Evaluating methods of predicting defects in forest highways

Robson José de Oliveira
UFPI

Luciano Cavalcante de Jesus França
UFLA

Vicente Toledo Machado de Morais Júnior
UFV

Carlos Cardoso Machado
UFV

Elisabete Oliveira da Silva
FANOR

Giovani Levi Sant’Anna
UFV
Unpaved forest roads play an important role in the socioeconomic development of a region, being responsible for the integration of forests and forestry companies. With that assumption, this paper presents the results of the analysis of two methods for classifying unpaved roads, in order to verify whether characterising Brazilian roads by these methods reflects reality in the field and can therefore be used as a basis for a system for road management. Objectively classifying unpaved roads by the Unpaved Road Condition Index (URCI) is compared to ratings obtained subjectively using the Gravel Paver Manual (GPM). Subjectively analysing the defects or problems of local roads, 32.50% of the units were classified as excellent for traffic, compared to the objective method where the percentage falls to 6.25%. From the data, it can be concluded that an objective method of analysis is more reliable. Defects on local roads need to be diagnosed and resolved as quickly as possible to prevent them from developing, generating more defects and compromising the whole highway.

**Keywords:** Management, Transport, Maintenance, Forest Management.
INTRODUCTION

During 2011, the domestic economy underwent a strong recovery, as measured by a growth of 7.5% in GDP, despite the global economic and financial crisis. The forestry sector has been one of the most important sectors in the domestic economy, contributing 4% of GDP, with Brazilian exports of products from planted forests amounting to USD 8.0 billion (3.1% of the total), a growth of 5.3% compared to 2010. Forest roads are the most important access routes to forests, serving to enable the traffic of labor and the means of production needed for forest investment (CARMO et al., 2013).

In addition, the forestry sector has great potential for growth. This can be seen in investments by the forest-based companies, both in the industrial area, expanding their installed capacity, and in the purchase of new areas for planting forests and more efficient machinery and equipment, always seeking to optimise the production process, from planting and maintenance to harvesting and transportation, with a view to reducing costs by economies of scale (NOCE et al., 2005). The area of trees planted for industrial purposes in Brazil totaled 7.84 million hectares in 2016, a growth of 0.5% over 2015; this change is exclusively the result of the increased area planted with eucalyptus. Areas planted with pine and other genera remained unchanged in the period. Eucalyptus plantations occupied 7.47 million hectares of the area of planted trees in the country; they are mostly located in the states of Minas Gerais (27.6%), São Paulo (18.1%), and Mato Grosso do Sul (15.1%) (IBÁ, 2021).

In Brazil, 85% of wood is transported by road, from the edges of the woods on the farms, to the company yards. Even with most of the roads in disrepair, it is sometimes the only way to connect the industries to their sources of timber, which are located at different places, i.e. covering separate areas across Brazil. For this reason, studies that seek to uncover the main problems and also how to solve them, are very important to forest road transport (SILVA et al., 2007).

In Brazil, approximately 89% of the entire national road network consists of local roads, of which 98% are unpaved. These roads are of vital importance, as they connect the producing communities to the large paved highways, which the goods take to their final destination. Due to their great economic and social importance, it is necessary to develop research into finding alternatives that may assist in the maintenance and rehabilitation of these roads by the rational use of available technical and financial resources arising from the transportation infrastructure (OLIVEIRA et al., 2007).

There are many ways of classifying the conditions of a road surface, and these can be divided into objective and subjective methods. As they work with indices of road surface conditions, objective methods have a higher acceptance among decision-making administrative bodies. The evaluation proposed by Eaton (1987), involves an objective method for
calculating the unpaved road condition index (URCI), based on values deduced from the defects and respective levels of severity found in the stretch under study. The defects are classified according to their dimensions in relation to the area of the section in which they occur, the roads therefore being classified according to average values for the URCI, which are obtained from each stretch of road being studied.

There are other methods of evaluation, such as the Gravel Paver Manual (GPM), created by the Transport Information Centre of the University of Wisconsin-Madison in the US, which aims to subjectively assess the conditions of gravel roads, using a scale ranging from 1 to 5, and a rating from impassable to excellent. The conditions of some of the factors that are considered, and which deteriorate gradually, such as cross section, drainage, thickness of gravel, surface deformations such as holes, wheel ruts and corrugations, and surface defects such as dust and loose aggregates, are more important in this method than details of the conditions of the surface that can vary from day to day, either with the weather, when it rains a lot for example, or with the heavy traffic.

There are other methods of subjective evaluation, such as Riverson, AGR and that proposed by Jamsa (1983), widely used in Finland and where the assessment team assigns grades ranging on a scale from 0 to 5 with reference to the conditions of the road surface, for the purpose of establishing when the roads are in need of maintenance.

As its objective of some importance, given that there is as yet no model adapted for use in Brazil, this study aimed to identify road defects and their severity, in order to aid the activities of management systems, in particular the process of decision-making regarding the allocation of financial resources which are available for the interventions necessary to preserve the good condition and usefulness of unpaved roads, by comparing two methods for evaluating the defects found in forest roads by subjective and objective analysis.

### MATERIAL AND METHODS

#### Data collection

Data on the amount and severity of seven defects (unsuitable cross section, inadequate lateral drainage, corrugation, excessive dust, holes, wheel ruts and loss of aggregates) were collected from two of the country’s large paper and cellulose companies, one located in the State of Bahia and the other in the State of Minas Gerais (Figure 1). The data were analysed using the objective URCI method, which is the method most applied to major defects.
Figure 1. Localization map of the study area (Minas Gerais and Bahia, Brazil).

An unsuitable cross section is a problem that is characterised by the inappropriate transverse geometric profile of the road. This eventually affects the flow of rainwater, preventing the use of any form of drainage device.

Inadequate lateral drainage is a defect seen when the side gutters are clogged and hamper the flow of water, leading to puddling and erosion of the roadside.

Corrugation is a problem that shows up in the form of undulations, spaced at regular intervals and perpendicular to the direction of the traffic flow, which are caused by the lack of support capacity of the sub base and absence or deficiency of a drainage system.

For the purposes of comparison, the same defects were analysed by the subjective GPM method. A manual count of existing traffic at the site was also carried out. Eighty sampling units of 50 meters each were used for collection (40 from each company), containing the main problems found in Brazilian forest roads.

A fifty-metre tape measure was employed to mark out the length of each of the 80 sampling units along 2 km of road; two small tape measures, a ruler and clipboard were used to note down the measurements of the defects and to number the sampling units. Measurements were taken in February of 2008 at the first company and in March of 2008 at the second.
**Objective method – URCI**

Determining defects in a road using the URCI method is carried out based on values that range from 0 to 100, where 100 (one hundred) indicates that the problem has no impact on the highway, and 0 (zero), where there is maximum impact and the defect in question has already compromised the whole highway or the section being studied. To calculate this index, the following steps were followed. The density was calculated for each defect separately, except for excessive dust:

\[
Density = \frac{\text{number of defects} \times k \times 100}{\text{unit area} \left( m^2 \right)}
\]

*Where:* \( k \) is a coefficient for the correction of metric units, which varies with the defect found on the road.

From the value for the density of each defect, the corresponding value was deduced from existing severity-level curves for each defect type, which when summed gives the total deduced value (TDV). Taking those defects where the deduced value was greater than five, gives a value for \( q \). From the total deduced value and the value \( q \), the unpaved road condition index (URCI) was found. This is a numerical index based on a scale ranging from 0 (zero) to 100 (one hundred) indicating the integrity of the highway: from 0 to 10 (bad), 10 to 25 (very poor), 25 to 40 (poor), 40 to 55 (fair), 55 to 70 (good), 70 to 85 (very good), 85 to 100 (excellent). As no calculation of density can be made for defects such as dust, there are no graphs for deduced values. In the Table 1 was used for classification of the forest roads. This is an idealised table based on the average daily volume of traffic.

**Table 1.** Classification of forest roads as a function of the average daily volume of traffic.

<table>
<thead>
<tr>
<th>ROAD CLASSIFICATION</th>
<th>ADV</th>
<th>URCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I</td>
<td>ADV &gt; 200 vehicles/day</td>
<td>URCI 70 - 100</td>
</tr>
<tr>
<td>Category II</td>
<td>ADV = 100 - 199 vehicles/day</td>
<td>URCI 55 - 70</td>
</tr>
<tr>
<td>Category III</td>
<td>ADV = 50 - 99 vehicles/day</td>
<td>URCI 40 - 55</td>
</tr>
<tr>
<td>Category IV</td>
<td>ADV = 0 - 49 vehicles/day</td>
<td>URCI 25 - 40</td>
</tr>
<tr>
<td>Highway impassable</td>
<td></td>
<td>URCI 0 - 25</td>
</tr>
</tbody>
</table>


**Subjective method – GPM**

The subjective GPM method is a method where road conditions are assessed visually and graded while going over the stretches to be analysed. The grades are compared to a scale, which varies from 1 to 5, for roads in following conditions: 1 – Poor, 2 – Bad, 3 – Fair, 4 – Good, and 5 - Excellent.
RESULTS

Table 2. shows the results obtained in the surveys conducted in the field at the two forestry companies. From the roads analysed using this table, the need for adequate and efficient maintenance on forest roads can be seen.

<table>
<thead>
<tr>
<th>Company</th>
<th>Sampling units</th>
<th>Class</th>
<th>Volume of traffic</th>
<th>Category</th>
<th>Ideal URCI</th>
<th>URCI found</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-20</td>
<td>Class 1</td>
<td>0 - 49 vehicles/day</td>
<td>Category IV</td>
<td>25 - 40</td>
<td>13</td>
</tr>
<tr>
<td>A</td>
<td>21-40</td>
<td>Class 2</td>
<td>0 - 49 vehicles/day</td>
<td>Category IV</td>
<td>25 - 40</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>41-60</td>
<td>Class 1</td>
<td>50 - 99 vehicles/day</td>
<td>Category III</td>
<td>40 - 55</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>61-80</td>
<td>Class 2</td>
<td>50 - 99 vehicles/day</td>
<td>Category III</td>
<td>40 - 55</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: the authors.

The general equation below represents the participation of each defect in contributing towards an impassable road. The sum of the percentage values for the defects should total 100%, as in:

\[ H = 0.29\% \text{ucs} + 0.35\% \text{ild} + 0.11\% \text{ho} + 0.10\% \text{co} + 0.08\% \text{wr} + 0.04\% \text{du} + 0.03\% \text{la} \]

Where \(M\) = value of the weighted defects, i.e. the hierarchy of importance of the defects; \(\text{ucs}\) = unsuitable cross section; \(\text{ild}\) = inadequate lateral drainage; \(\text{ho}\) = hole; \(\text{co}\) = corrugation; \(\text{wr}\) = wheel rut; \(\text{du}\) = dust; \(\text{la}\) = loss of aggregate.

It can be seen that such defects as unsuitable cross section and inadequate drainage are the most significant, as together, they account for around 64% of the problems found on forest roads. In Figure 2 and 3 below are shown the results of the methodologies used in evaluating the sampling units of the data collected at the forestry companies.

Figure 2. Road classification by the GPM method.
DISCUSSION

It was possible, using the subjective GPM method, to visualise road conditions by comparing at five points, roads classed as excellent or poor.

For results where high levels of severity are found for such problems as unsuitable cross section and inadequate lateral drainage, which are more worrisome defects, considered as serious, and which generate greater weightings, the result is a worse rating for the units, with the need being generated for more urgent recovery intervention.

The priority for maintenance/intervention is defined as a function of the URCI and the category of the highway, which is directly related to the average daily volume of vehicular traffic (Oliveira, 2008).

Based on Table 2, the roads belonging to company A fall into class IV, due to having an average daily volume of traffic (ADV) equal to 45 vehicles/day. The roads belonging to Company B have an ADV of 50 vehicles/day, but fall into class III. Due to these roads having more vehicular traffic, it was expected that better conditions of trafficability would be found, but this was not evidenced by the study. It can be seen that the values obtained for the URCI are well below the ranges required for the volume of traffic of each category of road (25-40 and 40-55 respectively). Maintenance priority in Company A will be given to class 1, which includes units in the worst of conditions, i.e. very poor. The lower result for class 1 compared to class 2 can also be explained by there being four sampling units classified as very poor in class 1 against none in class 2 for Company A.

Furthermore, in the two roads belonging to Company B, values were found that were well below the required URCI, necessitating more urgent maintenance, with the URCI for class 2 being half that of class 1. This was due to the fact that in the last twenty units, situations...
classified as very poor were found in 50% of the units under analysis, including the unit in the worst of conditions because of defects that compromise the overall operating performance of the road, and which were classified as having both high and medium levels of severity.

In a comparison of the methods being analysed, it was found that the GPM method, which evaluates roads subjectively, was not as efficient as the objective method, this is because it is based on visual observations and not on measurements using tape and rulers that quantify defects by size, as in the objective method. This claim is made, based on the results of the classification; in the total of the measurements for the two companies, 46.25% of the analysed units were classified as good and 32.50% as excellent by the subjective method, whereas the objective method employing the URCI, gave a result of 25% of good units and 6.25% of excellent, the method being more stringent and requiring a more detailed analysis. As an example, most of the units classified as being in a good state of conservation using the GPM method are classified as fair using the URCI, as illustrated in Figures 1 and 2.

The fact that there are many road units classified as fair is also due the company performing general maintenance on the road before going in with the machines to load the wood and the trucks to transport it, but as this represents a constant, high flow of heavy double and triple tractor trucks, buses to transport the workers and other passengers that live in the area, and farming vehicles, the roads deteriorate more quickly in those units where maintenance has recently been carried out than in others that have less traffic.

Serious defects of drainage, cross section, dust, holes and wheel ruts were found in unit 68, whereas in the best unit, number 50, only dust was detected and even that at low severity levels, showing that there is no need for such a rapid intervention as there is in unit 68.

When comparing the best and the worst results, using units 50 and 68 by the URCI method, the indices found were 98 and 2 respectively, resulting in a difference of 96 points.

The distances between the sides of the roadway were also measured on roads of both Company A and B. For Company A, there was a variation in width of from 4.5 to 10.5 m; for Company B there was less variation, with values between 3.2 and 5.3 m being found. Despite there being less variation, the problems for Company B are greater, starting with most of the units being below the required minimum width, i.e. 4 m.

There are other studies where the integrity of the roads is also evaluated, such as the article cited by Emert et al. (2010), in which he states that defects cause irregularities that lead to discomfort and, depending on the level of severity, may create risks to the safety of users, as well as adversely affecting the speed and operating costs of road transportation.

The prediction of defects on unpaved roads helps in making decisions on which interventions may become necessary, serving as an aid in the development of a regular program of preventive maintenance. With this in mind, it is suggested that in future studies, monitoring
of the critical points raised in this research be continued, with more intense interventions in those stretches of road that contain the more serious problems.

The study carried out by Emert et al. (2010), found poor situations on stretches of road where the worst defect was inadequate drainage, as was found in this work.

■ CONCLUSION

Under these conditions, the objective method was better for assessing experimental stretches of forest road, even when presenting some subjectivity due to their being quantified and measured. For Company B, where smaller lane widths were found, increasing the width along some stretches is recommended, so that trucks can travel in both directions. Also when constructing the roads they should be made to be slightly convex in the centre, which would result in an improvement in water runoff, thereby minimising the appearance of other defects, besides preventing some defects from getting worse.

It can be seen that defects such as unsuitable cross section and inadequate drainage are the most significant, as together, they account for around 64% of the problems found on forest roads.

■ REFERENCES


