EVALUATION OF THE CAR ROAD METER BY USING THE K-COEFFICIENT

Benjamin G. Fortin

The car road meter designed from Brokaw's concept is a practical and simple instrument that is quite useful in measuring the condition of the road surface through the response of a car as felt by the driver. This apparatus is fast and easy to operate and has a good reliability; therefore, a large network of roads can be covered during the summer season. The riding comfort index (RCI) can be measured safely because the operational speed of the road meter is close to the legal speed.

RIDING COMFORT INDEX

The RCI measured by a road meter is the sum of products of counters' readings by their location (or numerical order). RCI is expressed by the following equation:

$$\Sigma = (e/L)(C_1 + 2C_2 + 3C_3 + \ldots nC_n)$$

where

- Σ = riding comfort index,
- e = correction factor for the car speedometer,
- L = length of the section in miles, and
- C_1, C_2, C_3 = readings of the counter 1, 2, 3, n.

RCI is given as a value per mile at a given speed, normally 40 mph. In Quebec, the calibration of mounted apparatus is done by comparison to a standard car and meter maintained only for this purpose. This seems to be the normal procedure adopted by all users in Canada and the United States.

K-COEFFICIENT

The development of the K-coefficient resulted from a search to find a way to use RCI in a modified or simplified way. Previously, to compare RCI values to those obtained by using the present performance rating (PPR), which involves a panel of observers, we had to transform their values into logarithms. The same was true when comparing RCI values at different speeds for a given vehicle or among vehicles. Furthermore, the province of Quebec is currently evaluating the provincial road network, and values from the road meter were not readily compatible with results from the Benkelman beam. Therefore, by transforming the RCI equation, we came up with a new way of using data from the road meter. As stated previously, the RCI equation is as follows:

$$RCI = (C/L)(C_1 + 2C_2 + 3C_3 + \ldots nC_n)$$

The factor multiplying the counter's value is determined by the location of pairs of segments equidistant about the center. This factor is a multiple of 118 in. and directly proportional to the amplitudes of oscillations.

We can therefore say that

$$RCI = K(d_1C_1 + d_2C_2 + d_3C_3 + \ldots dnC_n) = K\,\Sigma dC$$

where

d = equal distance from center,
C = reading on counter, and
dC = moment of any segment.

However, if we take out the sum of moments from the preceding equation and set it against a resulting moment such as $\Sigma dC = D\Sigma C$, we can get a resulting moment arm D whose value will be $D = (\Sigma dC/\Sigma C)$. The equation of K-coefficient as used in calculation is $K = (\Sigma C/\Sigma dC)$; therefore, we can state that K-coefficient is the reciprocal of the resulting moment arm D.

ROAD METER VARIATIONS

Figures 1 through 3 were plotted from data collected using different road meters installed in the automobiles listed below:

Road Meter	Type of Automobile	Type of Suspension
4	1969 Ford	Heavy-duty, leaf
7	1967 Oldsmobile	Regular, coil
11	1971 Ford	Regular, coil
12	1971 Ford	Regular, coil

The test sections were selected for their wide continuous variation in roughness. However, no data were kept as to the geometric design of the sections, temperature variation during runs, weather, and so forth. Only tire pressure was maintained as recommended by the manufacturers. Each vehicle made double runs at 3 different speeds (30, 40, and 50 mph) on all test sections.

Figures 1 and 2 show the interrelation of values at different speeds for road meters 4 and 7; Figure 3 shows the relation of values at 40 mph for these 2 road meters (Table 1).

K-COEFFICIENT VERSUS RCI

For a given strip of road, the RCI will be expressed as a value per mile, whereas K, being inversely proportional to the average amplitude of roughness, is independent of length.

The K-coefficient is a fraction that normally will range from 0.2 to 1.0, and for practical purposes, the value is multiplied by 100. On the other hand, the values of RCI will start near 100 and increase up to and above 10,000, depending on the counters used.

Unless the surface of the road is relatively good, no correlation should be expected from the K-coefficient and RCI because RCI is determined by the sum of moments, whereas K is the arm of a resulting moment (Fig. 4).

RCI values will be quite dependable for roads with good surfaces but will become erratic as road surfaces get rougher and bumpier. The K-coefficient on the other hand is quite trustworthy for the surface conditions on most roads.

When the surface of the road is rough, the contact on central segments is very short, and counters will skip count. This undesirable condition will be detrimental to RCI values but will work in favor of the K-coefficient. Under adverse conditions, RCI values will be completely false, whereas K will exhibit a valid value (Fig. 5).

ADVANTAGES OF THE K-COEFFICIENT

The K-coefficient can be used advantageously in evaluating and interpreting data collected from the road meter.

Figure 1. Road meter 4 data.

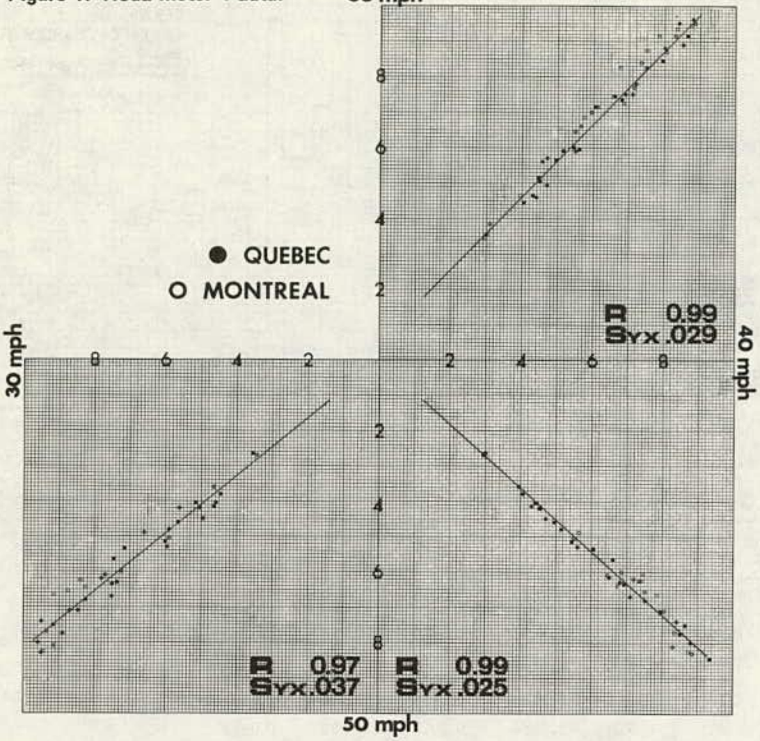


Figure 2. Road meter 7 data.

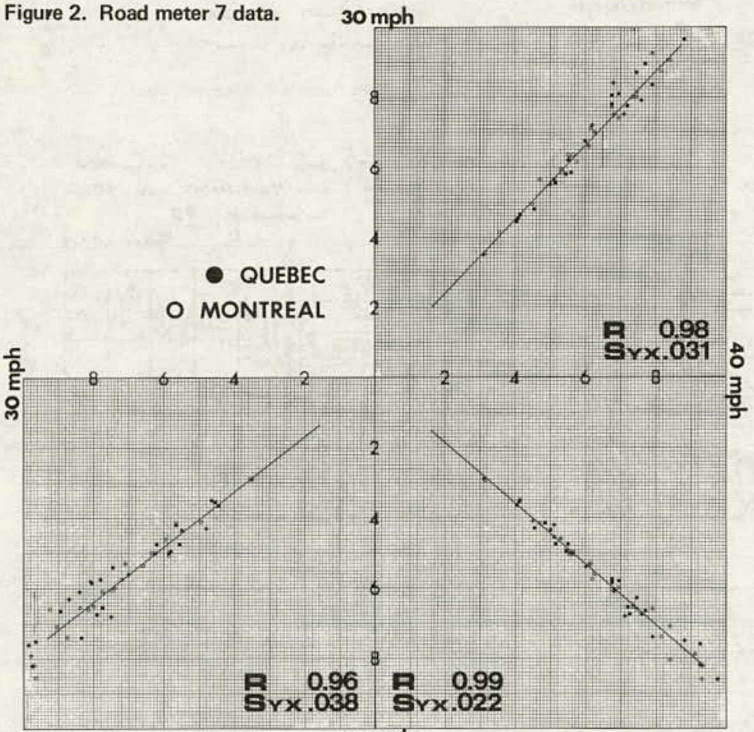


Figure 3. Comparison of road meters 4 and 7.

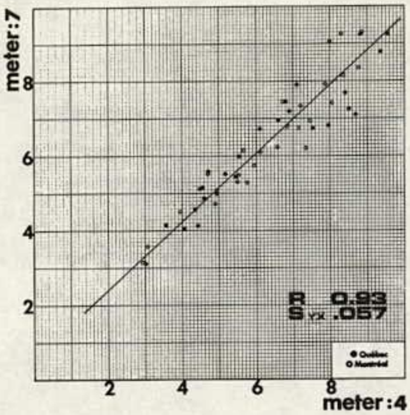


Figure 4. Comparison of RCI and K-coefficient.

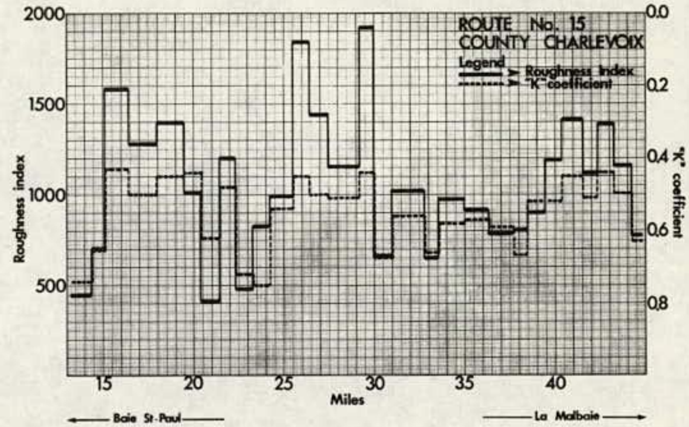
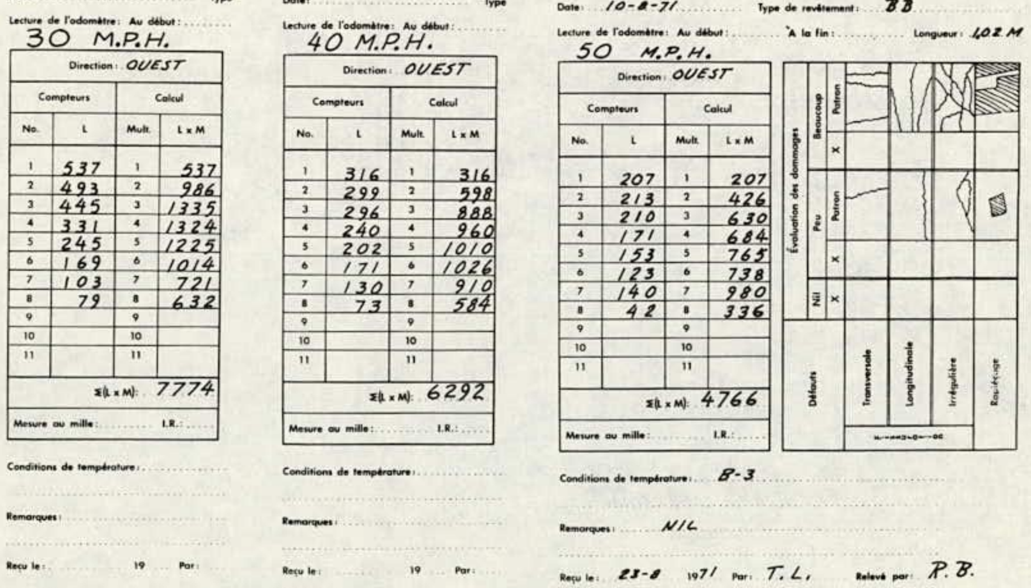


Table 1. Linear regressions.

Figure Number	Meter	Speed (mph)	$\overline{X}$	$\overline{Y}$	a	b	R	Syx
1	4	30 to 40	0.701	0.628	0.9610	0.0475	0.986	0.0289
		40 to 50	0.650	0.588	0.8839	0.0138	0.986	0.0254
		30 to 50	0.708	0.580	0.8152	0.0026	0.971	0.0365
2	7	30 to 40	0.695	0.628	0.9414	0.0281	0.983	0.0305
		40 to 50	0.656	0.580	0.8723	0.0081	0.988	0.0222
		30 to 50	0.706	0.564	0.7793	0.0139	0.960	0.0381
3	4 versus 7	40	0.635	0.642	0.8554	0.0923	0.932	0.0572

Figure 5. K-coefficient values.



MINISTÈRE DE LA VOIRIE — PROVINCE DE QUÉBEC

Service des Sols et Matériaux

MESURE DE L'INDICE DE ROULEMENT

Appareil: 1

Route no: Tour de l'Ile Tronçon no: 1 Section no: 26-A
Municipalité: St-Pierre Comté: Montmorency Vitesse: 50 (1)
Date: 10-8-71 Type de revêtement: BB
Lecture de l'odomètre: Au début: ... A la fin: ... Longueur: 1.02 M

30 M.P.H. — Direction: OUEST

No.	L	Mult.	L x M
1	537	1	537
2	493	2	986
3	445	3	1335
4	331	4	1324
5	245	5	1225
6	169	6	1014
7	103	7	721
8	79	8	632
9		9	
10		10	
11		11	
		Σ(L x M):	7774

40 M.P.H. — Direction: OUEST

No.	L	Mult.	L x M
1	316	1	316
2	299	2	598
3	296	3	888
4	240	4	960
5	202	5	1010
6	171	6	1026
7	130	7	910
8	73	8	584
9		9	
10		10	
11		11	
		Σ(L x M):	6292

50 M.P.H. — Direction: OUEST

No.	L	Mult.	L x M
1	207	1	207
2	213	2	426
3	210	3	630
4	171	4	684
5	153	5	765
6	123	6	738
7	140	7	980
8	42	8	336
9		9	
10		10	
11		11	
		Σ(L x M):	4766

Mesure au mille: ... I.R.: ...

Évaluation des dommages: Beaucoup / Peu / Nil; Patron; Défauts: Transversale, Longitudinale, Irrégulière, Roulement

Conditions de température: B-3

Remarques: NIL

Reçu le: 23-8 1971 Par: T.L. Relevé par: P.B.

K-0.31 K-0.27 K-0.26

A road meter, when installed in a vehicle, can be calibrated by making a series of runs at different speeds on several road sections chosen for their varied surface roughnesses. Then linear regressions can be calculated from the data collected.

From available calibration data on file, sets of graphs were plotted for each vehicle at various speeds and then among vehicles for a given speed for this study. We note the following:

1. The values can be plotted on regular arithmetic graph paper;
2. The values can be evaluated by use of linear regression;
3. Interrelation of values for a given vehicle at various speeds can be expressed (a) for any 2 speeds, as a linear regression of the first degree, such as $y = b + ax$, and (b) for the 3 speeds, as a linear regression in space, such as $z = aX + bY + C$;
4. At a given speed, the values from the different vehicles compared in pairs give a linear regression of the first degree; and
5. The coefficient of correlation in all cases is well above 0.90.

The value of the K-coefficient is effectively illustrated. The K-coefficient gets the best out of RCI in interpreting graphic data. Any error during calibration runs will stand out on the graph. To illustrate common errors, we shall assume the following:

1. The apparatus was not set at zero, or was operated improperly for a certain run (say, at 30 mph) but operated normally at other speeds. The points will be way off on the 30- to 40-mph and 30- to 50-mph graphs, but within normal tolerance on the 40- to 50-mph graph.
2. The apparatus became defective somewhere during the test. The points would be off the usual regression line and would have a tendency to form another linear regression on the graph so long as the fault remained more or less constant.

This behavior of the K-coefficient could be advantageously used in evaluating operators, detecting a sluggish or faulty apparatus, or carrying out trials to determine effects from temperature, wind, and so forth.

LIMITATIONS OF THE K-COEFFICIENT

The K coefficient has several weaknesses that one has to consider before using it as a tool in evaluating data from road meters. For example, when a road's surface is excellent, only counter 1 will have a value, and regardless of this value we always get the maximum value (100) for K. We are therefore unable to identify the degree of excellence of the road.

As stated previously, K is independent of the distance measured. This could be disadvantageous because K does not take into account the frequency of bumps; it is affected only by the amplitudes and distributions of the bumps.

To illustrate, suppose the readings on counters 1, 2, and 3 are as follows for a 1-mile survey:

C_1:	$240 \times 1 = 240$	$120 \times 1 = 120$	$60 \times 1 = 60$
C_2:	$120 \times 2 = 240$	$60 \times 2 = 120$	$30 \times 2 = 60$
C_3:	$60 \times 3 = 180$	$30 \times 3 = 90$	$15 \times 3 = 45$
	420 660	210 330	105 165
	K = 63.6	K = 63.6	K = 63.6

Finally, when using the K-coefficient to evaluate road roughness, it is important to closely observe the counters' readings. The value of K is quite reliable to describe the roughness of a given section of road, but if this road section is not homogeneous and is composed of 1 or 2 bumps or potholes, the value of K will be adversely affected.

CONCLUSIONS

The information presented is believed sufficient to support the following statements:

1. Very good linear regressions can be obtained from each vehicle at different

speeds. Therefore, by adopting a specific speed as standard, all values obtained at other speeds can be converted to those obtained at the standard speed.

2. By using a given speed common to all vehicles, values of K can be compared among vehicles.

3. Errors during calibration can be easily detected and the type of fault identified.

4. By giving a vehicle's operator the result of calibrations, either in the form of graphs or tables, he can check the vehicle when in doubt or do periodic calibration runs with the apparatus anytime and anywhere. This will prevent the accumulation of false values during inventory operations.

Finally, the K-coefficient is not intended to replace any current method of evaluation, but rather to serve as another tool in investigating pavement conditions and behavior. Although the K-coefficient is quite useful in its present state, improvements and modifications can be expected from its continued use.