Traffic Accidents and the Quality of Traffic Flow

BRUCE D. GREENSHIELDS, Traffic Engineer, Transportation Institute, University of Michigan, Ann Arbor

This is a report of an attempt to find if there is a correlation between the quality of traffic flow and the frequency of highway accidents. The term "quality" characterizes the traffic stream and indicates the manner in which vehicles move.

In making the study three sections of highway with different accident frequencies per million vehicle-miles were selected for investigation. Two of the sections are two-lane and the third is three-lane. The accident frequencies and the corresponding quality indices were as follows:

Road	Quality Index	Accidents Per Million Vehicle Miles
A (two lane)	618	2.98
B (two lane)	1023	1.03
C (three lane)	1930	1.66

The three-lane road with the highest quality index did not have the lowest accident rate. This indicates that there is no direct correlation between the index and accident frequency. On the other hand, it could reveal that a three-lane road should not be compared with a two-lane. Furthermore, it could be that single vehicle accidents are a better basis for a comparison of the two types of roads. Using single vehicle accidents only, the following comparisons were obtained:

Road	Quality Index	Single Vehicle Accidents Per Million Vehicle-Miles
A (two lane)	618	1.28
B (two lane)	1023	0.36
C (three lane)	1930	0.25

The table shows that for single vehicle accidents the higher the quality the lower the accident frequency.

The fact that there were more accidents on the curving road than on the straighter one, points to the need for including change of vehicle direction as well as change of speed in the quality index.

The results of this limited study show that improving the quality of traffic flow should reduce accidents. Apparently the inherent characteristics of flow in a traffic stream tend to make it safe or hazardous.

● A RELATIONSHIP between the characteristics of highway traffic flow and the frequencies of traffic accidents has long been recognized, but up to the present time there has been no attempt to measure this relationship with any degree of precision. This is a report of a preliminary attempt to make such a measurement. The investigation is a part of the traffic accident research being conducted by the Transportation Institute of the University of Michigan.

This research had its inception in the recognition of the magnitude and the complexity of the motor vehicle accident problem, the solution of which was beyond the realm of existing programs of safety education, driver training and highway construction. The key to the solution of the problem, an adequate knowledge of the causes of accidents, was missing and could be obtained only through research. Traditionally, research is the responsibility of the University. In keeping with this responsibility, the initiation of the present research program was made possible by a state legislature grant to the University in the summer of 1956.

The research covered in this report is limited to: (1) the selection of three sections of highway with different accident frequencies; (2) the collection of data for the determination of the quality of traffic flow; and (3) a comparison of the quality index with accident frequency.

For the sections studied there is a definite correlation between the quality index and accident frequency. A greater range of indices must be examined before it can be determined whether the same relationship holds throughout the possible range. It is suspected that in urban areas where the quality of flow index can be quite low that the relationship between the index and the frequency of accidents may be different than for rural areas. In slow, congested traffic where the quality index is quite low it is logical to suspect that the severity if not the number of accidents decreases. There is, however, no reason to suspect that there is no relationship.

Once the relationship between the quality of flow and the frequency of accidents has been established it should become possible to predict the accident proneness of a highway. It is better to make improvements to reduce accidents before the accidents happen than after they occur.

QUALITY INDEX

An index measurement of the quality of traffic was developed at the Yale University Bureau of Highway Traffic in 1954.[1] This index was deemed the best one for initial trial in the present study. It is dimensionless, and simple in application. It yields accurate and unbiased measurements, and at the same time reflects the feelings of the driver. Subjectively it is a measure of the satisfaction of the driver in operating his vehicle; objectively, it is a measure of the characteristics of the traffic stream.

The quality of flow index "Q_F" as developed in the former study is equal to the product of a constant times the average speed divided by the change of speed per mile times the square root of the number of changes of speed per mile.

This statement may be expressed much more concisely by the use of symbols. Letting Q_F = quality of flow per mile, S = average speed, Δ_S=change of speed per mile, f = frequency of change of speed per mile and K = a constant of 1000 to prevent the value of Q_F from becoming a small fraction, the equation may be written:

$$Q_F = \frac{KS}{\Delta_S \sqrt{f}}$$

Letting L = distance and T = time and omitting K and f, since they are pure numbers, the dimension equation may be written:

$$\frac{Q_F}{L} = \frac{\frac{L}{T}}{\frac{\Sigma\left(\frac{L}{T} - \frac{L}{T}\right)}{L}} \quad \text{or} \quad Q_F = \frac{\frac{L}{T}}{\Sigma\left(\frac{L}{T} - \frac{L}{T}\right)} = \frac{\frac{L}{T}}{\frac{L}{T}}$$

wherein $\Sigma\left(\frac{L}{T} - \frac{L}{T}\right)$ = summation of speed change; $\Sigma\left(\frac{L}{T} - \frac{L}{T}\right) = \frac{L}{T}$, dimensionally, and is never zero for there is always some change of speed in any appreciable distance traveled. (See discussion at end of report.)

[1] "Quality of Traffic Transmission." Bruce D. Greenshields, HRB Proc. (Jan. 1955).

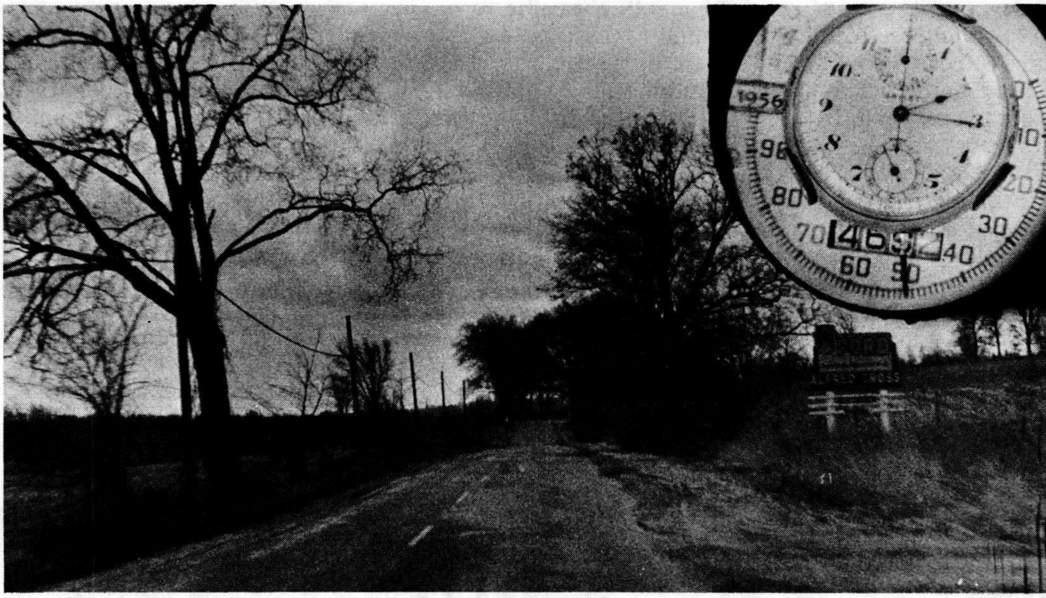

Figure 1. Picture taken with Markel camera showing chronometer and speedometer in upper right-hand corner.

After a study of the results obtained by this formula it was decided to try simplifying it by omitting the term giving the frequency of the speed changes, and decreasing the value of K. This simplification does not change the basic character of the index number. As may be seen by comparing the results given later in the report the simpler expression seems to be as accurate an indication of quality of flow as the other.

The denominator of either of the index numbers is a measure of the annoyance and frustration suffered by the driver as he is forced by highway deficiencies, conflicting traffic movements and congestion to stop, start , and change speed. The greater his speed changes the more annoyed he is.

COLLECTION OF FIELD DATA

While it is possible to obtain field data with present equipment, there is a need for development of new devices to give more complete information. It was indicated, for example, that it is desirable to record change of direction as well as change of speed. Since along with the measurement of quality of flow there is desired a measure of causes that affect flow there is needed a means of recording quickly and with sufficient accuracy the grade, curvature, roughness, and uneveness of highway surface.

At the beginning of the project the only equipment that was readily available and that seemed suitable for recording field data was a traffic camera obtained from Markel Service, Inc. This camera is mounted so as to take pictures through the windshield. In the corner of each picture, photographed by a separate lens, is the date, a watch, and a speedometer giving the speed of the car which contains the camera (Fig. 1). The speed of any chosen vehicle is obtained by trailing it and duplicating its speed as closely as possible.

In order to get an approximately continuous speed record, pictures were taken at two-second intervals. A shorter interval would have given a more nearly continuous record but it would have added to the cost and made the analysis more tedious. These intermittent pictures showed, along with the speed record, the road conditions and furnished a count of the on-coming traffic on the opposite lane. This count was found to be correct to within about 5 percent.

Later on in the work, the Highway Traffic Safety Center at Michigan State University cooperated on the project by lending their especially equipped test car for a series of runs. The part of the equipment applicable to the project was a recording speedometer. This recording speedometer was first designed and constructed for use on the Yale Bureau Project. It gives on a continuous chart the speed of the vehicle in which it is mounted. The speed is automatically plotted against time or distance, as desired. A set of six push buttons are connected to code pens, and may be used to record various items such as on-coming traffic or location of crossroads. A picture of the recorder is shown in Figure 2. A section of a recording is shown in Figure 3.

Starting at the bottom of the chart, pen A (line A) shows the time in six-second intervals; B shows one minute intervals; C gives the distance in 400-ft intervals; the irregular line in the center of the chart is continuous speed record; pens D, E, and F at the top are code pens that may be used as desired. Pen D for example shows points of curvature and the beginning and end of each run.

The data to be transferred from either the pictures or the speed record consists of the speed change per mile, and the number of speed changes per mile.

Starting at the left in Figure 3, the speed is 50 mph, then rises to 57 mph, changes and falls to 54 mph, and rises again to 70 mph, etc. The speed change per mile is the sum of the changes without regard to sign. The frequency is the number of speed changes per mile, a speed change being defined as a change from a rise to a fall in speed or the reverse. The average speed is obtained from the distance and time graphs.

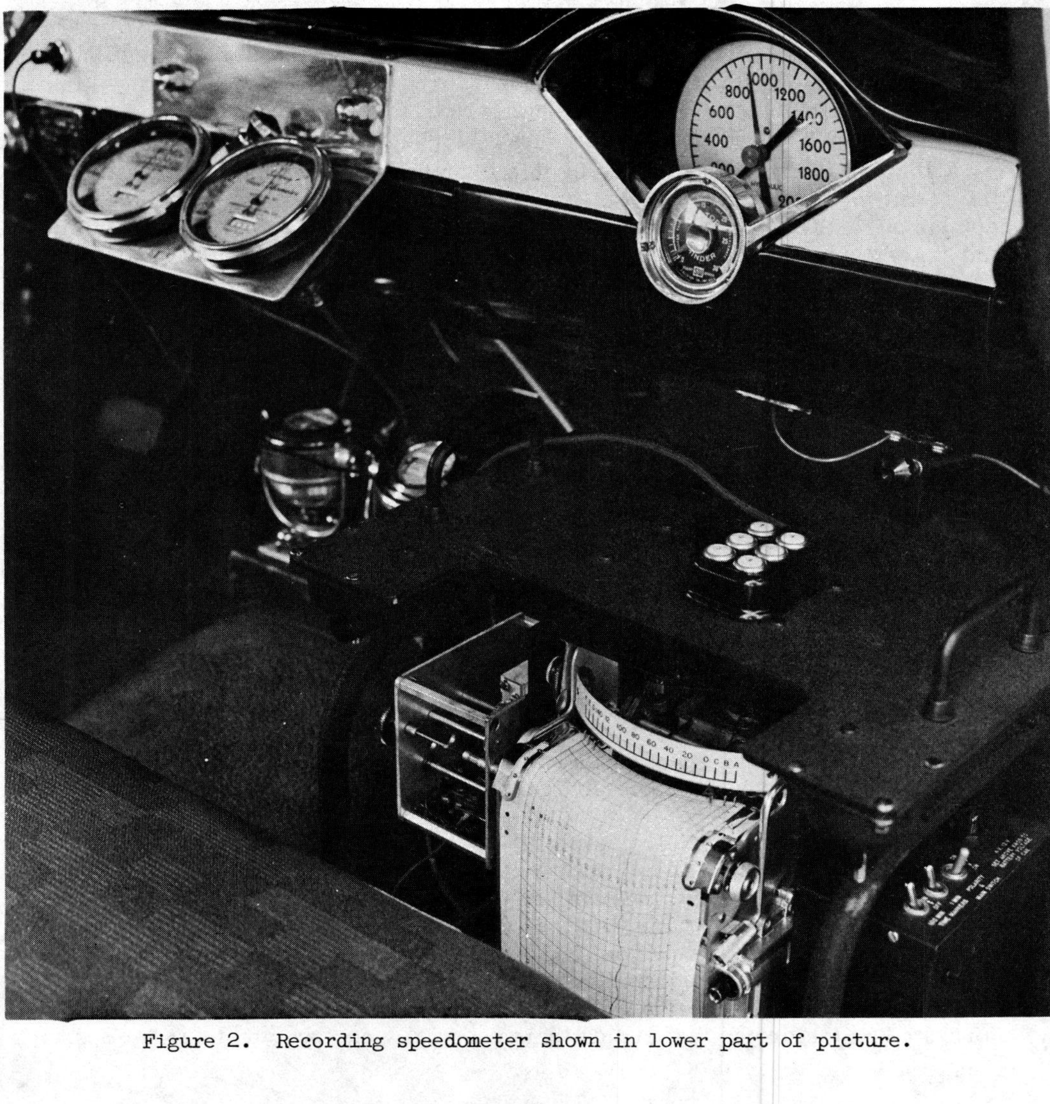

Figure 2. Recording speedometer shown in lower part of picture.

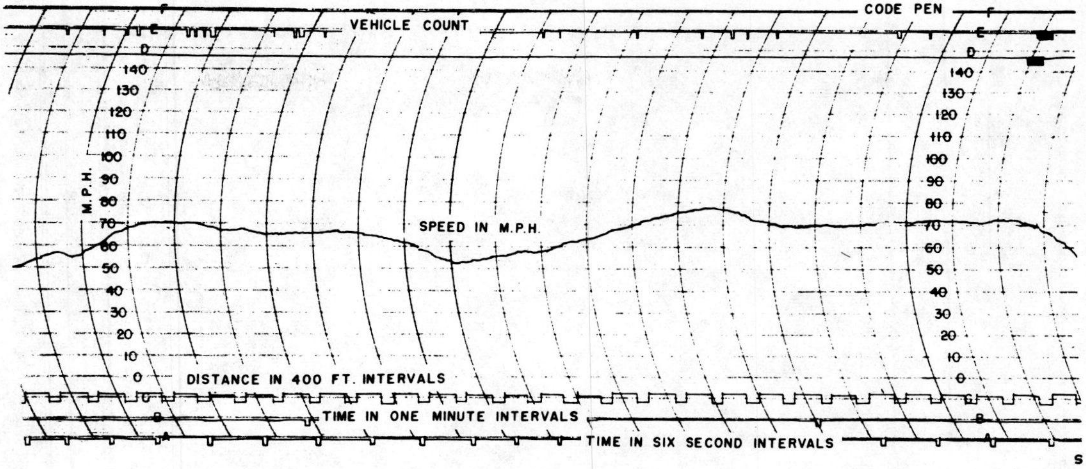

Figure 3. Traffic performance chart.

In the picture method the distance, time and speed is read from the pictures taken at two-second intervals. This discontinuous record gave a lower speed change than the continuous speed record. In order to bring the data to the same base all picutre data were prorated to equal the tape records. This ratio was based on the over-all average values and checked by picture and tape records taken simultaneously.

Before determining the correlations between the quality of flow and the frequency of accidents the sections of highway studied will be described and the accident experience for each section will be analyzed.

HIGHWAYS AND ACCIDENT EXPERIENCE

The traffic accident frequencies for the three sections of highway studied will first be discussed along with the traffic flow factors and then compared.

The section of the Dexter-Pinckney Road studied extends from the town of Dexter to to the McGregor Road, a distance of 5.7 mi (Fig. 4). This two-lane road, approxi-

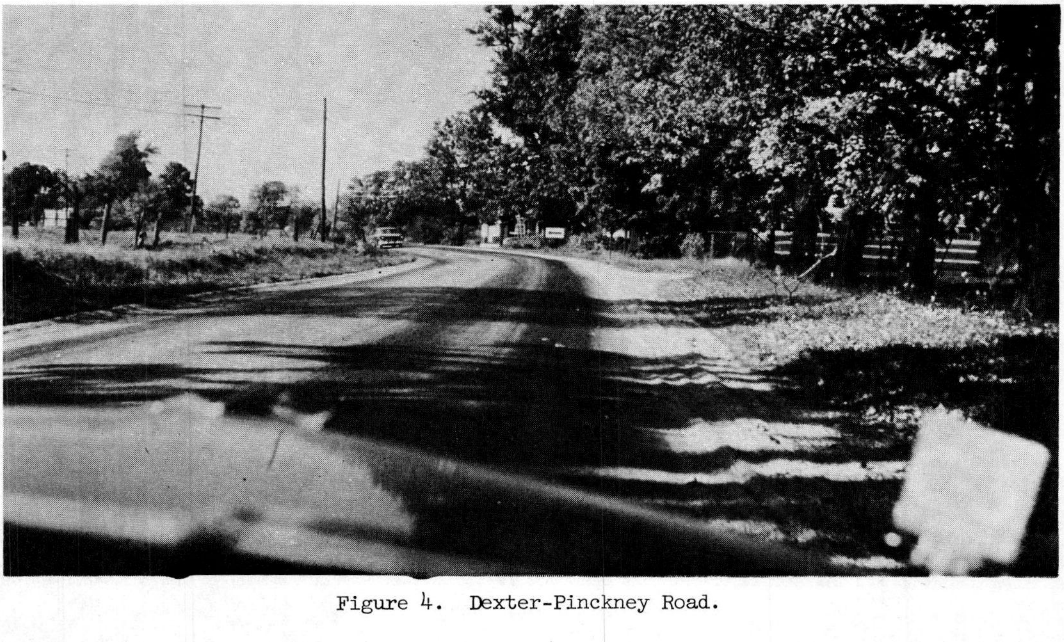

Figure 4. Dexter-Pinckney Road.

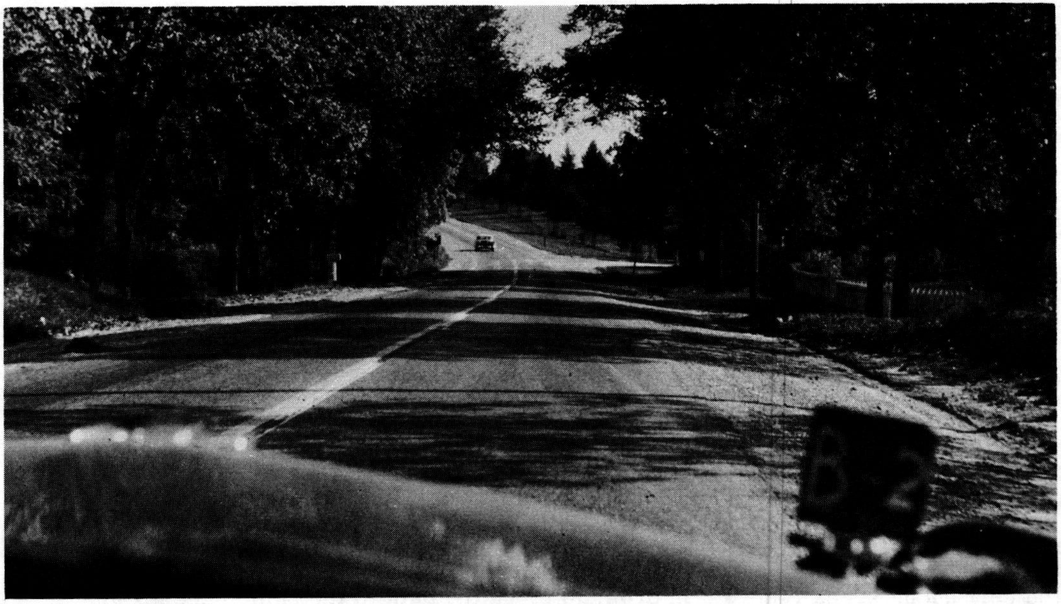

Figure 5. Plymouth Road, US 14.

mately 23 ft wide, has a very uneven blacktop surface. The road is curving and practically all of the section observed is signed for 45 mph safe speed.

The section of the Plymouth Road, US 14, studied extends eastward from Ann Arbor (Fig. 5) for a distance of 6.3 mi. It is a two-lane road approximately 20 ft wide, with blacktop surface in good condition.

The section of the Jackson Road, US 12, studied extends westward from Ann Arbor for a distance of about 6.7 mi (Fig. 6). This is a three-lane road approximately 31 ft wide, with concrete surface.

The type and frequency of highway accidents on the three highway sections is tabulated below. This information was taken from traffic accident records of the Michigan

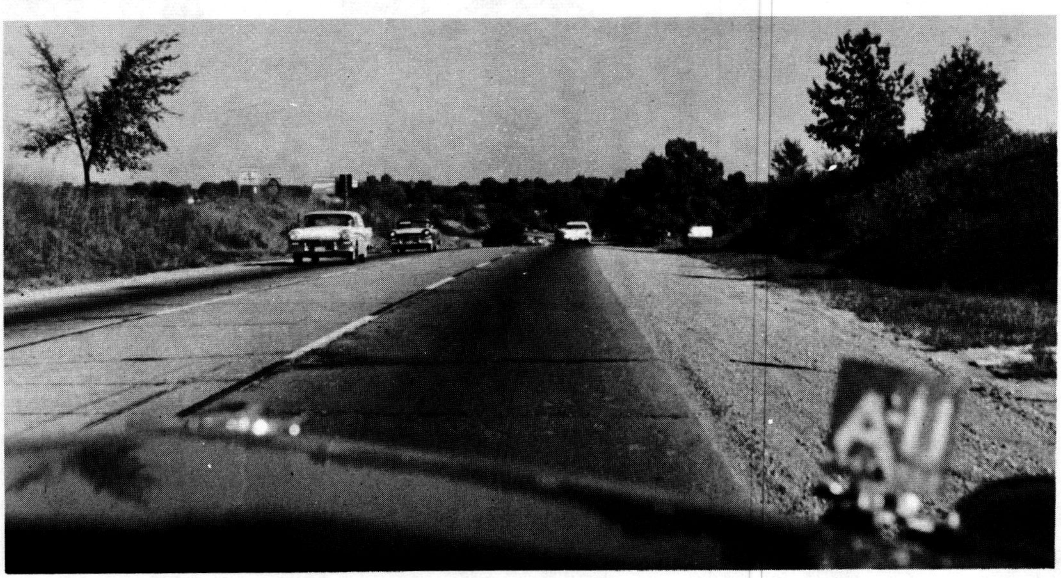

Figure 6. Jackson Road, US 12.

State Police. The total reported accidents, injuries and deaths for the three sections of highways are as follows:

Dexter-Pinckney Road

	1953	1954	1955	1956
Traffic Deaths	0	0	1	4
Injuries	5	6	11	10
Accidents	14	15	29	25

Plymouth Road

	1953	1954	1955	1956
Deaths	0	4	2	1
Injuries	11	16	12	10
Accidents	25	27	23	20

Jackson Road

	1953	1954	1955	1956
Deaths	1	1	2	0
Injuries	32	25	35	18
Accidents	54	44	45	34

A detailed analysis of these accidents is shown in the following tabulation, the four-year records being combined.

PERCENTAGE OF ACCIDENTS OF EACH TYPE

	Dexter-Pinckney Road	Plymouth Road	Jackson Road
Type:			
Collision between vehicles	47.5	58.0	78.0
With fixed object	26.0	23.0	10.8
Ran-off-road	17.0	13.2	4.6
Collision with pedestrian	2.5	-	3.1
Overturning	6.5	5.5	3.6
Violations:			
1. Excessive speed	81.0	48.5	40.8
2. Disregard of officer or controlling device	3.8	15.4	1.1
3. Wrong side - not passing	7.7	10.2	1.1
4. Failure to grant right-of-way	-	12.8	12.5
5. Under influence of alcohol	-	-	12.8
6. Improper passing	3.8	5.1	-
7. Improper turns	-	5.1	4.7
8. Follow too closely	3.8	-	22.0
9. Failed to signal - improper signal	-	2.6	1.6
Road Alignment			
1. Straight road - level	49.5	43.0	75.0
2. Straight road - hillcrest	2.1	5.5	0.4
3. Straight road - on grade	8.5	21.9	20.2
4. Curve or turn - level	26.5	14.9	1.3
5. Curve or turn - hillcrest	0.0	1.0	0.4
6. Curve or turn - on grade	6.3	11.7	1.7
7. Not stated			
8. Other curves - level	5.3	2.4	-
9. Grade - level	2.1	-	-

Time:	Dexter-Pinckney Road	Plymouth Road	Jackson Road
Midnight to 12:59 a. m.	7.4	4.3	5.4
1:00 a. m. to 1:59 a. m.	5.0	3.2	1.5
2:00 a. m. to 2:59 a. m.	9.9	3.2	3.0
3:00 a. m. to 3:59 a. m.	2.5	3.2	1.5
4:00 a. m. to 4:59 a. m.	1.3	-	3.0
5:00 a. m. to 5:59 a. m.	1.3	3.2	2.5
6:00 a. m. to 5:59 a. m.	2.5	3.2	2.0
7:00 a. m. to 7:59 a. m.	1.3	5.3	3.5
8:00 a. m. to 8:59 a. m.	8.6	4.3	3.0
9:00 a. m. to 9:59 a. m.	2.5	3.2	4.0
10:00 a. m. to 10:59 a. m.	2.5	4.2	4.0
11:00 a. m. to 11:59 a. m.	2.5	4.3	5.4
Noon to 12:59 p. m.			
1:00 p. m. to 1:59 p. m.	1.3	2.1	4.4
2:00 p. m. to 2:59 p. m.	6.6	8.5	6.9
3:00 p. m. to 3:59 p. m.	3.7	6.4	5.4
4:00 p. m. to 4:59 p. m.	7.4	2.1	6.4
5:00 p. m. to 5:59 p. m.	3.7	6.4	5.4
6:00 p. m. to 6:59 p. m.	2.5	3.2	4.0
7:00 p. m. to 7:59 p. m.	2.5	3.2	7.5
8:00 p. m. to 8:59 p. m.	1.3	4.2	7.5
9:00 p. m. to 9:59 p. m.	8.6	2.1	6.4
10:00 p. m. to 10:59 p. m.	3.7	4.3	4.4
11:00 p. m. to 11:59 p. m.	4.9	4.3	4.4
Age of Drivers:			
0-14			
15-19	17.5	1.5	2.8
20-24	22.0	17.1	13.9
25-29	22.0	18.6	15.9
30-39	16.6	24.6	2.7
40-49	9.6	20.1	19.6
50-59	8.8	9.7	14.5
60-69	3.5	6.7	4.0
69-70	-	-	0.6
70 and over	-	1.5	2.0
Age of Vehicle:			
0-0.9	14.4	6.9	1.5
1-1.9	23.2	10.3	4.7
2-2.9	13.5	4.8	9.1
3-3.9	12.6	7.6	7.0
4-4.9	12.6	19.2	18.8
5-5.9	10.8	11.7	11.5
6-6.9	5.4	13.7	11.8
7-7.9	1.8	7.6	11.2
8-8.9	-	9.6	9.1
9 and over	5.4	8.9	15.0
Experience:			
0-6 mo.	3.8	2.5	0.3
6.1-1	4.8	1.6	1.6
1.1-2	3.9	4.2	3.1
2.1-3	8.6	2.5	2.5
3.1-4	3.8	3.3	5.3
4.1-5	6.7	5.8	4.0
5.1-6	4.8	2.5	3.1
6.1-7	4.8	3.3	4.0
7.1-8	4.8	2.5	2.8

Experience (continued):	Dexter-Pinckney Road	Plymouth Road	Jackson Road
8. 1-9	3. 8	-	2. 8
9. 1-10	5. 7	5. 8	3. 1
10. 1-15	15. 4	14. 0	17. 2
15. 1-20	9. 6	12. 4	10. 3
20. 1-25	6. 8	12. 4	11. 3
25. 1-30	8. 6	6. 6	8. 8
30. 1-40	2. 9	18. 2	16. 3
40. 1 and over	11. 0	3. 3	3. 4
Male	70. 5	87. 5	86. 5
Female	29. 5	12. 5	13. 5
Day:			
Sunday	27. 4	18. 1	15. 4
Monday	10. 7	9. 6	16. 9
Tuesday	4. 8	10. 7	10. 0
Wednesday	9. 5	12. 8	7. 0
Thursday	10. 7	16. 0	13. 5
Friday	9. 5	10. 7	15. 4
Saturday	27. 4	22. 4	22. 0
Date:			
January	7. 2	10. 4	5. 2
February	9. 6	10. 4	9. 4
March	1. 2	4. 2	6. 8
April	9. 6	9. 4	13. 6
May	10. 9	6. 3	9. 4
June	8. 5	6. 2	12. 0
July	12. 0	6. 3	12. 5
August	7. 2	6. 2	7. 8
September	4. 8	10. 4	6. 8
October	13. 2	12. 5	8. 4
November	10. 9	5. 2	6. 3
December	4. 8	12. 5	7. 3
Condition of Driver:			
Defective vision (no glasses)	1. 5	0. 6	-
Same (wearing glasses)	4. 6	3. 0	4. 9
Ill	-	0. 6	-
Fatigued	-	2. 9	-
Asleep	2. 3	-	1. 5
Other handicaps	1. 6	-	0. 5
Condition not known	7. 8	9. 8	6. 0
Normal	62. 0	63. 5	61. 0
Had been drinking	-	-	5. 4
Drunk	3. 1	3. 5	1. 0
Ability impaired	-	1. 1	1. 0
Ability not impaired	6. 2	2. 3	1. 5
Not known whether impaired	3. 1	2. 9	2. 5
Not known whether drinking	8. 5	10. 3	11. 4
Vehicle Condition:			
Defective brakes	2. 0	-	-
Improper lights	2. 0	-	-
Steering	-	-	-
Tires	-	-	-
Windshield wiper	-	-	-
Other defects	11. 0	0. 7	8. 1
No defects	52. 0	33. 4	38. 8
Not known	45. 0	66. 0	52. 5

	Dexter-Pinckney Road	Plymouth Road	Jackson Road
What Drivers Were Doing:			
1. Going straight ahead	61.0	60.5	64.0
2. Making right turn	6.0	2.0	0.8
3. Making left turn	4.3	11.9	6.1
4. Making U-turn	-	-	0.5
5. Slowing or stopping	-	2.6	2.8
6. Starting in traffic lane	-	-	-
7. Starting from parked position	-	0.7	0.5
8. Stopped in traffic lane	5.2	1.3	1.3
9. Parked	10.9	0.7	1.3
10. Backing	-	0.7	-
11. Passing or overtaking	3.5	4.0	8.8
12. Avoiding vehicle, obj. or pedestrian	2.6	3.3	1.3
13. Skidding - before applying brakes	3.5	4.0	2.6
14. Skidding - after applying brakes	12.1	8.6	8.5
15. Driverless moving vehicle	-	-	2.5
16. Hit and run	-	-	2.5
Point of Impact:			
Front	35.6	20.6	22.8
Right front	6.7	8.4	13.5
Left front	7.7	16.0	12.5
Right side	14.4	10.3	10.2
Left side	10.6	14.1	12.3
Rear	12.5	9.6	10.0
Right rear	1.0	5.2	5.6
Left rear	6.7	6.4	8.2
All sides - car rolled over	1.0	0.6	-
Vision Obscured:			
Windshields - snow, rain	7.9	11.9	5.1
Trees, crops	-	-	-
Buildings	-	-	-
Signboard	1.0	0.8	-
Embankment	-	-	1.3
Hill evert	-	-	1.3
Parked cars	2.0	-	1.0
Moving cars	8.9	1.6	9.3
Other	2.0	3.2	2.9
Not obscured	78.5	90.5	86.0
Traffic Control:			
Warning sign or signal	-	18.2	-
Stop sign or signal	58.5	59.0	8.4
Blinker	-	9.1	10.8
Speed zone	41.5	13.6	80.0
Weather:			
Clear	45.0	51.5	53.0
Cloudy	17.8	27.0	21.0
Rain	19.2	9.7	14.4
Snow	6.9	7.6	6.1
Fog	8.3	4.3	4.4
Sleet	2.8	-	1.1
Light Darkness - Not lighted	40.5	33.4	34.2
Daylight	49.5	56.0	56.5
Dusk	2.9	7.6	6.7

	Dexter-Pinckney Road	Plymouth Road	Jackson Road
Light Darkness (continued):			
Dawn	7.3	21.5	2.8
Road Conditions:			
Dry	53.5	60.0	65.5
Wet	26.6	21.2	22.0
Muddy	0.0	-	-
Snowy	10.6	8.8	3.3
Icy	9.4	10.0	9.3
Speed Stopped:			
0-5	7.9	4.3	5.2
5.1-10	5.6	4.3	1.8
10.1-15	1.1	5.1	3.7
15.1-20	2.2	2.5	2.1
20.1-25	10.1	2.5	4.3
25.1-30	3.4	2.5	3.4
30.1-35	1.1	4.3	5.8
35.1-40	13.5	11.9	9.2
40.1-45	11.2	16.1	10.1
45.1-50	19.1	9.3	12.9
50.1-55	9.0	18.6	15.3
55.1-60	6.8	5.9	16.0
60.1-65	4.5	4.3	5.5
65.1-70	3.4	3.4	3.4
70.1-80	-	3.4	0.9
80.1 and over	-	1.7	0.3

COMPARISON OF ACCIDENT RECORDS

A comparison of the traffic accident records on the three sections reveals some striking differences.

The approximate number of miles traveled per accident for the three roads were respectively, Dexter-Pinckney Road, 287,600 mi; Plymouth Road, 690,000 mi; and Jackson Road, 500,000 mi. These calculations were made from the number of accidents per year and the average daily traffic; 3,000 vehicles per day for the Dexter-Pinckney Road, 7,500 for the Plymouth Road and 9,000 for the Jackson Road, as reported in 1955 by the Traffic and Planning Division of the Michigan State Highway Department.

The accident frequencies per million vehicle miles and the corresponding quality indices are shown in the following table:

Road	Average Quality Index	Accidents Per Million Vehicle Miles
Dexter-Pinckney Road (two-lane)	618	3.48
Plymouth Road (two-lane)	1023	1.45
Jackson Road (three-lane)	1930	2.00

The single vehicle accidents which include "with fixed object," and "ran-off-road" amounted to 43.0 percent of the total accidents for the Dexter-Pinckney Road, 36.2 percent for the Plymouth Road and 15.4 percent for the Jackson Road. The Dexter-Pinckney Road, which is the most curving and has the most uneven surface has the worst record.

The accident frequencies for single vehicle accidents are compared in the following table:

Road	Average Quality Index	Single Vehicle Accidents Per Mil. Veh. Miles
Dexter-Pinckney Road	618	1.47
Plymouth Road	1023	0.52
Jackson Road	1930	0.31

The Dexter-Pinckney Road had the highest speed for the existing conditions. Excessive speed on this road accounted for 81.0 percent of the traffic violations, while the percentage on the Plymouth Road was 48.5 percent and on the Jackson Road, 40.8 percent.

The number of accidents on curve sections roughly paralleled the percentage of curvature, the respective percentages being as follows:

Dexter-Pinckney Road	34.8 percent
Plymouth Road	27.6 percent
Jackson Road	3.4 percent

The percentages of accidents occuring between midnight and 3:00 a.m. is perhaps significant.

Dexter-Pinckney Road	21.3 percent
Plymouth Road	10.6 percent
Jackson Road	9.9 percent

The percentage of accidents happening in the three hours after midnight is more than twice as much as on either of the other two sections of roads. Local comment has it that the presence of a roadhouse located just beyond the north end of the section studied has something to do with the accidents occuring about closing time for the roadhouse. If, however, the conditions of the drivers involved in accidents is compared it is found that there is no significant difference for this road and the other two sections. It may be mentioned that the Dexter-Pinckney is more of a summer resort than the other two. But the number of accidents happening during July, August and September is not greater for this section than for the other two:

Dexter-Pinckney Road	24.0 percent
Plymouth Road	22.9 percent
Jackson Road	27.1 percent

Another item of interest is the percentages of accidents corresponding to the ages of the drivers involved:

	19 yr (or under)	24 yr (or under)
Dexter-Pinckney Road	17.5 percent	39.5 percent
Plymouth Road	1.5 percent	18.6 percent
Jackson Road	2.8 percent	14.7 percent

It can be seen that more young drivers were involved in the accidents on the Dexter-Pinckney Road than the other two roads.

The percentages of accidents on the three roads for drivers with one year or less experience were as follows:

Dexter-Pinckney Road	8.6 percent
Plymouth Road	4.1 percent
Jackson Road	1.9 percent

This shows that not only were more young drivers involved in the total number of accidents on the Dexter-Pinckney Road, but also that more drivers with less experience were involved.

The weekend accidents were much higher for the Dexter-Pinckney Road. The percentages for the Dexter-Pinckney, the Plymouth and the Jackson roads were respectively, 54.8 percent, 40.5 percent, and 37.4 percent.

The items just mentioned include the most significant. Others of less significance may be found among those tabulated. These factors are to be considered in comparing the quality of flow on the three sections of highway with the accident frequencies. Certain human factors are to be taken into account in comparing the quality of flow on the three sections of highway with the accident frequencies. Some human factors, such as the age involved, could be deemed to be independent of the road, the explanation being that a younger than average group of people travel the Dexter-Pinckney Road. On the other hand, it could be that the younger driver has more trouble in driving over a winding road with an uneven surface. Without knowing the age distribution of the drivers on the roads it is impossible at present to properly evaluate the age factor.

Regardless of the possible variation in driving behavior between large groups of drivers it is believed that the over-all human characteristics of any two large groups are much the same.

In a broad sense the highway environment can account for differences in human characteristics. The average age of drivers on a large university campus must be younger than drivers at large.

The main purpose of this study has been the obtaining of the correlation between the quality index and the accident frequency. It has been assumed that the primary reason for the differences in the quality of flow has been the differences in the roadways and their immediate environment. It is recognized, nevertheless, that part of the variation in the quality of flow could be due to the driver characteristics. In any case the characteristics of the highway and of the driver are the causes, not measures, of the differences in the quality of driving. Whatever the reason, if low quality coincides with high frequency of accidents, quality may be used to anticipate highway mishaps.

The Quality Index and Highway Accidents

The average quality index Q_F for the Dexter-Pinckney Road is shown graphically. The average for the section studied is 618 with the variation for each half mile ranging from a low of 400 to a high of 840. The average index for Q'_F is much less than Q_F due to the method of calculating Q'_F. The omission of the factor, $\sqrt{f}$, in the denominator tends to increase the value of Q_F over Q'_F, but the change of the K value of from 1,000 to 100 tends to decrease the ratio. The average speed equals 47.7 mph.

The values from which the graphical representation is made up are shown in Table 1. The values are for each half mile beginning at the south end of this section of highway.

TABLE 1

DEXTER-PINCKNEY ROAD

Q Values	403	620	745	682	703	565	588	849	706	545	414	
Standard D	285	286	410	391	429	369	279	586	573	407	342	
Standard Error of Mean	51 3	52 2	72.6	69.1	75 8	66 3	48.5	108.9	102 9	74 4	63.5	
Q'	84	131	159	164	142	153	135	170	164	171	115	96
SD	68 0	55 7	85 2	89.0	63 3	89.6	62 1	71 7	66 0	85.6	73 8	99 8
SEofM	14 2	10 0	15.1	16.5	11.8	16.4	11.2	12 9	12 1	16 2	14.5	25 8
Speed	43.8	46 3	47.4	48 1	48 3	47 5	47 0	48.7	48.8	48.1	48 4	48.6
SD	6.70	6 65	6.22	7 37	6 53	7.15	6 32	7 85	7.47	8.18	8 78	8.34
SEofM	1 46	1 24	1 12	1.32	1.15	1.26	1 12	1 43	1 39	1 47	1 66	2 64

The quality of flow was calculated for each half mile with the thought that the frequency of accidents might vary directly with the fluction in the Q values. Apparently this is not the case as can be seen by comparing the quality with the accident frequency spotted in Figure 4. This could be due to the lack of sufficient runs or the fact that the fluction in the quality is not sensitive enough to respond to a change in road features in a short distance.

Quality of Flow on Plymouth Road

The average quality of flow on the Plymouth Road was 1023. The range for the half-time sections varied from 397 to 1684. The average Q'_F was 198 with a range from 141 to 252. The average speed was 47. 5 mph. These values are given in Table 2.

TABLE 2

PLYMOUTH ROAD

Q Values	397.0	836 7	1145 8	1208.4	1282.2	790.6	799.1	541 7	866 7	1498.6	1683 5	1223 2
SD	203 5	598.7	1224 3	774.2	865 1	486.5	854.5	386 9	1363 2	1478 1	1558.7	1051 8
SEofM	54.38	124.83	244.87	154.84	169.66	95.41	164.45	74 46	272.65	289.8	318 18	262 96
Q'	252	208	155	235	219	169	177	174	195	196	245	141
SD	103.8	119.5	63.2	215.0	161 6	58.5	110.8	87.7	191.7	143.6	213 0	69.2
SEofM	31 3	26 1	13.2	43.9	31.7	11 7	22.2	17 5	38.3	28 7	43 5	17.9
Speed	43.4	46 0	47.1	50 1	49.2	47 0	45.6	43.4	45 8	49.3	52.1	51.5
SD	7.19	4.53	4.43	6.37	6 08	6 03	4.45	6 69	5.78	6 55	6.13	5.65
SEofM	2 09	0.99	0.92	1.30	1 24	1.21	0.89	1.31	1 16	1 29	1 28	1 57

If the quality of flow values are compared with the spot locations of the accidents, it is found that there is no correlation that may be detected. But if the Q_F for the entire section of the Plymouth Road is compared with that of the Dexter-Pinckney Road there is found to be a fairly good correlation.

Quality of Flow on the Jackson Road

The quality of flow on the Jackson Road was the highest of the three sections of road, being 1930. Other flow factors are given in Table 3.

TABLE 3

JACKSON ROAD

Q Values	1657	1831	2200	2407	2293	1486	1302	1876	2779	2014	1745	1741	1550	2230
SD	1345	2413	1835	2008	2145	1083	879	1184	1826	1431	1480	1342	1217	2245
SEofM	293.5	433 4	314.7	339 4	362 6	180 5	142 6	192.1	296.2	235 2	243 3	223 7	205 7	478 7
Q'	267	297	330	285	353	404	315	225	261	387	371	368	334	277
SD	188.6	196 0	220 6	200.7	226 7	276 7	171.1	108 0	160 2	282 7	220 3	290 3	207 7	175 4
SEofM	39.3	32.7	36 3	33 0	36 8	44.9	27 5	17.3	26 3	47 8	37 2	49 1	36 7	39 2
Speed	55.0	52.4	52 9	54.9	54.4	54.2	53 6	52.2	53.9	55.3	56.6	55 8	58 1	58 0
SD	8 28	7.38	7.23	8 15	7 91	6 70	7 61	7.21	9.35	8.50	7 64	8 47	8 90	7 87
SEofM	1 73	1 26	1.22	1 34	1 28	1.10	1 23	1 17	1 56	1 43	1 29	1 43	1 59	1 76

A study of the data shows no definite correlation of the quality of flow with accident frequencies. But the over-all value shows a distinctly higher flow quality than either of the other two sections. This is a different type of road, being three-lane with little curvature. The accidents per million miles of travel are greater than on the Plymouth Road. This is due to the preponderance of multiple vehicle accidents. This is to be expected on a three-lane road. It could account for the fact that the accidents per miles traveled is higher on this road as compared to the Plymouth Road where the Q_F value is lower.

DISCUSSION

The findings indicate that the flow index does not have the same correspondence with accident frequency on a three-lane road as on a two-lane road. The three-lane road presents a hazard in the rivalry for the use of the middle lane. Perhaps the freedom to use the middle lane for passing gives the driver a false sense of security in its use. On a two-lane road the right-of-way is clearly understood.

Since the drive-ability features of a highway largely determine the quality of traffic flow that may lead to accidents it is essential that there be developed the devices needed to measure this drive-ability. The features of a roadway that influence drive-ability consist of its geometric design, its surface condition, and the appearance of the road and its immediate surroundings.

Since the volume of traffic not only increases the accident exposure but affects the quality of flow, the amount of traffic flow must be considered in any study of traffic accidents.

It became clear during the study that change of direction should be taken into account in the quality index. A vehicle rounding a curve at constant speed has an increase in velocity due to change in direction.

Speed alone gives no indication of the added effort of driving on a curving road, turning out to pass, or the dangers involved in these maneuvers. Change of direction as well as change of speed requires effort on the part of the driver and thus increases his annoyance. Apparently the less effort involved in driving the better the driver is satisfied.

Adding a factor to give the change in direction must be accomplished without altering the dimensionless character of the index. This can be done by expressing the change of direction in radians which have no dimension.

In order to avoid introducing the factor zero when there is no change of direction, the factor may be one, plus the change of direction. If there is no change, dividing the quality index by one does not change its value. This same reasoning applies to the change of speed.

To express this quality index symbolically, let Δ_θ = change in direction per mile, and the other symbols be as given at the first of the report. The index becomes:

$$Q_F = \frac{KS}{(1 + \Delta_S)\ (1 + \Delta_\theta)}$$

A means of recording the change of direction has not been devised but it should be possible. One means could be the recording of the amount of turning of the steering wheel.

It is believed that once a sufficient number of highways together with their accident records have been studied that standards of flow performance may be established, and that these standards may be used to predict the accident proneness of a roadway. It also follows that the features of a roadway that cause low quality of flow can be detected and removed or changed. It is hoped that the use of the quality of flow index may lead to the construction of safer highways.