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The Implication of the International Road Roughness Experiment for Belgium

M. B. GORSKI

ABSTRACT

The International Road Roughness Experiment (IRRE) has had a double impact on the current practice of roughness evaluation. First it has upgraded the moving average statistics (CP) developed and used in Belgium for the assessment of evenness. The latter is based on a dynamic profilometer monitoring of the longitudinal profile of the road surface. Its scale of representation can be interpreted from different points of view (acceptability criteria associated with comfort and security, maintenance levels associated with structural integrity, and methods of assessment such as visual inspection). The link between CP scale and the roughness measures generated by response-type road roughness measurement systems (RTRRMS) adds a new dimension to the interpretation of the Belgian scale. It enables roughness to be predicted or estimated in terms of vehicle behavior because the RTRRMS results are expressed in scales simulating quarter-car response. The second impact is a consequence of the first. The IRRE demonstrates the need for further development of roughness evaluation and enhances the pavement management systems approach developed in Belgium in such a way that economic considerations can be assessed through relations between roughness and users' costs.

In order to appreciate the consequences of the International Road Roughness Experiment (IRRE), particularly for Belgium, a brief but complete review of the Belgian state of the art and current practices is necessary. The objectives of road roughness evaluation must be recalled, together with the methodology and the roughness scale used in Belgium. The acceptance of the latter will be stated. In this sense, the IRRE is more than just an exercise aimed at establishing a reference calibration procedure. It has enhanced the vision of what a roughness scale is designed for. In the case of the roughness (or evenness) scale developed in Belgium, a new dimension has been added to its interpretation. Beyond the ability of the roughness scale to contribute to problems linked with the maintenance of structural integrity of roads or with the comfort and safety of road users, the IRRE has opened the door to problems

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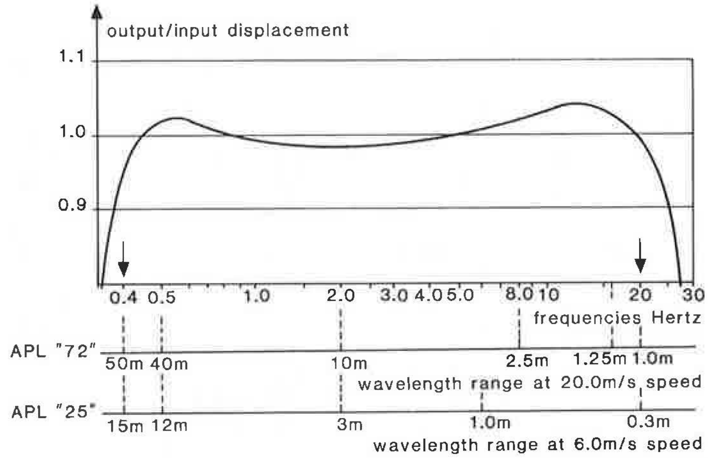

FIGURE 3 Frequency response of APL trailer to displacement input.

The effectiveness of this feature is actually verified in the course of the adjustment and calibration of each APL trailer on the shake table: the hitch system of the trailer is itself excited by a vibrator, and it is ascertained that this excitation has no influence on the transducer's response. The trailer is considered to be correctly adjusted only when the transducer response to an excitation of the hitch is less than 0.2 percent of the response to an excitation of the measuring wheel with the same amplitude. Each APL trailer is adjusted in this manner at construction, and those used in Belgium are recalibrated periodically (every 2 to 3 years).

Today, the calibration procedures are further refined by verifying the linearity of the transfer function of the APL trailer under signals representing the true conditions of very good and very poor road profiles, in addition to the conventional harmonic type of response curve that is also being determined. Furthermore, no test tracks are imperatively required.

Method of Measurement

Because the amplitude transfer function of the APL is constant to within 5 percent in the frequency range 0.5 to 20 Hz (Figure 3), the wavelength range of the defects detected by the APL, which is proportional to the speed of measurement, is as follows: (a) 1 to 40 m at 72 km/h (20 m/s) on motorways and other roads according to traffic possibilities; (b) 1 to 30 m at 54 km/h (15 m/s) on roads with limited traffic possibilities (cross-town links, speed limits of 60 km/h, bends, etc.); and (c) 0.3 to 15 m at 21.6 km/h (6 m/s) on construction sites, and rural roads.

Because the speed of measurement cannot be increased to infinity, it is, of course, admitted that the APL cannot completely describe a road profile in the sense that it certainly is no absolute leveling device. As far as is known, this is true for all dynamic road profilometers; however, this is not a hindrance. Indeed, those involved in maintenance and rehabilitation of road networks are essentially interested in the profile defects that can affect road users and the modification of which does not necessitate a modification of road alignments. With this objective in mind, the APL is perfectly capable of providing a sufficiently accurate image of the road, for all practical purposes, with the localization and quantification of irregularities up to 40 m long.

The results of measurement are processed to coefficients of evenness, CP (Belgian method, BRRC) (3).

This analysis consists of producing a geometric representation of the measured longitudinal profile. The mean surface area of the deviation of the measured profile from a reference line formed by the same profile after smoothing is determined (average of bump and hollows). This area is calculated by sampling the measured profile at intervals of 1/3 m or 1/6 m (for the speed of 21.6 km/h).

This calculation leads to the definition of a coefficient of evenness (CP), the dimensions of which are 1 CP = 10^{-5} m (10^4 mm²/km). It is determined in relation to the base length chosen for smoothing and the division of the scanned section into blocks of equal length, which has been set at 100 m.

Interpretation of CP Values

The coefficient of evenness for a given base smoothing length and a given block length is directly proportional to the mean surface area of the deviation of the measured longitudinal profile from the smoothed profile. The higher the coefficient of evenness for a given base length and a given block length, the poorer the quality of longitudinal evenness.

The use of the sliding-mean concept (moving average) to calculate CP values (smoothing of the profile) amounts to filtering the measured longitudinal profile. The result of this filtering is to eliminate the deformations with a longer wavelength than the base length chosen for smoothing. Thus the effect of short-span deformations is separated from that of long-span deformations, which makes it possible to characterize and locate the detected irregularities.

The use of one and the same evenness scale (CP values restricted to spans of 2.5 m and to medium spans of 10 to 15 m) makes it possible to ensure a transition between the "zero point" (acceptance test) and later tests carried out for monitoring purposes (4).

Acceptability Criteria

As stated earlier, the scale of evenness coefficients makes it possible to distinguish short-span irregularities (base lengths of the order of a few meters) from relatively longer medium-span deformations (base lengths of the order of 10 to 15 m).

A remarkable fact appears when comparing the different acceptability thresholds for evenness set in the various scales obtained for the different apparatus used in Belgium and in various other countries (Great Britain, France, Switzerland): they are in agreement when translated into values on the scale of coefficients of evenness. This holds true when comparing the acceptability thresholds for deformations with short spans (< 2.5 m) (Table 1) and with mean spans (Table 2). This was established through experiments on Belgian road sections designed to correlate CP values with the results obtained on the same sections by the APL from the Laboratoire Central des Ponts et Chaussées (France), the Swiss Winkelmesser, the Laser Profilometer from the Transportation and Road Research Laboratory (TRRL) (United Kingdom), and the Viagraph of the Belgian Road Administration.

The existence of such substantial consistency in the choice of acceptability thresholds can lead to the choice of acceptance level for contractual purposes. This is currently taking place in Belgium.

Management System for the Maintenance and Strengthening of Roads

Evenness measurements are integrated into a management system for the maintenance and strengthening of roads. The Belgian national report on Question II at the XVIIth Permanent International Association of Road Congresses (PIARC) World Road Congress (5) contains a concise description of the road assessment method that is currently being set up.

The final objective is to develop a management system for the maintenance and strengthening of the motorways and roads administered by the Roads Department of the Ministry of Public Works. The maintenance decision is based on a ranking system of evaluation.

The quality of the routes making up the motorway and road network is characterized by an overall index that reflects various assessment parameters collected by high yield apparatus and a factor representing the condition of the road surface. There is an intervention threshold for each of these data while the decision to carry out maintenance work to replace the pavement or to provide stronger structural elements is taken on the basis of the overall index, which characterizes both the quality of the route (or road link) under consideration and the type of intervention required (intervention affecting the surface, pavement, or structure). In the event of an intervention affecting the pavement or the structure, an individual project must be designed. The preparation of this project may require further assessment (borings through the structure, sampling of materials, evaluation of the bearing capacity of the soil etc.) in order to make a more thorough diagnosis.

The Belgian Road Administration has adopted the CP scale, which has been divided into five classes for the management of maintenance and strengthening activities on the Belgian state road network. The intervention thresholds for each base length selected for the calculation of CP correspond to the limits between the third and fourth class of evenness (Table 3 gives the partial quality criteria that are currently being used). It should be noted that visual assessment of road roughness versus the CP scale has been evaluated.

During a visual inspection campaign conducted in several Belgian state road maintenance districts, inspectors were asked to give visual appreciation of evenness ("good" or "poor"). The visual survey was conducted on foot by four independent teams of inspectors. A comparative study of the coefficients of evenness measured with the APL for the respective base lengths of 2.5, 10, and 30 m has shown that the judgment of visual inspection is best reflected by the CP_{10m} scale. The class of evenness visually categorized as good corresponds to Class A of the CP scale (Table 3), whereas the class categorized as poor corresponds with class B of the CP scale.

The Belgian Road Research Centre has conducted surveys of the national network to monitor road roughness on behalf of the Belgian Road Administration.

BELGIAN PARTICIPATION IN THE IRRE

The Belgian Road Research Centre has cooperated with the Laboratoire Central des Ponts et Chaussées of France by participating in the IRRE. The profile measurements made by a French APL were translated to the Belgian scale. The experiment consisted of comparing the results of measurements made with various

TABLE 1 Acceptance Level Thresholds Expressed in CP Values for Short Spans (< 2.5 m)

Hectometric Section	HSP Laser Profilometer, TRRL (Base 3 m) Threshold 1 mm $r^b = 0.916$	APL LCPC Evenness Marks 1 - 3.3 m Threshold 6.5 $r = 0.920$	BI TRRL 32 km/h Threshold 17.6 ARV (mm/s) $r = 0.928$	Swiss Winkelmesser Threshold $\bar{s}_w = 2.2‰$ $r = 0.776$
Evenness coefficient, CP[a] Base 2.5 m	32	34	32 (65 < v < 80 km/h)	27 (v < 80 km/h)

[a]Identical for all of the three APL speeds of measurement: 6, 15, and 20 m/s.
[b]r = correlation coefficient.

TABLE 2 Acceptance Level Thresholds Expressed in CP Values for Mean Spans (10 - 15 m)

Hectometric Sections	Viagraph Belgian Road Administration Threshold		HSP Laser Profilometer, TRRL (Base 10 m) Threshold 2.6 mm $r^b = 0.922$	APL LCPC Evenness Marks 3.3 - 13 m Threshold 7 (NR Inquiry) $r = 0.993$
	20 CDI	10 CDI		
Evenness coefficients, CP[a]				
Base, 10 m	111	93	90	88
Base 15 m (restricted to 21.6 km/h)	124 (r = 0.806)	103	–[c]	–[c]

[a]Identical for all of the three APL speeds of measurement: 6, 15, and 20 m/s.
[b]r = correlation coefficient.
[c]Not determined.

TABLE 3 Longitudinal Evenness, Classes and Limit Values for Coefficients of Evenness

Classes and Limit Values	CP_{40}/CP_{30}	CP_{10}	$CP_{2.5}$
Class A (very good)	< 160	< 80	< 40
Class B (good)	160 << 320	80 << 160	40 << 80
Class C (average)	320 << 480	160 << 240	80 << 120
Intervention threshold	480	240	120
Class D (poor)	480 << 640	240 << 320	120 << 160
Class E (very poor)	640 <	320 <	160 <

Notes: For the three base lengths of 40, 10, and 2.5 m and for blocks of 100 m measured with the APL (Belgium) at 20 m/s. Base 40 is replaced by 30 at 15 m/s.

devices on 49 sections of paved and unpaved roads in Brazil representing a wide range of evenness levels. The following devices were used: three Mays meters and one BPR Roughmeter (originating from the United States) used by the Brazilian Transportation Planning Agency (GEIPOT); one Bump Integrator trailer (United Kingdom), one vehicle-mounted Bump Integrator (United Kingdom), and one National Association of Australian State Road Authorities (NAASRA) meter (Australia) used by the TRRL (United Kingdom); two static profilometers--one conventional telescope and straightedge leveling system (used by GEIPOT) and one TRRL beam (United Kingdom); two dynamic profilometers--the APL (longitudinal profile analyzer) of the LCPC (France); and one General Motors (GM) profilometer (United States) used by GEIPOT.

The computations performed at the Belgian Road Research Centre concerned the APL signals recorded in Brazil at a measurement speed of 72 km/h (20 m/s). The sampling step length used was 1/3 m, and the coefficients of evenness (CP) were determined for 2.5, 10, and 40 m base lengths, which are the conventional values used. The coefficients of evenness were evaluated for hectometric sections. The figures given for the experimental section tracks of asphaltic concrete (CA), surface treatment (TS), gravel surfaced (GR), and earth (TE) were obtained from the mean value of three contiguous hectometric blocs, at the beginning of each section track (the test sections were 320 m long).

Linear regressions were also calculated at the Belgian Road Research Centre between the response type road roughness measurement systems (RTRRMS) average rectified velocity (ARV) numerics (for each surface type and speed of measurement) and the CP for the three bases $CP_{2.5}$, CP_{10}, and CP_{40}.

Correlations defined by the correlation coefficient are given in Table 4 for the purpose of illustrating the results of comparison with the response-type road roughness measurement systems driven at the speed of 50 km/h. The results of comparison versus the ARV scale [average rectified slope (ARS) = ARV x 360/v, where v is speed in km/h; ARV is in mm/s; ARS is in mm/km] reveal the following:

- The coefficients of correlation decrease in general when the base of determination of the CP value increases.
- Significant and high values are obtained for CP (base 2.5 m) with all RTRMMS devices on all test sites and for all the test speeds.
- By merging all data belonging to a given RTRMMS device and calculating the linear regression coefficients and the correlation coefficient for each test speed, the effects of speed and site factors that could influence a calibration plot needed to estimate the CP 2.5 numerics from measurements made with one of the RTRMMS can be expected to be evaluated. This case has been examined for both the Mays meter 2 and the bump integrator trailor. It has been found that the best fit for the CP 2.5 values is obtained through correlation with both devices traveling at 50 km/h and that no site type influences the correlation. The two examples are illustrated in Figure 4. Both correlations are significantly high ($r > 0.95$) and yield quasi-identical linear regression equations.

A comparison was also made with the Quarter-car Index (QI) scale. The Quarter-car Index was accepted as a standard measure of roughness on a previous Brazilian project (research on the interrelationships between the costs of highway construction, maintenance, and utilization, United Nations Development Program). Figure 5 shows the correlation between QI determined for right and left tracks on all sites (CA, TS, GR, and TE) measured with the TRRL beam and the CP 2.5 values obtained from the APL. The value of the coefficient of correlation reveals a significant linear relationship between the two scales without systematic effects induced by surface types.

The CP numerics have been demonstrated to be well correlated with both the ARV (ARS) scale and the QI

TABLE 4 Correlation Coefficient Values for the APL Results Expressed in Coefficient of Evenness and the RTRRMS (ARV) Measures Made at 50 km/h

	MM 01	MM 02	MM 03	BI CAR	NAASRA	BI TRL	BPR
Asphaltic Concrete Test Sites							
$CP_{2.5}$	0.9663	0.9369	0.9558	0.9803	0.9776	0.9678	0.8929
CP_{10}	0.9543	0.9486	0.9711	0.9292	0.9507	0.8836	0.8440
CP_{40}	0.8677	0.8823	0.8940	0.8475	0.8697	0.7877	0.7954
Test Sites with Surface Treatment							
$CP_{2.5}$	0.9717	0.9615	0.9591	0.9787	0.9818	0.9795	0.8770
CP_{10}	0.8451	0.8479	0.7931	0.8505	0.8429	0.7995	0.7255
CP_{40}	0.0331	0.0695	0.0574	0.0609	0.0517	0.0255	0.0656
Gravel Surfaced Test Sites							
$CP_{2.5}$	0.9659	0.9695	0.9716	0.9599	0.9652	0.9675	0.8667
CP_{10}	0.9312	0.9356	0.9199	0.9331	0.9389	0.7996	0.8809
CP_{40}	0.3547	0.3479	0.2644	0.3661	0.3542	0.3985	0.5646
Earth (Clay) Surface Test Sites							
$CP_{2.5}$	0.9452	0.9517	0.9523	0.9289	0.9510	0.9091	0.9435
CP_{10}	0.9226	0.9486	0.8466	0.9350	0.9398	0.9720	0.9701
CP_{40}	0.5111	0.5791	0.4299	0.7325	0.6091	0.6813	0.7260

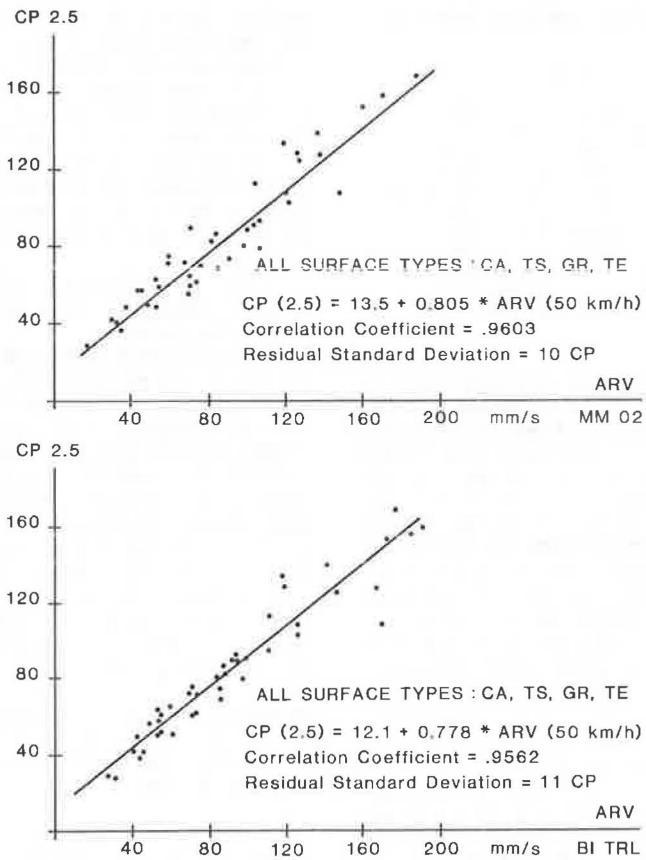

FIGURE 4 Comparison of APL 72 CP (2.5) values with RTRRMS measures made at 50 km/h.

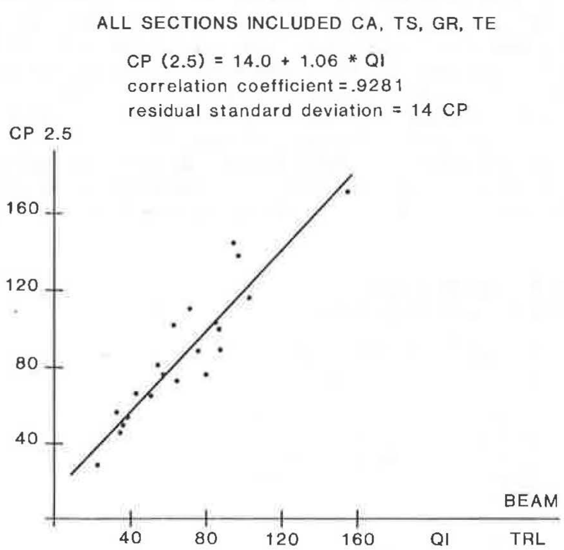

FIGURE 5 Comparison of QI values calculated from TRRL beam profiles with CP (2.5) derived from APL 72 signal.

scale, provided that a short basis of 2.5 m was used in its determination. It is expected that the choice of another basis, perhaps 3 m, could yield higher correlation coefficients with the QI scale.

In the same manner, optimization of correlation with the ARV scale obtained with different speeds could probably be achieved with a corresponding adjustment of the choice of the base for the CP determination. Nevertheless, from the practical purpose of comparing the different scales, the CP 2.5 has been demonstrated to be an acceptable roughness indicator. Of all the APL results, it is the CP 2.5 m numerics that produced the best correlation with the RTRRMS.

The issue of the experiment regarding the APL measuring equipment and the CP statistics associated as a roughness scale can be stated as follows: the APL trailer is validated as a profilometer against rod and level and that it falls within the Class 2 of measurement methods enabling the estimation of reference average rectified slope (RARS) using an independently calibrated instrument (2). In the particular situation in which CP 2.5 statistics are available for the APL, it can be used to estimate RARS using correlated statistics.

CONCLUSION

The IRRE has demonstrated that in order to carry a standard procedure to calibrate the RTRMMS, true roughness values must be assigned to the sites used as references for the measuring devices. It is commonly accepted that this true roughness numeric must be defined by a statistic based on profile geometry. This has triggered the interest in profilometric devices and has set a new trend in research concerning the performance of currently available devices and future needs. Among these, projects are underway at the Belgian Road Research Centre to thoroughly study the compatibility between topographic survey and dynamic profile measurement using the APL, particularly as an automatic leveling device during

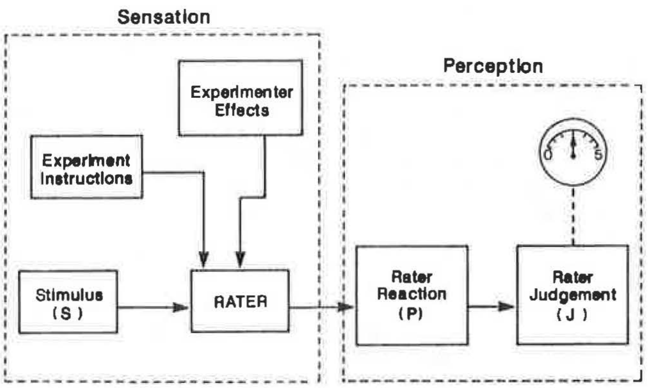

FIGURE 1 Systematized concept of rating.

suggested ways to avoid them) were kept in mind during the planning stages of the study so as to minimize or do away with them completely:

1. The error of leniency, which refers to the constant tendency of a rater to rate too high or to low for whatever reasons; remedied by statistical transformation of rater variance.
2. The halo effect, which refers to the tendency of raters to force the rating of a particular attribute in the direction of the overall impression of the object rated; avoided by accuracy and exactness in definitions.
3. The error of central tendency, which refers to the fact that raters hesitate to give extreme judgments of stimuli and tend to displace individual ratings toward the mean of the group; taken care of by introducing the judgment continuum as distinct from the sensory continuum.
4. The error of anchoring, which refers to the endpoints of the scale being rated; overcome by using accurate definitions.

EXPERIMENTAL DESIGN

In laying out the experiment design, the first step was to look through the "window" of applicability, the inference space. This is defined as that space within which the results of the study may be applied. When selecting the panel, if a wide distribution of members from various parts of Texas are chosen randomly, then the panel could be considered as representative of the people of the state of Texas.

Considerations such as the type and number of variables to include in the statistical analysis relating the profile data to the panel rating data are significant for future applications of the serviceability formulas. It is important to choose pavement test sections that include a wide range of wavelengths, as well as to consider this range of wavelengths as they influence Texas raters' judgments of ride quality. With these ideas in mind, 17 factors, along with their corresponding levels, were enumerated by a research team and a group of pavement engineers from the Texas SDHPT who were familiar with pavement roughness. To reduce the complexity of the analysis, some of the factors were studied in screening experiments and the remainder were studied in the main rating sessions.

SCREENING EXPERIMENTS

The following factors and corresponding levels were considered to be studied in screening experiments:

	Level	
Factor	0	1
Vehicle type	Car	Van
Position in car	Front	Rear
Rater's age	< 35 years	> 35 years
Rater's sex	Male	Female
Time	Night	Day

Factors associated with the type of pavement sections are listed as pavement variables as follows:

	Level	
Factor	0	1
Pavement type	Black	White
Surface texture	Coarse	Fine
Location of road	Rural	Urban
Maintenance	Unpatched	Patched
Functional class	Low	High
Surroundings	Poor	Good
Road width	Narrow	Wide
Lane position	Inside	Outside

In order to simplify the analytical procedure and also to make the computational procedure amenable to mainframe computer capacities, it was decided to drop the factors (a) functional class and (b) lane position. A panel of four engineers surveyed existing sections to obtain information about these factors using a form designed for this purpose. Definitions and clarifications as to the levels of each factor were provided. The need to locate more sections was realized. The objective was to fill the full factorial (2^6 or 64 sections) as completely as possible, recognizing that certain sections are impossible to exist or simply do not exist and then to run analyses of variance (ANOVAs), knowing that the factorial is not balanced. The sections used in the factorial for screening the experiments are shown in Figure 2.

			Patched				Unpatched			
			Wide		Narrow		Wide		Narrow	
			Good	Poor	Good	Poor	Good	Poor	Good	Poor
White	Fine	Urban					B4, B17			
		Rural					B6, B7, B16			
	Coarse	Urban		B24, B15			B2, B8	G1, B20		
		Rural	B12, B13				B3, B11	B14		
Black	Fine	Urban	A7, A20	A6, A25	A3	A9	5, B19	A11	A5	
		Rural		G2	A8	40, A10	7, 33	A4, A15	A14	35, 44
	Coarse	Urban	A24, C1	A1	A23	A13	19, 23, B18	37, A2	A21	15
		Rural	A22	A18, B1	39, A16	6, B22	36, 9	A12, A19	8, 38	2, 3

FIGURE 2 Sections used in the factorial for screening experiments.

MAIN RATING SESSIONS

The factors considered for analysis were

1. Rater profession,
2. Function in car,
3. Vehicle wheelbase,
4. Time of day,
5. Rater fatigue, and
6. Vehicle speed.

Selection of the Rating Panel

The selection of the panel was dictated by the strictest considerations as follows:

1. Panelists should represent the typical Texas traveling public,
2. Panelists should have a wide range of highway travel experience, and
3. Panelists should have no undesirable (biased) attitudes toward road travel in general.

Members of the rating panel consisted of personnel from the State Department of Highways and Public Transportation, the Center for Transportation Research (CTR), and volunteers from the general public.

The maximum size of the rating panel was 20, with 15 raters (5 vehicles, 3 to a car) and 5 drivers. The rating panel included both men and women of different ages with a wide range of driving and riding experience.

Selection of Vehicles

Two types of vehicles were selected to study the effect of vehicle wheelbase length: a subcompact model (Plymouth Horizon) and a mid-sized model (Mercury Zephyr and Ford Fairmont). These vehicles were taken as representative of typical vehicles owned and operated by an average middle class Texan. Two subcompacts and three mid-sized vehicles were used in the main rating sessions. Equal wear and tear of the vehicles (within each size category) was considered in their selection.

Selection of Sections

For the main rating sessions, the specific combination of characteristics in a section was not so important as the range of roughness of the section itself. The idea here is that to be able to predict serviceability indices from different kinds of roughness characteristics, it is essential to incorporate sections with these (and all other possible) characteristics. One important need, therefore, was to obtain as wide a range of roughness (serviceability indices) as possible. Because the existing pavement sections did not span the roughness spectrum, it became necessary to launch a search. With this objective in mind, roads in eight counties were surveyed. This search resulted in the location of 100 sections in all 8 counties, 77 of which were flexible and 23 of which were rigid pavement sections.

Rating Sessions

The rating method employed was similar to that used in the screening experiments, except for some improvements. The instructions to the raters were revised, based on experience from the screening sessions as to words or cues that were obfuscating and that raised a number of questions. The same instructions given to drivers in the screening sessions were given to drivers in the main rating sessions. Of course, because the drivers were required to rate the sections according to the experimental plan, they were also required to attend the training session.

A major enhancement in the training session was the use of videotaped instructions. By using videotaped instructions, the researcher hoped to achieve higher reliability through consistency and standardization. Again, the script for the videotape had to be carefully drafted to ensure the minimization of miscues and vague definitions. This technique was also used to alleviate some of the possible errors arising from scale construction such as anchoring effect, and so forth. After the classroom briefing, the panelists were driven over some of the sections. This orientation session was more extensive than the one in the screening experiments. The same rating form (see Figure 3) was used, except for the "age" column.

To analyze the factors vehicle speed and rater fatigue, seven sections with two levels of roughness were chosen, and runs were made corresponding to the levels of the variables. (The "tired" level of the variable rater fatigue corresponded to runs in which raters were at a continuous rating stretch of more than 2 hr, whereas the "fresh" level corresponded to less than 1.5 hr.) Rater profession and vehicle wheelbase could also be included in the factorial. To examine the effect of vehicle wheelbase, raters in the subcompact cars were switched to the mid-sized cars (and vice versa) and thus rated nine sections in both cars. Eight sections were chosen to be rated both in the morning and afternoon so that the effect of time (morning versus afternoon) could be investigated.

Of the 171 sections that were rated, 129 were flexible and 42 were rigid pavement sections. A maximum panel of 20 raters rated these sections in 5 vehicles over a period of 13 days.

Roughness Measurement

The profilometer was set for normal operating conditions, specifically the following:

1. Accelerometer filter wavelength: 200 ft,
2. Sampling frequency: 6.00 in.,
3. Profiling distance: 0.2-mi sections, and
4. Profiling speed: 20 mph.

Roughness measurements were also made using the Mays meter and the SIometer. Runs were made after proper calibration procedures were followed and under normal specified operating conditions.

ANALYTICAL PROCEDURES

Individual rater performances were examined by plotting the mean individual ratings against the mean panel ratings for each rater (Figure 4 shows a typical plot). The mean individual rating represents the average rating (mean over runs) for each section for that rater. The mean panel rating (PSR) is obtained by taking the mean of all the mean individual ratings of all the raters for a particular section. Thus each point on a rater performance graph corresponds to a test section wherein the vertical axis value represents the individual's mean rating for that section and the horizontal axis value represents the mean rating of the panel as a group (for that same section).

construction of relatively thin overlays for rehabilitation of pavements. A precise knowledge of the profile of a road surface needing maintenance is an important asset in determining the choice of technical solution for overlaying.

The maintenance and strengthening management system (PMS) developed in Belgium is based on the comparison of high-yield assessment parameters with the results of visual inspection. Moreover, unlike other management strategies for maintenance and strengthening that are based on the characterization either of the evenness or the bearing capacity of the existing pavement, the proposed system considers both criteria complemented by other parameters for the appreciation of the overall quality of the assessed route (or road link). The interplay of the overall index with the intervention thresholds themselves makes it possible to combine actions--often of a simple or inexpensive nature--that must be carried out locally or urgently (skid resistance) with actions of a general type, taking into account overall budgetary restrictions. In order to justify budgetary allocations, there is a growing need to present the technological arguments together with the economical arguments. This can be provided by the link created between roughness evaluation and users' costs; the roughness scale implemented in the PMS being the CP statistics. This scale can perform a significant estimation of a quarter-car simulation-type based roughness scale.

Road roughness is an important factor in pavement management systems, which are essentially aimed at an economic objective. Using PMS procedures can bring about a retroaction at the technical level conditioned by the sensibility of global rehabilitation costs to certain parameters such as roughness, thus encouraging designers and technicians to produce maximum efficiency. A good understanding of the meaning of roughness in such a context is particularly helpful for Belgian engineering consultants and contractors. In this respect, proper evaluation of experiments carried out by the World Bank in Kenya, Brazil, and India is of primary importance together with knowledge and the ability to use the highway design model. Acquaintance with the CP statistics used for the roughness scale can contribute to the translation of roughness data for use in existing foreign networks. Road roughness is the key interface between road structures and transportation performance.

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