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Unpaved Roads' Roughness Estimation by Subjective Evaluation

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Road agencies need to estimate road roughness when determining the economic evaluation of proposed maintenance and upgrading options, and in pavement management systems for planning and programming purposes. Instrumented measurement of roughness is desirable, but when instrumented measurement is not feasible, for example in the case of unpaved roads, recourse must be made to subjective estimation. This note presents two approaches to subjective estimation, both based on the World Bank's work in the development of the Highway Design and Maintenance Standards Model,(1) HDM-III, and the forthcoming Highway Development and Management Model, HDM-4.

INTRODUCTION

Roughness is irregularity of the road surface. It affects the operation of a vehicle – safety, comfort and speed of travel – and the rate of wear of vehicle parts. By extension, it impacts on vehicle operating costs, and hence on the economic evaluation of proposed road maintenance and upgrading expenditures. Roughness is measured using the International Roughness Index (IRI) which is a mathematically defined summary statistic of the longitudinal profile in the wheelpaths of a traveled road surface. The IRI describes a scale of roughness which is zero for a true planar surface, increasing to about 2 for paved roads in good condition, 6 for a moderately rough paved roads, 12 for a extremely rough paved roads, and up to about 20 for extremely rough unpaved roads.

On paved roads, roughness increases continuously over a year if maintenance is not applied. Roughness is generally measured with instruments, and one measurement on a paved road is sufficient to characterize the average annual roughness. On unpaved roads, however, roughness varies over a year as a function of the season, the changing location of the wheelpaths chosen by the vehicles, and the number and the effects of gradings and other maintenance activities. Therefore, a roughness measurement at a given point in time is not sufficient to characterize the average annual roughness of unpaved roads. The fragility of roughness measurement instruments makes them unsuitable for deployment on unpaved roads, hence road agencies are forced to define average annual road roughness of unpaved road by other means, for example by subjective methods.

The Objective of this Note is to present two methods of estimating the roughness of unpaved roads by subjective methods, both based on the World Bank's work in connection with the development of the HDM models. One ('The Guidelines') is based on the World Bank's 'Guidelines for Conducting and Calibrating Road Roughness Measurements' ([2]) and the other on the 'Limiting Speed' approach, based on field measurements in Brazil and Australia ([1]).

THE GUIDELINES

The World Bank Technical Paper Number 46 titled "Guidelines for Conducting and Calibrating Road Roughness Measurements" (2) by M. Sayers, T. Gillespie, and W. Paterson presents guidelines for the estimation of roughness of unpaved roads by subjective evaluation that can be summarized as follows.

The method provides adjective (and some quantitative) descriptions of the road surface conditions and ride sensations representative for several points on the IRI roughness scale. These descriptions enable an observer traveling in a vehicle, and occasionally stopping to inspect the road, to recognize the conditions and to estimate the roughness.

The accuracy of the method generally varies with the experience of the observer. Experienced observers will usually estimate roughness with accuracy within 2 to 3 m/km, or about 30%, while inexperienced observers may have errors of 2 to 6 m/km, or about 40%. The estimates of IRI are therefore approximate and this method should not be used when mechanical means are appropriate.

The following table provides a series of descriptors for selected levels on the roughness scale. These describe the typical categories of road, surface shape defects, ride sensation, and typical travelling speed associated with each given roughness level. The observer is expected to use all these to make an objective assessment of the roughness of the road while travelling along it. The most objective description relates to the surface shape defects, which are expressed as a range of tolerance under a 3m straightedge; these can only be assessed by a pedestrian inspector.

Roughness Range (IRI)	*Road Description*
1.5 to 2.5	*Recently bladed surface of fine gravel or soil surface with excellent longitudinal and transverse profile (usually found only in short lengths).*
3.5 to 4.5	*Ride comfortable up to 80-100 km/h, aware of gentle undulations or swaying. Negligible depressions (e.g. < 5mm/3m) and no potholes.*
7.5 to 9.0	*Ride comfortable up to 70-80 km/h but aware of sharp movements and some wheel bounce. Frequent shallow-moderate depressions or shallow potholes (e.g. 6-30mm/3m with frequency 5-10 per 50m). Moderate corrugations (e.g. 6-20mm/0.7-1.5m).*
11.5 to 13.0	*Ride comfortable at 50km/h (or 40-70 km/h on specific sections). Frequent moderate transverse depressions (e.g. 20-40mm/3m-5m at frequency 10-20 per 50m) or occasional deep depressions or potholes (e.g. 40-80mm/3m with frequency less than 5 per 50m). Strong corrugations (e.g. > 20mm/0.7-1.5m).*
16.0 to 17.5	*Ride comfortable at 30-40 km/h. Frequent deep transverse depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 5-10 per 50m); or occasional very deep depressions (e.g. 80mm/1-5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions except the worst.*
20.0 to 22.0	*Ride comfortable at 20-30 km/h. Speeds higher that 40-50 km/h would cause extreme discomfort, and possible damage to the car. On a good general profile: frequent deep depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 10-15 per 50m) and occasional very deep depressions (e.g. > 80mm/0.6-2m). On a poor general profile: frequent moderate defects and depressions (e.g. poor earth surface).*

It is important to realize that roughness is related only to vertical changes in the level of the road in the wheelpaths of the vehicle, and that the superficial appearance of the surfacing can sometimes be misleading. Patches in the surfacing, or a coarse surface texture which results in loud tire noise may mislead the observer to overestimate roughness. Alternatively, a defect-free surface or a recent reseal may mislead the observer to underestimate the roughness if the road is very uneven. The observer must therefore become attuned to vertical surface irregularities. The characteristics used to describe surface shape in this table are:

· *<u>Depressions</u>: Depressions are dish-shaped hollows in the wheelpaths with the surfacing in-place (by corollary, this includes humps of similar dimensions).*

· *<u>Corrugations</u>: Corrugations are regularly spaced transverse depressions usually across the full lane width and with wavelength in the range of 0.7 to 3.0 m.*

· *<u>Potholes</u>: Potholes are holes in the surface caused by disintegration and loss of material, with dimensions of more than 250 mm diameter and 50 mm depth.*

The pothole size is indicated by the maximum deviation under a 3m long straightedge, e.g., 6-20mm/3m, similar to a construction tolerance. The frequency is given by:

- *Occasional: 1 to 3 per 50 m in either wheelpath*
- *Moderate: 3 to 5 per 50 m in either wheelpath*
- *Frequent: more than 5 per 50 m in either wheelpath*

· *Ride: The "comfortable" ride is relative to a medium-size sedan car with regular independent shock-absorber suspension. Ride varies from car to car so detailed descriptions are generally not transportable, but an observer can quickly become "calibrated" for a given vehicle. The ride sensation can be described by the observer at a speed relevant to the level of roughness being defined. These descriptions can help considerably, but they must be developed for local conditions and vehicle types.*

· *Travel Speed: Travel speed indicate common travelling speeds on dry, straight roads without traffic congestion, with due considerations of care for the vehicle and comfort of the occupants.*

LIMITING SPEEDS

On the HDM models ([2]), the predicted vehicle speed on a given road is a probabilistic minimum of a number of limiting or constraining speeds and one of the limiting speeds (VROUGH) is associated with ride severity and comfort and is based on road roughness.

VROUGH is the limiting speed related to pavement condition, independent of all other factors: gradient, engine power, braking capacity, curvature, physiological, economic, safety, and other considerations.

For each roughness level, VROUGH represents the maximum speeds function of roughness alone and can be used to estimate road roughness on level, straight, and wide roads where the maximum speeds achieved by vehicles is mostly a function of road roughness. If speeds are being limited (constrained) by the vertical gradient, horizontal curvatures, engine power, or other psychological or economical considerations, VROUGH will not give a proper indication of the road roughness.

The following table presents the resulting values of VROUGH for a series of roughness levels as estimated by the HDM-III model based on the Brazil-UNDP Study conducted between 1976 and 1981.

Maximum Speeds Function of Roughness (km/h)						
Cars	Utilities	Buses	Light Trucks	Medium/ Heavy Trucks	Articulated Trucks	Rough_ ness (IRI)
136	125	111	102	93	68	6
102	94	84	76	70	51	8
82	75	67	61	56	41	10
68	63	56	51	46	34	12
58	54	48	44	40	29	14
51	47	42	38	35	26	16
45	42	37	34	31	23	18
41	38	33	30	28	21	20

The following table presents the resulting values of VROUGH for a series of roughness levels as estimated by the HDM-4 model based on the Australia Study (McLean, 1991).

Maximum Speeds Function of Roughness (km/h)						
Cars	Utilities	Buses	Light Trucks	Medium/ Heavy Trucks	Articulated Trucks	Rough_ ness (IRI)
106	105	105	105	94	84	6
80	78	78	78	71	63	8
64	63	63	63	57	50	10
53	52	52	52	47	42	12
46	45	45	45	40	36	14
40	39	39	39	35	31	16
35	35	35	35	31	28	18
32	31	31	31	28	25	20

The Australia Study is the most recent one and incorporates new technology vehicles, while the Brazil Study includes vehicles with 70's technology, therefore, the Australia Study results are recommended over the Brazil Study.

Information regarding typical unpaved road roughness predicted by the HDM-III model road deterioration equations can be found on the Rural Transport Technical Note 1.

TO LEARN MORE

1. Watanatada, Thawat, et al. 1987. The Highway Design and Maintenance Standards Model. Volume 1, Description of the HDM-III Model. The World Bank, Washington, DC

2.Michael W. Sayers, Thomas D. Gillespie, and William D. O. Paterson 1986. Guidelines for Conducting and Calibrating Road Roughness Measurements. World Bank Technical Paper Number 46. The World Bank, Washington, DC.

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