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Prioritization of Earth Roads Maintenance Based on Analytic Hierarchy Process

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Abstract: This paper has as objectives to report the application of a method based on the Multi-criteria Decision Analysis – MCDA. It is a methodology in the process of prioritization of earth roads maintenance, taking into consideration a set of variables which are related to physical, climatic, traffic, management and social aspects and that influence the functioning of those roads. The method for prioritization applies the Analytic Hierarchy Process – AHP through interviews with engineering professionals who are specialized in the conception and analysis of highway projects and that were divided into five groups according to their professional areas: a group of civil servants, a group of consultants, a group of professors, a group of Masters in Transportation Engineering and a group of Master degree students. In order to help in the application of the AHP, the software Expert Choice was used to make the calculation of the logical consistency of the comparison matrices more easily and indicated through a sensibility analysis in a real case, corresponding to the non-bituminous roads in the municipal district of Aquiraz, Ceará, in the northeast region of Brazil.

***Key words**: Analytic hierarchy process; Decision support systems; Highway maintenance; Low volume road..*

Introduction

Moreira [1] states that the terms "earth roads", "unpaved rural roads" and "vicinal roads" are some of the ways as the unpaved roads are known by the technical environment as well as by the local Brazilian population. These roads are usually used by an amount of less than 400 vehicles per day. Their width does not follow a standard size and they can be widened according to the need to fit a certain amount of cars which come with the traffic flow. When it comes to the drivers' visibility, it is very usual that it be impaired due to the great quantity of dust caused by the passing by of other vehicles during a very dry season, and also due to the growth of bushes whose branches get into the road and prevent the flowing of superficial water. It also needs to be highlighted that according to Geometry point of view, these roads also include trails or other pre-existent paths with a record of events such as steep slopes and reduced curvature radius. According to GEIPOT [2] the unpaved roads correspond to 90% of the Brazilian road network and it is through them that the wealth produced in the rural zone reaches out to the big centers.

Baeso et al [3] presents in his book several earth road maintenance techniques, where he admits that they are considered necessary to meet small towns' needs, to allow the regular flow of goods and services, to the development of the communities served by them, and consequently to guarantee improvement of the quality of the local inhabitants.

The highways, due to the fact that they are susceptible to natural deterioration through time, demand conservation services which guarantee them an appropriate functionality as it occurs in any work of engineering. Correia [4] and Correia et al [5] point out in their studies that without the appropriate providence of maintenance, the levels of road distress increase quickly, making it very expensive to keep its degree of usefulness.

In order to accomplish the activities of maintenance it is necessary to allocate the resources, Santana [6] established procedures whose main goal was to set budgets for the making of unitary costs to be applied to unpaved pathways and that were based in techniques which make possible intervention processes and further technical-economic analysis in the unpaved roads which are mostly responsibility of the municipal city halls. Such city halls often do not dispose of many financial resources to the execution of these activities, making indispensable that these resources be applied in a way to obtain the best results possible. A Pavement Management System – PMS is a tool which can be utilized successfully in the aid of allocation of these resources and maximization of the maintenance benefits.

According to Hass et al [7], in the technical literature there are several definitions for PMS and all of them present the same basic principles. According to these principles, it can be affirmed that a PMS is a set of tools or methods which help the decision making of optimized strategies in relation to the activities of paving which serve to keep the pavement in appropriate conditions of usefulness, making the coordination of these activities more easily performed by the manager institution in charge.

The activities of pavement management are divided into two levels: the network ones and the project ones. The decisions in the network level can be divided into project selection level and program level. The project selection level consists of the process of prioritization involving one or more groups of projects. In this work, a road (or a road segment) is seen as a project, therefore it is necessary that a model of prioritization exists in order to select them and aim them at receiving intervention.

The unpaved roads from Ceará, as well as the Brazilian ones, present a severe lack of resources to be applied to its maintenance and conservation. This fact reinforces the necessity for models which support the ones responsible for making decisions in what

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concerns the selection of roads which must suffer interventions for improvement.

Among the models presented in the technical literature and described in this work whose application is destined to unpaved roads it is relevant to mention: the model utilized by the USACE (United States Army Corps of Engineers) described in Eaton and Beaucham [8] and TM 5-626 [9]. The USACE method indicates unpaved road surface conditions from calculation of a certain index, which is a function of the distress characteristics of the surface. The index calculated is the Unsurfaced Road Condition Index (URCI). The model presented by Almeida [10] and Almeida et al [11] who developed their method resulting from the adaptation of the USACE method and which was named VENO. The VENO method uses USACE nomograms in order to determine the deduct values of the distresses according to their type and severity level. The VENO method also associates the same kind of index with each type of distress through the sum of the calculated deduct values for each severity level, thus obtaining a total deduct value called the Group Condition Index (GCI). The VENO method uses a scale that was developed according to every distress type taken into consideration by the ALYNOMO method developed by Moreira [1].

Models of Prioritization for the Unpaved Roads Maintenance

The models which prioritize the activity of maintenance found in the technical literature are a lot less numerous for unpaved roads than for the bituminous roads. In this work two different models are mentioned: the model utilized by the USACE and the model based on Artificial Neural Networks – ANN.

Model Utilized by the USACE (United States Army Corp of Engineers)

Among the models designed for the analyzed earth roads, there is the one utilized by the USACE. This objective evaluation method of unpaved roads was developed by Eaton and Beaucham [8], in the U. S. Army Corps of Engineers – USACE, it aimed to preserve the good conditions of the earth roads where the military machinery was transported. This method is made of four basic steps: network identification, inspection of the conditions of bearing surface, establishment of priorities for the maintenance and repair activities(M&R), and data management.

This model is described by Eaton and Beaucham [8] and TM 5-626 [9]. It has a principle to prioritize the road (or road segment) having as standards the value of the URCI (Unsurfaced Road Condition Index), index of condition of the pavement calculated in this method and of the traffic flow.

Model Based on ANN

In Nunes [12] it was developed a model of prediction of surface defects for unpaved rural roads based on ANN. Beyond the prediction of surface defects, this method contemplates mathematical techniques for the prioritization of the analyzed stretches considering a larger amount of variables than the method utilized by Eaton and Beaucham [8] and TM 5-626 [9], such as it is presented in Correia et al [5] and Oda [13].

In the model proposed by Nunes [12] , the surface defects are predicted and the level of priorities are attributed to the stretches considering the traffic flow, the drainage devices, the weather, the geometry (longitudinal and transversal) and the type of soil which constitutes the pavement courses.

According to Nunes [12], the experimental results obtained in unpaved roads from the municipal district of Aquiraz, in Ceará allowed him to conclude that this application of the ANN is viable. The author also concluded that the method can be applicable to stretches of other regions, being enough the adoption of procedures associated to the particularities and local restrictions.

Multicriteria Model of Prioritization of Unpaved Roads

Taking into consideration that variables such as weather, traffic, geometry, drainage, among others, which influence the behavior of an earth road, it was deducted that the creation of a model of prioritization of unpaved roads which would contemplate a higher number of variables in relation to the above mentioned methods would be a great contribution to the process of decision making of the highway stretches to go through intervention.

According to Schmidt [14], the multi-criteria approaches are techniques of analysis for the decision making and planning, which are based on the principle that the experience and the knowledge of the people are as valuable as the data utilized for the decision making.

In Rodrigues et al [15] it is asserted that the methods of multi-criteria analysis of help in decision making have a great potential for the contribution to the process of evaluation of alternatives in the transportation area.

Several works report applications of the Analytic Hierarchy Process – AHP in a wide variety of areas, among these, in the area of Transport Engineering, Schmidt [14], Rodrigues et al [15], Modarres and Zarei [16], Shapira and Goldenberg [17], Paez and Graham [18], Kumar and Bisson [19], and Celik et al [20].

Analytic Hierarchy Process

The AHP method was developed in the United States, at Wharton School of Business, by the professor Thomas Saaty in 1971. The AHP is a method characterized by the capacity of analyzing a problem of decision making through the construction of hierarchic levels, in other words, to have a global view of the complex relation inherent to the situation, the problem is composed of factors [14]. For Rodrigues et al [15], the diffusion and the power of the AHP are mainly due to the reunion of characteristics such as the simplicity in the application, the naturalness in dealing with subjective aspects and the flexibility of its use.

In the AHP method, the complexity of the problem is reduced with the division of the criteria in groups according to the characteristics they have in common. The groups are distributed in hierarchy levels, making the comprehension and the resolution of the problem even easier. Once this ranking is done, a global measure for each one of the alternatives is determined in a clear way through the synthesis of values of the decision agents, prioritizing them or classifying them when finalizing the method. As for the AHP

Table 1. Interpretation of Entries in a Pairwise Comparison Matrix [21].

Value	Interpretation
1	Objective *i* and *j* are of Equal Importance.
3	Objective *i* is Weakly More Important Than Objective *j*.
5	Experience and Judgment Indicate That Objective *i* is Strongly More Important than Objective *j*.
7	Objective *i* is Very Strongly or Demonstrably More Important than Objective *j*.
9	Objective *i* is Absolutely More Important Than Objective *j*.
2,4,6,8	Intermediate Values.

	(1)	(2)	(3)
(1)	1	A	B
(2)	$\frac{1}{A}$	1	C
(3)	$\frac{1}{B}$	$\frac{1}{C}$	1

Fig. 1. Pairwise Comparison Matrix.

limitations, the following aspects can be highlighted: the method works only with one positive reciprocal matrix of criteria. The fundamental scale stipulated by Saaty (see Table 1), in a few cases, it is not clear enough for the one in charge of making decisions.

The AHP method starts with the principle of determination of the importance and contribution of each criterion in order to obtain the final goal. This importance is established from the paired comparison of the elements of each group. All the elements of a group are compared among them and each comparison is applied with the intention of determining the influence of each one in the occurrence of a final goal. For instance, in the purchase of a domestic appliance, two criteria can be taken into consideration: the price and the guarantee. In this case, the question asked to the decider would be: in the purchase of a domestic appliance what do you consider mostly important, the price or the time of guarantee? From the answer of the decider, it would be possible to establish if for him the price is more important than the guarantee, if the guarantee is more important than the price or if both present the same importance. The paired comparison method is derived from judgments, which are accomplished according to the data, knowledge and experience about the subject analyzed.

The first steps which must be executed in the application of the method of hierarchic analysis are the definition and the structure of the problem. Defining the problem means to know how precisely which goal is intended to be achieved.

Next, it is necessary to establish criteria which are capable to influence in the reach of the final goal. In case these criteria present a significant level of complexity, they must be divided into sub-criteria which present common characteristics, allocating them in a hierarchic level inferior to the origin criteria.

As it was previously said, the fragmentation of criteria and the creation of hierarchic levels decrease the complexity of the model and offer a better visualization of the points to be solved. Therefore, a complex problem is fragmented, so its fragments are fragmented again and so on until a degree of acceptable complexity might be reached. This way, a hierarchic structure is generated in a shape of inverted tree where the main goal is on the top.

As it was above mentioned, the comparisons are accomplished through pairing and the result can fit into any of the three following situations:

a. element 1 is considered more important than element 2 to the reach of the goal;
b. element 2 is considered more important than element 1 for the reach of the goal; and
c. element 1 presents the same importance than element 2 for the reach of the goal.

According to Saaty [22], people have the capacity of sharing their responsibilities equally into three categories: high, medium and low. In order to decrease the complexity, they are still capable of refining this division and attributing to each category of responsibility more subcategories: high, medium and low. This capacity of human mind allows a person to judge with acceptable results even nine subdivisions of their responsibilities. The psychological limit of a human being allows to judge precisely 7±2 points, in other words, a maximum of nine points, Gomes et al [23]. Starting from this principle, the AHP attributes values to the comparisons which vary from 1 to 9. The degree of importance of each numeric value contained in this interval is presented in Table 1.

After the accomplishment of the comparisons, a square matrix of n order, in which n is the number of criteria in analysis, is used to determine the priorities obtained by each element and to the logical consistency of the results. A paired comparison matrix must be filled according to the following rules:

a. The diagonal principal must be filled with value 1. This indicates that an element when compared to itself must present the same degree of importance;
b. the elements must present the following property: $a_{ij} = 1/a_{ji}$; and
c. the values on the matrix must be those of the fundamental scale of the AHP presented on Table 1.

Each group of elements corresponds to a square comparison matrix in which the order of the matrix is given by the quantity of elements that belongs to the group. The matrix presents the results of the comparisons among the elements of a group that are made only once. The quantity of the comparisons that occur in a group of elements is calculated by the following equation:

$$C = \frac{n(n-1)}{2} \tag{1}$$

in which:
C: number of comparisons in the group; and
n: number of elements of the group.

The AHP generates models from the subjectivity of the deciders involved in the process, who are generally specialists on the subject analyzed. However, it is necessary to determine to what extension the results are efficient, since the human mind is subject to changes in thoughts. The efficiency of these results is determined through the calculus of the logical consistency of the answers obtained in a paired comparison matrix. The logical consistency of a comparison matrix must be calculated when the group compared presents more than two elements.

After the acquisition of the comparison matrix, the normalized matrix must be determined dividing each element a_{ij} of the matrix by the sum of the elements of the *i*-th column. The vector *w*, with the weights of the n attributes, is obtained by the arithmetic average among the elements of the normalized matrix, that is:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} a_{ij} \tag{2}$$

The calculus of the consistency *S* must be done based on the following equation:

$$S = \frac{1}{n}\sum_{i=1}^{n} \frac{\text{ith entry in } Aw^T}{\text{ith entry in } w^T} \tag{3}$$

The Consistency Index *CI* is obtained by:

$$CI = \frac{S-n}{n-1} \tag{4}$$

In order to determine the consistency of the experiment, the ratio between the consistency coefficient and the random index must be inferior to 10%. In Table 2, the values of the random index for quantities of attributes determined are presented. Following there is an example of the AHP method application in order to facilitate the comprehension and utilization of it. A civil construction company wishes to carry out a study about the most relevant attributes in terms of relationship with its suppliers. The managers of this company get together to select the most important criteria which are: cost(C1), quality(C2), delivery time(C3), and delivery reliability(C4).

As it is a problem with multiple attributes to be taken into consideration, the AHP technique has been chosen to be used. The following matrix presents an illustration of the comparisons among the analyzed attributes according to Saaty's scale:

$$A = \begin{pmatrix} 1 & 0.2 & 7 & 3 \\ 5 & 1 & 9 & 7 \\ 0.14 & 0.11 & 1 & 0.33 \\ 0.33 & 0.14 & 3 & 1 \end{pmatrix} \tag{5}$$

Next, there is the calculation of a normalized matrix by the division of each "*i*" element by the sum of the elements of the "*i*" column, an illustration of it follows down below:

$$A = \begin{pmatrix} 0.15 & 0.14 & 0.35 & 0.26 \\ 0.77 & 0.69 & 0.45 & 0.62 \\ 0.02 & 0.08 & 0.05 & 0.03 \\ 0.05 & 0.10 & 0.15 & 0.09 \end{pmatrix} \tag{6}$$

Table 2. Values of the Random Index [21].

n	Random Index (RI)
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.51

The vector presenting the weights of each attribute is obtained by the arithmetic average among the elements of the *i*-th line of the normalized matrix, according to the Eq. (2): w_1 = 0.23, w_2 = 0.63, w_3 = 0.04, w_4 = 0.10. Lastly, the consistency calculus must be done based on the Eq. (3), having as result *S* = 4.28. Applying the Eq. (4) to the analyzed data, the result is *CI* = 0.09.

For this experiment, the ratio *CI*/*RI* turned out to be 10%. It has been concluded that the experiment must be re-done in order to correct this little inconsistency.

Multicriteria Model for the Selection of Non-bituminous Roads

The methods for the management of road maintenance traditionally place a special emphasys on aspects related to surface conditions. However, road maintenance is a matter that involves a great number of variables, such as physical, climatic, trafficking, administrative, and social related. Thus, it demands the application of a multiple criteria contemplating approach. The AHP method has been widely applied to the solving of problems that require the consideration of several criteria, and this happens through the establishment of weights. This way, the alternatives can be evaluated having in mind the considerations among the multiple criteria involved in decision making problems.

In the case of unpaved roads maintenance, the AHP method can be used in order to determine the mostly influential criteria weights to the maintenance process, allowing a better solution to this problem.

Definition of the Indicators and the Criteria to be Analyzed.

Having the criteria selection as the starting point, the first idea was to identify what elements were responsible for the appearance of the surface defects on the unpaved roads surface. Analyzing the works of Moreira [1], Baesso et al [3], Correia [4], Correia et al [5], Eaton and Beaucham [8], TM 5-626 [9], Nunes [12], Oda [13], Fontenele [24], and Nunes et al. [25], the causes of the main surface defects presented in unpaved rural roads were identified, according to Table 3.

The surface problems presented in Table 3 are the following: A - improper cross section; B - inadequate roadside drainage; C – corrugations; D – dust; E – potholes; F – ruts; G – loose aggregates; H – sand ground; I – formation of mud; J – slippery road; K –

Table 3. Variables Associated to the Surface Defects.

Surface Defects	Materials		Geometry		Traffic		Drainage		Rainfall
	Type	CBR	Longitudinal	Transversal	Type	Volume	Surface	Profunda	
Improper Cross Section				X					X
Inadequate Roadside Drainage							X	X	X
Corrugations	X	X		X	X	X			X
Dust	X				X	X			
Potholes	X			X		X	X	X	X
Ruts		X		X	X	X	X	X	X
Loose Aggregate	X		X			X			
Sand Ground	X		X	X		X			
Formation of Mud	X			X			X	X	X
Slippery Road	X		X	X			X	X	X
Erosions	X		X	X			X	X	X
Machete	X					X			

erosions; and L – machete.

The following group of variables were defined throughout the study, associated to the causes of the surface defects: (i) materials: group that embodies the variables of the material type and the bearing capacity; (ii) geometry: group that embodies the longitudinal geometry and the transversal geometry variables; (iii) traffic: group that embodies the variables of the traffic and traffic volume variables; (iv) drainage: group that embodies the superficial and deep drainage variables; and (v) rainfall: group that embodies the rainfall data variable. Besides these variables, the model still embodies variables that take into consideration the social and administrative importance of a non-bituminous road.

Many interviews with technicians specialized in the area of transports were done, aiming at the conception of a satisfactory questionnaire. The structure of the resulting criteria of a series of opinions was developed and it is illustrated in Table 4. Besides the

Table 4. Hierarchy Structure Proposed.

Criteria	Indicators			Measurement
Level 1	Level 2	Level 3	Level 4	
Physical Aspects	Surface Conditions			Surface condition index
	Drainage	Simple Dispositive		Quantity
		Surface Drainage	Gutter in the Cuts	% in Extension of The Road
			Ditches on the Crests of the Cuts	% in Extension of The Road
		Special Dispositive		Quantity
	Materials	Type of Soil	Granular Soil	% of the Area with This Material
			Silty and Clay Soil	% of The Area with This Material
		Strength	CBR<=20%	% of The Road with This Indicator
			CBR>20%	% of the Road with This Indicator
	Geometry	Longitudinal	Grade< 3%	% of The Road whit This Characteristic
			Grade between 3% and 8%	% of The Road whit This Characteristic
			Grade>8%	% of The Road whit This Characteristic
		Transverse	With Bulging	% of Sections with These Characteristics
			With Gutter	% of Sections with These Characteristics
			Mixed	% of Sections with These Characteristics
Climatic Aspects	Rainfall			Rainfall Indicator
Traffic Aspects	Type	Light		% of Vehicles
		Average		% of Vehicles
		Heavy		% of Vehicles
	Volume			Daily Average Volume
Management Aspects	Managing Agency	Municipality		% of the Road with this Jurisdiction
		State		% of the Road with this Jurisdiction
		Federation		% of the Road with this Jurisdiction
Social Aspects	Relevance	Access to Schools		Quantity of Accessed Schools
		Access to Hospitals		Quantity of Accessed Hospitals
		Access to Urban Centers		Quantity of Accessed Urban centers
		Access to Industries		Quantity of Accessed Industries

Table 5. Partial Weights for Each Criteria.

Criteria	Measurement	Partial Weight	Criteria	Measurement	Partial Weight
Physical Aspects		0.274	Transverse		0.46
Surface Conditions	Surface Condition Index	0.267	With Bulging	% of Sections with These Characteristics	0.539
Drainage		0.269	With Gutter	% of Sections with These Characteristics	0.175
Simple dispositive	Quantity	0.389	Mixed	% of Sections with These Characteristics	0.287
Surface drainage		0.199	Climatic Aspects	Rainfall Indicator	0.162
Gutters	% in Extension of The Road	0.623	Traffic Aspects		0.306
Ditches	% in Extension of The Road	0.377	Volume		0.313
Special dispositive	Quantity	0.412	Type		0.687
Materials		0.177	Light	% of Vehicles	0.342
Type of soil		0.477	Average	% of Vehicles	0.341
Granular soil	% of The Area with This Material	0.72	Heavy	% of Vehicles	0.317
Silty and clay soil	% of The Area with This Material	0.28	Management Aspects		0.097
Strength		0.523	Municipality	% of the Road with This Jurisdiction	0.323
CBR ≤ 20%	% of the Road with This Indicator	0.25	State	% of the Road with this Jurisdiction	0.401
CBR > 20%	% of the Road with This Indicator	0.75	Federation	% of the Road with this Jurisdiction	0.276
Geometry		0.288	Social Aspects		0.161
Longitudinal		0.54	Access to Schools	Quantity of Accessed Schools	0.238
Grades <= 3%	% of The Road whit This Characteristic	0.459	Access to Hospitals	Quantity of Accessed Hospitals	0.27
Grades between 3 and 8%	% of The Road whit This Characteristic	0.365	Access to Urban Centers	Quantity of Accessed Urban Centers	0.225
Grades > 8%	% of The Road whit This Characteristic	0.176	Access to Industries	Quantity of Accessed Industries	0.267

criteria and the indicators, in Table 5 the forms of measurement of the variables in analysis are also presented.

As a remarkable characteristic of the AHP, it is the reduction of the complexity of a problem through the act of structuring it in hierarchic levels, so the criteria that presented measurement difficulty were divided in sub-criteria, in lower hierarchic levels, up to the point that they had an acceptable level of complexity. The objective of the decision process in focus is to assess the priority of a road to be chosen for operations of maintenance and repair, based on the criteria divided in four levels.

Presentation and Discussion of the Results Obtained

31 questionnaires presented by Almeida [10] were applied to professionals of the area of transports, aiming at increasing the knowledge related to the relative weights of the criteria in analysis.

3 unpaved rural roads in the municipal district of Aquiraz, in Ceará, northeast Brazil, were selected, henceforth referred to as AQZ-1, AQZ-2 and AQZ-3, and they will have the indication of priority for repairing activities and maintenance based on the criteria in analysis.

In this work, the data related to the three roads aforementioned were obtained in the works of Moreira [1], Correia [4], Nunes [12], and Silva [26], as well as complementary collects. Next, in Table 6, the characteristics of the analyzed pathways are illustrated. 5 criteria related to physical, climatic, traffic, management and social aspects were considered. Each one of them, except the one related to the climatic aspects, were divided in sub-criteria according to the AHP hierarchical structure.

In this work, the 11th version of the Expert Choice software was used in order to determine the logical consistency of the normalized matrices obtained through the questionnaires and also to establish a combined judgment for the interviewed group. The main function of Expert Choice was to determine the most appropriate order of priorities, due to a sensibility analysis for the roads analyzed in the municipal district of Aquiraz.

Data from the questionnaire responses were tabulated in the Expert Choice software, allowing the comparison matrix formation, which works as the basis in determining the criteria weights.

By using the Expert Choice, it was possible to determine the logical consistency of each comparison matrices and a global judgment for the whole group of interviews. Table 5 presents the partial weights for each criteria existing on the hierarchy structure proposed. The criteria are presented as follows: physical aspects (1), climatic conditions (2), traffic aspects (3), administrative aspects (4) and social aspects (5). The relative weights for the criteria in analysis, determined by Expert Choice, were the following: w_1 = 0.274, w_2 = 0.162, w_3 = 0.306, w_4 = 0.097 and w_5 = 0.161.

According to the specialists consulted, for the prioritization of maintenance and repair of unpaved rural roads, the criteria in the analysis have the following descending order of importance: 3, 1, 2, 5 and 4. According to their opinion, traffic aspects and physical aspects are the ones that have a bigger impact on the decision of prioritization, with the climatic conditions and the social aspects in a second level of importance, followed by the administrative aspects.

In order to explain the meaning of the indicators that comprehend a criterion, consider the following example. The traffic aspect has a relative weight of 0.306. The indicator of second level “traffic

Table 6. Characteristics of The Three Roads Analyzed.

Road		AQZ-01	AQZ-02	AQZ-03
Extension (m)		1070.67	802.3	234.73
Tranverse section (%)	With bulging	17.50	19.35	51.90
	With gutter	45.00	67.74	35.44
	Mixed	37.50	12.91	12.66
Total		100.00	100.00	100.00
Longitudinal geometry (%)	Grade< 3%	87.50	67.74	84.81
	Grade between 3% and 8%	12,50	32.26	13.92
	Grade>8%	0.00	0.00	1.27
Total		100.00	100.00	100.00
Soil type (%)	Granular soil	37.50	80.65	
	Silty and clay soil	62.50	19.35	
Total		100.00	100.00	0.00
Load capacity (%)	CBR < 20%	0.00	0.00	0.00
	CBR > 20%	100.00	100.00	100.00
Total		100.00	100.00	100.00
Daily average volume (vehicle/day)		17	26	35
Traffic type	Light	64.70	17.65	17.65
	Average	38.46	26.92	34.62
	Heavy	37.14	28.57	34.29
Total		100.00	100.00	100.00

volume” has a relative weight of 0.313. Thus, when it comes to the prioritization of roads for activities of maintenance and repair, the indicator “traffic volume” has a global relative weight of 0.306 x 0.313 = 0.096. The meaning of this value is that, in all the criteria contemplated, the indicator “traffic volume” has an impact of 9.6% in the prioritization of a road. The same thinking can be applied to all criteria and indicators.

Table 7. The Order of Priority for The Three Roads Analyzed.

Order	Road	Weight
1st.	AQZ-2	0.380
2nd.	AQZ-3	0.374
3nd.	AQZ-1	0.246

The supporting model of decision provided the relative weights for the criteria in analysis. Based on the real characteristics of the analyzed roads, it is possible to determine the priority order through the multiplication of each relative weight observed of each indicator. After applying the generated comparisons by the indicators of each alternative, the Expert Choice provided the priority order indicated in Table 7.

According to the characteristics of the roads in study and the relative weights obtained, the roads must have their maintenance prioritized according to the order: AQZ-2, AQZ-3 and AQZ-1.

Sensibility Analysis

The sensibility analysis is a technique, used in the studies in the area of Operational Statistics and Research, which consists of the controlled variation of values of variables that cannot be precisely measured. It is possible to evaluate the impacts of these variations on the results when a systematic variation of the variables’ values is carried out.

The weights, through the AHP technique, calculated based on the

Table 8. Sensibility analysis.

Scenario	Criteria	Weights (%) AQZ-1	AQZ-2	AQZ-3
1	$w_1 = 1, w_2 = 0, w_3 = 0, w_4 = 0, w_5 = 0.$	0.254	0.414	0.332
2	$w_1 = 0, w_2 = 0, w_3 = 1, w_4 = 0, w_5 = 0.$	0.220	0.391	0.389
3	$w_1 = 0, w_2 = 0, w_3 = 0, w_4 = 0, w_5 = 1.$	0.112	0.405	0.483
4	$w_1 = 0.5, w_2 = 0, w_3 = 0.5, w_4 = 0, w_5 = 0.$	0.238	0.401	0.361
5	$w_1 = 0.5, w_2 = 0.5, w_3 = 0, w_4 = 0, w_5 = 0.$	0.294	0.373	0.333
6	$w_1 = 0.5, w_2 = 0, w_3 = 0, w_4 = 0.5, w_5 = 0.$	0.294	0.373	0.333
7	$w_1 = 0.5, w_2 = 0, w_3 = 0, w_4 = 0, w_5 = 0.5.$	0.183	0.409	0.408
8	$w_1 = 0, w_2 = 0, w_3 = 0.5, w_4 = 0, w_5 = 0.5.$	0.167	0.397	0.436
9	$w_1 = 0, w_2 = 0.5, w_3 = 0.5, w_4 = 0, w_5 = 0.$	0.271	0.368	0.361
10	$w_1 = 0, w_2 = 0, w_3 = 0.5, w_4 = 0.5, w_5 = 0.$	0.271	0.368	0.361
11	$w_1 = 0, w_2 = 0.5, w_3 = 0, w_4 = 0, w_5 = 0.5.$	0.223	0.369	0.408
12	$w_1 = 0, w_2 = 0, w_3 = 0, w_4 = 0.5, w_5 = 0.5.$	0.223	0.369	0.408
13	$w_1 = 0.33, w_2 = 0.33, w_3 = 0.33, w_4 = 0, w_5 = 0.$	0.270	0.378	0.352
14	$w_1 = 0.33, w_2 = 0, w_3 = 0.33, w_4 = 0.33, w_5 = 0.$	0.270	0.378	0.352
15	$w_1 = 0.33, w_2 = 0, w_3 = 0.33, w_4 = 0, w_5 = 0.33.$	0.195	0.403	0.402
16	$w_1 = 0, w_2 = 0.33, w_3 = 0.33, w_4 = 0.33, w_5 = 0.$	0.307	0.360	0.333
17	$w_1 = 0, w_2 = 0.33, w_3 = 0.33, w_4 = 0, w_5 = 0.33.$	0.233	0.384	0.383
18	$w_1 = 0, w_2 = 0.33, w_3 = 0, w_4 = 0.33, w_5 = 0.33.$	0.259	0.357	0.384
19	$w_1 = 0.25, w_2 = 0.25, w_3 = 0.25, w_4 = 0.25, w_5 = 0.$	0.286	0.367	0.347
20	$w_1 = 0.25, w_2 = 0.25, w_3 = 0.25, w_4 = 0, w_5 = 0.25.$	0.231	0.385	0.384
21	$w_1 = 0.25, w_2 = 0.25, w_3 = 0, w_4 = 0.25, w_5 = 0.25.$	0.259	0.371	0.370
22	$w_1 = 0.2, w_2 = 0.2, w_3 = 0.2, w_4 = 0.2, w_5 = 0.2.$	0.251	0.375	0.374

expert's answers, cannot be determined with precision. The sensibility analysis will be consisted of a systematic variation of values of the weights regarding the criteria. The aim is to determine the impact of such variation in the decision-making process.

The Expert Choice, in its Sensibility Analysis, allows the global weights of the criteria presented in the first level of the hierarchy structure (in this case the Physical Aspects, the Climatic Conditions, the Traffic Aspects, the Administrative Aspects and the Social Aspects) to be easily changed. This permits that the prioritization of the unpaved rural roads can be verified under the perspective of those several aspects that were analyzed.

Besides the result provided by the judgment of the group (Table 5), 22 different scenarios were established from the several combinations, focusing on the five criteria located on the first level of the hierarchy. The results of these analyses, illustrated in Table 8, were taken as basis to indicate the most appropriate order of the roads that were studied.

The weights obtained from each scenario are the elements which the Sensibility Analysis consists of. This software carried out a systematic variation of weights of the five criteria contemplated in the proposed model. This was in order to evaluate the impacts of the uncertainty about the weights on the selection of a road.

Considering the data presented in Tables 5 - 7, it can be verified that in the group of 23 situations that were analyzed (22 scenarios and the result of the judgment of the group), 18 scenarios (78.26%) presented the same priority order and only 5 scenarios (21.74%) presented a different one. Therefore, it can be assumed that, for the considered indicators and for interviewees' answers, the most appropriate order for the three analyzed roads must be the same shown in Table 7.

Conclusions

The contribution of this work, concerning the prioritization of the maintenance of unpaved rural words, consists in the organization of data to the AHP method, used to show the most appropriate order of priorities for the analyzed roads. The method takes into consideration physical, traffic, climatic conditions, administrative and social aspects.

Contrary to what occurs in other methods mentioned in the literature, as the USACE for instance, the use of the AHP allows us to contemplate the multiple criteria involved in decisions related to maintenance of unpaved rural roads. In order to contemplate several criteria, we hope the decisions made supporting the proposed approach in this work are rich as to the practical viewpoint.

The order of priority obtained using this methodology is just indicative. The global and partial weights established for each criterion are valid only for the answers of the deciders and for the analyzed indicators. In order to prioritize other roads, all the methodological process of application of the AHP and collection of data must be repeated.

Although the application of the AHP method requires the realization of a series of questionnaires, as well as their processing and analysis, the benefits of its application for the unpaved roads management justify its utilization.

We should reinforce that the results originated from the application of the AHP are of a subjective nature, and they are not an ideal solution to be implemented. Thus, the results must be interpreted as subsidies to the decision-making process.

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