Causes of Variation in Automobile Speed Along a Parkway

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The results of research conducted to determine what factors most strongly affect variations in drivers' speed patterns along a roadway are described. Field surveys were conducted on the Gatineau Parkway in Quebec to collect data on the following factors: (a) driver age and sex, (b) vehicle age and size, (c) number of occupants in the vehicle, and (d) geometric configuration of the highway. Speed-change data were divided into three components: (a) frequency of speed changes along the parkway, (b) magnitude of the speed change, and (c) direction (increase or decrease) of the speed change. Analysis of covariance was used to determine the degree of relationship between the first two components and the driver, vehicle, and geometric variables. A manual overlay technique was used to analyze the third component, to check the statistical results, and to verify a technique developed by Leisch to obtain speed profiles. The study found that route geometry and driver age played a significant role in the frequency of speed changes. Driver variables such as age and sex were the most significant factors affecting the magnitude of speed changes. Route geometry affected the magnitude of speed change much less than did the location of the speed change, and it affected the direction of speed changes much less than did driver age.

Research has shown that sudden changes in vehicle speed contribute to accidents (1). For example, at an 8-km/h (5-mile/h) speed reduction, the accident-to-speed ratio is 2.0; at a 16-km/h (10-mile/h) reduction, the ratio is 3.7; at a 24-km/h (15-mile/h) reduction, the ratio is 8.9; and at a 32-km/h (20-mile/h) reduction, the ratio is 15.9 (2,3). There are many possible causes for these sudden speed changes. Some can be linked to the driver, some to the vehicle, and some to the geometry of the highway. Leisch (3), for example, believes that speed variations are directly related to characteristics of road geometry such as joint horizontal and vertical alignment, curvatures, and gradients. Leisch also devised a theoretical technique for using speed profiles to relate changes in vehicle speed to changes in road geometry. This paper summarizes a research project conducted at Carleton University on the causes of sudden changes in automobile speed along the Gatineau Parkway in Canada (4).

PURPOSE AND SCOPE OF STUDY

The purpose of this research was twofold:

1. To determine what factors most strongly affect the speed patterns of drivers along a route and
2. If geometric variables do affect speed variation, to determine how well Leisch's technique works in a practical situation.

The scope of the research was limited to studying private automobiles on a parkway and the following variables: sex and age of the driver; number of occupants in the vehicle; size, age, and physical condition of the vehicle; and horizontal curves, vertical grades, and tangents. These variables were selected from a literature review of the causes of speed variations.

CAUSES OF SPEED VARIATION CITED IN THE LITERATURE

Driver Capabilities

Vehicle operating speed is altered by such driver-related variables as sex, age, driving experience, and occupation (5,6). Various studies on driver-related variables have concluded that trip distance has the greatest effect on speed. The number of passengers in the car and the sex of the driver alter driving speed to a lesser extent. There is, however, no information to indicate whether these factors or others affect consistency in speed along a route. In this study, data on the following driver characteristics were recorded to determine whether they have any impact on variation in speed: sex and age of the driver, number of passengers in the vehicle, and (whenever possible) relationship of the passengers to the driver.

Vehicle Characteristics

The literature on performance characteristics has generally classified highway vehicles as passenger cars, single-unit trucks, combination trucks, and buses. This classification is based on factors of gross weight and power rating (expressed in kilowatts or horsepower), which affect such operating characteristics as maintainable speed, load capacity, safety, and service.

Gross Weight

In various studies carried out on gross vehicle weight (3,7,8), there is no consensus of opinion on whether operating speeds vary with different vehicle weights. Lefeve (7) indicates that operating speeds do not vary with weight, whereas Lawshe (8) and others suggest that operating speeds tend to be higher for heavier passenger cars. None of these studies shed any light on whether heavier vehicles show greater or lesser tendency to change speed than lighter vehicles.

Power Rating

Certain studies (6) suggest that vehicle operating speed is not affected by power rating, whereas other studies (9) indicate just the opposite. But, again, none of these studies dwell on the possible relation between speed variation and power rating.

Speed Maneuverability

Vehicle maneuverability is a third vehicle characteristic that can affect operating speed. Maneuverability tends to vary with the size of the wheel base. Small cars are better able to negotiate tighter curves than larger vehicles. No studies were found to show whether, in fact, small-wheel-based vehicles have the potential for fewer speed changes. It would appear that a dependent relation exists between vehicle maneuverability and consistency in speed.

Age of Automobile

Various investigations of highway travel characteristics have shown that new cars have higher average speeds than older ones (5,7,10,11). The reasons given for this are that new cars have higher velocities, ride more comfortably, travel more smoothly and quietly, handle better, and are generally in better mechanical condition. Thus, it is quite likely that consistency in speed will also differ between older and newer cars.

Route Geometry

Various studies have been done to determine to what extent geometric roadway features affect travel speeds. Geometric features that could affect operating speed include horizontal, vertical, and cross-sectional alignment and pavement type.

Horizontal Alignment

Various studies (9) found that "vehicular speeds are lower on horizontal curves than on tangent alignments". The horizontal components that affect vehicle speed on a horizontal curve are superelevation, sight distance, and degree of curve. Superelevation has been investigated by a number of authorities to determine its effect on speed reduction (12-14). These studies indicate that higher speeds occur as the degree of superelevation increases. But the changes were not significant.

Studies by Taragin (12,13) on the influence of curvature and sight distance under comparable conditions indicate that curvature caused almost three times as great a change in speed as sight distance.

Vertical Alignment

All vertical-alignment variables appear to cause some variation in vehicle speed. This variation is more pronounced for trucks than for passenger cars.

The effect of grades on passenger cars is to cause the driver to reduce speed on upgrades greater than 7 percent (15) and to increase speed on downgrades greater than 3 percent (9). Length of grade is not considered to affect the speeds at which passenger cars operate.

Drivers reduce their speed as they approach crest vertical curves. The rate of the speed reduction appears to increase with the decrease in sight distance (9). Sag curves do not affect speed variation to any great extent (9).

No research data were found to show the effects on speed patterns of a simultaneous change in horizontal and vertical alignment, such as the introduction of a horizontal curve on a vertical grade.

Cross-Sectional Geometry

Studies on cross-sectional geometry and its impact on speed variation show that there are three factors that can be related directly to speed variation: a sudden change in any one of the cross-sectional elements, the presence of a two-lane highway where a driver is constantly meeting traffic traveling in the opposite direction, and a restriction of lateral clearance created by an object on the shoulder of the route (16,17).

Pavement

Vehicle speeds tend to vary when the pavement type changes or when the pavement is in very poor condition (7). These two variables are subject to the control of the appropriate maintenance agency.

Environmental Factors

The operation of a vehicle on the highway is affected by factors independent of the driver's capabilities, the roadway geometry, and the characteristics of the vehicle. These factors include such variables as land use, traffic volumes, weather, time of day, trip purpose, and physical view. These factors occur randomly and are therefore difficult to correlate with speed variation. Studies have shown that speed varies with season, time of day, and the severity of the weather, but there is no conclusive evidence to show any direct relation in the variability of these factors (6). In this study, therefore, it was necessary to limit the influence of these factors on speed fluctuations.

FIELD WORK

From the literature survey, a number of variables were selected that have the potential of being related to speed changes. These were age and sex of the driver, age and size of the vehicle, number of occupants, and route geometry. Field work was conducted to collect the appropriate data to determine whether these variables are in fact related to speed.

Selection of Test Route

The selection of a test-route section was based on the following criteria. The route must

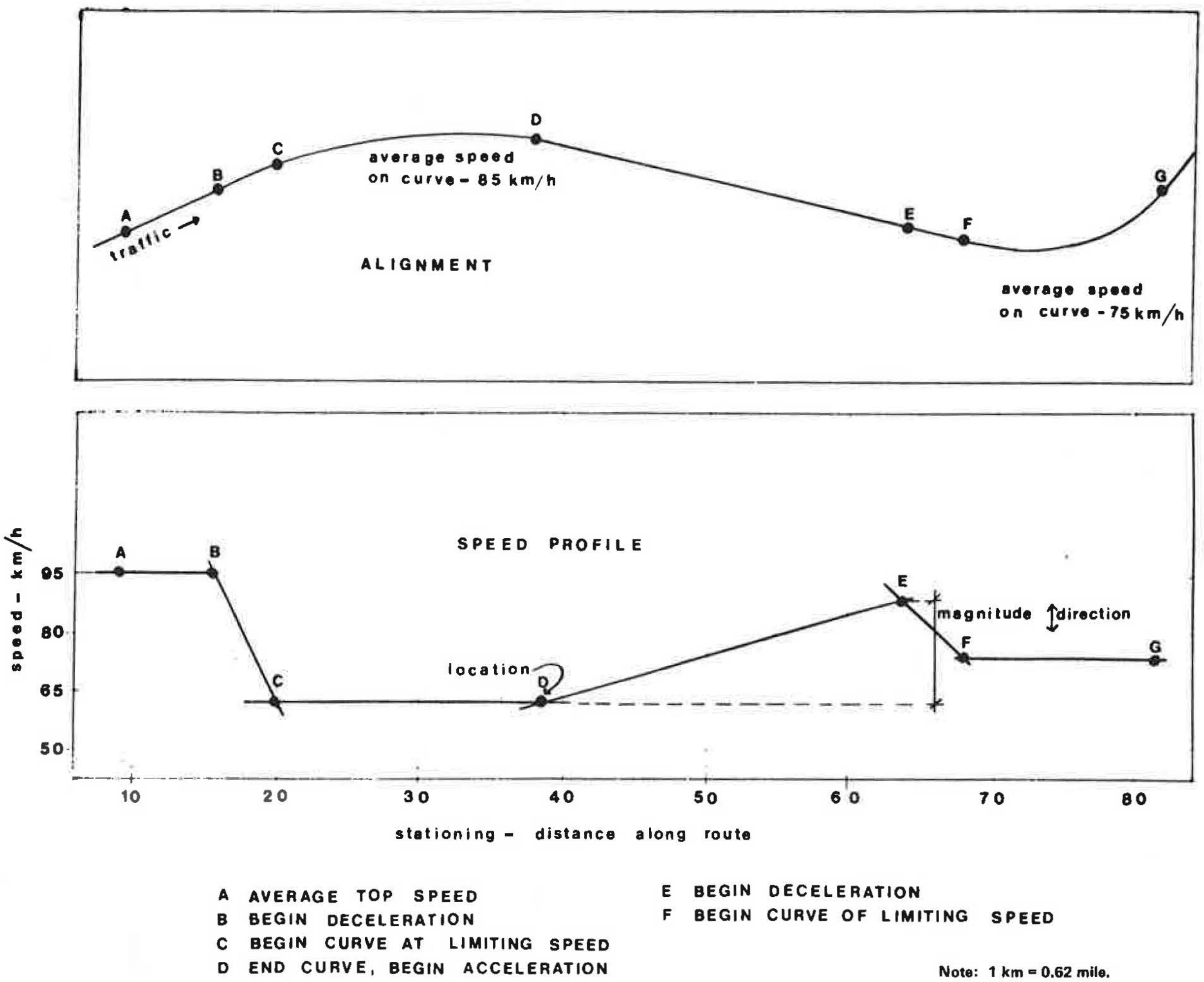
1. Be one for which standard design plans exist;
2. Contain a variety of horizontal curves, lengths of tangents, vertical curves, and degrees and lengths of grades as well as combinations of vertical and horizontal alignments;
3. Have a continuous type of pavement in good condition as well as consistency in cross-section geometry and superelevation;
4. Cater to one type of trip purpose and pass through only one type of land use area; and
5. Serve different types of passenger cars and drivers and varying numbers of passengers.

The Gatineau Parkway, a route approximately 65 km (40 miles) in length located approximately 25 km (15 miles) north of Ottawa in the Canadian province of Quebec, was felt to be most suitable for this research. Since the route was designed as a parkway and passes through the rugged, rocky, tree-covered terrain of the Gatineau Park, there is an abundant supply of curves and grades. The Gatineau Parkway provides access for the residents and visitors of the region to such recreational activities as picnicking, hiking, and general viewing of the scenic landscape. Because the route was built for recreational purposes, the land use pattern is consistent along its full extent. Furthermore, because the parkway has no destinations other than recreational ones, trip purpose is also constant. Another advantage in selecting this route for the study is the fact that it caters to a large variety of users whose primary mode of transportation is the private automobile.

The Gatineau Parkway was built with many adjacent belvederes and pull-offs to give users ample opportunity to view the surrounding terrain. These stopping points provided the necessary opportunities to gather the driver and vehicle data.

On weekends the parkway operates at near-capacity levels of traffic, but during the week traffic volumes are well within the level of "free-flow" conditions, which was a requirement for this research.

Figure 1. Speed profiles for passenger cars.



The parkway has been designed generally to meet the following standards (1 km = 0.62 mile; 1 m = 3.3 ft):

Criterion	Value
Design Speed (km/h)	60
Average running speed (km/h)	60
Maximum radius of curvature (m)	120
Maximum gradient (%)	10
Surface width (m)	6.8
Rounding	Variable
Shoulder width (m)	1.0
Side slopes	3:1
Back slopes	Variable
Minimum sight distance (m)	85
Minimum passing sight distance (m)	420

The geometric design data for various geometric variables were extracted from the original design plans (see Figure 1).

The pavement is bituminous asphalt along the full extent of the route and is in excellent condition. Even though the parkway has only two lanes, there is expected to be little interference from oncoming traffic because of the 3.75-m (12-ft) lane width and the paved shoulders.

Because the route is so long, only a portion of it was used for the research project. The section selected is at the terminus of the parkway--Champlain Lookout. Unfortunately, approximately 1.6 km (1 mile) south of the Champlain belvedere, the parkway splits and one route goes to Camp Fortune and the other returns to Hull and Ottawa. Because it is impossible to predict which route the user will take, two sets of data were collected, one for each route.

Besides the fact that it meets all of the data requirements, there are other reasons for selecting this section of roadway. Users must travel approximately 35-50 km (22-31 miles) through the park to reach this destination. By the time they reach it, they are well acclimatized to the landscape, so that any effects the scenic terrain may have on their speed patterns are reduced. A large pull-out is located at the terminus of the parkway. This was the point from which the necessary driver and vehicle data were collected. Because of the size of the pull-out, the data could be collected inconspicuously, from a distance.

Data Collection

Speed-Variation Patterns

To measure speed-variation patterns, a motor-driven camera was attached to the inside cab of an observation vehicle so that it focused on the speedometer and the odometer. This camera was operated by remote control by a second person so as not to interfere with the driving of the vehicle.

When a subject vehicle pulled into the belvedere, the responsibility for collecting all vehicle and driver data rested with the person riding in the back seat of the observation vehicle (this was necessary because the driver was fixed in position behind the camera equipment). This second person got out of the observation vehicle and closely approached the subject vehicle under the pretense of looking at the view, thereby collecting some of the necessary data. He took a photograph of the rear of the subject vehicle so that the license number was clearly recorded. This was easy to do because cameras are so frequently used to take pictures of the scenery. He then returned to the observation vehicle and, when the subject vehicle left the belvedere, the observation vehicle simply followed behind, recording the necessary speed data.

The observers followed a subject vehicle at a fixed distance, recording all speed changes on film from instrument readings. This method obtained both a continuous speed reading and, by means of the odometer, the distance location of all observed vehicles traveling through the test section of the parkway.

A distance of 90 m (300 ft) was kept between the observation vehicle and the subject vehicle so as not to influence the driving patterns of the subject. This distance requirement was maintained by using a transparent grid on the windshield that represented the width of a large car 20 m (65 ft) away.

Driver and Vehicle Characteristics and Route Geometrics

A camera and data forms were used to record the field data on vehicle and driver variables. The camera took pictures of the subject vehicle and its license number while it was stopped at the belvedere. Data such as the age of the driver, the number of persons in the car (by sex and age), the time of day, and weather conditions were recorded on forms.

Measures for route geometry were derived indirectly by using a new technique devised by Leisch (3), which involves regulating the road geometry to maintain the necessary consistency in operating speed along the road. This technique requires setting up a speed profile that takes into account the joint configuration of horizontal and vertical alignment as well as individual curvatures and gradients. The technique makes use of existing design standards outlined by the American Association of State Highway Officials (AASHO) (18). In setting up the required theoretical speed profile, design speeds on curves and tangents are used.

A speed profile developed from these standards (see Figure 2) provides a continuous plot of the average speed of vehicles along a highway under free-flow conditions. The configuration of the speed profile combines horizontal and vertical alignment features and instantly points out where speed changes occur because of the road geometry.

Sample Size

During 10 days in June 1977, the speed-variation patterns of 60 subjects were observed and recorded. Unfortunately, 18 samples had to be rejected because various extraneous factors affected the speed-variation patterns. This left 22 sets of data for route 1, 11 for route 2, and 9 for portions of the two routes, for a total sample size of 42.

DATA ANALYSIS

Dependent Variables

The primary purpose of this research was to determine which factors most strongly affect speed variation. The magnitude of the speed changes along a route segment was represented by the following variation term:

$$\text{Magnitude of speed} = [\Sigma(X - \bar{X})^2/n]^{1/2} \quad (1)$$

where

X = speed measurement taken every kilometer along the route segment,
$\bar{X}$ = sum of measured speeds divided by n, and
n = number of kilometers in the route segment.

The collected speed-variation data were plotted as speed profiles (Figure 2), and the various speed measures were extracted from these profiles. Further research into speed variation was also undertaken. This included determining the factors that most strongly affect the frequency and the direction (increase or decrease) of the speed change. Frequency of speed change along a route was represented by the number of times a vehicle changed its speed along the test section of roadway. The direction of the speed change was extracted from the speed profiles.

Independent Variables

It was hypothesized that each of the three measures of speed variation is a function of the following independent variables: age and sex of the driver, age and size of the vehicle, number of occupants in the vehicle, and route geometry. Measures for driver and vehicle characteristics were determined directly from the field data. Since the Leisch technique is based on geometric variables of the route, it is a simple matter to extract corresponding expressions for frequency of speed change and magnitude of speed change to represent the independent variable, route geometry.

Analysis Techniques

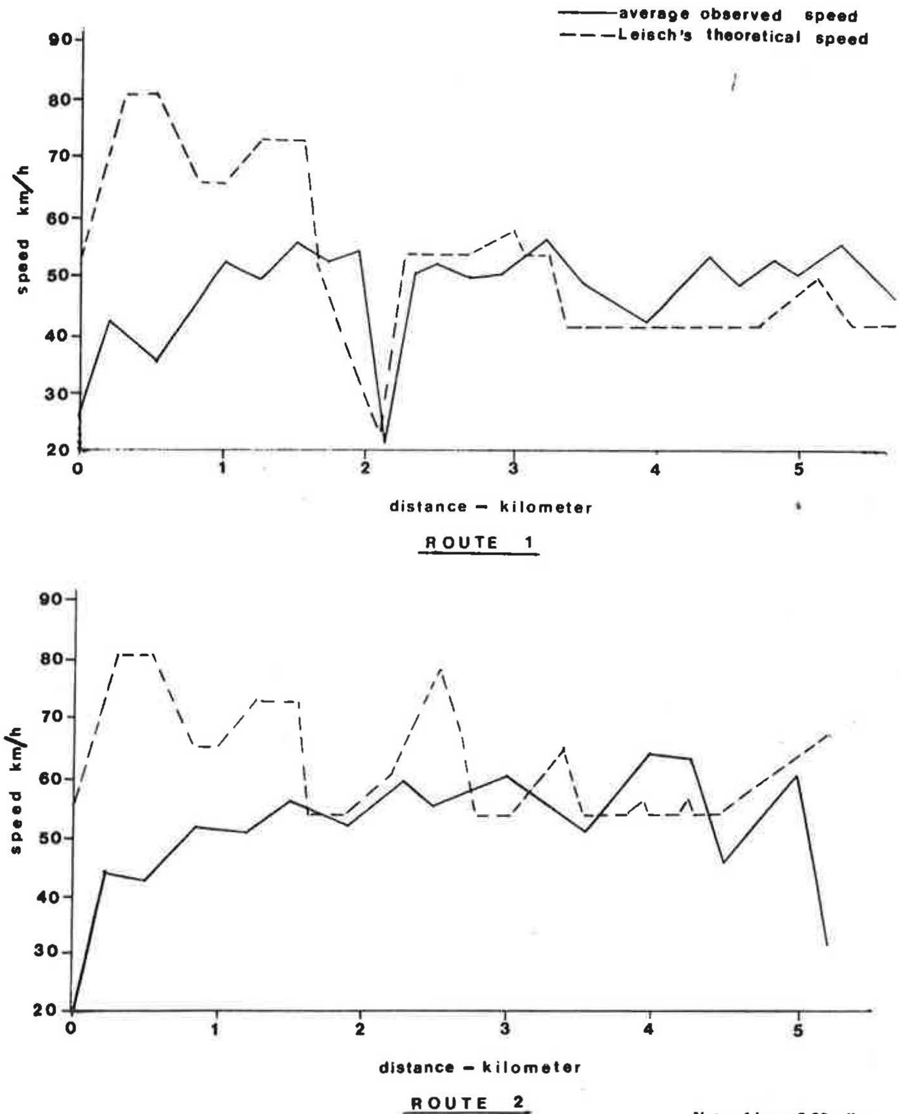
The first two measures of speed variation--frequency and magnitude of speed change--and the associated independent variables--driver age and sex, vehicle age and size, number of vehicle occupants, and route geometry--were analyzed by using statistical methods. The third measure of speed variation--direction of speed change--was analyzed by using a graphical overlay method.

Statistical Methods

Because the data base contained categorical (nonmetric) data as well as integral (metric) data, analysis of covariance was used to analyze the data. The nonmetric variables were the driver and vehicle characteristics, and the metric variables were the geometric and number-of-occupants variables (these variables are expressed as absolutes rather than as category data).

The first step in the analysis was to determine the interactions between the metric and nonmetric data. A correlation matrix that uses Pearson's correlation coefficient (R^2) was considered appropriate for this purpose. The results of this analysis are given in Table 1. There appear to be no significant interactions between any of the metric and nonmetric variables. The most

Figure 2. Speed profiles for routes 1 and 2 of the Gatineau Parkway.



Note: 1 km = 0.62 mile.

significant interaction occurs between number of occupants and driver age (correlation 0.2542). These results indicate that analysis of covariance can be safely carried out on all of the metric and nonmetric variables listed without concern about possible interactions between the two types of variables that would confuse the results.

The results of the analysis of covariance are given in Tables 2 and 3. Table 2 gives the results of the analysis between the dependent variables and the independent variables. For frequency of speed change, columns 1 and 2 of this table show the overall model to be significant at the 0.0021 level. Therefore, the variables selected are the ones most likely to influence the location of a speed change, and no other possible factors have been omitted. The fact that there are no significant interactions between any of the nonmetric variables suggests that none of the nonmetric variables affect the dependent variable by affecting each other. Because this research considers a 0.01 level of significance to be adequate, the joint additive main effect is also insignificant. In the same way, none of the nonmetric variables independently account for any significant portion of the variation present in the dependent variable.

On the other hand, the covariates are very significant (0.0000); the significant factor is route geometry expressed in terms of frequency of speed change.

Table 3 elaborates on the statistical findings of Table 2 by showing both unadjusted and adjusted deviations (the mean of each category expressed as a deviation from the grand mean) for each nonmetric variable. The η^2 for each variable indicates the portion of variation in the dependent variable explained by that specific variable. In the frequency-of-speed-change variables (columns 2 and 3), the observed number of speed changes = 16 percent (0.397^2) by any one nonmetric variable. Age of the vehicle and sex of the driver each independently account for 7, 6, and 2 percent of the variation in the dependent variable. Route geometry independently accounts for the greatest portion of variation: 70 percent.

When controlling for the confounding effects of the other variables, the contribution made by each metric variable to the variation in the dependent variable decreases (column 2). Driver age still remains the one nonmetric variable that accounts for the largest portion of the variation in the dependent variable: 5.24 percent.

The multiple R, the statistic at the bottom of

Table 3, indicates the overall relation between the dependent variable and the independent variables, whereas R^2 represents the portion of variation in the dependent variable explained by the additive effects of all metric and nonmetric variables. Both statistics show the ability of the independent variables to explain the variation in the dependent variable ($R = 0.897$ and $R^2 = 0.805$).

From this analysis, it can be concluded that

1. The variables selected to study the frequency of speed changes are a fairly complete set.
2. The route geometry represented by Leisch's frequency of speed change is the strongest single factor affecting the frequency or the location of a speed change.
3. Driver age is the second most significant factor affecting frequency of speed change.

Columns 4 and 5 of Tables 2 and 3 deal with the analysis of the second measure of speed variation, magnitude of speed change. The fact that the overall effect is not significant suggests the possibility that other factors besides those listed affect the dependent variable. The overall two-way interaction approaches significance (0.02), and interactions occur between the variables for vehicle age and vehicle size, which are close to significant (0.08). But, as specified before, only levels of significance 0.01 or greater were accepted. Therefore, because of the nonsignificant two-way interactions, none of the nonmetric variables indirectly accounts for the variation in the dependent variable through another nonmetric variable. Neither the joint additive effect nor any of the main effects account for a significant portion of the total variation. Therefore, none of the nonmetric variables affects the dependent variable, and none of the metric variables or covariates affects the dependent variable.

Columns 4 and 5 in Table 3 show that driver age is the single most significant variable, accounting for 12.82 percent of the variation in the dependent variable. This variable is followed in significance by driver sex, vehicle age, and vehicle size, which are responsible for 1.06, 0.49, and 0.372 percent, respectively, of the total variation of the dependent variable. The two metric variables account for 1.35 and 1.3 percent of the variation. This makes these two variables the second and third most significant variables affecting the dependent variable. Because of the near-significant overall two-way interaction, this prohibits further analysis of the data (i.e., the adjusted nonmetric deviations).

The multiple R and R^2 indicate the small amount

Table 1. Correlation between metric and nonmetric variables.

Metric Variable	Nonmetric Variable: Driver Age	Driver Sex	Vehicle Age	Vehicle Size
Leisch's frequency of speed change	-0.020 4	0.097 76	0.058 81	0.032 25
Leisch's magnitude of speed change	0.052 58	0.113 61	0.157 86	0.095 4
Number of occupants	0.254 2	0.012 49	0.080 9	0.283 8

Table 2. Analysis of covariance.

Source of Variation	Frequency of Speed Change: F	Frequency of Speed Change: Significance of F	Magnitude of Speed Change: F	Magnitude of Speed Change: Significance of F
Covariates	43.535	0.000 00	0.810	0.458 92
Leisch's frequency of speed change	84.573	0.000 0	-	-
Leisch's magnitude of speed change	-	-	1.013	0.326 27
Number of occupants	1.736	0.202 51	1.257	0.275 59
Main effects	2.127	0.076 71	1.045	0.441 09
Driver				
Age	1.998	0.146 76	2.604	0.080 22
Sex	0.458	0.506 12	0.034	0.854 66
Vehicle				
Age	2.007	0.160 50	0.131	0.878 32
Size	0.478	0.627 04	0.011	0.989 48
Two-way interactions	0.569	0.819 79	2.661	0.029 96
Age and sex of driver	0.013	0.910 07	2.193	0.154 22
Age of driver and age of vehicle	0.489	0.620 18	2.189	0.138 12
Age of driver and size of vehicle	0.640	0.639 85	0.475	0.753 81
Sex of driver and age of vehicle	1.314	0.260 77	1.314	0.260 77
Sex of driver and size of vehicle	0.030	0.864 44	2.265	0.147 977
Age and size of vehicle	0.140	0.870 21	2.738	0.088 89
Explained	5.329	0.002 1	1.792	0.098 79

Table 3. Results of multiple classification analysis.

Variable	Frequency of Speed Change: Unadjusted Deviations	Frequency of Speed Change: Adjusted Deviations	Magnitude of Speed Change: Unadjusted Deviations	Magnitude of Speed Change: Adjusted Deviations
Leisch's frequency of speed change	-	β 0.835 544 3	-	
Leisch's magnitude of speed change	-	-		β 0.116 179 8
Number of occupants	-	β 0.443 428 8		β 0.114 689
Age of driver (years)	η 0.397	β 0.229	η 0.358	β 0.413
16-20	-0.642 285 28	-2.455 804	1.952 573	2.184 088
20-35	-1.880 948	-0.312 347 4	0.099 993 71	0.105 120 7
35-50	0.741 760 3	-0.810 638 4	-0.409 163 5	-0.483 649 3
50	4.357 147	2.793 198	0.180 948 3	0.270 786 3
Sex of driver	η 0.108	β 0.072	η 0.103	β 0.031
Male	0.199 249 3	0.133 056 6	0.036 590 58	-0.010 833 74
Female	1.892 853	-1.264 755	-0.347 621 0	0.102 840 4
Age of vehicle (model year)	η 0.242	β 0.198	η 0.070	β 0.137
Pre-1970	4.857 147	-0.606 079 1	0.152 485 8	0.669 809 3
1970-1975	1.489 014	-1.625 046	-0.109 162 3	-0.032 409 67
Post-1975	0.357 147 2	0.827 209 5	0.041 263 58	-0.034 021 38
Size of vehicle	η 0.164	β 0.103	η 0.061	β 0.023
Large	-0.279 220 6	-0.461 349 5	-0.038 514 14	0.040 445 33
Intermediate	1.357 147	0.875 396 7	0.098 528 86	-0.006 198 883
Compact	-0.809 524 5	-0.350 418 1	-0.047 625 54	-0.020 256 04
Multiple R^2		0.805		0.191
Multiple R		0.897		0.437

of explained deviation provided by the metric and nonmetric variables (R^2 = 0.191 and R = 0.437).

From this analysis, it can be concluded that

1. The variables selected to represent the variation in the magnitude of speed change do not adequately reflect this variation.
2. Among the variables studied, the driver characteristics (age and sex) seem to have the strongest influence on the magnitude of speed change.
3. Route geometry, in terms of the variables studied, is the second most significant factor affecting the magnitude of speed change, but the amount of variation it accounts for is very small (1.35 percent).

Comparing Overlays

Besides using analysis of covariance to determine the significant factors that affect speed variation, speed profiles of the observed vehicles were drawn up on transparencies based on the same format and scaling used in Leisch's speed profiles. The purpose of this was to verify the statistical results. By using relevant variables to categorize the observed profiles, composite drawings were produced that showed similarities and differences in speed patterns. These composite drawings also permitted the third component of speed variation--the direction of the speed change--to be studied.

In the attempt to group all profiles by some common denominator, grouping by driver age appears to provide the best possible fit. Driver age is therefore the factor that best accounts for direction of speed change.

Figure 2 shows, for each of the two routes, the relation between Leisch's theoretical speed profile and an average speed profile derived from the collected field data. These graphs reinforce the statistical findings. They also shed some light on the third component of speed variation, direction of speed change. It would appear that other variables besides route geometry affect this variable.

CONCLUSIONS AND RECOMMENDATIONS

This project had two objectives: (a) to determine which factors influence changes in automobile speed along a roadway and (b) to evaluate Leisch's speed-profile technique.

With respect to the first objective, the following conclusions are drawn:

1. Route geometry has a significant effect on the location of speed-change frequency.
2. Driver age is the only other variable that significantly affects the frequency of speed change.
3. Variables such as the age and sex of the driver are the most significant factors affecting the magnitude of the speed change.
4. Route geometry affects the magnitude of the speed change but much less than do driver characteristics.
5. Driver age seems to be the factor that most strongly affects the direction of the speed change.
6. Route geometry does not appear to have a strong effect on the direction of the speed change.
7. Other variables besides those researched in this project appear to affect speed variation to a certain extent, especially the magnitude of the speed change.

With respect to the second objective, it can be concluded that Leisch's technique, as it has been formulated, is an acceptable technique for determining where speed changes take place. But, since it does not incorporate into its diagnostics the driver element, which appears to affect the amount and the direction of speed changes, the technique should be researched further so that a driver factor can be incorporated into it.

In the area of research, the following recommendations are made:

1. Because certain speed patterns appear randomly across the various factors studied as seen throughout the manual technique, there is need to further assess other possible factors that affect speed variation. The following factors are felt to be worthy of study, to determine their impact on speed variation: (a) mood of the driver, (b) familiarity with the route, (c) trip purpose, (d) posted speed limit, (e) whether the route is a high-design highway, and (f) whether the route has fewer geometric changes.
2. Further research on Leisch's technique is recommended so that driver characteristics, such as age and sex, can be incorporated into the technique.

In the area of highway design, the following suggestions are made:

1. Because the variation in automobile speed occurs where the horizontal alignment changes, the designer should carefully check to ensure that adequate sight distances are provided in these locations, especially those that could cause speed changes greater than 15 km/h (9 miles/h).
2. As the results for the magnitude of speed change show, there is little the designer can do to control this factor.
3. The designer can do little to affect the direction of the speed change.

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Mandatory Safety-Belt Law: The Saskatchewan Experience

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The results of five surveys conducted in Saskatchewan to determine rates of safety-belt use are summarized. On July 1, 1977, legislation was passed requiring all front-seat occupants of motor vehicles to use the available safety restraints. The survey results indicate the changes in rates of safety-belt use from May 1977, the period just before the law was passed (when there was an intensive campaign to educate the public to the use of safety belts), to May 1979, two years after enactment of the law. Information was gathered on various driver, vehicle, restraint-system, and trip characteristics to determine what relations exist between these characteristics and safety-belt use. Among the characteristics considered were driver age and sex, educational level, level of driver education, frequency of safety-belt use, accident experience, and number of miles driven per year; roadway speed limit; length of trip; and vehicle size, model, and year of manufacture. Rates of safety-belt use were higher for various conditions, including drivers between the ages of 26 and 36; male drivers; drivers with a high school education or better; and compact, foreign-made, and/or newer vehicles. It was found that, since the passage of the safety-belt law, injury and fatality rates have decreased in the province even though total accidents and miles driven per year have increased.

In an effort to increase the use of safety belts in vehicles, the province of Saskatchewan passed a law on the mandatory use of safety belts on July 1, 1977. To measure the effects of the law and of publicity campaigns and enforcement, five surveys of safety-belt use were conducted and analyzed to obtain an unprecedented picture of safety-belt use before, during, and after the introduction of the law.

Table 1 indicates the extent of the major surveys, which were conducted in the month of May in 1977, 1978, and 1979. The surveys were made at sampling stations throughout the province, on urban streets, provincial highways, and municipal roads. All vehicles except emergency vehicles, buses, and trucks with a gross vehicle weight (GVW) greater than 10 000 lb were included in the surveys.

RATES OF SAFETY-BELT USE

The May 1977 survey indicates the rate of safety-belt use before the law was passed and reflects the effects of an intensive educational program conducted during that period. The average rate of use at that time was slightly less than 20 percent.

Rates of safety-belt use appeared to be a function of a number of factors. Various driver and vehicle characteristics had a favorable effect. Rates of use were better for post-1974 vehicles, American Motors vehicles, compact and subcompact models, vehicles equipped with safety-belt warning systems, drivers under the age of 45 and particularly between the ages of 26 and 35, and drivers with a high school education or better.

A limited survey conducted in July 1977 indicated the effects of the safety-belt legislation. The average rate of use had increased to more than 52 percent. A second limited survey conducted in October 1977 indicated the effects of enforcement and ongoing publicity campaigns. On an overall basis, the rate of safety-belt use had increased to more than 70 percent.

During May 1978, a fourth survey was conducted to determine the effects of ongoing publicity and varying levels of enforcement. Rates of safety-belt use had declined to slightly more than 55 percent. The effect of enforcement was more significant in larger urban centers than in smaller urban centers that had more nonlocal and out-of-province traffic. Nonlocal drivers may have been less aware of local laws and police policy.

A fifth survey was conducted in May 1979 as part of the continuing program to monitor safety-belt use. Rates of use had leveled off to an average of 64 percent. Enforcement levels were also being monitored and were compared with corresponding rates of use at specific locations.

The total number of accidents and miles driven in the province have increased each year, whereas since July 1977 injury and fatality rates have decreased. In order to keep injuries and fatalities to a minimum, it will be necessary to maintain a high rate of safety-belt use by means of publicity campaigns and enforcement.

SURVEY DESIGN

The design for the Saskatchewan surveys attempted to

1. Establish profiles of vehicle, driver, and environmental characteristics;