle’s wheels in such a way he avoids any negative impact on safety and comfort. But in the event of vehicle crossing, which is a more plausible axiom, each driver will have to move over to his own side: following the tracks becomes more difficult and such a manouvre entails the straddling of ruts by the vehicle wheels, which could lead to accidents. This is when the width of ruts becomes a significant parameter of comfort and safety.

Because of their importance these parameters will be taken into account to improve the OCDE method of degradation assessment used so far.

4.1 Application of the Proposed Method

For the application of the method proposed, the section of roads, the conduct of survey and the evaluation of degradations' parameters are initially chosen.

4.1.1 Choice of Road Stretches

The road sretches selected were within the priority network, that is, the 23,939 km long road network that is regularly maintained. The choice was made taking into consideration the country's climatic diversity. It includes a zone with heavy rainfall (equatorial climate) and one with light rainfall (sahelian climate) and is presented in table 7 below and administration map showing provinces presented in Figure 6. The census stations left behind after the 2004 National Road Census campaign served as survey stations for this work. In all, 2,931 km of roads distributed all over the national territory were investigated.

Figure 6. Administrative's Map Source: La nouvelle géographie 5e, EDICEF 2006

Table 7. Investigated road stretches

Road category	Province	Road stretch	Length (Km)
Classified earth roads	Adamawa	Ngaoundéré-Babongo-Meinganga-Mboussa	226
	Adamawa	Magba-Nyamboya-Banyo-Mbamti-Tibati	252
	Adamawa	Beka (N15A)-Paro-Tignère	91
	Centre	Bafia-Boura II-Fleuve Mbam-Koro-Ntui	74
	Centre	Batchenga-Natchigal-Ntui-Matsari-Yoko-Sangbe	334
	Centre	Ngoumou-Otélé-Makak-Eseka	83
	Far-North	Moulvoudaye-Kalfou	17
	Far-North	Yagoua-Chad border	2
	Far-North	Kousseri-Logone Birni-Zina-Pouss-Yagoua	193
	Far-North	Maroua-Lara	52
	East	Bertoua-Bombi-Deng Deng-Goyoum	95
	East	Mandjou-Batouri-Ngoura-Kenzou-Frontière RCA	192
	East	Ngoura-Ndelele-Yola-Yokadouma	159
	Littoral	Edéa-Pouma	34
	Littoral	Bonepoupa-Yabassi-Nkondjock- West limit	169
	North-West	Nkambe-Berabe-Ako-Nigeria border	55
	North-West	West limit – Jakiri	12
	North	Figuil-Chad border	10
	North	Mayo Djarendi-Mandigrin-Chad border	53
	West	Bangangté-Foumbot-Baleveng	93
	West	Malanden-Foumbot	26
	South-West	Eyumodjock-Otu (Nigeria border)	30
	South	Lolodorf-Ebolowa	70
Rural roads	Far-North	Maroua-Dogba-Tchere	40
	Far-North	Mindif-Gagadje-Kalfou	60
	Far-North	Mindif-Salak	24
	North	Ganadje-Djiboa	54
	North	Pitoa-Banaye-Kefero-Basheo	45
	Littoral	Dizangue-Mariemberg	35
	Littoral	Kake-Miang-Mpobo	47
	South-West	Bakume-Nlog-Ndum-Nkut	37
	South-West	Foto-Fonjumetaw-Bamumbu	30
	West	Babajou-Bagam- Bliigam limit	32
	East	Lomié-Mimpele towards Mintom	70
	South	Eleng-Dja par Mbout	40
	Centre	Yoko-Nbarden-Mandja-River Kim	95
	Total		2931

Source : MINTP Programming Unit, 2004

Earth roads which have been classified are National Roads (linking provincial headquaters to the capital city, Yaounde or those linking Cameroon to the neighbouring countries), provincial roads (road linking divisional headquaters to the provincial headquater and are located in the same province), divisional roads (those in the same province division: which link subdivisions to the divisionsal headquarter) and rural roads which are farm to market roads and are also considered earth roads.

4.1.2 Conduct of Surveys

The surveys were carried out in two phases: measuring of parameters by technicians and interviewing of users. Measurements were taken early in the morning and recorded in the survey sheets, meanwhile interviews were conducted (appendix 1) throughout the day to have more appraisals. The surveys were taken daily over an average period of nine (9) months, for all the stretches involved. At the end of each day, the sheet (appendix 2) was filled by giving parameter's value, the number of each type of appreciation (good, fairly good, poor) and the number of vehicles that passed on the section of the road. Let us notice that appendix 2 is filled by compilation of the information so far recorded in Appendix 1.

The users do not have inevitably idea of degradations existing on the road, they deliver their opinion on the conditions of circulation (comfort, safety) during the investigations. Measurements raised in the various cards and compiled are made by trained technicians.

4.1.3 Assessment of Degradation Parameters

Degradation identification is simple and requires no sophisticated equipment as follows: landmarks, tape lines, graduated wooden rules, etc. Each type of degradation is measured on the basis of the above-mentioned parameters.

Though subjective the user appraisal of the road condition may be, it is a pertinent indicator of road safety and comfort. Now, these elements are linked to the new parameters we have just taken into consideration to determine the condition of the road. The table 8 presents the correlation between the condition of the road and the mark awarded (OCDE, 1990).

Table 8. Scoring of user appraisal

Mark	Appraisal	Road condition
1	Good	Road with an even surface
2	Fairly good	Degraded but passable road
3	Poor	Road in an advanced state of degradation, impassable

Source : OCDE, 1990

Based on data in the above table, the various parameters with their appreciations are presented in the table 9 below.

Table 9. Parameters considered and their appeciations

Degradation type	Parameters			Appraisal
Corrugation	L	d_c	h	
	V1	V2	V3	Good Fairly good Poor
Rutting	l	L	p	
	V1	V2	V3	Good Fairly good Poor
Gullies	L	l	p	
	V1	V2	V3	Good

				Fairly good
				Poor
	s	p	n	
Pothole	V1	V2	V3	Good
				Fairly good
				Poor

Note that Vi are the values corresponding to an appreciation "good", "fairly good" or "Poor"

5. RESULTS AND DISCUSSION

5.1 Main Findings

Table 10 below presents the values of degradation parameters obtained after compilation and compare common values to those of the OCDE.

Table 10. Parameterization and degradations value limits of the two methods

Degradation	Parameter			Value		Mark
	No	OCDE	Proposed Method	OCDE	Proposed Method	
Corrugation	1	h : amplitude (depression depth, in mm)	h : amplitude (depression depth, in mm)	≤ 20	≤ 30	1
				20 & 50	30 & 70	2
				> 50	> 70	3
	2	Not taken into consideration	d_c : period (distance between successive ridges, in mm)	-	≤ 60	1
					60 & 100	2
					> 100	3
	3	L : Length as a percentage in a sub section	L : Length as a percentage in the road section	≤ 10	≤ 20	1
				10 & 50	20 & 60	2
				> 50	> 60	3
Rutting	1	Not taken into consideration	l : Rut width, in mm	-	≤ 45	1
					45 & 200	2
					> 200	3
	2	p : Depression depth, in mm	p : Depression depth, in mm	≤ 20	≤ 25	1
				20 & 50	25 & 60	2
				> 50	> 60	3
	3	L : Length of depression as a percentage in a sub section	L : Length of depression as a percentage in the road section	≤ 10	≤ 20	1
				10 & 50	20 & 50	2
				> 50	> 50	3
Gullies	1	L : Length of depression as a percentage in a sub section	L : Length of depression as a percentage in the road section	≤ 10	≤ 10	1
				10 & 50	10 &50	2
				> 50	> 50	3
	2	Not taken into account	l : erosion width, in mm	-	≤ 40	1
					40 & 150	2
					> 150	3
	3	p : erosion depth, in	p : erosion depth, in	≤ 20	≤ 30	1

		mm	mm	20 & 50	30 & 60	2
				> 50	> 60	3
Pothole	1	Not taken into account	s : average area, in mm²	-	≤ 10000	1
					10000 & 40000	2
					> 40000	3
	2	p : average depth, in mm	p : average depth, in mm	≤ 20	≤ 15	1
				20 & 40	15 & 40	2
				> 40	> 40	3
	3	n : number/100m	n : number/100m	≤ 5	≤ 20	1
				5 & 15	20 & 60	2
				> 15	> 60	3

An analysis of Table 10 reveals the existence of a significant difference at the level of parameter n (number of potholes). Accountable for this is the influencial nature of the two other parameters (area and depth). On its own, the number n does not suffice for proper appraisal of road condition because, depending on the size and depth of the pothole, you can go, with the same number n, from “Good” to “Poor”.

It is appears that, changing the stretch of road may lead to a slight variation in the values of the proposed method, but without a substantial big impact on the results.

5.2 Limits

5.2.1 Degradation-related Limits

The parameters of two degradations (loss of materials and loss of camber) are not evaluated at this stage for the following reasons :

- Regarding loss of materials, measurement complexity (prior knowledge of the initial thickness of the road structure), on the one hand, and the time required to assess the lost layer (you will need at least one year to obtain a loss of 1 cm for a traffic of less than 10 vehicles per day), on the other hand, do not make it possible to obtain reliable results right away ;
- As for loss of camber, it occurs as soon as rutting or gullies begin and is therefore related to these degradations.

Given the complexity of measurement of these two degradations and knowing their importance, the values of the parameters suggested by OCDE method were fully considered.

5.2.2 Method-related Limits

Taking isolated parameter values cannot provide an adequate appraisal of any given degradation. For an effective appraisal of such degradation, it will be necessary, in another study, to combine all the parameters thereof in a matrix dubbed “assessment matrix”. Such a matrix will enable the obtainment of a more complete analysis of each degradation.

6. CONCLUSIONS

The new system of parameterization of earth road degradations developed in this study takes into account more parameters of degradations than the two methods most used in Cameroon. It serves as a data base for the complete identification of degradations by means of simple and easily exploitable methods. Another advantage of the system is that, for the most part, it enables the use of labour-intensive techniques (It is a technique which encourages the use of the local labour together with small available tools).

The training of neighbouring populations by technicians of decentralised local authorities or staff of the technical services of ministries in charge, on the use of parameterization to check the evolution of degradations, will be highly beneficial for the improvements of the road network. This is important because, "further improvements of the road network are a necessity to provide for peoples needs in the future" Jaarsma (2000).

This study may serve as a basis (input) for the evaluation of degradations, therefore the values obtained not taken into consideration by the OCDE method must be considered.

7. ACKNOWLEDGEMENTS

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APPENDIX 1

SURVEY SHEET

Date of survey:……………………………………………………………………………………
Survey station : Km ….……………………..……. from (town)……...………………………
Names and qualification of investigator : ……………………………………….……..……
Weather : …………………………………………………………………………………….

Degradation	Parameter	Appraisal's number: Good	Fairly good	Poor	N'ber Vehicles: *Light*	*Heavy*	Remark
Corrugation	L d_c h						
Rutting	l L p						
Gullies	L l p						
Potholes	s p n						

d_c : Average period or distance between two (2) successive ridges (in mm)
h : Average amplitude or depth of degradation (in mm)
L : Length of degradation (as a %)
p : Average depth of depression, settlement or deflection (in mm)
l : Average width of degradation (in mm)
s : Average area degraded (in mm)
n : Number of potholes (number per 100 m)

Light Vehicles : All four-wheeled vehicles of below 3.5 tonnes
Heavy Vehicles : All vehicles with over four wheels or over 3.5 tonnes in weight

APPENDIX 2

SURVEY SHEET

Date of survey:………………………………………………………………………………
Survey station : Km ….……………………..……. from (town)……...………………………
Itinerary : …………..……………………..………………………………………………….
Name and qualification of investigator : ……………………………………….……..……
Weather : ……………………………………………………………………………………….

Degradation	Parameter			Appraisal	N'ber of Surveys	N'ber Vehicles		Remark
						Light	*Heavy*	
Corrugation	L	d_c	h	Good Fairly good Poor				
Rutting	l	L	p	Good Fairly good Poor				
Gullies	L	l	p	Good Fairly good Poor				
Potholes	s	p	n	Good Fairly good Poor				