A MODEL OF ROAD DETERIORATION CONSIDERING LINK RELIABILITY IN COLOMBIA

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1 INTRODUCTION

Road disruptions are very common in developing countries. When more than one route is available between two points, large proportions of traffic tend to be diverted to other roads when the lowest cost route gets blocked, increasing the volumes on other network links. Traditional road deterioration analyses only consider the effects of average daily traffic running on the network. This paper, however, argues that as disruptions are very common, diverted traffic should also be considered in the calculation of road deterioration for maintenance purposes. Dunkerley (2000) showed that unexpected road closures caused large volumes of freight vehicles to divert through alternative routes. The vehicles were found to be much heavier than usual, increasing road damage on the alternative routes, as firms consolidated loads confronted with higher costs and lower vehicle utilisation. Alternative roads in developing countries tend to have lower design specifications and are in general structurally weaker than main routes. For all these reasons, rerouted traffic becomes even more important.

This paper examines if the maintenance policy of the alternative route between Bogota and Villavicencio in Colombia is significantly improved by the inclusion of diverted traffic due to disruptions in road deterioration models.

2 METHODOLOGY

To examine if maintenance policies are significantly improved considering diverted traffic, we employed a road deterioration model employing equations found in the HDM-III program from the World Bank (Watanatada et al, 1987). The objective of the model is to obtain the levels of road deterioration caused by traffic, comparing damage caused with and without rerouted vehicles. Assuming that the road is intervened once roughness reaches a certain level, the output of the model is the amount of time taken from the last maintenance routine until the road needs to be treated again. The model is run twice:

a) Using regular (average) traffic on the road
b) Using the average traffic plus the rerouted traffic due to disruptions.
The hypothesis is confirmed if the period of time in-between maintenance is substantially shortened as a result of the road damaged caused by re-routed traffic.

2.1 Routes chosen for the analysis
The Bogota-Villavicencio link in Colombia was chosen for the analysis because it is an important link between the capital Bogota and the main cattle raising area of the country, located next to the city of Villavicencio. Additionally there was data available on traffic volumes and how they were affected by sudden road closures (Dunkerley, 2000). Most data for volumes and road characteristics was taken from the traffic count surveys in the 1990s. There is now another route much more reliable on this corridor which has been recently opened to service, but this has not considered in this study. In the 1990s, the shortest route between Bogota and Villavicencio was 95 Km through the town of Caqueza; the alternative route was three times longer (313 Km), and passed through the village of Cumaral.

2.2 Link selection for the road deterioration model
The link between Chepero and Cumaral (6 Km) was chosen on the alternative route to assess the effects of diverted traffic on road deterioration. This was the weakest link on the alternative road, as it was unpaved. The main maintenance procedure carried out is regrading. Other maintenance policies for unpaved roads are not as frequent as regrading, and were not considered in this analysis.

2.3 Traffic volumes and rainfall levels
The traffic volumes on the main and the alternative route between Bogota and Villavicencio were obtained from the traffic counts done by the Ministry of Transport. The volumes of re-routed traffic were estimated using origin destination freight surveys carried out in the 1990s (Dunkerley, 2000). Rainfall levels are also required for the deterioration models, and were obtained from the Departamento Nacional de Planeacion (1993).

2.4 Road roughness models
The HDM-III relationships (Chesher and Harrison, 1987) for roughness and speed estimated in Brazil for medium cars were employed in this model. The maximum roughness allowed for the unpaved stretches of the road corresponds to a speed of 50 Km/h and a roughness level of 15 m/Km IRI on the HDM-III model. The roughness after regrading is 3 m/Km IRI (Dunkerley 2000). The values were later replaced in the expression:

\[ QI(TG2) = QIMAX_j - b \times [QIMAX_j - QI(TG1)] \]

Where :
- TG1 and TG2 are the first and the last day of the regrading period respectively.
- QI(TG2): road roughness at TG2, in counts/km QI
- QI(TG1): road roughness in counts/km QI at time TG1, which is the time of the last grading
- QIMAXj: the maximum accepted level of road roughness, in counts/km QI.
And $b$ is defined as

$$b = e^{c(TG2-TG1)}$$

and $c$ is

$$c = -0.001 (0.461 + 0.0174 ADL + 0.0114 ADH – 0.0287 ADT MMP)$$

Where:
- $ADL$: average daily light traffic in both directions, in veh/day
- $ADH$: the average daily heavy traffic in both directions, in veh/day
- $ADT$: the sum of light and heavy traffic per day $ADL + ADH$
- $MMP$: mean monthly precipitation, in m/month

The main output of this model is the days between regradings. Replacing the values found for the particular case of the Chepero-Cumaral link, we found that a permanent closure of the main road would increase the volumes of heavy traffic from 411 to 722, and the volumes of light traffic from 483 to 669, as traffic from the main road takes the alternative route. If these volumes of diverted traffic continued permanently, the time between regradings would decrease from 695 days with normal traffic to 475 days, a decline of around 30%.

### 2.5 Effects of temporary closures of the main route on the deterioration of link on alternative route

Now we present a sensitivity analysis looking at the effects of different number of days with road closure on the main road, and the effects these have on the number of days between regradings. We already know that with normal traffic the time between regradings is 695 days. Using the model described in the last section we obtain the following function

$$d_1 = 695 - 1.465 d_2$$

where $d_1$ and $d_2$ are the days with normal traffic, and normal traffic plus re-routed vehicles respectively in each regrading cycle. The number of days between regradings is then $d_1 + d_2$. The plot of this function is in Figure 1, and shows how the number of days when the main road was closed affects the periods between regradings of the Chepero-Cumaral link on the alternative route. The vertical axis shows the days between regradings $d_1 + d_2$, with an horizontal line marking the number of days between re-gradings if no re-routed traffic is sent by the alternative road. The horizontal axis is labelled with the number of days that the main road is closed in a regrading cycle when re-routed traffic was sent by the alternative route. For example, when the road is closed during 30 days in a maintenance cycle, the time between regradings decrease from 695 to 681 days. Looking at the historical records of disruptions (Dunkerley, 2000), it is highly likely that the road could be closed for 60 days due to disruptions within one regrading cycle. This means that the alternative road might have received diverted traffic for enough time in one maintenance cycle to change significantly the time between regradings. These 60 days of disruptions would have pushed up the annual maintenance costs by 5% or US $3,750 annually for 40 years (Dunkerley, 2000).
3 CONCLUSIONS

In the case of the alternative road between Bogota and Villavicencio, the model shows clearly that diverted traffic has some effect upon the period between regradings. In the short term, the effect is not very large. Over ten years for example, the diversions of traffic caused by disruptions may add up to 5% to the costs of regrading the road. This is a very conservative estimate, as it does not take into consideration the heavier loads carried by diverted traffic.

Caution must be taken when interpreting the results of this model, because the range of error of this type of models is traditionally large. However, volumes of buses and trucks, the heaviest vehicles, increased by 75% on the alternative routes, leading to much higher congestion and road damage in a very short space of time. It seems then that there is a sort of “domino” effect, in which as soon as one link fails in the network, the additional traffic diverted speeds up the damage on alternative links, increasing the probability of failure on other parts of the network. This leads to the suggestion that policy makers must start taking into consideration the reliability effects on traffic volumes in their maintenance policies. Additionally, reliability modellers must also estimate the probability of link failure with functions showing the dependency on other links through the mechanism of traffic diversion.
REFERENCES


