ROAD METER OUTPUT AND ITS CORRELATION WITH PANEL RATINGS IN SASKATCHEWAN

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The history of attempting to obtain a systematic measure of the performance of highway pavements began in Saskatchewan in the early 1950s. These early studies were carried out in cooperation with the Canadian Good Roads Association, now renamed the Roads and Transportation Association of Canada (RTAC).

These early ratings of performance were carried out by panels of experts who rated the present performance rating (PPR) on a scale of 0 to 10 (1). The term PPR has lately been renamed riding comfort index (RCI) in Canadian terminology. This method of rating is very similar to that reported by Carey and Irick (2) for determining a present serviceability rating (PSR) and that estimated by using physical measures and a mathematical formula to obtain the present serviceability index (PSI). The major difference is that of scale.

In 1965 the Saskatchewan Department of Highways and Transportation purchased a British Road Research Laboratory profilometer, which is described in detail by Culley (3). One major drawback of this unit is that it operates at speeds of 3 mph or less and requires a substantial crew. This unit measures surface smoothness as related to a 12.5-ft traveling datum. Although riding quality is indirectly related to surface smoothness, it is vehicle response or even passenger response to surface irregularities that governs riding quality.

Because a systems approach to highway management requires a large inventory on pavement performance, the PCA road meter was chosen as the most promising unit based on RTAC evaluations (4, 5, 6, 7). As a result of these reports, the Department purchased a unit in the spring of 1971. Recently RTAC has suggested that this type of road meter be referred to as a car road meter (CRM).

CRM DESCRIPTION

The CRM sensing and recording units were purchased from Soiltest, Inc., and follow the general principles as detailed by Brokaw (8). The main difference is that the Saskatchewan unit has 2 recording consoles that can be operated independently of each other. This allows consecutive sections to be tested without having to stop to record data and zero counters between each test section. The recording consoles are mounted above the transmission hump ahead of the front seat. Between the 2 consoles is a toggle switch that controls their operation. A switching plate is mounted on the deck behind the rear seat and is vertically connected to the center of the differential housing. Figure 1 shows the unit.

Distances are recorded by an A-I-Fab Gemini odometer that registers each $^{1}/_{100}$ mile. For purposes of this study, the section lengths were also accurately measured by survey instruments.

The vehicle in which the CRM is mounted is a 1970 Chevrolet Biscayne sedan with 350-cu in. V-8 motor, F40 heavy-duty suspension, 119-in. wheelbase, 216-in. overall

Figure 1. Car road meter.

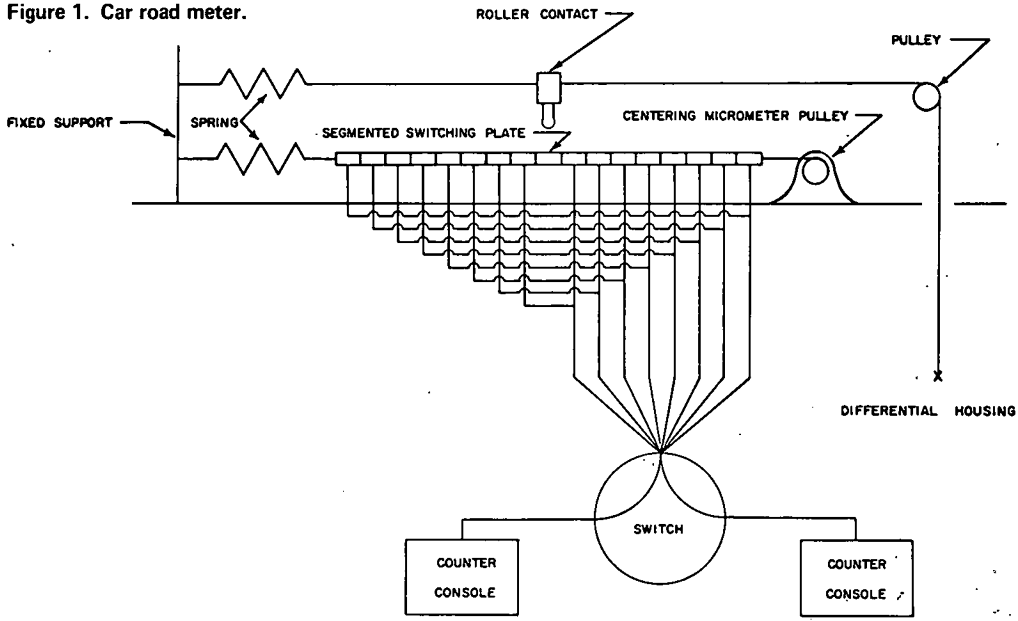


Table 1. RCI rating summary for CRM correlation studies.

Control Section	From Mile	To Mile	Panel 1 Rating Avg.	Panel 1 Rating S. D.	Panel 2 Rating Avg.	Panel 2 Rating S. D.	Panel 3 Rating Avg.	Panel 3 Rating S. D.	Panel 4 Rating Avg.	Panel 4 Rating S. D.	All Panels Combined Avg.	All Panels Combined S. D.
1-10	2.000	3.014	6.65	0.52	8.12	0.05	7.59	0.29	7.14	0.54	7.38	0.67
6-04	7.400	8.401	5.62	0.62	–	–	7.09	0.29	5.97	0.83	6.23	0.87
6-04	7.140	8.140	–	–	6.17	0.26	–	–	–	–	6.17	0.26
6-04	0.100	1.081	5.47	0.75	6.42	0.63	6.77	0.20	6.00	0.82	6.16	0.77
6-03	22.700	23.693	5.25	0.80	5.77	0.05	6.64	0.31	5.72	0.53	5.84	0.69
6-03	23.700	24.696	4.70	0.93	4.37	0.49	5.85	0.97	5.07	0.93	4.99	0.96
39-06	1.100	2.096	6.90	1.60	8.05	0.36	8.27	0.40	7.90	0.46	7.78	0.96
39-06	17.000	17.986	6.80	0.63	6.70	0.40	7.20	0.47	6.95	0.44	6.91	0.49

Table 2. Effect of vehicle speed on road meter Σ- counts.

Control Section	From Mile	To Mile	Vehicle Speed (mph)	Run Number (Σ-counts per mile) 1	2	3	4	5	Avg.	S. D.
39-6	1.100	2.096	50	239.96	252.01	238.96	260.04	227.91	243.77	12.46
39-6	17.000	17.986	50	419.87	402.63	412.78	464.50	518.26	443.60	47.96
6-3	22.700	23.693	50	818.73	754.28	732.13	798.59	850.96	790.93	48.04
6-3	23.700	24.696	50	1,276.10	1,266.06	1,263.05	1,252.01	1,176.71	1,246.79	40.12
6-4	0.100	1.081	50	691.13	622.83	644.24	608.56	645.26	642.40	31.27
6-4	7.400	8.401	50	604.39	600.40	566.43	562.44	534.47	573.62	29.03
1-10	2.000	3.014	50	472.39	539.45	493.10	466.47	530.57	500.38	33.25
39-6	1.100	2.096	40	172.69	184.74	144.58	143.57	167.67	162.64	18.05
39-6	17.000	17.986	40	327.59	315.42	337.73	354.97	344.83	336.09	15.28
6-3	22.700	23.693	40	627.39	592.15	638.47	598.19	591.14	609.46	21.93
6-3	23.700	24.696	40	1,024.10	1,026.10	1,005.02	996.99	988.96	1,008.23	16.44
6-4	0.100	1.081	40	622.83	638.12	590.21	620.80	635.07	621.40	18.97
6-4	7.400	8.401	40	520.48	498.50	526.47	520.48	518.48	516.87	10.68
1-10	2.000	3.014	40	302.76	293.89	296.84	285.01	305.72	296.84	8.09
39-6	1.100	2.096	60	357.43	385.54	381.53	396.59	378.51	379.91	14.31
39-6	17.000	17.986	60	465.52	495.94	510.14	515.21	518.26	501.01	21.60
6-3	22.700	23.693	60	928.50	979.86	973.82	1,012.08	988.92	976.63	30.58
6-3	23.700	24.696	60	1,251.00	1,310.24	1,285.14	1,360.44	1,327.31	1,306.82	41.54
6-4	0.100	1.081	60	888.89	839.96	888.89	915.39	832.82	873.18	35.38
6-4	7.400	8.401	60	764.24	700.30	734.27	809.19	730.27	747.64	41.48
1-10	2.000	3.014	60	555.23	524.66	530.57	645.96	527.61	556.80	51.29

Note: In all tests, there were 2 vehicle occupants, tire pressure of 27 psi, and one-half (plus) full gas tank.

length, and 20.75-imperial gal gas tank capacity. The tires are G78-15 Goodyear Custom Powercushion Polyglass belted tires and are subjected to periodic wheel balancing and alignment.

For the initial correlation and study the unit had 10,000 miles on the odometer and 34,000 miles during the study of temperature effects.

OUTLINE OF TEST PROGRAM

The test program consisted of (a) determining the RCI for several sections of highway in the Regina area; (b) following this, and within the same week, making replicate runs with the CRM under so-called standard conditions; and (c) then repeating the CRM runs with these conditions varied.

DESCRIPTION OF TEST SECTIONS

Seven sections of highway located within a 50-mile radius of the city of Regina were chosen as being representative of the range of riding quality existent over the major portion of the paved highway system. All sections had an asphaltic concrete surface course, and the ride within each section was considered uniform. Each section length was determined to $1/1{,}000$ mile, and the beginning and end points were marked on the pavement.

The 3 sections given in Table 1 as 1-10 and 39-06 are old pavements having a history of very slow change in RCI, and all had been overlaid in 1970. The sections noted as 6-04 are older pavements whose performance history has also shown a very slow rate of change. The sections shown as 6-03 are constructed on a lacustrine clay soil with swelling properties that result in a rapid loss in pavement performance. Sections 6-03 therefore represent pavements of low performance.

DETERMINATION OF RCI

The RCI was determined for each section by using a large panel of 16 people, with the exception of section 6-04, mile 7.400 to mile 8.401, which was evaluated by a 12-man panel. The panel was subdivided into groups of 4, each group traveling in a different automobile. These automobiles were similar to the unit previously described as carrying the CRM.

The panelists were senior members of the Department who travel extensively on the highway system. No effort was made to select the panel on a statistical basis because it was felt that the panel size was sufficient to nullify any errors.

Table 1 summarizes the data from the panels. The data are analyzed by subgroups as well as for the overall group. In the correlation studies, the average of the 16-member (12-member in 1 instance) panel was used as the true value of the RCI; thus each point on the forthcoming figures represents 16 RCI values.

CRM STANDARD OPERATING CONDITIONS

Prior to carrying out the correlation and variable effects study, certain arbitrary conditions of CRM operation were assigned. These conditions are the "standard" conditions referred to further in this paper.

A vehicle speed of 50 mph was chosen as the standard operating speed. At speeds above this, traffic conflicts make it difficult to maintain constant speed. At lower speeds, the CRM unit tended to act as a traffic obstruction.

The standard load was chosen as 2 people plus the gas tank more than one-half full plus one spare tire in the trunk. The choice of gas tank level was strictly arbitrary. The choice of 2 people was based on unit efficiency.

The mass inventory was set up such that the RCI was to be determined on 2-mile sections of highway. This meant that, at 50 mph, a 2-min, 24-sec time interval existed during a specific test. As previously mentioned, the CRM unit is equipped with 2 independent counter consoles activated by a toggle switch. Thus, the passenger has time to record the data and clear a console in 2 min, 23 sec. By switching consoles back and forth, he can make a continuous series of tests.

Table 3. Effect of vehicle speed and number of occupants on road meter Σ-counts.

Control Section	From Mile	To Mile	Vehicle Speed (mph)	Number of Vehicle Occupants	Run Number (Σ-counts per mile) 1	2	3	4	5	Avg.	S.D.
39-6	1.100	2.096	65	2	418.68	400.60	414.66	387.55	335.34	391.36	33.63
39-6	17.000	17.986	65	2	556.80	619.68	618.66	628.80	589.25	602.63	29.62
6-3	22.700	23.693	65	2	1,127.90	1,133.90	1,113.80	1,092.70	970.80	1,087.82	67.32
6-3	23.700	24.696	65	2	1,318.27	1,455.82	1,433.78	1,411.65	1,391.57	1,402.21	52.77
6-4	0.100	1.081	65	2	817.53	792.05	949.03	830.79	815.49	840.97	62.00
6-4	7.400	8.401	65	2	675.32	737.26	765.23	723.28	783.22	736.85	41.60
1-10	2.000	3.014	65	2	656.81	748.52	662.72	714.99	687.38	694.08	38.13
39-6	1.100	2.096	50	1	273.09	292.17	296.19	299.20	330.32	298.18	20.63
39-6	17.000	17.986	50	1	462.48	441.18	443.21	495.94	454.36	459.42	22.15
6-3	22.700	23.693	50	1	782.48	894.26	780.46	767.37	813.70	807.65	51.31
6-3	23.700	24.696	50	1	1,133.53	1,133.53	1,172.69	1,177.71	1,233.94	1,170.28	41.29
6-4	0.100	1.081	50	1	668.71	642.20	693.17	627.93	749.24	676.24	47.85
6-4	7.400	8.401	50	1	566.43	565.43	567.43	585.41	600.40	577.01	15.44
1-10	2.000	3.014	50	1	463.51	409.27	431.95	395.46	421.10	424.25	25.80
39-6	1.100	2.096	50	3	247.99	232.93	261.04	273.09	241.97	251.40	15.85
39-6	17.000	17.986	50	3	381.34	375.25	449.29	504.06	521.30	446.24	67.52
6-3	22.700	23.693	50	3	901.31	833.84	900.30	915.41	981.87	906.54	52.68
6-3	23.700	24.696	50	3	1,015.06	1,096.39	1,158.63	1,163.65	1,124.50	1,111.65	60.50
6-4	0.100	1.081	50	3	781.86	664.63	697.25	735.98	730.89	722.11	44.04
6-4	7.400	8.401	50	3	586.41	737.26	680.32	614.39	664.34	656.53	58.81
1-10	2.000	3.014	50	3	481.26	483.24	509.86	500.99	502.96	495.65	12.69

Note: In all tests, tire pressure was 27 psi and gas tank was one-half (plus) full.

Table 4. Effect of vehicle speed, tire pressure, and gas tank level on road meter Σ-counts.

Control Section	From Mile	To Mile	Tire Pressure (psi)	Gas Tank Level	Run Number (Σ-counts per mile) 1	2	3	4	5	Avg.	S.D.
39-6	1.100	2.096	22	Plus ½	264.06	285.14	272.09	259.04	270.08	270.07	9.86
39-6	17.000	17.986	22	Plus ½	488.84	484.79	488.84	432.05	447.26	468.35	26.79
6-3	22.700	23.693	22	Plus ½	905.34	789.53	871.10	830.82	769.39	833.22	56.17
6-3	23.700	24.696	22	Plus ½	1,185.74	1,176.71	1,152.61	1,143.57	1,208.84	1,173.49	26.18
6-4	0.100	1.081	22	Plus ½	725.79	771.66	745.16	656.47	760.45	731.90	45.54
6-4	7.400	8.401	22	Plus ½	548.45	617.38	676.32	753.25	595.40	638.15	79.06
1-10	2.000	3.014	22	Plus ½	496.06	492.11	441.81	500.99	464.50	479.08	25.19
39-6	1.100	2.096	32	Plus ½	325.30	340.36	349.39	353.41	321.29	337.94	14.26
39-6	17.000	17.986	32	Plus ½	553.75	607.51	494.93	569.98	640.97	573.42	55.41
6-3	22.700	23.693	32	Plus ½	932.53	1,020.14	1,128.90	1,077.54	916.42	1,015.10	91.43
6-3	23.700	24.696	32	Plus ½	1,245.98	1,279.12	1,255.02	1,371.49	1,335.34	1,297.39	54.09
6-4	0.100	1.081	32	Plus ½	767.58	854.23	821.61	824.67	819.57	817.53	31.27
6-4	7.400	8.401	32	Plus ½	733.27	768.23	832.17	763.24	857.14	790.80	51.69
1-10	2.000	3.014	32	Plus ½	490.14	500.99	528.60	530.57	491.12	508.28	19.90
39-6	1.100	2.096	27	Below ¼	349.40	332.33	313.25	361.45	341.37	339.55	18.18
39-6	17.000	17.986	27	Below ¼	527.38	501.01	583.16	453.35	523.33	517.64	46.98
6-3	22.700	23.693	27	Below ¼	941.59	873.11	988.92	1,019.13	927.49	950.04	56.53
6-3	23.700	24.696	27	Below ¼	1,287.15	1,278.11	1,317.27	1,247.99	1,266.06	1,279.32	25.79
6-4	0.100	1.081	27	Below ¼	780.84	757.39	722.73	797.15	766.57	764.93	27.97
6-4	7.400	8.401	27	Below ¼	638.36	636.36	691.31	716.28	614.39	659.33	42.57
1-10	2.000	3.014	27	Below ¼	476.33	449.70	463.51	431.95	490.14	462.32	22.64
1-10[a]	2.000	3.014	27	Plus ½	416.17	394.48	562.14	701.18	858.97	586.58	196.13
39-6[b]	17.00	17.986	27	Plus ½	430.02	478.70	433.06	441.18	458.42	448.27	20.26

Note: In all tests, there were 2 vehicle occupants, and vehicle speed was 50 mph.

[a]Head wind of 23 mph gusting to 35 mph. [b]Road surface had free water with tire splashing continuously during tests and continuous rainfall during tests.

Table 5. Effect of temperature on CRM.

Control Section	From Mile	To Mile	Σ-counts[a] at +35 F	RCI[b]	RCI[c]	Σ-counts[d] at -33 F
39-6	1.100	2.096	306	7.58	7.99	182
39-6	17.00	17.986	495	6.72	6.92	314
6-3	22.700	23.693	1,595	4.63	5.89	1,558
6-3	23.700	24.696	2,382	3.92	5.07	2,128
6-4	0.100	1.081	738	6.01	6.26	–
6-4	7.400	8.401	637	6.27	6.46	–
1-10	2.00	3.014	533	6.59	6.70	–

Note: The CRM values are averages of 5 individual runs.

[a]Taken on 3/14/72.
[b]Estimated from Figure 3.
[c]Estimated from Tables 2 through 4.
[d]Taken on 3/1/72.

The standard tire pressure was arbitrarily set at 27-psi cold-inflation pressure. This was constant in all 4 tires and was 2 psi above normal operating pressure for this type of tire. This pressure was chosen to minimize the probability of reductions in tire life due to blowouts.

The maximum wind velocity during testing was chosen at 10 mph because the literature (8) indicated that, up to 15 mph, wind velocity had a negligible effect on CRM output.

During testing, the road surface had to be dry, that is, free from water or snow. Temperature restrictions were arbitrarily placed at +32 F ambient temperature or higher because the literature (8) indicated that little effect was noted when temperatures were above +10 F.

DETERMINATION OF CRM VALUES

In determining CRM values, each section was tested 5 times under given sets of conditions. These values are given in Tables 2 through 5. In all correlation work, the average of the 5 readings was used.

Although Brokaw (8) has suggested that data from the CRM unit be reduced to the sum of the squares [$\Sigma(D^2)$] of road-car deviations, Canadian practice (4, 5, 6, 7), has been to reduce the data as the summation of the extended counter readings (Σ-counts) per mile. These 2 methods of reduction are related as follows:

$$64\ \Sigma(D^2) = \Sigma\text{-counts}$$

This formula holds true where the segmented switching plate is divided in 1/8-in. increments.

CRM-RCI CORRELATION

Figure 2 summarizes correlation curves as reported by some Canadian agencies (4, 5, 6, 7). The data from Alberta and Ontario agree very closely, whereas the Quebec curve is somewhat steeper. The Saskatchewan curve tends to have an intermediate slope falling between the Ontario-Alberta slope and the Quebec slope.

Figure 3 shows the actual correlation of the Saskatchewan curve. In this correlation, the range of RCI values is limited to 4.99 to 7.78. This limited range is justified because, for the major portion of highways, only limited extrapolation is required to estimate RCI values outside this range. One area where difficulty might arise is in evaluating new construction, where the high intercept would indicate RCI values in excess of 10. This may indicate that a more complex relation exists than the equation would indicate for the narrow range studied. Thus, at 50 mph the relation is

$$\text{RCI} = 17.815 - 4.116 \log_{10} \Sigma\text{-counts}$$

where correlation coefficient = 0.946 and standard error = 0.338.

The correlation coefficient appears to be equal to or higher than that found by others and indicates that the CRM operating at high speeds will adequately estimate RCI.

EFFECT OF CRM UNIT SPEED ON ESTIMATING RCI

The effect of vehicle speed on the output of the CRM was assessed at 40, 50, 60, and 65 mph. All other controllable variables previously listed were held constant at the prestated values.

Figure 4 compares the summation of the counts at 50 mph with those at the other speeds. The analysis indicates that the slope of the curves tends to become steeper as vehicle speed increases.

Figure 5 shows a correlation of RCI and Σ-counts for the various speeds. In all instances the correlation is high; however, at 40 mph it is exceptional at 0.977. Generally, the repeatability, as given in Table 2, is also better at 40 mph. This higher degree of correlation is in line with that reported by Tessier (7).

Figure 2. Summary of correlation curves.

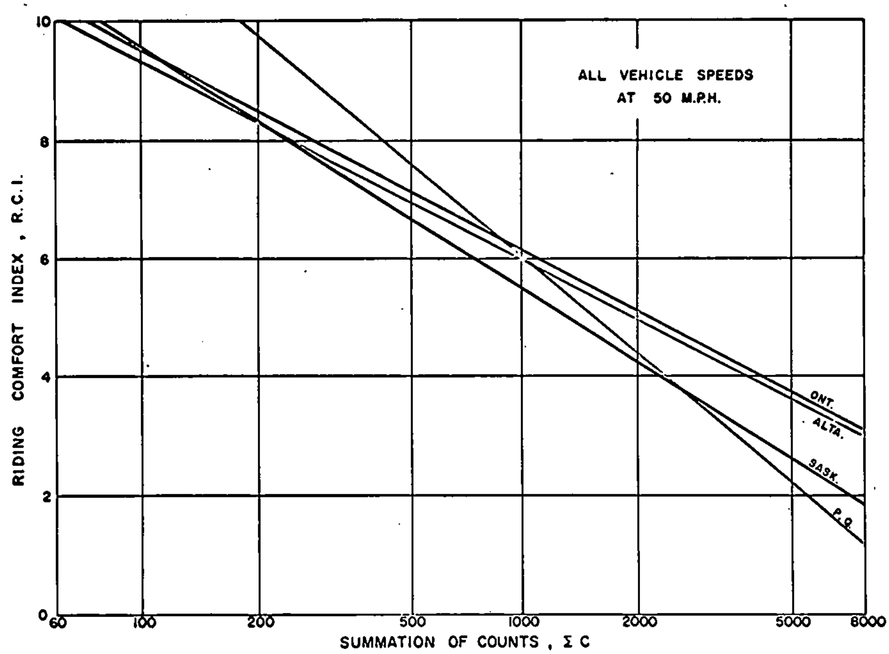


Figure 3. Correlation of CRM and RCI at test speed of 50 mph.

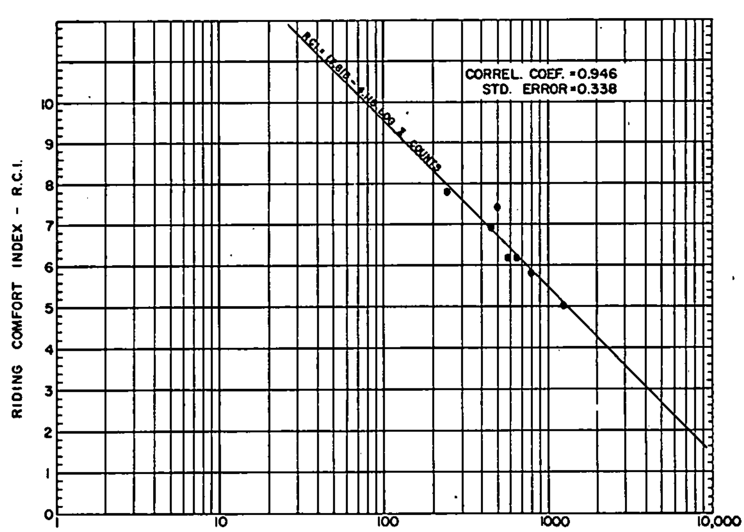


Figure 4. Effect of vehicle speed on rating value.

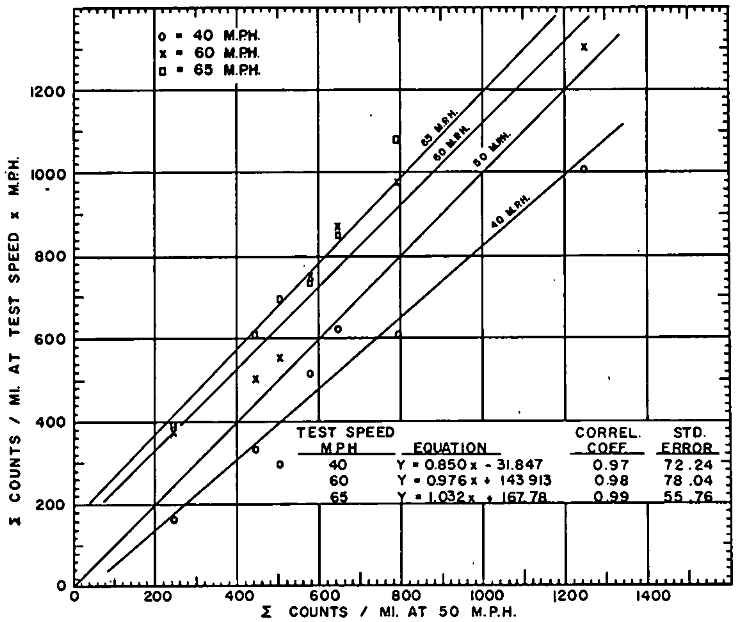


Figure 5. Effect of vehicle speed on CRM for estimating RCI.

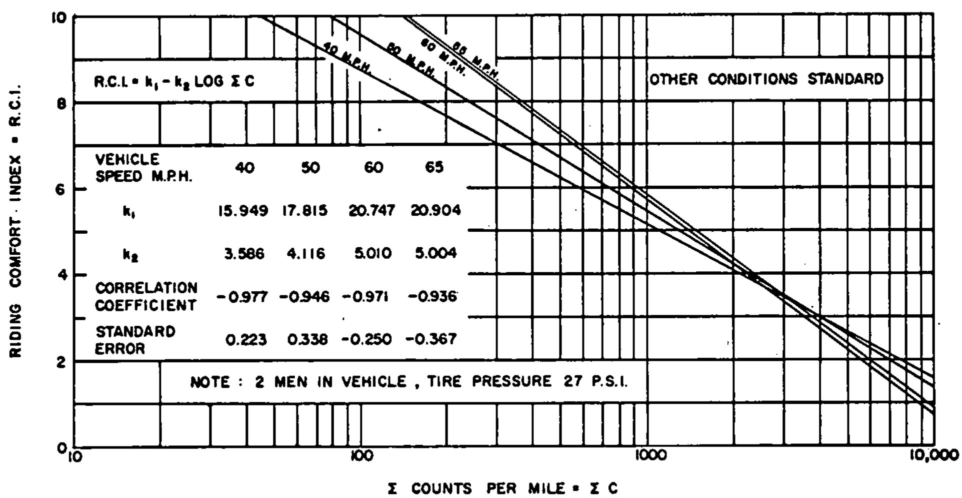
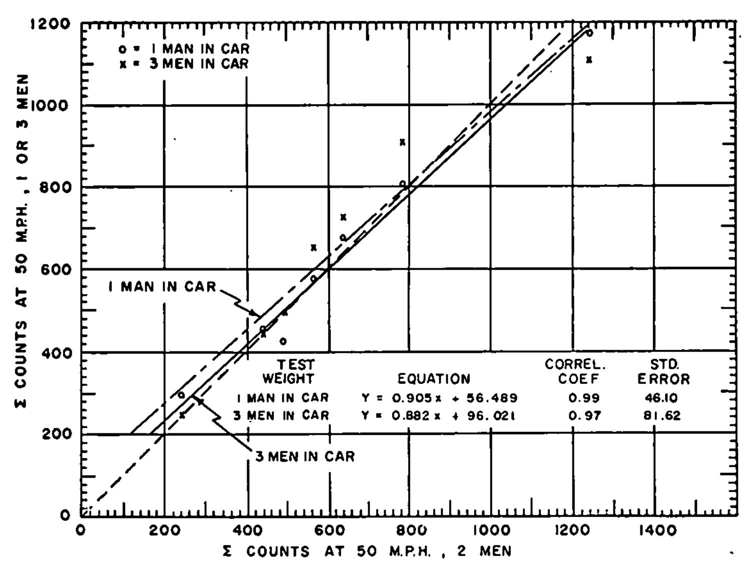


Figure 6. Effect of number of vehicle occupants on rating values.



It is also interesting to note that the curves for various speeds tend to cross at RCI values of 3 to 4 or Σ-counts values of 2,000 to 4,000. This could indicate that at higher speeds the vehicle tends to float over some of the rough areas of pavement; the extrapolated curves intersecting an RCI of 2 indicate that the higher the speed, the less is the movement between vehicle axle and car body.

EFFECT OF VEHICLE LOAD ON CRM UNIT OUTPUT

Two effects of vehicle load were studied: one was the effect of the number of people in the car, and the other was the effect of gas tank level.

The effect of the number of people was assessed using 1, 2, and 3 men in the vehicle. When 3 people were in the vehicle, the third person rode in the rear seat behind the driver. Figure 6 compares the Σ-counts with 2 men in the vehicle versus 1 and 3 men in the vehicle. The curve for 1 and 3 men is flatter than for 2 men.

Figure 7 compares the effect of a full gas tank versus a gas tank less than one-quarter full. The 2 curves are almost parallel with a decrease in gas load indicating a similar increase in car body-axle deviations at all levels of roughness studied.

The total effects of change in the vehicle live load are shown in Figure 8. Although the correlation coefficient is high in all instances, it would appear that better correlation is achieved by a decrease in live load. The correlation coefficient of 0.989 found with less than one-quarter tank of gas and all other variables standard is the highest correlation attained in this study.

EFFECT OF VARIATION IN TIRE PRESSURE ON CRM UNIT

To determine the effect of tire pressure, we made replicate tests in which the tire pressure was varied by ±5 psi from the standard of 27 psi. In all instances, the tire pressure was measured when the tires were cold.

Figure 9 indicates that, for a decrease of 5 psi, smoother pavements showed an increase in Σ-counts, whereas rougher pavements showed a slight decrease in Σ-counts. On the other hand, an increase in tire pressure of 5 psi showed a somewhat constant increase in Σ-counts of approximately 130 units over the entire range tested. Figure 10 shows the effect of change in tire pressure on estimating RCI. Here again, all correlation coefficients are high, with the correlation coefficient of -0.985 for 32-psi tire pressure almost the same as the coefficient determined with the gas tank less than one-quarter full.

EFFECT OF TEMPERATURE ON CRM UNIT

Brokaw (8) indicates that temperature does not affect the CRM until temperatures fall below +10 to +15 F. At the maximum stipulated wind speed, the wind chill could be far lower than this level. Therefore, it was desirable to determine the effect of equivalent extremely low temperatures.

On March 1, 1972, a sharp drop in temperature occurred to -33 F. This allowed testing of 4 of the test sections, the results of which are given in Table 5. Each value is the average of 5 runs. On March 14, 1972, the temperature rose to +35 F, at which time all 7 test sections were tested with 5 replicate runs, the average of which is given in Table 5.

To estimate the RCI of March 14 when the temperature was +35 F, the following mathematical model was used:

$$\text{RCI} = 17.815 - 4.116 \log \Sigma\text{-counts}$$

Utilizing the calculated RCI values of March 14 as being the actual values of March 1, we correlated RCI and Σ-counts at -33 F.

Figure 11 shows that the summation of counts at low temperatures is less than the summation of counts at high temperatures over the range of roughness tested. This probably results from stiffening of the vehicle suspension caused by increased viscosity of the lubricants at suspension points and in the shock absorber. The effect of tempera-

Figure 7. Effect of gas tank level on rating values.

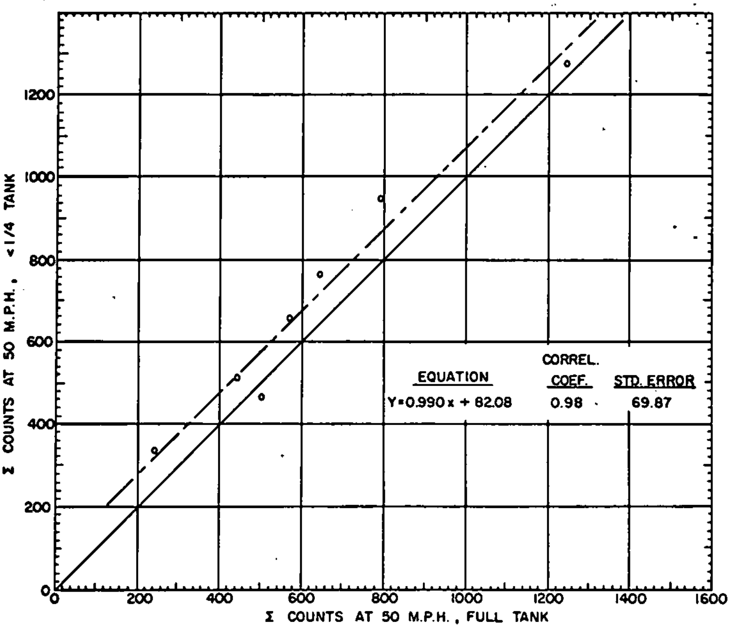


Figure 8. Effect of number of vehicle occupants and gas tank level on CRM output.

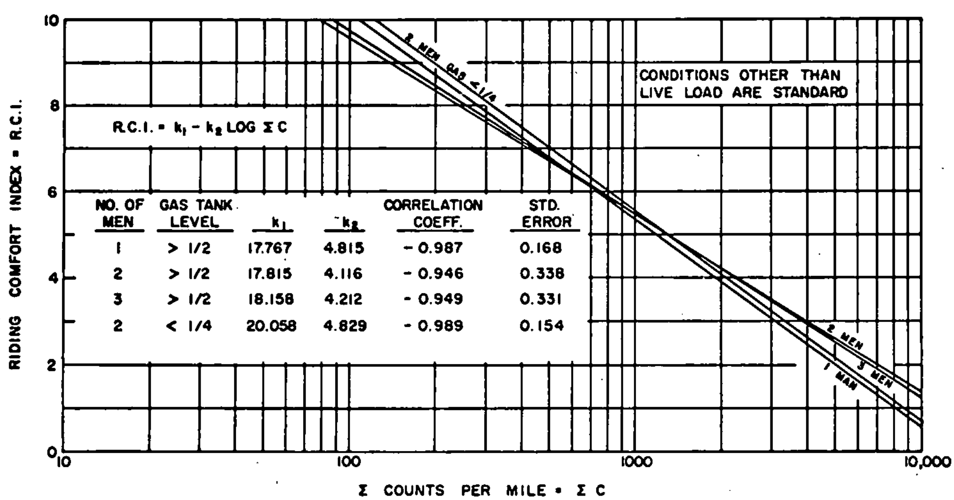


Figure 9. Effect of tire pressure on rating values.

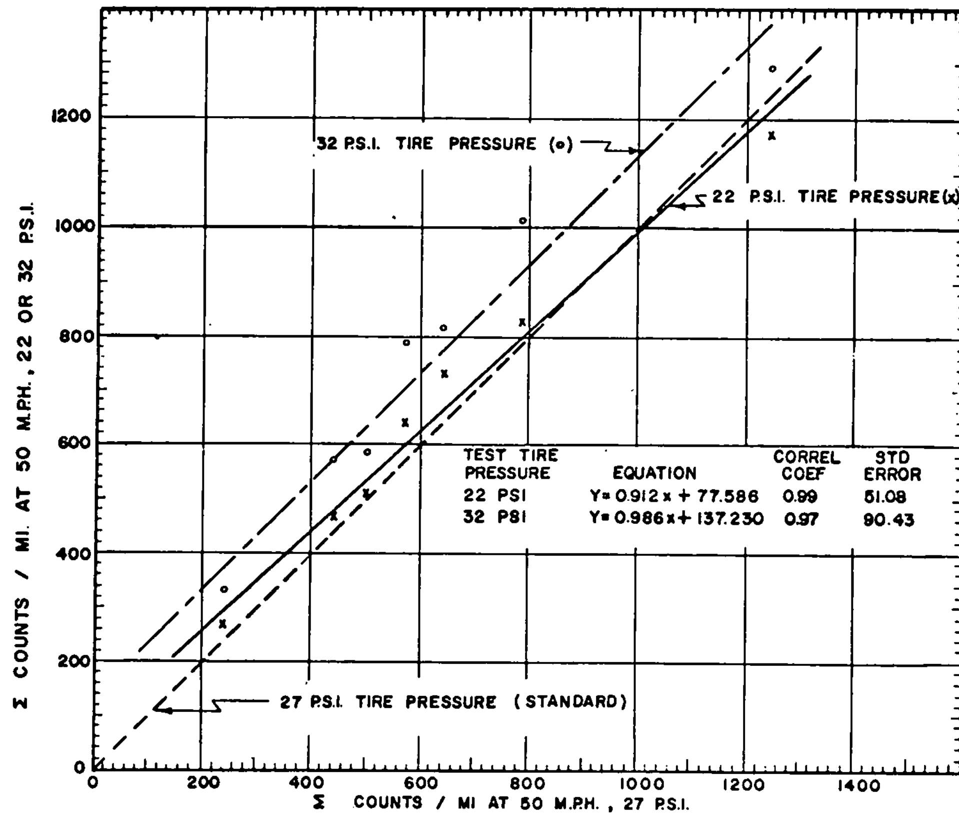
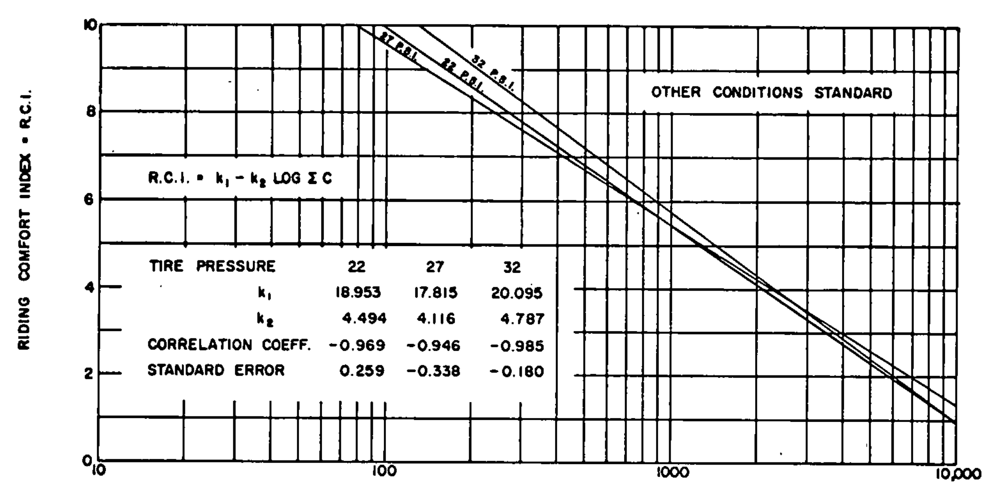


Figure 10. Effect of tire pressure on CRM for estimating RCI.



ture on tires is either negligible or counteracted by suspension dampening because there is less total travel between vehicle axle and the vehicle body at low temperatures.

Figure 12 shows the correlation between RCI at +35 F and -33 F. The correlation coefficients here must be ignored because they are not correlations between panel rating and CRM but between RCI's estimated by the CRM unit at +35 F and the CRM output at -33 F.

REPEATABILITY AND CORRELATION

All CRM tests in this study were replicated 5 times. The results of each run, with the exception of the temperature effect series, are given in Table 2 as are the average and the standard deviation calculated for each of the 5 test series. Generally, there appears to be an increase in standard deviation with an increase in the summation of counts (Fig. 13). Correlation coefficients of these curves are low but give an indication of what repeatability may be expected under varying conditions.

The best repeatability under most ranges of roughness occurred with the standard conditions and at a speed of 40 mph. Figure 13 shows that, at this speed, one may expect one standard deviation to vary between 13 and 25 for a Σ-counts range of 85 to 2,300 respectively. Figure 5 shows that these variations would result in an RCI change of 0.2 for a very smooth roadway and have no effect on a rough roadway.

Under standard conditions, including a speed of 50 mph, Figure 13 shows a standard deviation varying from 25 to 70 for a Σ-counts range of 140 to 2,300 respectively. Figure 5 shows that one standard deviation of the Σ-counts on a smooth roadway would result in an RCI change of approximately 0.3, whereas a change of one standard deviation on a rough roadway will result in a change in RCI of approximately 0.1. In the preceding 2 paragraphs smooth and rough roadways were considered to be roadways having RCI's of 9 and 4 respectively.

Table 6 summarizes the various correlation coefficients when relating RCI determined by panel to Σ-counts per mile for the various conditions of this study and for those reported by other agencies (6, 7, 9). The constants k_1 and k_2 for the mathematical model RCI = k_1 - k_2 log Σ-counts are also noted.

Although all correlation coefficients studied here are relatively high, the correlations for the variables of 40 mph, 60 mph, 1-man unit, gas tank less than one-quarter full, or tire pressure of 32 psi are exceptionally high. However, it is noted that repeatability with high tire pressures is rather poor and at 40 mph is very good, whereas the other variables tend to group in between (Fig. 13). Tessier (7) has also reported better correlation coefficients at speeds of 30 to 40 mph than at 50 mph.

The correlation coefficients may be higher than those noted in the literature because of the technique of averaging the large panel group and CRM runs. Also, the number of sections studied and the range are limited.

DATA RECORDING SYSTEM

The CRM data are reduced by computer to an equivalent RCI value, and the total data are stored on magnetic tape. Figure 14 shows a typical computer output sheet for a section of roadway, with all data shown being stored. The program uses PPR rather than RCI. The formula used to calculate the RCI (PPR) is shown and may be replaced by other formulas if, for example, a speed other than 50 mph is used in the CRM testing.

CONCLUSIONS

This study indicated that the variables considered each had an effect on the ability of the CRM to predict the RCI and that each variable should be controlled. This is most crucial when testing pavements that have high RCI values.

Assessments of pavements having a high RCI, as in new construction, appear to be more accurate when a vehicle speed of 40 mph is used.

When assessing pavements having a relatively high RCI, and where accuracy is important, one should perform replicate tests.

Figure 11. Effect of temperature on CRM output.

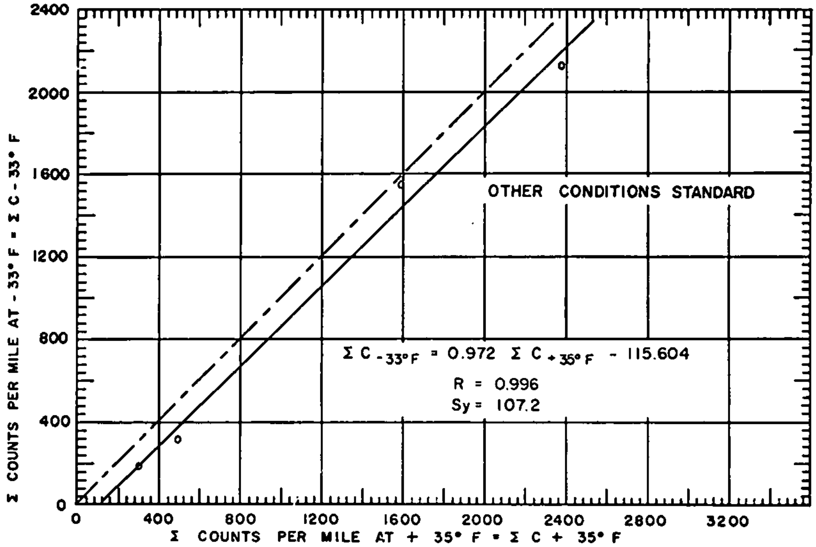


Figure 12. Effect of temperature on CRM for estimating RCI.

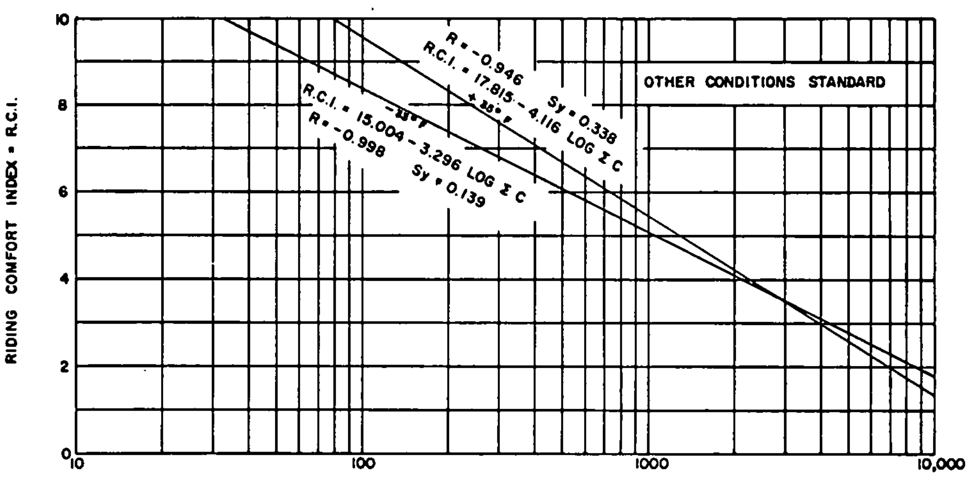


Table 6. Summary of RCI-CRM correlations.

Characteristic	Speed (mph)				Number of Occupants		Gas Tank	Tire Pressure (psi)		Temperature	Agency[c]		
	40	50[a]	60	65	1	3	<¼ full	22	32	-33 F[b]	Ontario	Alberta	Quebec
k_1	15.949	17.815	20.747	20.904	19.767	18.158	20.058	18.953	20.095	15.004	16.440	16.03	22.280
k_2	3.586	4.116	5.010	5.004	4.815	4.212	4.829	4.494	4.787	3.296	3.438	3.35	5.437
Correlation coefficient	-0.977	-0.946	-0.971	-0.936	-0.987	-0.949	-0.989	-0.969	-0.985	-0.998	-0.907	-0.843	-0.779
Standard error	0.223	0.338	0.250	0.367	0.168	0.331	0.154	0.259	0.180	0.139	–	–	–

Note: RCI = k_1 - k_2 log Σ-counts.

[a]Standard test conditions.

[b]Correlation by estimating RCI using mathematical model for standard test conditions for tests made 13 days prior at T = +35 F.

[c]Data taken from references 6, 7, and 9; all runs at 50 mph and other variables not constant.

Figure 13. Standard deviation versus Σ-counts.

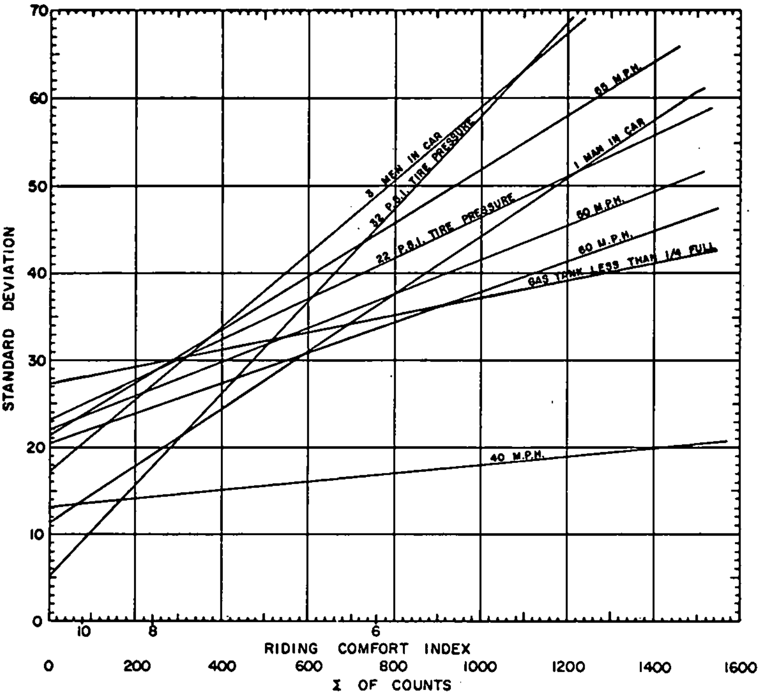
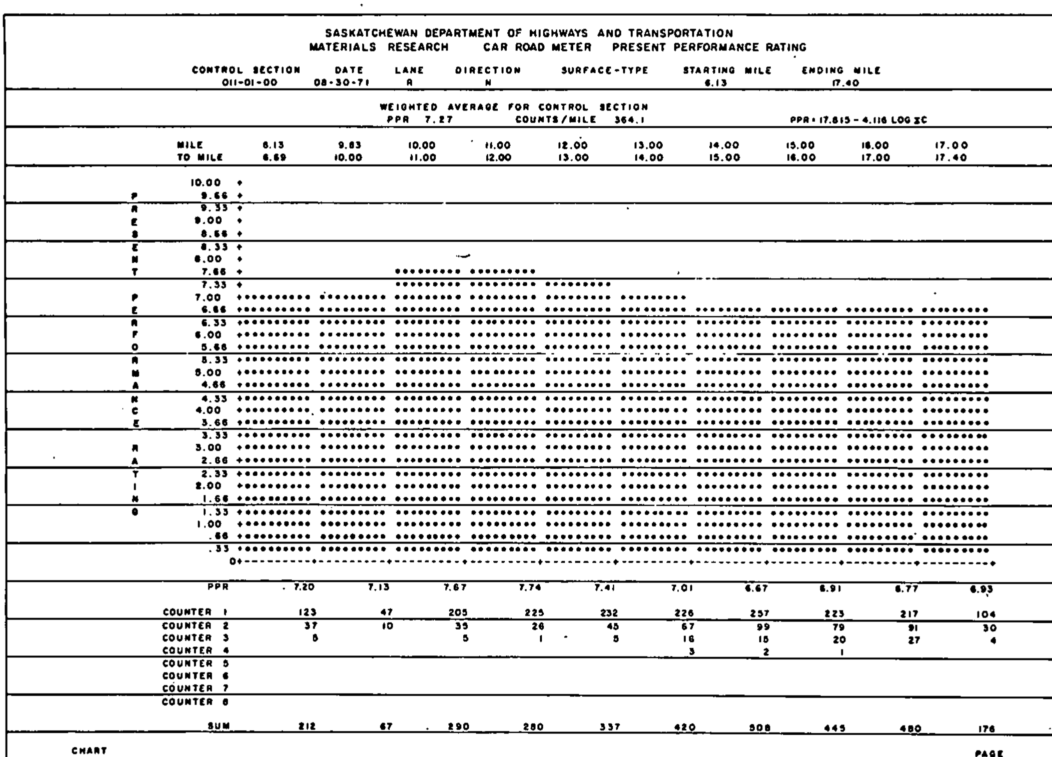


Figure 14. Computerized data sheet.



SASKATCHEWAN DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
MATERIALS RESEARCH CAR ROAD METER PRESENT PERFORMANCE RATING

CONTROL SECTION 011-01-00 | DATE 08-30-71 | LANE R | DIRECTION N | SURFACE-TYPE | STARTING MILE 6.13 | ENDING MILE 17.40

WEIGHTED AVERAGE FOR CONTROL SECTION
PPR 7.27 COUNTS/MILE 364.1 PPR = 17.615 − 4.116 LOG ΣC

MILE	6.13	9.83	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
TO MILE	6.69	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	17.40
PPR	7.20	7.13	7.67	7.74	7.41	7.01	6.67	6.91	6.77	6.93
COUNTER 1	123	47	205	225	232	226	257	223	217	104
COUNTER 2	37	10	35	26	45	67	99	79	91	30
COUNTER 3	5		5	1	5	16	15	20	27	4
COUNTER 4						3	2	1		
COUNTER 5										
COUNTER 6										
COUNTER 7										
COUNTER 8										
SUM	212	67	290	280	337	420	508	445	480	176

PRESENT PERFORMANCE RATING (scale 10.00 to 0 in steps of .33)

CHART PAGE

Although the standard deviation of the CRM output increased with decreasing RCI, its sensitivity for predicting RCI increased because of the logarithmic relation.

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