Factors Influencing the Transferability of Maintenance Standards for Low-Volume Roads

GERARD LIAUTAUD AND ASIF FAIZ

Among the many parameters that influence the selection of maintenance strategies for unpaved roads, two factors have been selected in this paper to illustrate that caution needs to be exercised when attempting to transfer policies or standards from one set of conditions to another. These two factors are *factor costs* (not budgets) and *material resources.* Broadly speaking, the definition of a maintenance policy for an unpaved network implies that besides routine activities such as vegetation control and ditch and culvert cleaning, consideration should be given to the frequency of grading and also to the timing of graveling operations. Drawing from the experience collected in two widely different environments, one in the equatorial forest region of central Africa—where maintenance costs are high and gravel resources scarce—and the other in northeast Brazil, it is shown that maintenance standards are highly dependent not only on traffic volume but also on the properties of surfacing materials and the unit cost of grading. As shown and explained in this paper, the optimum grading frequency derived from economic analyses for a given volume of traffic may vary by a factor of 5, ranging between 2 and 10 times per year. Similarly, the threshold value of traffic volume at which surfacing an earth road with gravel becomes economically justified can range from below 20 to more than 100 vehicles per day, depending on cost of graveling and physical properties of the subgrade to be graveled. Such wide variations suggest the need for a careful definition of local conditions before an attempt is made to transfer maintenance standards across countries or even across regions within a country.

Even under the best maintenance policy, vehicle operating costs on unpaved roads are usually 10 to 30 percent higher than those on well-maintained paved roads, mostly because of differences in average surface roughness conditions. Furthermore, the neglect of maintenance on an unpaved network may cause vehicle operating costs to increase by a factor of 2 to 3, because roughness can rise quickly from 5 m/km international roughness index (IRI) (on a newly graded road) to upward of 20 m/km within a few weeks if traffic volume is high. On paved roads, the situation is different: not only is the rate of progression of roughness slower, but also a smaller range of values is observed between a pavement in good condition (IRI = 3) and the same pavement at the end of its useful life, that is, in poor condition (IRI = 6 to 8), with the difference in vehicle operating costs generally not more than 30 percent.

Therefore, maintaining a network of unpaved roads requires relentless attention as well as a well-defined program of recurrent activities in order to keep the level of service of the roads within acceptable limits. Among the recurrent activities to be carried out, grading and graveling operations are the primary maintenance-related determinants of road conditions, and in turn of the cost of operating vehicles.

The World Bank, 1818 H St. N.W., Washington, D.C. 20433.

The frequency at which bladings are to be performed and the timing at which an unpaved road is to be surfaced or resurfaced with gravel constitute the basic requirements of any rationally designed maintenance program, and methods are now available that enable the definition of optimum standards both for grading frequencies and for appropriate timing of gravel surfacing (*1–3*). However, these standards are strongly dependent upon local conditions and a number of parameters such as traffic, level of service required, the importance of the road, climate (in particular, rainfall), budget constraints, material resources, and unit costs of grading and graveling. In this paper, the effect of the last two parameters is evaluated.

EFFECT OF MATERIAL RESOURCES ON MAINTENANCE STANDARDS

Grading Frequency

Depending on the availability of materials, the wearing course of unpaved roads may consist of a wide variety of soils, ranging from fine-grained silts or clays to fairly coarse gravel. Although the rate of surface deterioration is mostly influenced by traffic volumes, roughness progression is also governed by the physical and geotechnical properties of the surfacing material, that is, its particle size distribution and plasticity. Table 1, giving the mean rate of progression of roughness observed for various types of materials (*2,4,5*), shows, for example, that a surface course consisting of a sandy soil will, under the same traffic volume and similar climatic conditions, deteriorate some 20 times faster than a lateritic gravel wearing course. Consequently, and assuming that both roads were to be maintained at an identical level of service (i.e, at a given level of roughness), the frequency of grading in the first case would be substantially higher. Economic considerations suggest that an optimum level of service is governed not only by traffic volume but also by the expenditure corresponding to the number of gradings necessary to keep the long-term average roughness of the road within acceptable limits.

Figure 1 shows the difference in maintenance standards adopted for two regions in the same African country (Gabon); in one region the predominant soils were sandy clays with a mean rate of roughness progression of 0.5 m/km IRI per 1,000 vehicles, and in the other region the predominant soils were well-graded lateritic gravel with a rate of roughness progression of 0.08 m/km IRI per 1,000 vehicles. For the sandy clay surface road, the optimal grading frequency was about once every month, with a resulting average roughness of 8 m/km IRI. For the laterite road, the

TABLE 1 Mean Rate of Roughness Progression for Various Types of Materials (4-6)

Materials	Max. particle size, in mm	Plasticity Index	Soaked CBR at 95% Mod.AASHO	Increase in IRI/1000 veh, m/km
Fine-Grained				
Sands	2	<10	5-20	1.3 to 1.8
Silts, silty clays	1	5-20	5-15	0.8 to 1.2
Clays	0.1	10-50	<10	0.3 to 0.6
Coarse-Grained				
Silty gravel	10	16	>15	0.07
Lateritic gravel	15-25	5-25	10-50	0.04 to 0.19
Crushed calcareous rock	30	10	85	0.09
Sandstone gravel	25-30	6-8	>15	0.18
Quartzitic gravel	20-30	14-20	10-35	0.10 to 0.25
Cinder gravel	20	N.P.	>20	0.20
Basalt gravel	30-75	20-30	>20	0.20 to 0.24
Volcanic gravel	30	17	7-28	0.08 to 0.24

optimum grading frequency was about once every 4 months, with a resulting average roughness of 5 m/km IRI. Both roads had an average daily traffic (ADT) of 200. Similarly, and assuming that two roads have a gravel wearing course, the optimum grading frequency will depend upon the nature of the gravel material: for example, if the ADT is 200 vehicles and the desired year-round maximum roughness on these roads were to be fixed at 8 m/km IRI, a lateritic gravel course would need to be bladed three times a year, whereas a quartzite gravel course (with a greater maximum particle size, rounder aggregates, and less plasticity) would require grading eight times a year.

Graveling Threshold

The faster the rate of roughness progression on a road (as may result from poor geotechnical properties of the surfacing material), the closer will be the intervals between gradings needed to meet a given standard of roughness and consequently the higher will be the maintenance cost. In the Gabonese experience related above, embedding 1/2-in. stone in the silty clay subgrade at a rate of 10 L/m^2 proved effective in reducing the rate of roughness deterioration from 0.5 m/km to 0.24 m/km. As a result of this improvement, threshold values of traffic volumes at which full thickness graveling (15 cm) was justified changed from about 20 veh/day to nearly 50 veh/day. Since traffic volumes in that area were generally below this threshold and naturally occurring gravel is scarce, the economic return resulting from "nailing" the clay with a moderate amount of single-sized stones was very high.

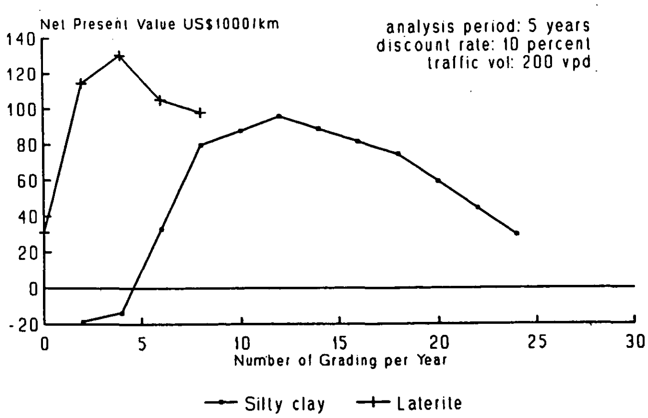

FIGURE 1 Influence of material properties on grading frequency.

EFFECT OF UNIT COSTS ON MAINTENANCE STANDARDS

By any standards, Gabon stands out as a country where unit costs of road construction and maintenance are exceedingly high because of particularly difficult physical and environmental conditions: predominance of dense primary forests, high rainfall, rolling or mountainous terrain, poor subgrade soils, and relatively high cost of labor. Assuming that the maintenance standard to be met corresponds to about 7 m/km IRI average roughness, the average cost of maintaining 1 km of unpaved road, including periodic regraveling, ranges between U.S.$20,000 and U.S.$30,000 for traffic volumes of 50 and 200 vehicles per day, respectively. By way of comparison, and to comply with the same standard, the average maintenance cost for 1 km of unpaved road located in northeastern Brazil varies between U.S.$2,000 and U.S.$3,000 for the same traffic volume, 10 times less. In either case, the average unit costs of maintenance are from competitive bids and include the cost of labor, materials, and equipment rental as differentiated below:

	Unit	*Brazil*	*Gabon*
Labor	U.S.$/hr	0.50	3
Gravel material	U.S.$/m^3	5	25
Grader rental	U.S.$/hr	35	125

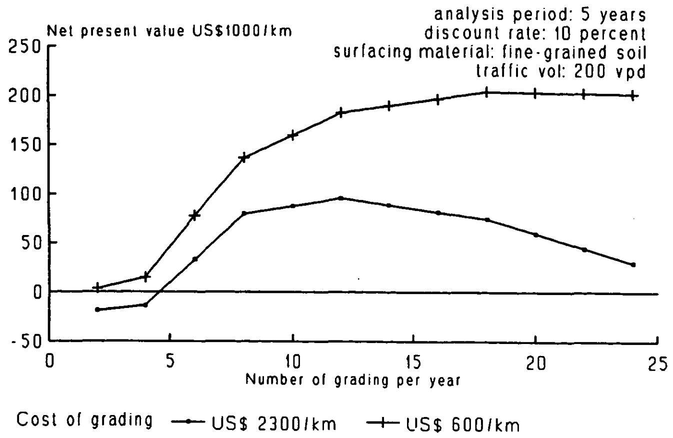

FIGURE 2 Influence of cost on optimum frequency of grading.

Under Gabonese conditions, and more generally wherever road maintenance and construction costs are high, competitive procurement procedures and careful evaluation of bids can result in substantial cost reductions. For example, under one maintenance contract, the lowest evaluated bid proposed a unit cost of grading equivalent to U.S.$600 per km, whereas the average cost submitted by other bidders was U.S.$2,000 per km. Economic analyses showed that awarding the contract to the lowest bidder meant that the unpaved network could be graded once every 15 days, thereby maintaining a level of roughness of about 6 m/km IRI throughout the year. Had the contract been awarded to the average bidder, the same network would have been graded about once a month with only a fair to poor level of roughness, about 9 m/km IRI, for an ADT of 200 vehicles per day (see Figure 2).

The magnitude of graveling costs can also have a significant impact upon the standard of maintenance. As in many other countries, there are large areas in Gabon where naturally occurring gravels are difficult to find and the cost of haulage of the material over long distances can more than double the total cost of graveling operations. In areas where lateritic gravels are abundant, the average unit cost of graveling is of the order of U.S.$15/m^3. In the eastern part of the country, where sands are predominant, the cost of providing 1 m^3 of gravel may be as high as U.S.$40. In the latter case, graveling thresholds would increase from about 25 veh/day to 45 veh/day, thereby introducing a significant change in the maintenance policy.

TABLE 2 Differences in Maintenance Standards Between Gabon and Northeast Brazil

Costs	Brazil	Gabon	
		low case	high case
Vehicles operation US$/veh*km			
for IRI=2	0.24	0.82	0.82
IRI=5	0.31	0.93	0.93
IRI=10	0.46	1.16	1.16
IRI=15	0.67	1.43	1.43
IRI=20	0.98	1.78	1.78
Graveling US$/ cu.meter	5.0	15	40
Grading US$/ km	200	600	2000
Standards			
Optimum number of grading/year			
for ADT=50	5	3	2
ADT=100	10	4	3
ADT=150	14	6	5
ADT=200	19	8	6
ADT=300	23	10	8
Gravelling threshold (ADT) vpd	10	25	45

Note: The above grading frequencies apply to a gravel surface having an average rate of roughness progression of 0.14 m/km per 1,000 vehicles, and will result in a maintenance level of service corresponding to an average 5 to 6 m/km IRI throughout the year.

COMPARISON OF OPTIMAL BLADING FREQUENCY AND GRAVELING THRESHOLD

To illustrate the differences in maintenance standards that may occur between two widely different environments, a comparison was made using the results of two studies on optimal grading frequencies for Gabon and northeastern Brazil. In both cases, vehicle operating costs were calculated with the HDM III model (*6,7*), duly calibrated for local conditions. Assuming a lateritic gravel wearing course for both cases, the optimal blading frequency was taken as the value that yielded the maximum net present value, discounted at 10 to 12 percent. Table 2 gives the results of the comparison and shows, for example, that for an average traffic volume of 100 vehicles per day, the appropriate grading frequency would be 10 times a year under Brazilian conditions and only 3 to 4 times a year under Gabonese conditions. The corresponding maintenance level of service was an average 4 to 5 m/km IRI for Brazil and an average 6.5 to 7 m/km IRI for Gabon.

Regarding graveling operations, the sheer difference in unit cost for graveling between Gabon and Brazil had a significant impact upon the graveling threshold. The cost of providing 1 m^3 of gravel in Gabon (when borrow pits are readily available) is about U.S.$15, as compared with a cost in Brazil of about U.S.$5 under similar material availability conditions. Calculations show that a cost ratio of this magnitude (about 3) would entail a graveling threshold ratio varying between 1.5 and 2, depending on the rate of roughness progression of the earth road before graveling is carried out. In other words, if graveling were justified in Brazil whenever the ADT reached 50 vehicles, such justification in Gabon would only occur for an ADT between 75 and 100 vehicles.

CONCLUSIONS

A comprehensive maintenance policy embodying appropriate standards for grading frequencies and graveling thresholds cannot be properly formulated unless due consideration is given to local conditions, in particular, to traffic volumes, materials resources specifications, and unit costs of blading and graveling operations. The optimum level of service to be aimed at, in terms of year-round average roughness on the network, cannot be determined by simply transferring maintenance standards from one country to another country or from one geographical region within a country to another. For example, blading frequencies applicable in one country may be well above the optimum values in another country, leading to substantial economic losses should such standards be transferred without an analysis of local conditions.

Management of unpaved road requires not only reliable traffic volume data and unit costs of maintenance activities but also regular condition surveys aimed at assessing surface material properties and the rates of roughness progression for the major types of wearing course materials constituting the unpaved road system. The reliability of factors influencing maintenance service levels for unpaved roads suggests several distinct maintenance standards or strategies that should be evaluated for each specific set of cost and material resources parameters peculiar to a region.

REFERENCES

1. Harral, C., and A. Faiz. *Road Deterioration in Developing Countries: Causes and Remedies.* The World Bank, Washington, D.C., 1988.
2. Patterson, W. D. O. *Road Deterioration and Maintenance Effects.* World Bank, Johns Hopkins Press, 1987.
3. Callao, R. A. *HDM Manager Version 2″.* Transport Division, The World Bank, Washington, D.C., 1993.
4. Parsley, L. L., and R. Robinson. *The TRRL Road Investment Model for Developing Countries (RTIM2).* TRRL Laboratory Report 1057, Transport and Road Research Laboratory, Crowthorne, Berkshire, England.
5. Liautaud, G. Le Comportement des Routes en Afrique Occidentale et Centrale: Synthese de 20 Ans d'Observations. World Bank, Washington, D.C., 1993.
6. Watanatada, T., C. G. Harral, W. D. O. Patterson, A. M. Dhrareshwar, and K. Tsunokawa. *The Highway Design and Maintenance Standards Model, Volume 1: Description of the HDM-III Model.* World Bank, Washington, D.C., 1987.
7. Watanatada, T., C. G. Harral, W. D. O. Paterson, A. M. Dhareshwar, A. Bhandari, and K. Tsunokawa. *The Highway Design and Maintenance Standards Model, Volume 2: User's Manual for the HDM-III Model.* World Bank, Washington, D.C., 1987.

Publication of this paper sponsored by Committee on Low-Volume Roads.