A set of aerial photographs made by the Agricultural Adjustment Administration covering the county are filed in the engineer's office. It would now seem impossible to function properly without them, but we are still looking forward to having a set of contour maps.

CONCLUSION

The combined record of the ninety-nine counties of our state working under the county unit system of secondary road administration casts a favorable reflection upon that method, for conditions existing in Iowa. We hope that Linn County has been able to sustain the average rating established.

DEPARTMENT OF TRAFFIC AND OPERATIONS

WILBUR S. SMITH, *Chairman*

A STUDY OF VEHICLE, ROADWAY, AND TRAFFIC RELATIONSHIPS BY MEANS OF STATISTICAL INSTRUMENTS

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AND

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SYNOPSIS

The Committee on Vehicle Characteristics, with the cooperation of the automotive industry developed a group of statistical instruments measuring speed, fuel economy, deceleration, torque, and throttle opening. This paper covers the development and use of these instruments.

The report is divided into two sections. The first section includes a discussion of the apparent need for means of measuring effects and relationships existing between the motor vehicle characteristics, highway characteristics, and the traffic conditions. Also included in the first section is a description of the instruments, their development, and operation.

The second section of the report pertains to the experience with the use of the instruments and the results obtained. The results include the comparison and rating of highways under different conditions of traffic in rural and urban areas, and the comparison of different types of traffic control systems by means of the instrumentation. Also included is a comparison of different drivers by means of the instruments.

The Highway Research Board Committee on Vehicle Characteristics was organized in September, 1946. Its assignment was to make a study of the characteristics built into motor vehicles and their relation to traffic problems.

The first meeting of the Committee was held in Washington, D. C., on Wednesday, December 4, 1946, at which time the objectives and their related problems were discussed and a plan of action was laid out. Since that time progress has been made on the plan, and although the work is far from complete, it was felt that sufficient results had been obtained to warrant a report.

It appears that there is one general objective toward which all people having anything to do with the motor vehicle are working. That objective is the provision of the most rapid individual transportation possible, consistent with the maximum possible safety, and the greatest possible economy. This Committee is concerned with the characteristics of the motor vehicle built into it by the manufacturer, how these characteristics are used by the driving public, and how their use is related to traffic and highway.

Motor vehicles have many built-in characteristics which can be studied with interest. Of these, however, there are only a few which are related directly to the vehicles' behavior

on our highways and under traffic conditions. The Committee selected for study, "Velocity," "Acceleration," "Deceleration" and "Fuel Economy" as being the most basic. Certain values of these characteristics are built into motor vehicles by the manufacturer, and data regarding them can be obtained for individual makes and models of cars. To what degree the driving public takes advantage of what the manufacturer gives them is only a matter of speculation.

The immediate objective of the Committee, therefore, was to devise ways and means of studying these four basic characteristics, as to how they are used by the driving public, how this use affects traffic conditions, and how roads and traffic in turn affect their use. Insofar as could be ascertained, there are very little data available bearing directly on these problems.

The Committee was faced with the problem of developing tests and instruments which could be used in this type of study. A Sub-Committee on Finance was appointed to obtain the funds necessary for development and testing of these instruments. Through the efforts of this Sub-Committee assistance was provided in the form of engineering, labor, and material by the Bureau of Public Roads, Chrysler Corporation, and General Motors Corporation. Subsequent to the construction of the instruments, financial assistance was obtained from the Automobile Manufacturers Association, and cooperation and assistance obtained from the Traffic Department of the City of Detroit, Michigan State Highway Department, Connecticut State Highway Department, University of Michigan, and the Bureau of Highway Traffic at Yale. Without the help of these agencies, this work would not have been possible.

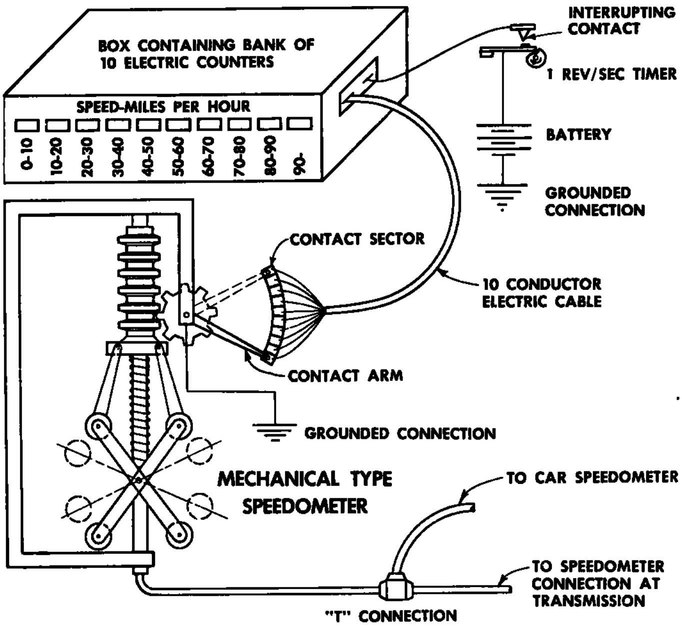

Figure 1. Schematic Diagram of Instrument Recording Speed Characteristics

A Sub-Committee on Instrumentation was established and this group has designed and built one set of instruments for recording data on the four basic characteristics designated by the Committee. These are "Velocity," "Deceleration," "Fuel Economy," and "Acceleration." Acceleration is not recorded directly, but as two related quantities, namely, engine torque and throttle opening, which are roughly proportional to acceleration.

The recorders are contained in cases which are placed in the test car. Connections between the instruments and the car are made

quite easily. They consist of certain electrical connections, a tube connection with the windshield wiper vacuum outlet on the intake manifold, a "T" take-off drive from the speedometer cable. A contact sector on the throttle, and a fuel meter in the carburetor gas line must also be installed. All instruments record their data in the form of numbers on banks of electric counters. The data, therefore, are statistical in nature and can be plotted in the form of graphs or charts.

Figure 1 is a schematic diagram of the instrument recording speed characteristics. The heart of this device is the distributing speedometer seen at the lower part of the diagram. This is a heavy mechanical speedometer driven by a "T" take-off from the regular speedometer cable of the car. The indicating hand of the speedometer is replaced with an arm which sweeps over a sector divided into contact plates, so designed that each one covers a specific increment of speed. Each contact plate is connected electrically to an electric counter. The circuit from the bank of counters is continued through an electric timer, through a battery, and finally back to the swinging arm of the speedometer, completing the electric circuit through the grounded connections.

Each counter in the speed bank represents a range of speed in miles per hour.

At the end of any trip, the number totaled up on any counter represents the number of seconds during the trip that the vehicle was travelling in that particular speed range. Data from this instrument are plotted in graphical form, the vertical axis representing percent of time.

Figure 2 is a schematic diagram of the instrument recording braking. The heart of this device is a distributing spring-mass decelerometer unit, having as the indicating hand a contact arm sweeping over a sector as in the speed recorder. The electrical circuits through the bank of counters and timer are identical with the velocity instrument and need no further explanation. The decelerometer unit itself is an adaptation of the design used for many years in the General Motors Brake Machine, which has proven to be very rugged and reliable.

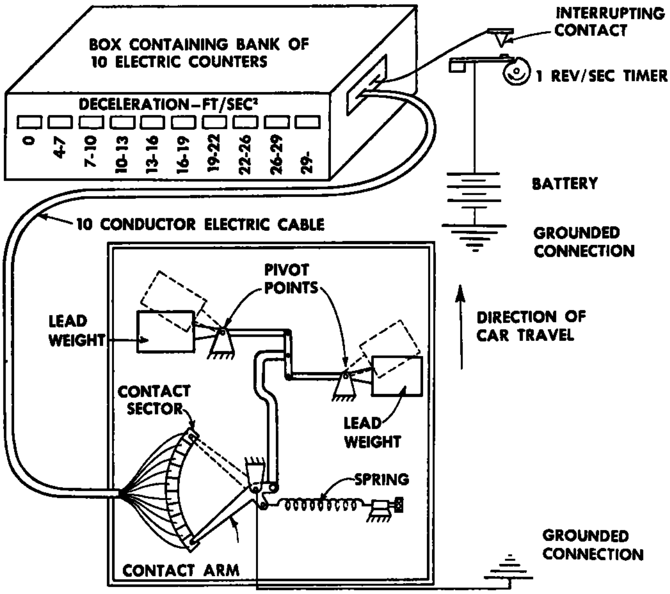

Figure 2. Schematic Diagram of Instrument Recording Braking

Each counter above No. 1 in this counter bank represents a range of deceleration. The number of counts on any counter above Counter 1 in a trip is the total number of seconds that the brakes were applied in the range of deceleration represented by that particular counter. Data are plotted showing ranges of deceleration and the percent of time of application.

Measurement of acceleration is much more

difficult than deceleration, because the range of acceleration varies widely in the different gears, and because the maximum acceleration is a small percent of gravity. The requirements for a direct reading accelerometer, therefore, are such that the instrument of necessity becomes delicate and complicated to the point that it is impractical for this type of work. Ways and means were therefore sought to provide a practical indirect measure of acceleration. Acceleration in a motor vehicle is brought about by an increase in engine torque, which is roughly proportional to throttle position. In other words, when you wish to accelerate your car, you "step on it." Therefore, a record of the degree of throttle opening is a rough indication of the driver's desire to accelerate on a level terrain. In hilly terrain this is not true, because of the different throttle openings required to maintain constant speed on different gradients.

Engine torque is roughly proportional to the differential pressure existing between the intake and exhaust manifolds of the engine. However, the pressure in the exhaust manifold contributes only a small part of the proportionality so that we can say that the engine torque can be roughly measured by the degree of pressure existing in the intake manifold. The attractive part of this is that it offers a very easy and rugged means of recording the torque or force which is required of the engine to drive the car over a certain trip. There is a considerable difference of opinion in the Committee as to the desirability of obtaining information by either of the above methods. However, instruments have been devised for recording these data and the results are being studied.

Figure 3 is a schematic diagram of the intake manifold vacuum instrument. The vacuum device itself is a metal bellows to which is attached a calibrated spring and a swing arm passing over a sector divided into contact plates representing ranges in vacuum. As in the instruments described before, the electrical circuit distributes to a bank of counters and is interrupted by timing contacts.

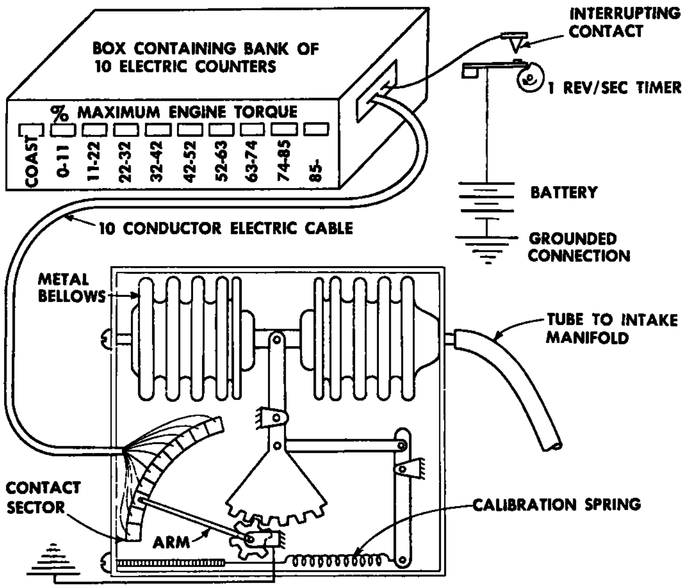

Figure 3. Schematic Diagram of the Intake Manifold Vacuum Instrument for Determination of Engine Torque

Figure 4 is a schematic diagram of the instrument relating throttle opening with percent of total time. The basic part of the instrument again consists of a sector having a series of contacts over which sweeps an arm connected with the throttle mechanism so that each contact represents some degree of throttle opening. The electric circuit is identical with those previously described.

Data from both of these instruments are plotted in the form of graphs, the vertical axis representing percent of time. In the case of throttle opening, the horizontal axis is in ranges of percent of throttle opening. In the case of engine torque, the horizontal axis may be in ranges of percent of engine torque or in certain cases where a single automobile is

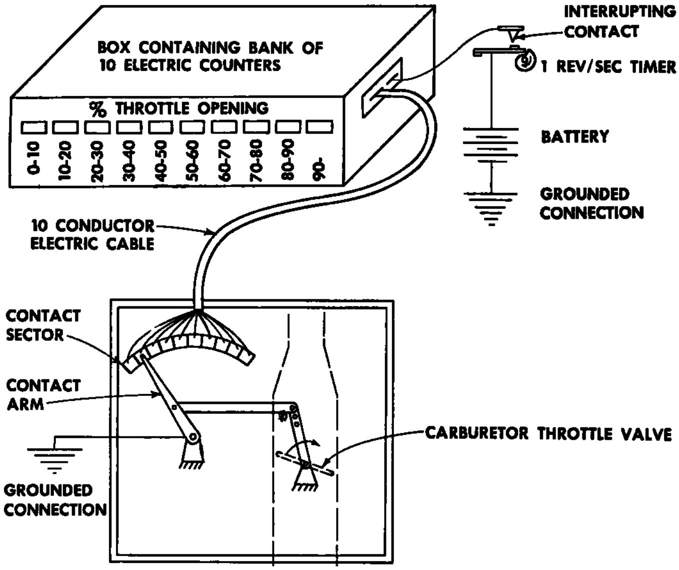

Figure 4. Schematic Diagram of the Instrument Recording Throttle Opening

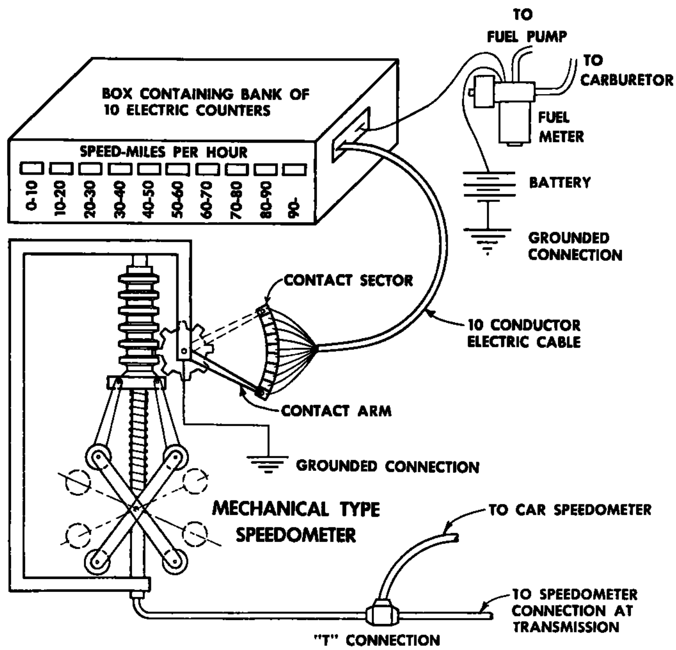

Figure 5. Schematic Diagram of the Instrument Recording Fuel Consumption

used as a test car, torque can be converted into force driving the car. In the latter case, the horizontal axis is in ranges of force.

Figure 5 is a schematic diagram of the fuel economy instrument. The general layout of this device is identical to the speed instrument (Fig. 1) except that the fuel economy unit is introduced into the circuit in place of the timing interrupter. The fuel unit is connected in the fuel line of the vehicle between the carburetor and the fuel pump. Fuel under pressure from the pump enters the inner side of a metal bellows which is displaced against gasoline surrounding it in a metal chamber. This gasoline is forced out of the chamber through the fuel line to the carburetor. The displacement continues until the bellows is stopped by a rigid contact which actuates the electrical circuit throwing up one number on the counter, and reversing an electrically operated gasoline valve attached to the top of the bellows chamber. The reversal of this valve directs the gasoline from the fuel pump into the chamber surrounding the bellows and connects the fuel line to the carburetor with the inside of the bellows. Flow from the inside of the bellows causes it to contract until it strikes a rigid inner electrical contact. When this occurs, the electric valve is reversed, directing gasoline from the fuel pump into the inner side of the bellows, repeating the cycle. All energy for reversing the valve and operating the counter is taken from the electrical circuit and not from the pressure of the gasoline. Adjustment for calibration is accomplished by positioning the electrical stops. The present instrument is calibrated so that each cycle and therefore each number totaled up on the counter bank represents 0.001 gallon of gasoline used. Since the counts are distributed on the bank according to speed, the fuel economy data are shown as the percent of the total gasoline used on a trip in the ranges of speed used.

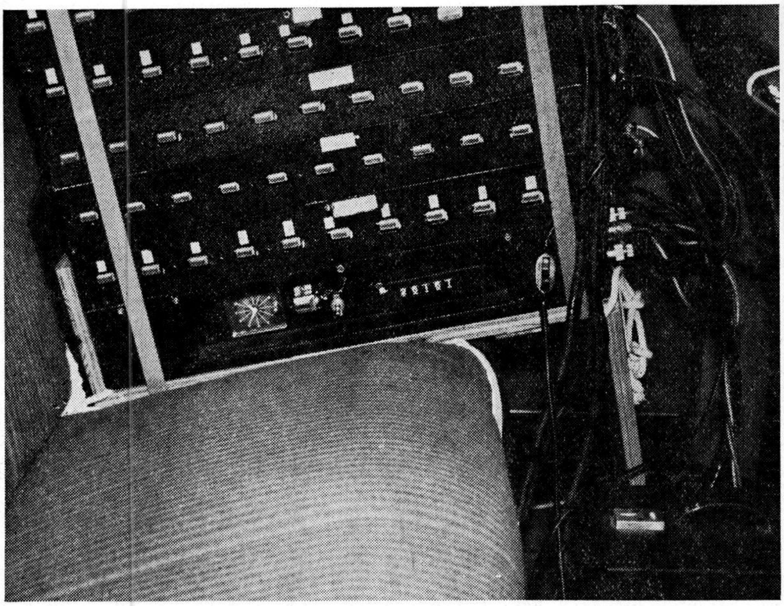

Figure 6. Instruments Installed in a 1950 Model Plymouth Showing the Five Counter Boxes and the Box Housing the Timing Device—Box on floor houses component parts of the instruments.

As was pointed out at the beginning of this report, the data obtained from all instruments are in the form of accumulated numbers, each number being the sample of a condition over a short interval. All these instruments could have been designed so as to draw line charts of the different variables. Since, however, phenomena having to do with flow of traffic vary rapidly over wide ranges, analysis of line chart recordings would have involved a

tremendous amount of calculation. The accumulating type of instruments permits a large number of samples to be taken rapidly and easily and reduces the work of analysis to a minimum.

It is not within the scope of this report to give complete design and calibration details of these instruments. Such detail will be made available by the committee in the near future.

This highly experimental set of instruments (Fig. 6) was installed in a 1950 model Plymouth and the testing program commenced on April 25, 1950. The purpose of the testing program was to determine the utility of the

TABLE 1
CONNECTICUT RATING COMPARED TO DATA OBTAINED WITH INSTRUMENTS
(Length of all tests—50 mi.)

Section Test No.	Connecticut Rating[a]	Average Speed	Fuel Economy	Braking	Force Mean	Throttle Opening Mean
		mph.	*mpg.*	*sec. per mi.*	*lb.*	%
3	72	64.9	18.4	1.2	344	33.6
5	67	56.6	19.2	.4	290	27.2
1	55	52.5	20.4	1.4	262	22.9
6	54	55.9	[b]	.9	296	27.3
4	46	38.5	21.4	4.0	234	17.4
2	28	40.9	22.3	1.9	244	16.3

[a] Max. possible 80 points
25 pts. Surface width
12 pts. Maintenance cost
30 pts. Accident records
13 pts. Curvature data
—
80 pts. Total—Perfect Road
[b] Not Recorded

information obtained by the use of these instruments and also to prove their durability. The object of this report is to present data relevant to determining the effectiveness of this instrumentation in the study of traffic and vehicle operating characteristics.

The experimental work was divided into five sections. These sections deal with: (1) the use of the instruments to measure the differences in the roadway itself; (2) with the differences due to drivers; (3) with differences due to a change in the urban street, whether one-way or two-way; (4) with the differences due to the traffic volume; and (5) with the differences due to the type of signal system.

1. *Rural Roadway Comparisons*—Highway departments are working toward a system of rating the roads under their jurisdiction for the purpose of establishing a priority of construction and maintenance, and for the purpose of allocating funds on an engineering basis. Some highway departments rating systems are based, in part, on observations made by engineering personnel. Other systems are based on the physical characteristics and accident records of the roads. The use of instruments as the sole method or as an aid to rating highways would simplify the work necessary and would make it possible to compare roads of one state with those of another.

Test runs were made in Connecticut on sections of highway rated by the Connecticut State Highway Department. The Connecticut State Highway Department's rating system, at present, is based on surface width (25 pts.), maintenance costs (12 pts.), accident records (30 pts.) and curvature data (13 pts.). Thus a perfect score is 80 points.

The sections of highway chosen for test each carried about the same annual daily traffic volume. The test sections varied in length from five miles to fifteen miles. The test car was driven for 50 miles on each section. During tests maximum speeds, compatible with safety and comfort, were achieved. The test driver was not told what rating had been assigned that road by the Highway Department. Table 1 shows the results of these test runs. Of the six test sections, test section No. 3 was rated highest with 72 points. This section had the highest average speed, 64.9 mph., and the lowest fuel economy, 18.4 mpg. The brake application instrument showed 1.2 seconds per mile, the third lowest amount of braking. The mean force propelling the vehicle was the highest of the six test sections, 344 lb., and the mean percent throttle opening necessary to maintain the speed was the highest, 33.6 percent.

The results presented in Table 1 show a close correlation between the Connecticut ratings and the average speed obtained for the 50 mile test runs. There is an inverse relationship between the ratings and the fuel economy, the higher the rating the lower the fuel economy. The braking could possibly be an indication of sight distances, the brakes being used more when short sight distances obscured slower moving vehicles. The force and throttle opening are an indication of speed and also of the grades; more throttle and force are neces-

sary to maintain an average speed on grades than on level roads. For example, test section No. 6 had a lower average speed than test section No. 5, and yet the mean force and throttle opening were higher. This indicates that there were more grades on test section No. 6 than there were on No. 5.

2. *Differences Due to Drivers*—During October and November, 1950, with the cooperation of the Yale Traffic Bureau, the project to determine the differences due to drivers was undertaken. Sections of five different types of roads were chosen as test sections, and each driver tested was instructed to drive as he normally would on each type of road. The sections chosen were: US 1, Four-lane highway; Wilbur Cross Parkway, four-lane divided; two-lane Connecticut State Highway; narrow two-lane country road; and New Haven radial street. Thirty drivers were tested on each of the five sections. The object of this testing program was to determine if the information concerning the differences in drivers thus obtained was of sufficient value to warrant a testing program large enough to secure a representative sample of American drivers.

Table 2 gives the high value, the low value and the mean value of speed, fuel economy, braking, torque and throttle opening for the thirty drivers. The range in average speeds was greatest on the parkway and smallest on

TABLE 2

HIGH VALUE, LOW VALUE, & MEAN FOR THIRTY DRIVERS TESTED ON SAME SECTIONS OF FIVE TYPES OF ROADWAY

Type of Road	Speed			Fuel Economy			Braking			Force at Rear Wheels			Throttle Opening		
	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
	mi. per hr.			*mi. per gal.*			*sec. per mi.*			*pounds*			*percent*		
4-lane divided parkway	62.4	48.0	55.1	21.9	17.3	19.7	5.5	0.1	1.7	338	225	283	31.4	19.4	25.4
4-lane, US 1	50.9	39.3	45.4	23.9	18.3	20.8	15.3	1.7	5.9	277	208	239	21.9	14.3	18 1
2-lane State Highway	48.0	36.3	43.1	21.5	15.7	18 9	10.0	0.3	2.7	329	240	281	24.9	14.8	20.0
Country Road	39.0	30.2	33.6	23.8	19 2	21.4	13.3	5.9	9.1	228	188	211	19.9	11.6	14.5
City Street	31.0	23.2	26.8	23.5	18.0	20.9	30.5	5.4	13.8	231	180	202	14.8	9.4	11.6
Complete Trip	42.6	34.9	39.3	21.8	18.3	20 5	11.3	3.4	6.3	254	212	234	19.9	14.5	17.0

TABLE 3

AVERAGE PERCENTAGE OF TIME SPENT IN VARIOUS SPEED RANGES BY THE THIRTY DRIVERS

Type of Road	Range of Speed—*Miles per Hour*								
	0–8	8–11	11–18	18–23	23–34	34–45	45–55	55–66	66–Above
	%	%	%	%	%	%	%	%	%
Four-lane (US 1)					3.4	52.7	43.0	0.9	
Parkway					1.2	7.3	47.5	43.0	1.0
State Highway			0.1	0.3	9.9	60.2	29.5		
Country Road		0.1	2.1	5.0	52.6	39.1	1.1		
City Street	7.4	2.2	9.8	12.8	44.6	21.6	1.6		

TABLE 4

PERCENTAGE OF GASOLINE USED AT VARIOUS SPEEDS

Average for Thirty Drivers

Type of Road	Range of Speed—*Miles per Hour*								
	0–8	8–11	11–18	18–23	23–34	34–45	45–55	55–66	66–Above
	%	%	%	%	%	%	%	%	%
Four-lane (US 1)					3.3	46.6	48.4	1.7	
Parkway					1.0	6.5	45.5	45.9	1.1
State Highway				0.2	7.5	55.9	36.3		
Country Road		0.1	1.7	3.5	46.7	45.9	2.1		
City Street	5.1	1.9	8.3	11.3	45.0	25.6	2.8		

the city street. The range in fuel economy was approximately the same for the five test sections. The mean fuel economy of the thirty drivers was lowest on the state highway, although the average speed was only the third highest. The reason for this low fuel economy on the state highway was that there were more grades on that test section than on the others. The presence of more grades is shown by the high mean force and throttle opening obtained on the state highway route. There is a close correlation between speed, braking, force and throttle opening which can be seen when the test sections are arranged according to mean speed. The less restrictive the road, the faster the average speed, the smaller the amount of braking, the greater the force and throttle opening.

TABLE 5
PERCENTAGE OF TIME BRAKING IN THE VARIOUS DECELERATION RANGES FOR THE THIRTY DRIVERS

Type of Road	Deceleration Range—*Ft. per Sec.*^{2}		
	4–7	7–10	10–13
	%	%	%
Four-lane (US 1)	86.5	13.4	0.1
Parkway	96.2	3.8	
State Highway	84.9	15.1	
Country Road	79.4	18.9	1.7
City Street	83.8	15.3	0.9

TABLE 6
AVERAGE PERCENTAGE OF TIME SPENT IN EACH FORCE RANGE FOR THIRTY DRIVERS

Type of Road	Coast	Range of Force—*Pounds*							
		0–79	79–158	158–237	237–316	316–395	395–474	474–553	553 to 632
	%	%	%	%	%	%	%	%	%
Four-lane (US 1)	2.0	2.9	13.5	36.7	26.7	10.5	4.2	2.5	1.0
Parkway	6.7	6.8	7.2	14.2	20.2	20.8	14.8	6.8	2.5
State Highway	2.3	3.7	6.0	20.3	29.8	22.5	10.7	3.6	1.1
Country Road	13.8	19.0	12.5	13.0	11.0	10.4	9.6	5.8	4.9
City Street	5.0	20.4	19.1	21.0	12.7	8.5	6.1	3.8	3.4

Tables 3, 4, 5, 6, and 7 show the percentage of time spent by the thirty drivers in each range of speed, braking, force and throttle opening, and the percentage of gasoline they used in the various speed ranges. These tables indicate to what degree the thirty drivers tested used the characteristics built into the motor vehicle. Speeds used ranged from 0 to 70 mph. The maximum deceleration rate used was 10 to 13 ft. per sec.^{2}, but approximately 86 percent of the braking was in the lowest deceleration range of four to seven ft. per sec.^{2}

Table 6 shows the percentage of time the thirty drivers spent in each of the force ranges. All force ranges were used one percent of the time or more. The highest force range, 553 to 632 lb. was used by the thirty drivers 5 percent of the time on the country road, while on the parkway this highest range was used only half as much. The mean force used to propel the vehicle on the five test sections was 37 percent of the maximum force available to propel the vehicle.

The greatest percentages of time spent in the various ranges of throttle opening, Figure 7, were spent in the ranges from 0 to 40 percent open. All the ranges of throttle opening were not used. The mean values of throttle opening and force vary directly with each other, although the time spent in the throttle opening and force ranges are not comparable.

The work of comparing individual drivers has not yet been completed, but there is a difference between drivers even though they obtained the same average speed. Some drivers used their brakes less and used less fuel than others. Several drivers who drove with an "in a hurry" attitude used more force to average the same speed as others. Of the fifteen drivers who drove below the average speed obtained by the thirty drivers on the parkway section, more than half of these drove faster than the average speed on the city street.

3. *Differences Due to a Change in Urban Street Operation*

Two-Way Versus One-Way—Charlevoix, Mt. Elliott, and Congress; and Larned, Mt. Elliott and Vernor, are two parallel routes extending northeast from downtown Detroit.

These routes, which serve both Detroit City residents and those residing in the suburbs northeast of Detroit, carry approximately 31,000 vehicles each week day and are similar in physical characteristics. Only the Larned and Congress sections of these two routes were propelling the vehicle after one-way operation. The mean throttle opening increased from 8.8 to 9.5 percent open.

4. *Differences Due to Traffic Volume*—The Detroit Traffic Engineering Department fur-

TABLE 7
AVERAGE PERCENTAGE OF TIME SPENT IN THROTTLE OPENING RANGES BY THE THIRTY DRIVERS

Type of Road	Throttle Opening—*Percent*									
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
	%	%	%	%	%	%	%	%	%	%
Four-lane (US 1)......	7.9	59.9	27.9	3.7	0.5	0.1				
Parkway	10.5	19.5	37.7	25.9	5.4	0.6	0.3	0.1		
State Highway........	8.4	46.8	35.2	8.5	0.8	0.2	0.1			
Country Road.........	44.6	30.4	16.3	6.0	1.6	0.5	0.3	0.1	0.1	0.1
City Street.......... .	52.9	35.0	8.4	2.5	0.7	0.3	0.2			

one-way streets when the Detroit Traffic Engineering Department decided to make the routes one-way streets extending to the city limits. The object of the tests was to find out if this change had any effect on traffic for the entire route and not just for the sections changed. Approximately 5½ miles of the 7-mile routes were changed from two-way operation to one-way operation.

The average speeds on the two routes were improved during eighteen of the twenty-two test runs. This improvement ranged from 0.2 to 3.6 mph. The percentage of time delayed (i.e. operating in the range of from 0 to 6 mph.) was decreased during 16 of the 22 runs. The saving in time ranged from a few seconds to almost five minutes for the 7-mi. test run.

As the average speeds were increased, the fuel economy should be expected to decrease, but because less fuel was used standing still, the fuel economy before and after one-way operation was about the same. Six and one half percent of the fuel was used standing still before the change to one-way operation, and 4.0 percent of the fuel was used standing still after one-way operation. The overall average fuel economy was about 20 mpg. with a high of 22.2 mpg. and a low of 17.3 mpg.

The amount of braking was reduced approximately 11 percent. The average amount of braking was 8.3 sec. per mi. before and 7.4 sec. per mi. after one-way operation. The intensity of braking was about the same.

The mean force used was increased from 155 lb. before one-way operation to 167 lb.

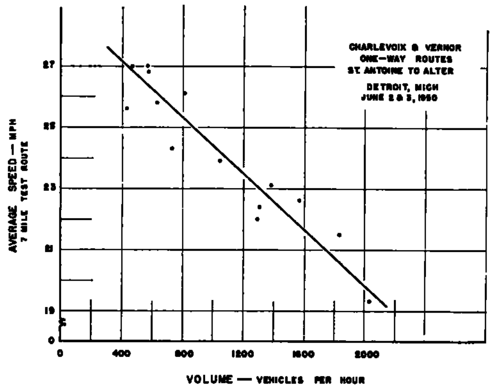

Figure 7. Volume vs. Speed—Volume Recorded at One Point on the Routes Compared to the Average Speed Attained for the Seven-Mile Test Run

nished volume counts taken on Charlevoix and Vernor just after the test runs, described in the preceding section, were made. Charlevoix and Vernor have about the same physical characteristics. They vary in width from 34 to 40 ft. There are no obstructions on the streets, and they are paved with bituminous concrete. Generally, parking was not allowed on either side of the street during rush hours. Gasoline buses operate on the streets, and the signal system is set for a progression of 30 mph. Figure 7 is a graph comparing the average speeds with volume during the 7-mi. test runs on both of the one-way routes. Several of the points are an average of two runs made

within the same hour, while the other plotted points are the results of a single run.

Figure 8 shows the relationship between volume and fuel economy. The greater the volume on a given street, the greater the loss in fuel economy.

Figure 9 shows the relationship between the amount of braking, expressed in seconds per mile and volume. The greater the volume on a given street, the greater the amount of braking. Not enough data have been collected to definitely set the shape of the fuel and braking curves.

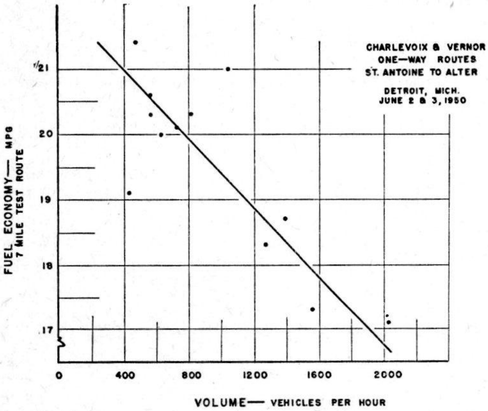

Figure 8. Volume vs. Fuel Economy—Average Fuel Economy for the Seven-Mile Run vs. Volume Recorded at One Point on the Routes

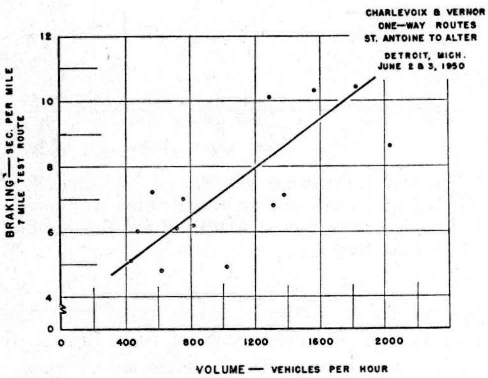

Figure 9. Volume vs. Braking—The Amount of Braking During Seven-Mile Test Runs vs. Volume Recorded at One Point on the Routes

5. *Signal Comparisons—Part 1*

Speed Data—Test runs were made to compare Grand River Avenue, Detroit, with seven other Detroit streets. Grand River is a main radial thoroughfare which carries a volume of approximately 46,000 vehicles a day, and was the only Detroit street on which the "simultaneous" system of traffic signals was in operation. The traffic on the seven other Detroit streets tested was controlled by the "progressive" system of signals. The "floating car" testing technique was used during all test runs where traffic was present, and when traffic became very light, the posted speed limit was maintained.

Figure 10 is a picture of Grand River Avenue taken at 5:00 p.m., just before the rush hour peak. Left turns were prohibited at all times, and parking was prohibited during rush hours. A system of reversible lanes was in effect during rush hours only. Four lanes were used by the predominate flow of traffic, with two lanes used by vehicles travelling in the opposite direction. The 57 signalized positions of the "simultaneous" system operated on a simultaneous 90-second cycle: 35 seconds red, 51 seconds green, and an average of $3\frac{1}{2}$ seconds amber. Thus, every 51 seconds, all vehicles using the street were forced to stop.

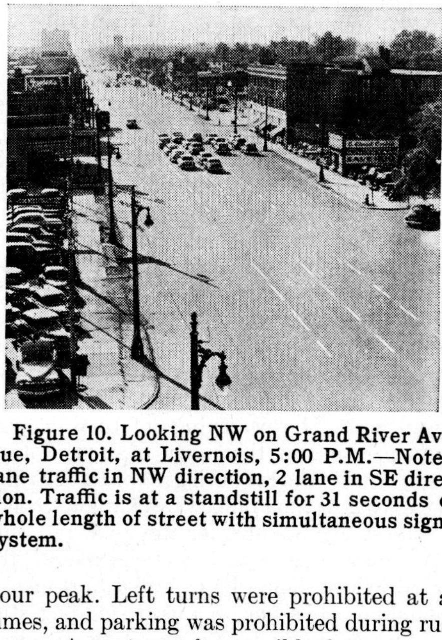

Figure 10. Looking NW on Grand River Avenue, Detroit, at Livernois, 5:00 P.M.—Note 4 lane traffic in NW direction, 2 lane in SE direction. Traffic is at a standstill for 31 seconds on whole length of street with simultaneous signal system.

The results of sixty-five tests show that the average speeds on Grand River were 3 to 5 mph. lower than on the other streets tested and that a larger percentage of time on Grand River was spent standing still than on any

other street. The test results also show that the motorists using Grand River exceeded the speed limit, especially when traffic was heavy; but motorists using the other streets tested did not exceed the speed limit.

son graph is representative of all the tests made during the rush hours. The highest percentage of time, 40 percent, on Grand River was spent travelling 0 to 6 mph., while on the other streets the highest percentage of time

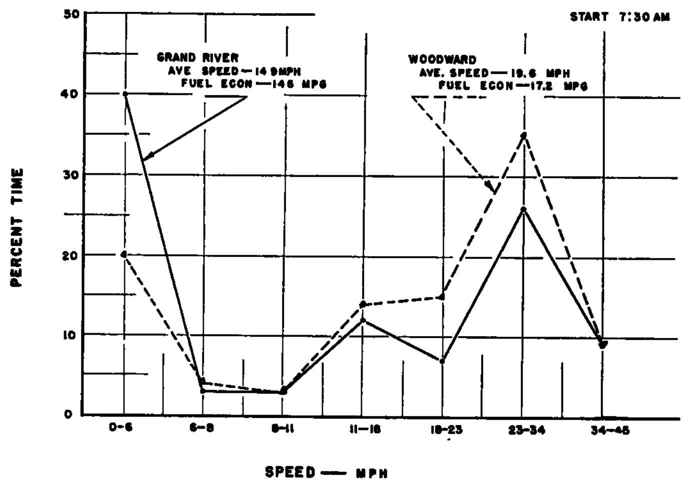

Figure 11. Speed Results, Grand River and Woodward Avenues, Detroit—Curves are typical of all results obtained in heavy traffic.

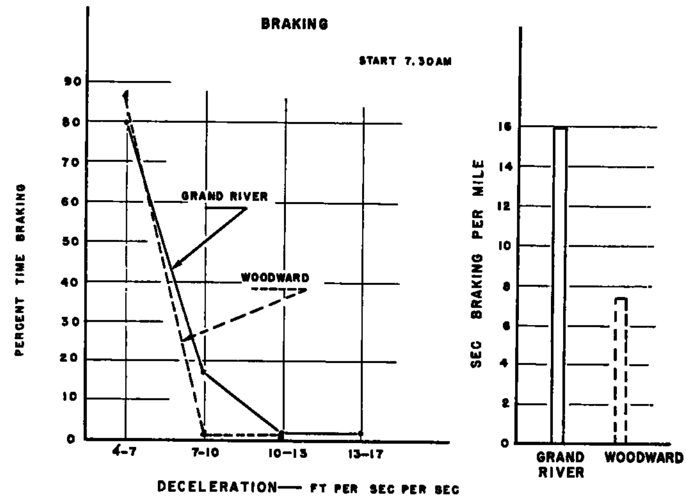

Figure 12. Braking Results, Grand River and Woodward Avenues, Detroit—Curves are typical of all braking results obtained in heavy traffic.

Figure 11 compares the speed data at 7:30 a.m. during one test on Grand River and one test on Woodward Avenue. For ease in comparison, the percentage of time spent in the various speed ranges is plotted as a line graph rather than a bar graph. This speed comparison

was spent in travelling from 23 to 34 mph. The time spent in the 0- to 6-mph. range was approximately the time spent standing still because the test car travelled at 8 mph. in third gear with the throttle in the idle position. Therefore, more time was spent standing

still than in any speed range on Grand River during the rush hours.

Test runs made in relatively light traffic show that almost one-third of the time travelling on Grand River was spent standing still,

TABLE 8
GASOLINE ECONOMY AND AVERAGE SPEEDS
GRAND RIVER AVENUE—SIMULTANEOUS
VS. PROGRESSIVE SIGNAL SYSTEM[a]

Route, Distance and Date	Trip Starts	Direction	Average Speed	Fuel Economy
Simultaneous Signal System				
			mph	*mpg*
Southfield to Cass; 9.9 miles; June 1 and 6, 1950	Midnight	S	20.8	18.2
	12:40 a.m.	N	20.9	17.8
	Midnight	S	21.1	18.0
	12:40 a.m.	N	21.6	18.3
Mean			21.1	18.1
Progressive Signal System				
Oakman to Cass; 5.9 miles; June 23, 1950	Midnight	S	28.3	23.1
	1:00 a.m.	N	27.8	23.8
	1:20 a.m.	S	28.3	23.3
	2:00 a.m.	N	27.8	23.9
Mean..............		....	28.1	23.5

[a] Tests made during early morning hours; absolutely no hindrance from traffic.

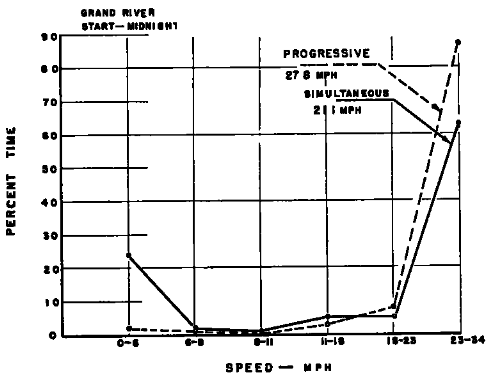

Figure 13. Speed Results—Simultaneous System vs. Progressive System

while the highest percentage of time standing still on the other streets tested was only nine percent.

Although the average speed was only 14.9 mph. at 7:30 a.m. on Grand River, nine percent of the total trip time was spent in the 34 to 45 mph. range, Figure 11, even though the entire test run had a posted speed limit of 30 mph. At noon, five percent of the total trip time was spent in this illegal speed range, while during the 5:00-p.m. rush, six percent of the time was spent in this range. Thus, the motorists spent more time in the illegal speed range when traffic was heavy than they did when traffic was light. Woodward Avenue was the only street, other than Grand River, on which the traffic travelled in the 34- to 45-mph. speed range, but Woodward was posted for 35 mph. or faster for about two miles of the 8.8-mi. test run.

Fuel Economy—The fuel economy data show a loss in fuel economy due to traffic congestion, whether real, as in the case of heavy traffic, or because of artificial congestion, as in the case of the "simultaneous"

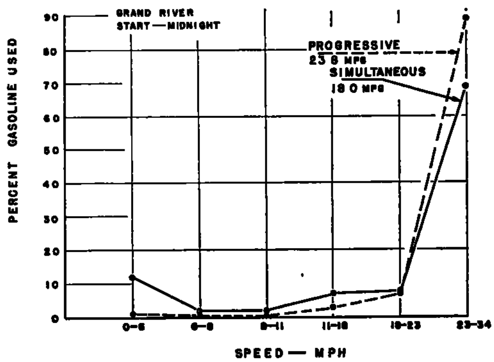

Figure 14. Fuel Consumption Results—Simultaneous System vs. Progressive System

system of traffic signals. The fuel economy was low on Grand River because a larger percentage of the total fuel used was used at the lower speeds. Nineteen percent of the fuel consumed during tests on Grand River was consumed in the speeds from 0 to 11 mph., while only about half as much, ten percent, was consumed in this same speed range, 0 to 11 mph., on the other streets.

The average fuel economy for all runs made in heavy traffic on Grand River was 14.0 mpg., and in heavy traffic the other streets tested averaged 16.7 mpg. In the light traffic, the average gasoline mileage obtained was 16.0 mpg. on Grand River and 19.8 mpg. on the other streets. This loss in fuel economy costs the 46,000 motorists who used Grand River each day almost a quarter of a million dollars each year.

Braking—Figure 12 is representative of the braking data obtained. The line graph

which indicates intensity of braking, shows the percentage of braking time spent in each of the ranges of deceleration, while the bar graph indicates the amount of braking, expressed in seconds of braking per mile. In general, the undesirable and even dangerous rates of deceleration were used more often on Grand River[1] and twice the amount of braking was generally used on Grand River as compared to the other streets. Because the motorists must stop every 51 seconds on Grand River, they had to use their brakes almost as much in light traffic as they did in heavy traffic.

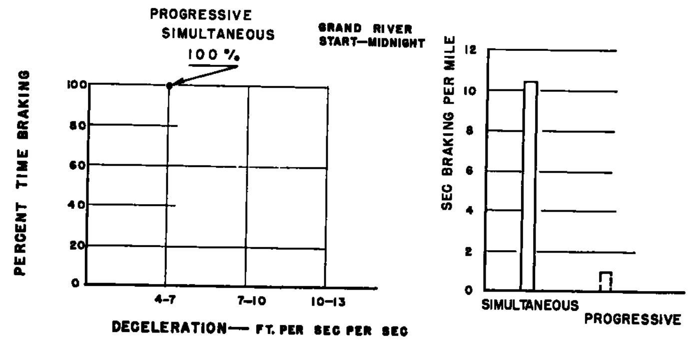

Figure 15. Braking Results—Simultaneous System vs. Progressive System

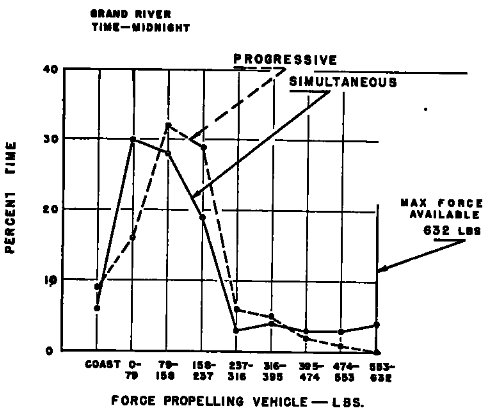

Figure 16. Force Information—Simultaneous System vs. Progressive System

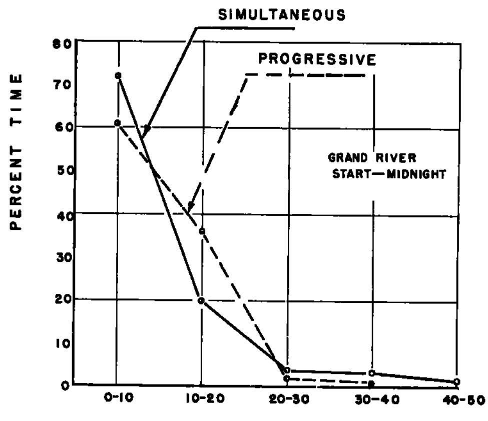

Figure 17. Throttle Opening Results—Simultaneous System vs. Progressive System

5. *Signal Comparisons—Part 2*—Prior to June 3, 1950, the simultaneous system of traffic signals on Grand River Avenue, Detroit, was in operation 24 hours a day. After this date, a progressive system of traffic signals was placed in operation during the late evening and early morning hours, extending from downtown Detroit for a distance of 5.8 mi. Thus an opportunity was presented to show directly how well the instruments would record the differences between vehicle operating characteristics under the two systems, on the same street.

The test results, presented in Table 8 show that during the early morning hours the simultaneous system of traffic signals permitted an average speed 24 percent less than the progressive system (21.1 mph. compared with 27.8 mph.) and yielded an average fuel economy 24 percent lower than the progressive system (18.0 mpg. as compared to 23.8 mpg.). Thus the simultaneous system here lowered

[1] E. Wilson, *Proceedings*, Highway Research Board, Vol. 20 (1940).

significantly the speed and economy of individual transportation. Figures 13 through 17 show the results of this before and after study on Grand River. At no time during the tests did traffic hinder the test car. The speed limit of 30 mph. was maintained except when traffic lights forced the driver to stop. The only variable in the tests was the signal systems, the same car and driver being used for all tests.

Figure 13 shows the distribution of time spent in the various speed ranges. The average speed was improved 6.7 mph. by the progressive system, and this improvement was due to reducing the time spent standing still (i.e. 0–6 mph.) by 22 percent. Figure 14 shows the speed ranges in which the fuel was consumed. The addition of 5.8 mpg. to the fuel economy is highly significant with gasoline costing about 26 cents per gallon. This rise in fuel economy was accomplished by the reduction of the amount of fuel consumed in the lower speed ranges.

While all the braking during both tests was in the deceleration range of 4 to 7 ft. per sec.[2] (Figure 15) the amount of braking (represented by the bar graph) was greatly reduced by the progressive system, from 10.5 to 1.0 seconds per mile.

Figure 16 shows the force used to propel the vehicle during both tests, while Figure 17 shows the percentage of time spent in each ten percent increment of throttle opening.

Conclusions—While definitive results have not been obtained, conclusions can be drawn regarding the instruments and their use.

1. The instruments show significant relationships regarding speed, fuel economy, braking, force and throttle opening in the rating of highways. There is a comparison between the results obtained with the instruments and the character of the highway rated by the Connecticut State Highway Department.
2. The instruments indicate differences due to drivers, and to what extent the characteristics built into the motor vehicle are used by the public.
3. The instruments reflect a difference in performance due to a change of street operation.
4. The instruments measure a difference in vehicle performance due to a change in volume.
5. The instruments measure significant differences of performance and economy due to different signal systems.

It is the opinion of the authors that a more conclusive analysis can be made of performance, driver demand and highway design through extended development and use of instruments of this type.