NEW EARTH ROAD DEGRADATION CHARACTERISATION AND ASSESSMENT APPROACH

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ABSTRACT

This article proposes a method for effective and efficient programming of road maintenance works.

Based on the usual methods of the Organisation for Economic Co-operation and Development (OECD) and of the Laboratoire Centrale des Ponts et Chaussées (LCPC), our approach covers a wider spectrum of measurable parameters to describe the six (6) degradations most frequent on earth roads in Cameroon. They include: corrugations, ruts, potholes, gullies, loss of materials and loss of camber. Each one of them has been described through the following measurable parameters: length (L), width (l), depth (p), number (n) and size (s).

This approach makes use of simple tools and reveals the importance of parameters not taken into consideration in the above-mentioned methods. It will permit a global assessment of the pavement and an objective evaluation of works quantities.

The appreciation of road users through investigations on the road quality permitted to fix limits (boundary-marks) parameters, what will drive to the development of a decision matrix, permitting a better maintenance work programming

Survey findings have enabled us to validate this method which is similar to the OECD method of degradation assessment.

1. INTRODUCTION

The transportation in many developing countries is substantially by road [1]. Cameroon's road network measures about 52 770 km, of which 4 918 km are paved and 47 852 km earth [2]. Valued at about 6 000 billion CFA F (One Euro = 656 CFA F, and US$ = 600 CFA F), it constitutes a major national asset worthy of being preserved through appropriate maintenance measures.

A poor maintenance of the road multiplies the cost of repairs from 200% to 300% after every rainy season. This affects expenses on vehicle repairs that rise to more than 50% for the paved roads and a lot more for earth roads [1].

Today in Africa (South Africa not includes), more than 80% of earth roads are a rather fairly good state, and 85% of secondary rural roads are in bad state and cannot be used during the rainy season [3].

Earth roads make up 90% of the network and ensure 80% of the transportation of people persons and goods [4]. In the case of Cameroon, they are the most used by heavy traffic (transportation of timber, traffic transit towards Chad, CAR, Congo and Gabon) and 70% of earth road, the network are generally in a poor state [2]. The main difficulty of maintaining this important network stems from certain dysfunctions [5], from a survey of approximate degradations and from a flawed system of works programming.

Indeed, the system of road maintenance works programming in Cameroon is based on a two-prong network inspection : visual and detailed. 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 leads, thus, to wrong quantification of works.

It is in an attempt to provide a solution to this problem that we are proposing a new approach to the characterisation and assessment of earth road degradations using readily available and affordable instruments. This method is similar to that of the Organisation for Economic Co-operation and Development but takes into account a larger number of parameters, to enable a more complete degradation assessment [6].

2. USUAL METHODS OF SURVEYING EARTH ROAD DEGRADATIONS

There are two main methods of surveying degradations on earth roads :

- the OECD assessment method ; and
- the LCPC method.

2.1 The OECD assessment method

Based on World Bank recommendations, the OECD method comprises two basic aspects: measuring the level of gravity and the extent of degradation [5]. "Level of 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 1.

Table 1 - 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

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 2 below.

Table 2 - Condition of the carriageway overall score as per the OECD method

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

2.2 The LCPC method

The LCPC method is based on the characterisation of four main types of degradation which affect earth roads, namely: deformations, potholes, corrugation, gullies [7].

The degradations are awarded marks per level (0, 1, 2 and 3) as shown in the table 3 below.

Table 3 - LCPC method overall score for carriageway condition

Deffect	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

These degradations lead to an overall score comprising four levels as seen in Table 4 below.

Table 4 - 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

2.3 Disadvantages of the usual methods

Programming of earth road maintenance works on the basis of degradations identified using the above-mentioned methods shows the following disadantages :
- non-consideration of certain parameters that characterise various degradations shown in Table 5 ;
- under-estimation of quantities ;
- use of sophisticated equipment that is very often non-existent in developing countries.

2.3.1 Non-consideration of certain parameters

The table below presents parameters not taken into consideration in the OECD and LCPC methods.

Table 5 - Parameters not taken into consideration

Degradations	Method	
	OECD	LCPC (VIZIRET)
Corrugation	- Distance between two successive ridges	- Distance between two successive ridges
Gullies	- Width	- Width, length
Potholes	- Area	- Depth
Rutting	- Width	- Length

2.3.2 Under-estimation of works

Works are under-estimated because all the parameters are not taken into consideration. Taking them into account enables a more accurate estimate of the volume of materials to be brought in, and the appropriate type of maintenance.

2.3.3 Equipment issue

Consulting firms face financial difficulties and are therefore not able to purchase all the relevant equipment for proper appraisal of degradations. Such equipment are very costly and are beyond their reach.

3. NEW APPROACH TO THE CHARACTERISATION OF EARTH ROAD DEGRADATIONS

The new model of characterisation of earth road degradations is based on the complete parameterization of recurrent degradations. This leads to a better quantification of works to be executed and, consequently, to better programming thereof, the ultimate goal being to optimise maintenance works on these roads.

3.1 Methodology

The methodology we used comprises the following points :

3.1.1 Choice of road stretches

We chose road sretches 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 6 below. Census stations left behind after the road census campaign also served us as survey stations. In all, 2 931 km of roads distributed all over the national territory were investigated.

Table 6 - Investigated road stretches

Road category	Province	Road stretch	Length (Km)
Classified earth roads	Adamawa	Ngaoundéré-Babongo-Meinganga-Mboussa	226
		Magba-Nyamboya-Banyo-Mbamti-Tibati	252
		Beka (N15A)-Paro-Tignère	91
	Centre	Bafia-Boura II-Fleuve Mbam-Koro-Ntui	74
		Batchenga-Natchigal-Ntui-Matsari-Yoko-Sangbe	334
		Ngoumou-Otélé-Makak-Eseka	83
	Far-North	Moulvoudaye-Kalfou	17
		Yagoua-Chad border	2
		Kousseri-Logone Birni-Zina-Pouss-Yagoua	193
		Maroua-Lara	52
	East	Bertoua-Bombi-Deng Deng-Goyoum	95
		Mandjou-Batouri-Ngoura-Kenzou-Frontière RCA	192
		Ngoura-Ndelele-Yola-Yokadouma	159
	Littoral	Edéa-Pouma	34
		Bonepoupa-Yabassi-Nkondjock- West limit	169
	North-West	Nkambe-Berabe-Ako-Nigeria border	55
		West limit – Jakiri	12
	North	Figuil-Chad border	10
		Mayo Djarendi-Mandigrin-Chad border	53
	West	Bangangté-Foumbot-Baleveng	93
		Malanden-Foumbot	26
	South-West	Eyumodjock-Otu (Nigeria border)	30
	South	Lolodorf-Ebolowa	70
Rural roads	Far-North	Maroua-Dogba-Tchere	40
		Mindif-Gagadje-Kalfou	60
		Mindif-Salak	24
	North	Ganadje-Djiboa	54
		Pitoa-Banaye-Kefero-Basheo	45
	Littoral	Dizangue-Mariemberg	35
		Kake-Miang-Mpobo	47
	South-West	Bakume-Nlog-Ndum-Nkut	37
		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 : Ministry of Public Works Programming Unit, 2005

3.1.2 Conduct of surveys

The surveys were carried out in two phases: measuring of parameters and interviewing of users. Measurements were taken early in the morning and recorded in the survey sheets, meanwhile interviews were conducted throughout the day. The surveys were taken regularly over an average period of nine (9) months, for all the stretches involved. The findings were recorded in sheets a model of which is hereto appended.

The aim of this study is to know as from which parameter value the user's appraisal changes from "Good" to "Fairly Good" or from "Fairly Good" to "Poor". The investigation stopped whenever we reached the value corresponding to a poor condition.

Here-below in Table 7 is an example of a survey sheet, filled at the end of a day's work .

3.1.3 Example of a filled survey sheet

Beginning of survey: 6 September 2005
Survey station : Km 22 + 00 from Mindif town towards Lara
Survey date : 23 March 2006 Survey time : 9am to 4pm
Itinerary : Maroua – Lara, through Mindif Departure : 8.05am Arrival : 9.03am
Name and qualification of investigator : Jules Abdou (Civil Engineering Technician)
Season : Dry Weather : Clear

Table 7 - Example of a survey sheet filled

Degradation	Parameter			Appraisal	Number of surveys	Number of vehicles		Remarks
						Light	Heavy	
Corrugation	L	d_c	h		52	96	08	Predominance of corrugation (Heavy traffic) Very little washout (Dry season)
	73	115	80	Good				
				Fairly good				
				Poor				
Rutting	l	L	p					
	60	15	50	Good				
				Fairly good				
				Poor				
Washout	L	l	p					
	5	20	3	Good				
				Fairly good				
				Poor				
Pothole	s	p	n					
	3500	30	48	Good				
				Fairly good				
				Poor				

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

3.2 Characterisation of degradations

This characterisation involved degradations most recurrent on earth roads, namely : corrugation, rutting, potholes, gullies, loss of materials and loss of camber.

3.2.1 Corrugation

These are permanent ondulatory and regular deformations perpendicular to the road centre line [8]. They were characterised by their amplitude (h), period (d_c) and length (L) (Figure 1). This deffect 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 [9]. It is one of the main causes of user-cost increase.

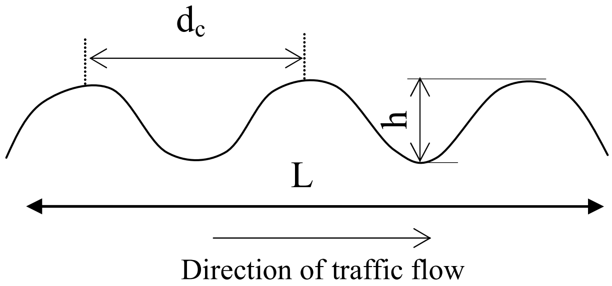

Figure 1 - Corrugation

3.2.2 Rutting

These are permanent longitudinal depressions affecting the wearing course [8]. 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 2).

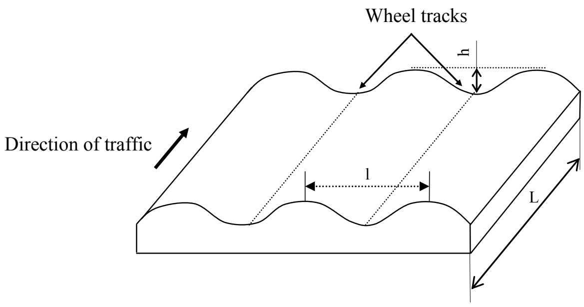

Figure 2 - Rutting

3.2.3 Potholes

Potholes are small cavities of various shapes created on the road surface by localised dislodgement of materials [8]. 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 3).

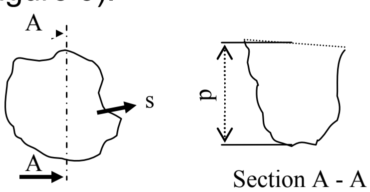

Figure 3 - Potholes

3.2.4 Gullies

These are deep, extended depressions dug out by flowing surface water [6]. They may be longitudinal (steep inclination) or transverse (steep superelevation). They are characterised by their depth (p), length (L) and width (l) (Fingure 4).

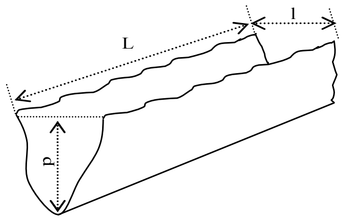

Figure 4 - Gullies

3.2.5 Loss of materials

It is the reduction of the wearing course through dislodgement of isolated or grouped aggregates [6]. This is compounded by rainfall and leads to the development of potholes. It is characterised by the difference between the initial thickness (e_i) and the final thickness (e_f) (Figure : 5).

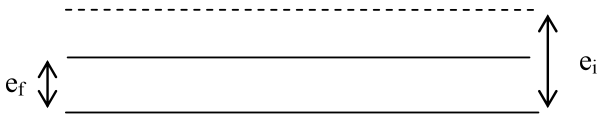

Figure 5 - Loss of materials

3.2.6 Loss of camber

These are distortions and deformations of the road tranverse profile [6]. The softening of the road structure leads to the rapid development of ruts and potholes. They are charaterised by the initial (d_i), and final (d_f) superelevations (Figure 6).

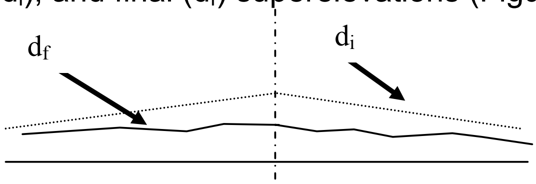

Figure 6 - Loss of camber

3.3 Degradation assessment

Degradation identification is simple and requires not very sophisticated equipment : landmarks, tape lines, graduated wooden rules, etc. Each type of degradation is measured on the basis of the above-mentioned parameters, in other words, the volume of materials lost is assessed. For each parameter, the boundaries between levels of service (Good, Fairly good, Poor) are set after user interviews.

Assessment degradation through this method is more complete because new parameters are taken into account. These parameters are as follows :
- the distance between two successive ridges, in corrugation;
- the width of ruts;
- the width of gullies;
- the size of potholes.

The distance between corrugation ridges greatly affects the level of comfort and vehicle exploitation 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.

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 as to avoid 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.

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.

Whatever the value of the other parameters, area is a very important element with regard 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. Subjective though 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.

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

4. FINDINGS AND DISCUSSION

4.1 Main Findings

Table 9 below presents the values of degradation parameters obtained after interviewing users to set limit values and compare commun values to those of the OECD.

Table 9 - Parameterization and degradations value limits of the two methods

Degradation	Parameter			Value		Mark
	No	OECD	Proposed Method	OECD	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
Washout	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 mm	p : erosion depth, in mm	≤ 20	≤ 30	1
				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 9 reveals the existence of a significant difference at the level of parameter n (number of potholes). Accountable for this is the highly influencial nature of the two other parameters (area and depth). Alone, the number n does not surfice 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”.

As for other parameters, it is observable that certain values generally have slightly greater intervals, and this can be explained :

- scarce financing due to the economic recession led to the network remaining constantly in a poor condition, which users became used to ;

- about 50% of the network is fairly well maintained, that is why the majority of users interviewed said they had driven on roads which had for long remained without maintenance.

To our mind, changing the stretch of road may lead to a slight variation in the values of the proposed method, but without much impact on the results. This is simply because what the user feels is dependent upon his habit and attitude towards a given stretch of road.

4.2 Limits

4.2.1 Degradation-related limits

Two degradations, loss of materials and of camber, are excluded from this study 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.

4.2.2 Method-related limits

Taking parameter values in isolation 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 the degradation.

5. CONCLUSION

The new system of parameterization of earth road degradations developed in this study falls within the framework of a new procedure for efficacious programming and management of earth roads. 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.

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 [10].

This study may serve as a basis (input) for devising a system of decision-making to enable timely intervention on earth roads, through the preparation of a decision-making matrix which will contribute to better programming of road maintenance and to the payment of effectively executed works. Values obtained by appraising parameters using the new and the OECD methods are alike. This leads to the conclusion that values obtained for the parameters not taken into consideration by the OECD method are reliable.

ACKNOWLEDGEMENTS

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APPENDIX 1

Survey sheet

Beginning of survey : ………………………………………………………….…………………
Date of survey:……………………………………………………………………………………
Survey station : Km ….……………………..……. from (town)……...………………………
Survey time : from …………………..…..………. to………………………………………
Itinerary : …………..……………………..………………………………………………………….
Departure time : ……..……………......……….. Arrival time : ………………….……..........
Name and qualification of investigator : ……………………………………………..……
Season :……………………………………………………………………………………….
Weather : ……………………………………………………………………………………….

<table>
<tr><th rowspan="2">Degradation</th><th rowspan="2" colspan="3">Parameter</th><th rowspan="2">Appraisal</th><th rowspan="2">N'ber of Surveys</th><th colspan="2">N'ber Vehicles</th><th rowspan="2">Remark</th></tr>
<tr><th>Light</th><th>Heavy</th></tr>
<tr><td rowspan="4">Corrugation</td><td>L</td><td>d_c</td><td>h</td><td></td><td></td><td rowspan="16"></td><td rowspan="16"></td><td rowspan="4"></td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Good</td><td></td></tr>
<tr><td>Fairly good</td><td></td></tr>
<tr><td>Poor</td><td></td></tr>
<tr><td rowspan="4">Rutting</td><td>l</td><td>L</td><td>p</td><td></td><td></td><td rowspan="4"></td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Good</td><td></td></tr>
<tr><td>Fairly good</td><td></td></tr>
<tr><td>Poor</td><td></td></tr>
<tr><td rowspan="4">Washout</td><td>L</td><td>l</td><td>p</td><td></td><td></td><td rowspan="4"></td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Good</td><td></td></tr>
<tr><td>Fairly good</td><td></td></tr>
<tr><td>Poor</td><td></td></tr>
<tr><td rowspan="4">Potholes</td><td>s</td><td>p</td><td>n</td><td></td><td></td><td rowspan="4"></td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Good</td><td></td></tr>
<tr><td>Fairly good</td><td></td></tr>
<tr><td>Poor</td><td></td></tr>
</table>

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