RESEARCH TRIANGLE INSTITUTE

RTI PROJECT SU-409

SPEED AND ACCIDENTS
VOLUME I

RESEARCH TRIANGLE INSTITUTE

JUNE 26, 1970

FINAL REPORT

PREPARED FOR:

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY SAFETY BUREAU
WASHINGTON, D.C. 20591

CONTRACT NO. FH-11-6965

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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Prepared by:

Research Triangle Institute

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FOREWORD

The Research Triangle Institute (RTI) and the Institute for Research in Public Safety of Indiana University have jointly performed a study to gather accident and speed information in order to better define the role that speed (primarily the speed deviation of accident-involved vehicles) plays as a contributing factor in vehicle accidents. This study was under contract number FH-11-6965 to the National Highway Safety Bureau (NHSB) of the Federal Highway Administration. Dr. Robert J. Taylor of the Mathematical Analysis Division under the direction of Mr. Donald Mela of the NHSB is the contract manager. The Research Triangle Institute is the prime contractor and the work is being performed in the Statistics Research Division (SRD) under the direction of Dr. A. L. Finkner. Dr. Herbert H. Hill is project leader and the following members have assisted in this study: S. B. White, Jr., J. W. Dunn, L. B. West, A. C. Nelson, Jr., R. L. Beadles, H. J. White, J. R. Batts, Mary J. Artz, and R. E. Kirk.

The Institute for Research in Public Safety is the subcontractor to RTI and has been primarily responsible for the data collection activity. This investigation has been under the direction of Dr. Kent B. Joscelyn and the following members have contributed to this report: G. H. Reinier, J. S. Merritt, T. H. Bryan, J. L. Shambach, S. P. Malak, J. R. Kinney, R. L. Chapman, R. G. Rockenbaugh, F. J. Connelly, R. N. Wolff, J. R. Treat, and K. J. Waymire.

The specific objectives of this study were to:

A. Gather more reliable accident data by using trained accident investigators rather than relying on the usual police and insurance accident reports,

B. Gather speed survey information over a selected representative sample of roadways in order to determine involvement rates in relation to miles traveled for different amounts of deviation from the average traffic speed, and

C. Determine the interaction between speed deviation and other factors precipitating accidents.

The authors wish to express their appreciation to Mrs. Patricia Daniel and Mrs. Linda Tingen for the typing of the tedious mathematical equations and tables, and to Mrs. Susan Bergeron for editorial assistance.

The report is contained in two volumes. Volume I is a summary report and contains the major results and conclusions along with examples of tables and figures from Volume II. Volume II contains the detailed information and analyses. In particular, the summary data for all of the accidents is contained in Volume II.

Many people have contributed to the success of this project. Immediate and accurate accident notification was furnished by the Bloomington Police Department, the Monroe County Sheriff's Department, and the Indiana State Police. Sheriff Clifford Thrasher and the deputies of the Monroe County Sheriff's Department deserve a special thanks for providing continuous communications support for the accident investigation teams. The excellent service provided by the staffs of Indiana Bell Telephone and Public Service of Indiana was particularly helpful during the implementation of the computer-sensor system. Finally, the Indiana State Highway Commission provided consistent support and, in particular, authorized the in-road installation of the detector hardware for the computer-sensor system.

ABSTRACT

The major findings of this investigation of involvement rate as a function of speed deviation of the accident-involved vehicle from the mean traffic speed are given in this volume. The primary result is that the likelihood of involvement as a function of speed deviation is a U-shaped relationship. The likelihood of involvement is estimated to be greater by a factor of about 6 to 21, depending on the type of road, for large speed deviations as opposed to small speed deviations and ignoring the accidents involving turning maneuvers. The latter include about 44% of all of the observed accidents.

This volume contains a brief statement of the objectives, plan of research, a summary of the results, recommendations and conclusions. In addition the pertinent single page tables and figures from Volume II are included and an example page is given of the long tables.

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1. OBJECTIVES

The major objective of this project was to gather and analyze accident and speed data that would quantitatively define the relationship between speed (primarily speed deviation of accident-involved vehicles) and the frequency of occurrence of corresponding motor vehicle accidents. In order to attain this objective it was necessary to:

a) Gather reliable accident data using trained accident investigators;

b) Estimate the speeds of vehicles involved in accidents at the time immediately before the collision sequence began;

c) Estimate the speed distribution of traffic flow at the time and location of the occurrence of each accident investigated;

d) Using the speed data as found in b) and c) above, quantify the correlation between speed deviation and accident rates, and to determine interactions, if any, between speed deviation and other factors precipitating accidents; and,

e) Analyze other related factors which appear to be important in describing the mechanisms of accidents.

2. PLAN OF RESEARCH

The Research Triangle Institute (RTI), acting as prime contractor and the Institute for Research in Public Safety (IRPS) of Indiana University, serving as subcontractor to RTI, contracted with the National Highway Safety Bureau, Department of Transportation, to provide the personnel, facilities, and special equipment to attain the objectives enumerated above. Under this arrangement, the responsibility for data collection was given to the IRPS, while RTI was assigned the tasks of analysis and evaluation.

All state highways and all the county roads in Monroe County, Indiana, with a speed limit of 40 mph or over - or where the mean speed was 40 or more mph - were included in the study. This involved approximately 70 miles of state roads on which two hundred (200) accident investigations were completed during the 13 months of active investigation.

The research team and selected faculty members of the Department of Forensic Studies of Indiana University trained accident investigators for the on-site investigation. Accident investigation was initiated December 7, 1968. Based on the physical documented evidence, witness reports, and driver interviews, subjective estimates of the pre-crash (sequence) speeds were determined.

A computer-sensor system was installed and the appropriate software developed for providing real time speed, length, and headway information on all vehicles at eight detector locations (both lanes) as of May 7, 1969. The system comprises eight magnetic loop detectors on Highway 37 passing North and South through Bloomington, Indiana. Whenever possible and appropriate, the data from the computer-sensor system were integrated into the pre-accident speed estimation process.

The on-site investigation was discontinued on August 1, 1969, in favor of a follow-up scheme in which the speed estimates were based on the computer-sensor system output, the accident report of the investigating law enforcement agency, and statements of witnesses.

The computer-sensor system was expanded from eight to fourteen detector locations, each monitoring two lanes of traffic, and was operating as of November 4, 1969. The data collection funded under this project terminated December 31, 1969.

3. SUMMARY

The results of this study are summarized below. Pertinent tables, graphs, and figures and a sampling of the detailed results given in Volume II are given in Section 5 of this Summary Report for easy reference. Furthermore, the summary statements are subdivided by: A. Accidents, B. Traffic Flow, and C. Computer-Sensor System. The references to sections in Volume II where the reader may find more detailed information are given in parentheses following each summary statement.

A. Accidents

1. Over a thirteen month period, 200 accidents, involving 353 vehicles were investigated on the state roads of Monroe County, Indiana. In addition, 94 accidents which occurred on county roads were investigated. These accidents are listed in this report but are not included in the involvement rate analysis because of insufficient volume-time information on county roads. (Section 3)

2. The results of this study indicate a U-shaped relationship between involvement rate and speed deviation. The following table gives the numerical values of the involvement rate as a function of speed deviation for all state roads in Monroe County, Indiana. These rates were obtained after eliminating those accidents which involved a turning maneuver. (Section 3)

Speed Deviation Class Interval (mph)	Involvement Rate (No. Involvements per MVM)
< -15.5	9.8
-15.5 to - 5.5	0.8
- 5.5 to + 5.5	0.8
+ 5.5 to +15.5	1.3
> +15.5	9.8

3. These results confirm the hypothesis that slow driving as well as fast driving increases the likelihood of being involved in an accident. However, the curvature of this U-shaped relationship is not nearly as pronounced as that given in a previous study [1]. The likelihood of involvement at higher speed deviations also depends on the type of road. The values in the above table are averages of results for State Highway 37 and other state roads. (Section 3)

4. Forty-four percent of all accidents (and 56% of the involvements) involved at least one vehicle which was either in a turning maneuver or influenced by another vehicle which was in the process of turning. (Section 3)

5. Thirty-nine (39) out of 183 drivers, or 21 percent, having seat belts available were using them. (Section 3)

6. As expected, there is a speed deviation and age interaction, that is, younger drivers occur more frequently in the high-speed deviation class and older drivers in the low-speed deviation class. (Sections 2 and 3)

7. A breakdown of the types of accidents by roads is given below.

		Multiple			
	Single	Head-on	Rear-End	Side	Totals
Highway 37 North	17	10	22	16	65
Highway 37 South	14	5	17	13	49
All Other State Roads	36	9	38	20	103
Totals	67	24	77	49	217

The major point to be made relative to this table is that the percentage of multiple (single) vehicle involvements decreases (increases) as the traffic volume decreases. Even though Highway 37 North appears to a driver to be a safer highway than 37 South, the likelihood of being involved is greater due to the multiple vehicle accidents. (Sections 2 and 3)

B. Traffic Flow

Utilizing radar and the computer-sensor system data, traffic flow characteristics (mean speed, speed variability, and volume) were examined for each of the roads included in the study. For Highway No. 37, these characteristics have been examined with respect to changes over time. Some general conclusions resulting from these analyses are:

1. Large differences in mean speeds exist among the various roads included in the study. This was anticipated in view of differences in road geometry, surface, type, width, topography, concentration of population, etc., existing within the road network. (Section 6)
2. Mean speeds at night and especially the early morning hours are consistently higher than daytime mean speeds. (Section 6)
3. Mean speeds are generally higher for dry roads than for wet roads. There were stations where wet roads exhibited mean speeds equal to or even greater than dry roads; however, this could be a situation where rain had just ended and there was good visibility, but the road was still wet. (Section 6)
4. Speed variability is relatively stable over the entire road network system. (Section 6)
5. Speed variability is generally greater, but by only a small amount, during night driving as compared to daytime driving. (Section 6)
6. Three linear prediction models consisting of 3, 6, and 15 variables were examined to determine those variables which explain best the variation in hourly mean speeds. Of all the variables studied, volume of vehicles in same direction is the most important single factor. (Section 5)
7. Speed distributions are adequately described by the normal distribution. (Section 5)

8. One approach for evaluating the effectiveness of countermeasures pertaining to speed deviations is described in Section 2 of Volume II. For given speed distribution and likelihood of accident involvement one can estimate the maximum reduction possible in overall likelihood (ignoring intersection-turning maneuver accidents) which can be achieved by particular countermeasure programs. The effectiveness of a program to reduce the involvement rate must be considered relative to the maximum possible reduction, and then the potential value of a particular C/M program can be estimated. (Section 2)

9. There was not sufficient data available to allow a full analysis but it appears that this study reinforces the setting of speed limits at the 85th percentile speed. The drivers having speeds between the mean and two standard deviations above the mean are definitely in a low involvement group. Speeds at two standard deviations above the mean correspond to approximately the tolerance level allowed by police agencies. Thus the higher level of enforcement occurs when the accident-involvement likelihood function begins to increase significantly resulting in a more cost effective C/M.

If minimum speed limits are set a similar argument would lead to the conclusion that the limit should be placed at about the 15th percentile speed with enforcement at about the 5th percentile. (Section 2)

C. Computer-Sensor System

1. The Computer-Sensor System (CSS) has provided data on speed, density, headways, and mix of vehicles on the roadway during the time of the accident in a very satisfactory manner. Data are now available that have not been previously collected regarding the overall traffic parameters in a traffic stream containing AIV's. (Section 4)

2. The CSS is capable of detecting either the AIV or the platoon of vehicles containing the AIV approximately 25 percent of the time with high confidence (Section 3). This capability is dependent on some accident investigation which identifies the particular vehicles, location and time of the accident, and statements of witnesses concerning (unusual) speeds and relative positions of vehicles having extreme lengths. (Section 4)

3. The standard deviations of the estimated vehicle speeds and lengths as recorded by the CSS are approximately 1 mph and 1 foot respectively. (Section 4)

4. The CSS has provided considerable data on vehicle speeds, lengths, and headways which can provide data for better understanding of traffic flow behavior. To our knowledge no data on a two-lane road such as State Road No. 37 exists to the extent that they are available from this data collection effort. (Section 4)

5. For the 22 weeks beginning with June 23, 1969, through November 23, 1969, the weekly system availability ranged from about 57% to 96%, adjusting for scheduled maintenance of four hours per week. System availability is the proportion of up-time for the system to total time, in this case 164 hours per week. During this period of time considerable downtime was scheduled for system analysis, expansion, and improvements. During three weeks the availability exceeded 90% indicating that it is capable of high level performance. (Section 4)

4. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. The major conclusion resulting from this project is that the likelihood of being involved in an accident is increased by a factor of about 10 if one is driving at speeds which deviate considerably (approximately 15 mph) from the mean speed of the traffic. Because of a study performed early in the investigation with respect to the error in estimating involvement rates as a function of speed deviations [3], it is necessary to subdivide speed deviation values into a small number of intervals (5 are used in this study) to minimize the effect of the error in estimating the speeds of accident-involved vehicles. The conclusion above, with reference to the speed deviation, is dependent on how finely one can subdivide the range of speed deviation values. The likelihood of involvement varied from about 6 to 21 accidents/million vehicle miles for the high-speed deviations compared to about unity for the low-speed deviations.

2. The second conclusion is that the large proportion of accidents on two-lane roads, such as those in Monroe County, are initiated by vehicles either turning left off the main road or by vehicles entering the road from numerous access points. Thus, it becomes important to review the highway design standards in order that left turn lanes, intersection design, and proper traffic control standards are used to minimize the likelihood of accident involvements of this type. The design and traffic control improvements to be made would necessarily be a function of traffic volume which correlates with the likelihood of an accident.

3. The Computer-Sensor System provides an excellent method for collecting data concerning traffic flow characteristics during the occurrence of an accident. Some improvement in the hardware and software needs to be made in order to increase the accuracy and precision of the data; furthermore, quality control procedures need to be introduced to maintain collection of good quality data.

4. The Computer-Sensor System is a costly system if its only purpose is to identify accident-involved vehicles and to provide estimates of these speeds. For this project its purpose was two-fold; in addition to estimating the speeds of the accident-involved vehicles, it is to estimate the mean speed, volume, and traffic mix, using effective vehicle length estimates. The value of these data cannot be measured as such information is not available from any other traffic flow data collection system to our knowledge.

B. Recommendations

1. It is suggested that an investigation be made of an analog device in conjunction with the present computer-sensor system in order to assist in the identification of vehicles; for example, the wave forms obtained from the magnetic loop sensors could be correlated with vehicle types.

2. Portable sensors should be used to study traffic flow in the vicinity of intersections and at traffic signals. In the latter case, information is needed concerning the traffic flow as the vehicles depart from the control signal.

3. A great deal of traffic flow data on a two-lane road is available on magnetic tape as a result of the data collection activity of this project. Information concerning vehicle speeds, lengths, direction of travel and headway are available for further

analysis. In addition, a weather log has been maintained at Indiana University for correlating weather conditions with traffic flow characteristics. These data are particularly valuable for performing the traffic flow studies concerning the following:

a. Speed distributions,

b. Headway distributions,

c. Platoon characteristics,

d. Traffic flow at the time of an accident, and

e. Effect of trucks (long-length vehicles) on a. through d. above.

4. Several countermeasures (C/M's) have been recommended in the literature [4, 5] relative to control of vehicle speeds, use of appropriate traffic controls, and law enforcement techniques. Some of these countermeasures are listed below. These C/M's need to be studied for their potential pay-off in decreasing the likelihood of accident involvement for high-speed deviations. An approach for doing this is provided in Section 2 of Volume II.

a. Control of vehicle speeds

(1) Top speed limiting device,

(2) Performance freeze on speeds,

(3) Automatic car-following speed control.

b. Use of appropriate traffic controls

(1) Posting of both minimum and maximum speed limits,

(2) Posting of variable speed limits as a function of environmental conditions (for example 35 mph on icy roads),

(3) Automated monitoring for traffic speed violations.

c. Law enforcement techniques

(1) Increased enforcement of speed limits, both minimum and maximum,

(2) Graded driver licensing (for example, restricting some older or physically handicapped drivers to non-high-speed roads),

(3) Automated speed monitoring and traffic violations.

4. The continuous volume-time data for each of the sensor locations on Highway 37 can be utilized very effectively in developing and evaluating sampling procedures and techniques for estimating average annual daily traffic (AADT) and the speed distribution. Such a study is recommended in view of the current practices employed in estimating these important statistics. The development of efficient techniques for estimating the 85th percentile (or some other appropriate characteristic) of the speed distribution would aid in setting the speed limits.

5. Additional study needs to be made of the dependency of the likelihood of involvement on the road type. Also the errors in estimating the speeds of the accident-involved vehicles cannot be estimated with available data. It would be desirable to have such data in order to place confidence limits on the likelihoods given in the U-shaped distribution.

5. PARTIAL TABULATION OF RESULTS

Explanations and comments are given below for each table and figure when the results are not self-explanatory. This section is subdivided into the three sections: A. Accidents, B. Traffic Flow, and C. Computer-Sensor System.

A. Accidents

The relatively large number of accidents associated with a turning maneuver (44 percent) is illustrated in Table 5.1. This is not an unexpected result for the state roads surrounding Bloomington, Indiana because of the large number of intersections, T-junctions, business access points and lanes to private dwellings along each of these roads. In Table 5.2 the relationship between involvement rate and speed deviation is given for only those accidents which are not associated with a turning maneuver. The latter have been excluded because such accidents involve vehicles which have come to a stopped or near-stopped condition and do not yield a measure of the likelihood of accident involvement for slowly moving vehicles. In addition the C/M's for accidents involving turning maneuvers will be different from those for vehicles traveling at speeds less than the mean speed but not in the act of turning or stopping. This table also illustrates the comparison of Highway No. 37 with other state roads in Monroe County. There is a significant difference in the likelihood of involvement as a function of the road types. Table 5.3 gives a comparison of the involvement rates for day versus night on each of the state roads. Table 5.4 indicates that the number of involvements on Highway No. 37 North is significantly greater than those on Highway No. 37 South; however, in Table 5.5 it is shown that the number of accidents on Highway No. 37 North is not significantly greater than that on Highway No. 37 South. These results indicate that there were a large number of multiple involvements on Highway No. 37 North. Figure 5.1 gives the accident locations on all of the state roads in Monroe County. One should keep in mind that the accident investigation was terminated on all roads except Highway No. 37 as of August 1, 1969. Table 5.6 provides a classification of the accidents by various driver, vehicle, and environmental characteristics. Those instances of alcohol involvement reported reflect the driver status as noted on the investigating officer's report. Neither strict guidelines nor legal aids exist in Indiana to provide for the identification of the drunk driver. Except in the extreme case where a blood-alcohol test was administered, most reported incidences of alcohol were based on the subjective judgement of the investigating officer. For each of the accidents investigated during this project a complete file has been maintained at the Institute for Research in Public Safety (IRPS) of Indiana University. In this report a short summary of each accident is given in accordance with the format of Table 5.7. This is a sample page including nine accidents of the total number of accidents investigated. The mean speed of the traffic flow surrounding the occurrence of the accident is estimated by means of radar and/or the Computer-Sensor System. For all those accidents on Highway No. 37 (location identified by either the 100 or 200 series) and occurring after May 7, 1969, the Computer-Sensor System may be used in estimating the mean speed of the traffic flow as well as the speed of the accident-involved vehicle (AIV). Some indication of the effectiveness of the Computer-Sensor System is given in Table 5.8 for the period August 1, 1969 to December 31, 1969.

Table 5.1 Total Accidents and Number Associated with Turning Maneuver

			Associated With Turning Maneuver	
	Total No. Accidents	Total No. Involvements	Number Accidents	Number Involvements
Highway No. 37	114	216	56	132
Other State Roads	86	137	32	67
Total	200	353	88	199

Table 5.2 Relationship Between Involvement Rate and Speed Deviation (Adjusted*)

Speed Deviation Class Interval (mph)	Number Involvements	Total Vehicle Mileage (MVM)	Rate (Involvements per MVM)
Highway No. 37 (North and South)			
< -15.5	12	1.890	6.3
-15.5 to - 5.5	11	16.243	.7
- 5.5 to + 5.5	32	39.976	.8
+ 5.5 to +15.5	16	16.243	1.0
> +15.5	13	1.890	6.9
Highway No.'s 46 (East and West), 45 (East and West) and 48 (West)			
< -15.5	12	.571	21.0
-15.5 to - 5.5	9	8.429	1.1
- 5.5 to + 5.5	22	23.621	.9
+ 5.5 to +15.5	16	8.429	1.9
> +15.5	11	.571	19.3
Total (All State Roads in Monroe County)			
< -15.5	24	2.461	9.8
-15.5 to - 5.5	20	24.672	.8
- 5.5 to + 5.5	54	63.597	.8
+ 5.5 to +15.5	32	24.672	1.3
> +15.5	24	2.461	9.8

*Accidents involving at least one vehicle in a turning maneuver or influenced by another vehicle involved in the process of making a turn have been excluded.

Table 5.3 Number of Accidents, Number of Involvements and Associated Rates by Road by Time-of-Day*

Road	Time-of-Day	Number of Accidents	Number of Involvements	No. Acc. per MVM	No. Inv. per MVW
No. 46 East	Day	8	14	1.2	2.1
	Night	5	8	2.5	3.9
	Total	13	22	1.5	2.5
No. 46 West	Day	20	36	2.2	4.0
	Night	5	7	2.0	2.8
	Total	25	43	2.2	3.7
No. 45 East	Day	14	22	5.4	8.4
	Night	5	5	6.8	6.8
	Total	19	27	5.7	8.1
No. 45 West	Day	18	35	2.1	4.0
	Night	4	8	1.7	3.4
	Total	22	43	2.0	3.9
No. 48 West	Day	6	9	1.0	1.6
	Night	1	1	.8	.8
	Total	7	10	1.0	1.4
No. 37 North	Day	48	105	1.5	3.3
	Night	17	29	1.7	2.9
	Total	65	134	1.6	3.2
No. 37 South	Day	30	51	1.1	1.9
	Night	19	33	2.2	3.8
	Total	49	84	1.4	2.4

*For Highway No. 37 the time period covered is December 7, 1968 through December 31, 1969. For all other State Roads the time period is December 7, 1968 through July 31, 1969.

Day is defined as the time period 6:00 A.M. to 7:00 P.M.

Table 5.4 Observed and Expected Number of Daytime Involvements on Highway No. 37

	Observed No. Involvements (O)	Expected No. Involvements* (E)	$\frac{(O - E)^2}{(E)}$
Highway No. 37 North	105	85	4.7
Highway No. 37 South	51	71	5.6
			χ^2 = 10.3

Table 5.5 Observed and Expected Number of Daytime Accidents on Highway No. 37

	Observed No. Accidents (O)	Expected No. Accidents (E)	$\frac{(O - E)^2}{(E)}$
Highway No. 37 North	48	42.5	.71
Highway No. 37 South	30	35.5	.85
			χ^2 = 1.56

*Number of involvement expected under the null hypothesis that both roads have the same rate (i.e. rate averaged over both roads). The average rate times the vehicle mileage for a given road gives the expected number of involvements for that road.

Figure 5.1 Accident Locations - Monroe County

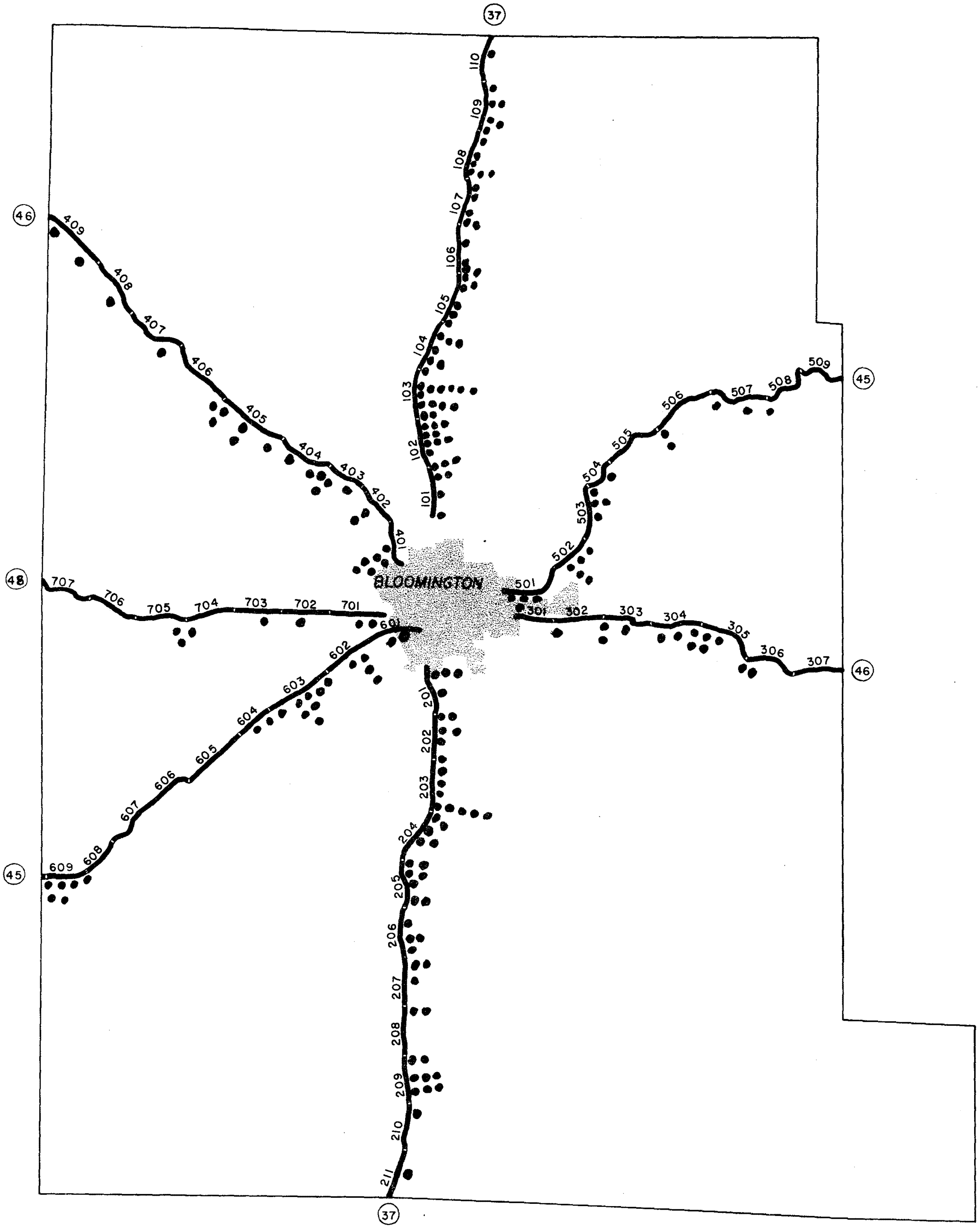

Table 5.6 Accidents Classified According to Type, Location, Environment, Driver and Vehicle Characteristics

(a) Type of Accident

Single		110
Multiple		184
Head-on	32	
Rear-end	81	
Side	71	

(b) Location

Highway #37 North	65
Highway #37 South	49
Highway #45 East	19
Highway #45 West	22
Highway #46 East	13
Highway #46 West	25
Highway #48 West	7
Other County Roads	94

(c) Day of Occurrence

Weekday	188
Weekend	106

(d) Light Conditions

Day	173
Night	103
Dusk	12
Dawn	6

(e) Seat Belt Usage

Used	39
Not Used	144
Not Installed	84
Use Unknown	254

(f) Evidence of Alcohol

Yes	40
No	438
Unknown	34

(g) Weather Conditions

Clear	174
Rain	59
Snow	13
Ice	6
Overcast	37
Fog	5

(h) Sex of Driver

Male	368
Female	136
Not Identified	8

(i) Age of Driver

$\leq$ 19	102
20 - 24	119
25 - 29	59
30 - 34	46
35 - 39	28
$\geq$ 40	147
Unknown	11

(j) Year of Vehicle

1970	1
1969	56
1968	67
1967	60
1966	60
1965	66
1964	50
1963	44
1962	37
1961	11
1960	12
< 1960	37
Unknown	11

Table 5.7 Accident Investigation Information (Example page including nine accidents)

Accident Number	Location	Date	Time	Weather	Light Condition	Type	Damage	Speed Limit	Vehicle Identification	Direction	Traffic Characteristics: Mean Speed	Traffic Characteristics: Std. Dev.	Speed of Accident-Involved Veh: Est.	Speed of Accident-Involved Veh: Min.	Speed of Accident-Involved Veh: Max.	Driver: Age	Driver: Sex	No. Occupants	Vehicle: Make	Vehicle: Year	Seat Belts	Alcohol	Contrib. Circum.
272	S. Rogers at That Rd.	6/11/69	1550	Clear	Day	Side	P.D.	30	V-1	S	N/A	N/A	70	60	75	16	M	Unk	Ply	64	U.U.	No	V-2 pulled out of That Rd. in prep. for turn onto Rogers, V-1 unable to stop.
									V-2	E			00	00	03	68	M	1	Ford	62	U.U.	No	
273	205.8	8/27/69	2213	Clear	Nite	Side	P.D.	55	V-1	N	53	5.2	40	35	45	45	M	Unk	ChevTk	60	U.U.	No	V-1 lost wheel; Wheel then hit V-2.
									V-2	S	49	4.8	50	48	52	24	M	Unk	Ford	67	U.U.	No	
274	107.3	8/27/69	1445	Clear	Day	Side	P.D.	65	V-1	W	56	6.8	0†	0†	0†	26	M	Unk	Chev	60	U.U.	No	V-1 pulled out in front of V-2.
									V-2	S	56	6.8	45	35	50	18	M	Unk	Ford	69	U.U.	No	
275	103.2	8/27/69	1015	Clear	Day	Rear End	P.D.	65	V-1	N	56	8.3	0	0	0	61	F	2	Cad.	68	N.U.	No	V-1 stopping for flagman.
									V-2	N	56	8.3	59	Unk	Unk	69	F	2	Volvo	68	U.U.	No	
276	103.2	8/28/69	1840	Clear	Day	Side	P.I.	65	V-1	S	57	5.6	30	20	50	76	M	Unk	Chev	66	U.U.	No	V-1 turning; V-2 attempted to pass.
									V-2	S	57	5.6	50	40	60	29	M	Unk	Olds	68	U.U.	No	
277	203.2	8/30/69	0234	Fog	Nite	Rear End	P.I.	45	V-1	P	43	6.0	0	0	0	No Driver			Semi	60	N/A	N/A	V-1 parked; V-2 hit by V3; V2 then hit V1; V4 unable to stop hit V-3.
									V-2	S	43	6.0	20	15	30	38	M	1	FordTk	Unk	U.U.	No	
									V-3	S	43	6.0	70	60	75	22	M	1	Chev	69	U.U.	No	
									V-4	S	43	6.0	48	43	53	29	M	Unk	IntTk	68	U.U.	No	
279	106.1	9/2/69	1920	Rain	Nite	Side	P.D.	65	V-1	N	56	8.2	55	50	60	26	M	Unk	Chev	65	U.U.	No	PU in front of V-2 stopping to turn; V-2 unable to stop - lost control.
									V-2	S	61	6.2	50	45	55	65	M	Unk	Olds	68	U.U.	No	
280	103.8	9/10/69	1735	Clear	Day	Head-on	P.D.	65	V-1	N	56	7.2	60	55	65	24	F	Unk	Pont	62	U.U.	No	V-1 unable to stop in time to avoid veh stopped in ft; entered on-coming lane & was struck head-on by V-2.
									V-2	S	54	7.8	53	50	55	38	M	Unk	IntTk	63	U.U.	No	
281	204.1	8/30/69	1905	Clear	Day	Head-on	P.I.	55	V-1	S	44	5.1	46	40	55	39	M	Unk	Ford Van	69	U.U.	No	V-1 lost control on curve; crossed center & struck V-2.
									V-2	N	46	5.4	40	40	55	25	M	Unk	Chev	67	U.U.	No	

Table 5.8 Accident History

Observed Information	Number of Cases	
Total number of accidents	48	
Accidents within the Computer-Sensor System (CSS)	36	
Number of accidents for which the CSS speeds were used for at least 1 involved vehicle for estimating its speed	23	
Number of accidents in which vehicles were identified with high confidence (greater than 90% for the platoon containing the AIV)	14	
1. Number of accidents subject to the above high confidence of identification and for which the estimated speeds given by the CSS are considered highly relevant		9
2. Other cases for which the speeds are not relevant because of the type of the accident (e.g., a rear-ender remote from the sensor)		5
The number of accidents within the "thick" Computer-Sensor System which was installed as of November 4, 1969	0	
The number of accidents for which RTI has made a track of the AIV's	5	

B. Traffic Flow

Table 5.9 contains an example of the volume of vehicles (vehicles/hour) by time of day relationship based on volumes at Loop Sites 0 and 1. These sites are located immediately South of the City of Bloomington. One should note the change in the volume/time relationship for weekday versus weekend days and Friday afternoon. Figures 5.2 and 5.3 are two examples of comparisons of radar speed data collected at several stations along Highway No. 37 North and South. These figures illustrate the differences in mean speeds for various environmental conditions and the stability in the standard deviation of vehicle speeds. Table 5.10 is an example of a summary of the radar speed survey and the complete table has been provided in Volume II. The information in this table is self-explanatory.

One particular study made in this project was the relationship between hourly mean speed and hourly volume of vehicles in the same direction and several other factors. The hourly volume was found to be the most significant factor in determining the speed of the vehicles (See Figure 5.4). An example of how the mean speed and standard deviation of speed variation from day to day is given in Figure 5.5 for two loop sites (0 and 12). The speed distribution seems to be adequately represented by the normal distribution as shown in Figure 5.6; that is, the cumulative distribution is given approximately by a straight line fitted to the data points. Several figures of this type are given in [2].

The regression equations for hourly mean speed as a function of X_1 (hourly volume in the same direction), X_2 (hourly volume in opposite directions), and X_3 (product of X_1 and X_2) are given in Table 5.11 for Loop Sites 8, 10, 12, and 14. Typically, the mean speed decreases as the hourly volumes in either direction increases (as is expected). R^2, the square of the multiple regression coefficient, gives the percentage of the variation in mean speeds which is explained by the regression equations.

Table 5.9 Volume-Time Relationship - Highway No. 37

	LOOP #0				LOOP #1			
Hour Ending	Mon.-Thur.	Fri.	Sat.	Sun.	Mon.-Thur.	Fri.	Sat.	Sun.
1	75	92	172	194	39	46	98	94
2	48	54	112	137	26	32	61	60
3	44	54	98	81	27	36	60	39
4	20	27	51	48	11	15	34	29
5	21	24	38	34	12	13	23	19
6	31	35	48	26	18	18	26	14
7	117	116	74	41	89	88	46	20
8	199	204	153	72	123	127	84	43
9	211	205	208	113	123	110	128	79
10	247	257	327	212	151	152	200	165
11	293	305	418	280	177	178	240	203
12	334	345	508	379	177	180	286	250
13	370	390	557	415	193	198	311	282
14	336	365	492	386	179	204	299	283
15	349	399	454	379	208	233	285	284
16	418	471	463	387	244	260	286	281
17	594	651	473	388	407	421	291	288
18	575	662	458	393	329	405	274	270
19	351	493	384	363	205	298	248	242
20	309	476	371	337	167	280	233	220
21	308	490	385	315	157	292	226	203
22	304	448	387	249	148	273	216	133
23	206	312	282	188	89	177	135	89
24	111	192	235	103	48	93	102	55
Total ADT	5,871	7,067	7,148	5,520	3,347	4,129	4,192	3,645

Figure 5.2 Speed Profiles - Highway No. 37 North

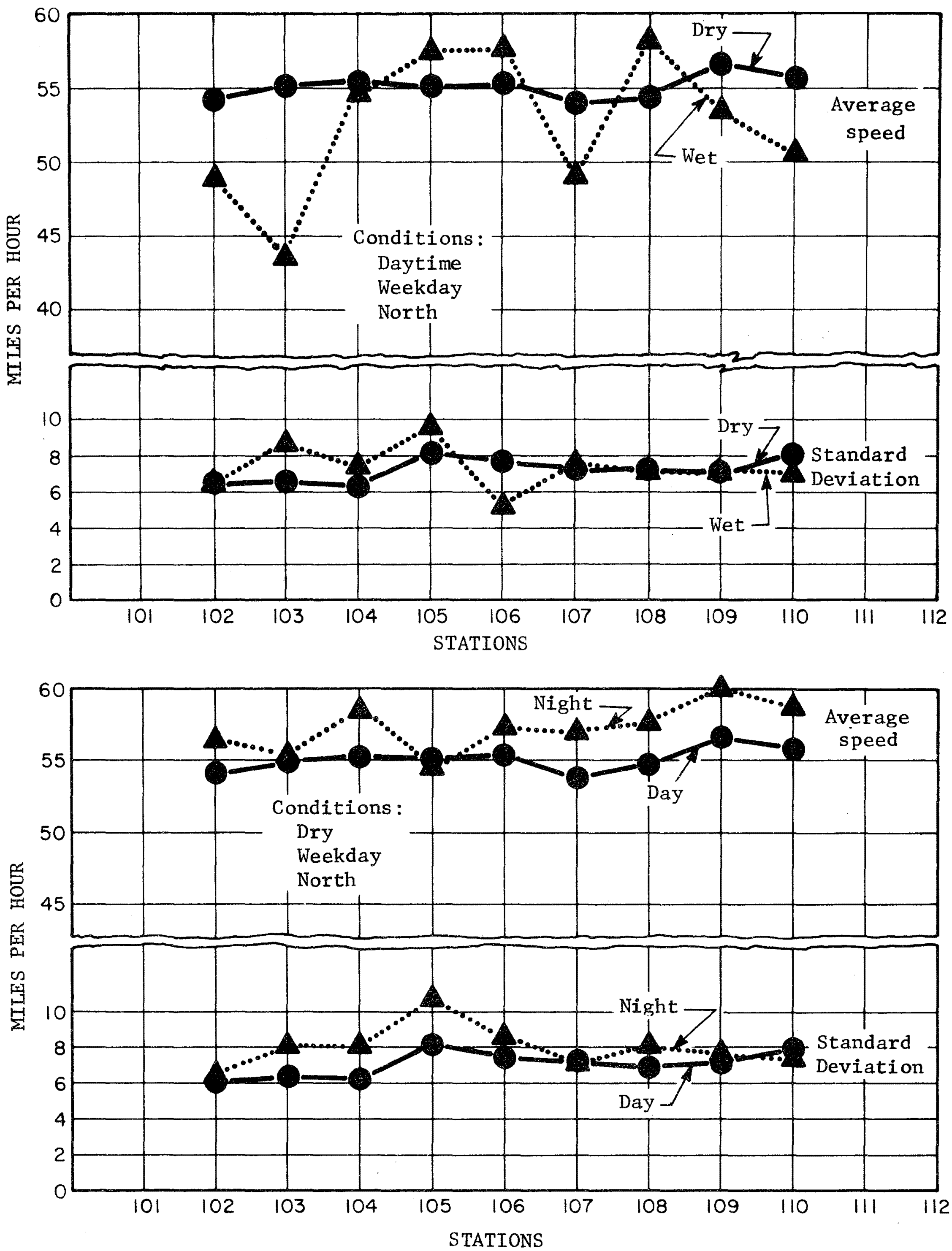

Figure 5.3 Speed Profiles - Highway No. 37 South

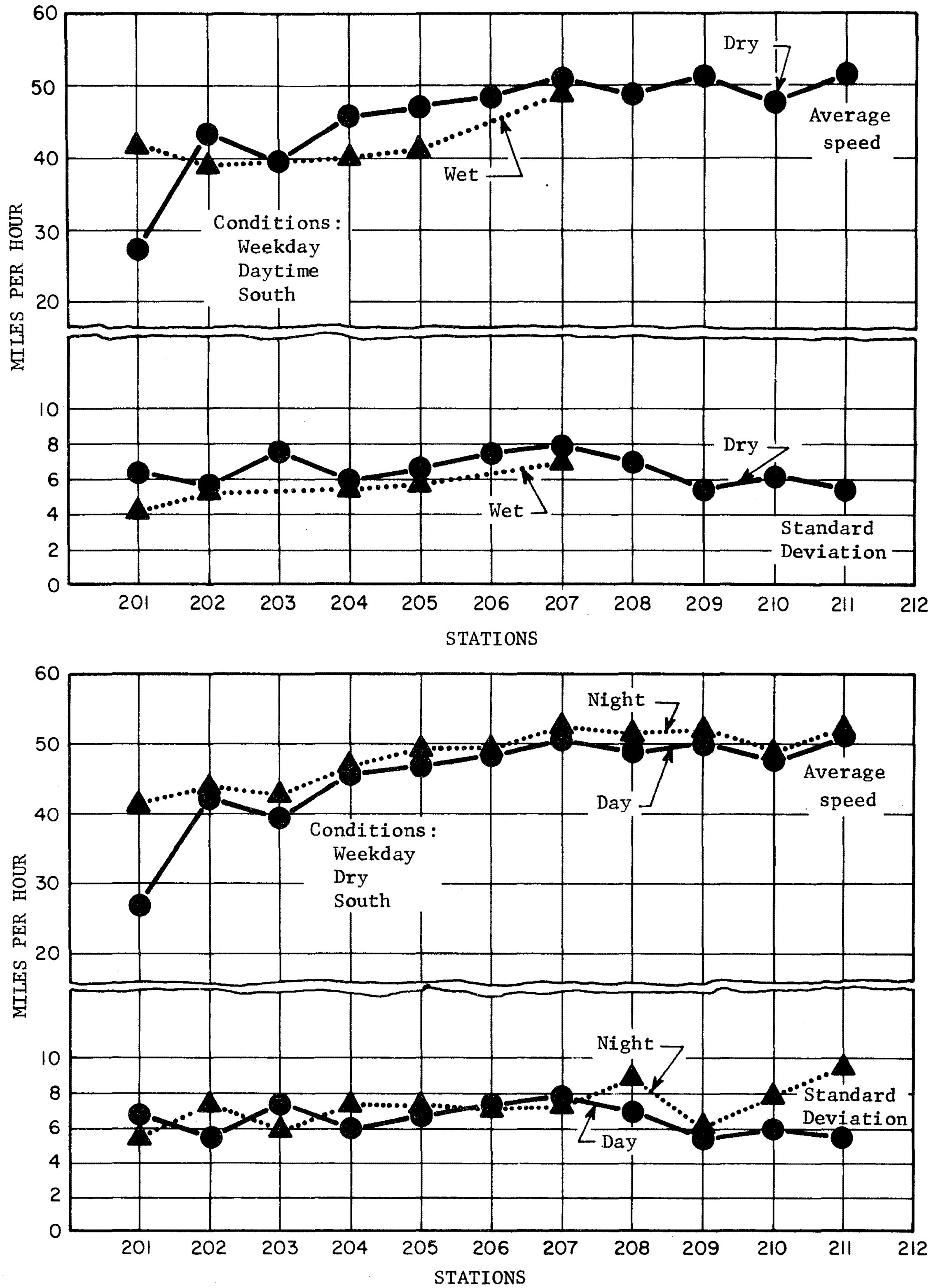

Table 5.10 Speed Survey Data Summary

WEEKDAY

	DAY								NIGHT							
	DRY		WET		ICE		FOG		DRY		WET		ICE		FOG	
Station	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
MEAN SPEED																
101	54								*	*	*	53				
102	54	55	49						57	57	53	52	48	52		
103	55	54	44						56	55	55	51	44	48		
104	55	55	55	35		38			59	58	55	53	*	53		
105	55	55	58						54	54	53	53				
106	56	56	58	56					57	60	56	55	47	45		
107	54	56	49	52					57	56	51	56				
108	55	57	58	55					58	57	*	61				
109	57	56	54	56					60	57	*	54				
110	56	57	51	57					59	59	*	58				
STANDARD DEVIATION																
101	6.3								*	*	*	7.2				
102	6.6	6.2	6.7						6.8	7.3	6.0	6.8	4.6	12.4		
103	6.6	6.6	8.7						8.3	6.8	7.8	6.6	5.3	7.8		
104	6.4	7.0	7.5	4.5		5.7			8.2	7.6	7.9	6.8	*	8.7		
105	8.3	6.6	9.6						10.8	7.9	7.4	8.5				
106	7.8	6.6	5.3	4.2					8.6	8.1	8.5	7.5	6.7	5.4		
107	7.6	7.1	7.8	7.4					7.6	7.7	9.2	6.6				
108	7.2	7.6	6.9	8.1					8.1	7.6	*	6.8				
109	7.2	6.7	7.6	5.8					7.7	8.3	*	7.3				
110	8.1	6.6	7.0	6.3					7.6	7.2	*	9.1				
SAMPLE SIZE																
101	57								5	2	1	13				
102	1212	823	66						162	152	87	118	21	17		
103	1521	1010	622						201	308	59	64	22	18		
104	952	1370	69	84		44			235	308	62	120	5	16		
105	1110	992	57						299	389	63	79				
106	774	959	113	31					208	211	47	71	17	21		
107	1076	1058	165	115					247	437	24	38				
108	1106	951	68	62					258	420	6	15				
109	856	644	95	145					262	266	9	18				
110	692	867	132	178					231	265	8	17				

WEEKEND

	DAY								NIGHT							
	DRY		WET		ICE		FOG		DRY		WET		ICE		FOG	
Station	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
MEAN SPEED																
101																
102	54	51					63	56	53	56						
103	54	55					54	55	54	58						
104	54	56					60	57	56	59						
105	55	55					57	55	56	59						
106	55	56					54	52		51						
107	55	60					58	53	55	59						
108		59							59	58						
109		56							60	59						
110		57					54	57	56	60						
STANDARD DEVIATION																
101																
102	6.2	14.3					7.2	6.7	6.8	7.3						
103	6.5	6.0					7.0	5.1	6.8	4.0						
104	6.4	5.7					12.2	6.2	7.4	7.0						
105	7.4	6.2					5.6	6.5	5.3	5.8						
106	10.8	7.9					9.0	6.0		5.4						
107	7.9	5.4					5.6	6.9	7.2	7.8						
108		6.1							3.7	7.5						
109		5.9							7.0	7.6						
110		6.8					5.5	5.6	5.9	8.8						
SAMPLE SIZE																
101																
102	427	477					43	75	161	93						
103	632	167					87	102	183	36						
104	357	382					31	42	122	38						
105	436	132					51	68	22	26						
106	475	203					67	54		65						
107	286	208					12	27	104	44						
108		162							15	34						
109		195							45	40						
110		223					67	69	122	101						

Figure 5.4 Hourly Mean Speed Versus Hourly Volume for Loop 8

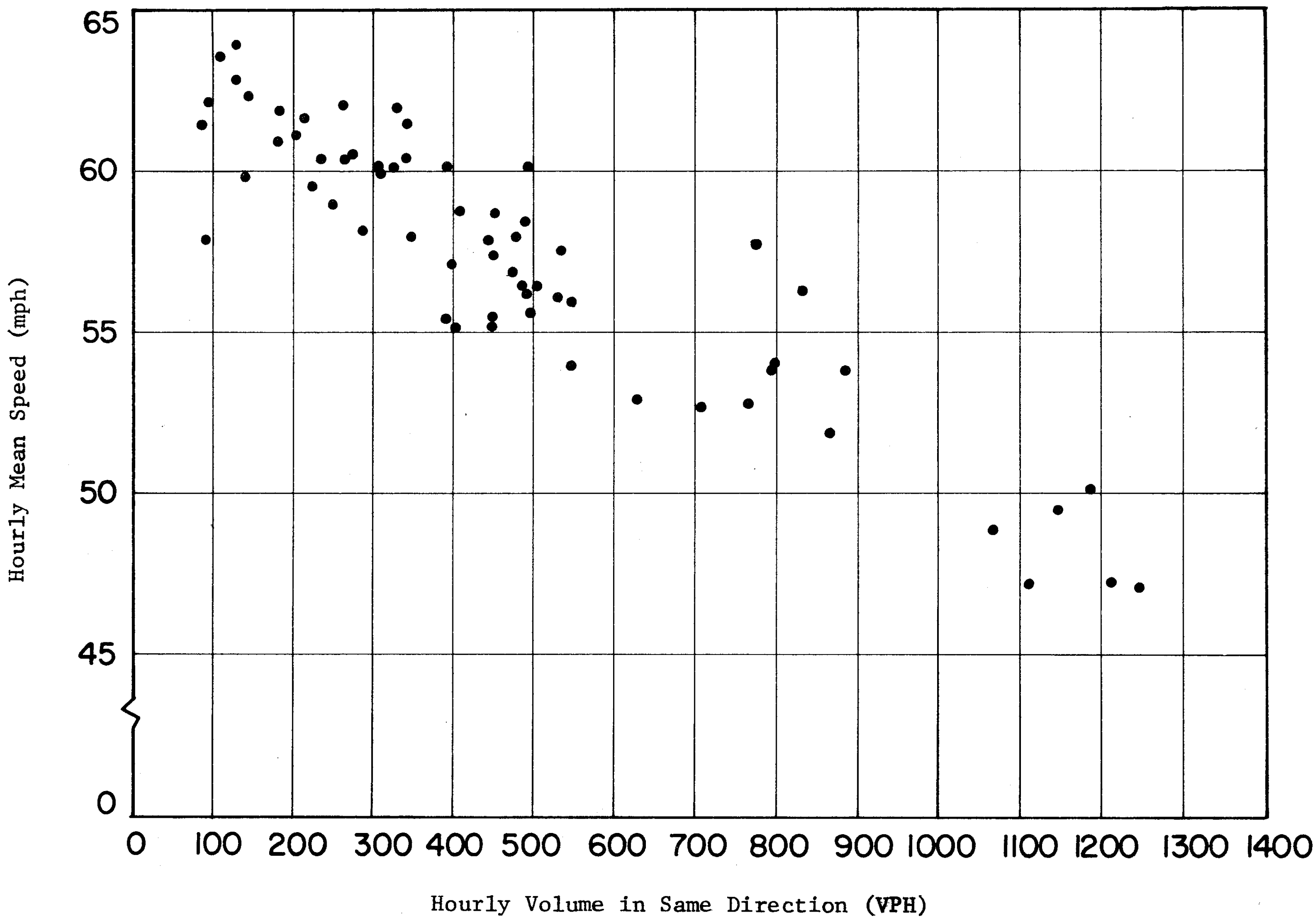

Figure 5.5 Daytime (0600-1900) Mean Speed and Standard Deviation Versus Time

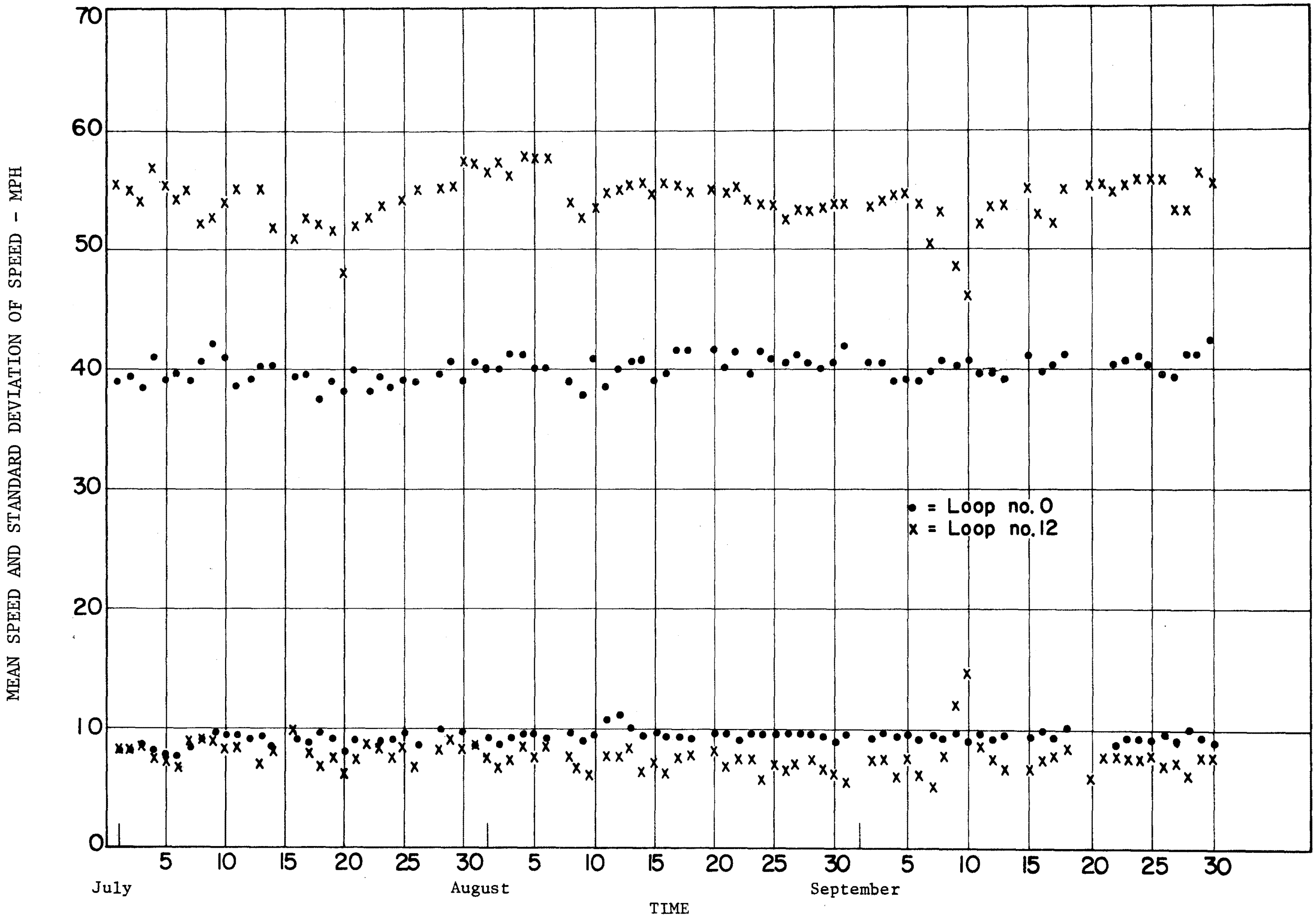

Figure 5.6 Speed Distribution - Station 203

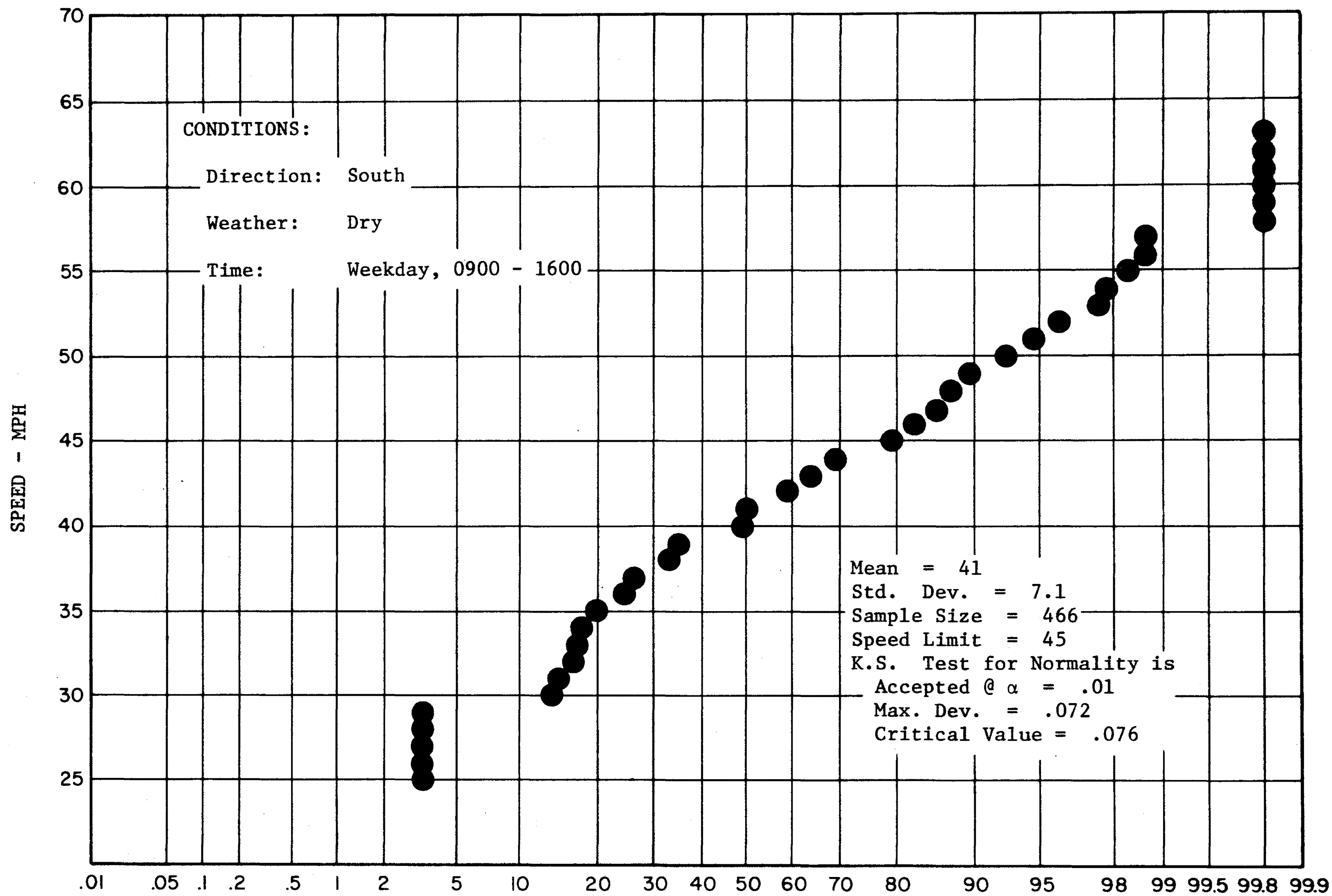

Table 5.11 Regression Equations and R^2 for Four Locations Using Model I with Hourly Mean Speed as the Dependent Variable

Location	Regression Equation	Independent Variables	R^2
Loop 8	$Y = 63.3 - 1.26X_1$	X_1	.840
	$Y = 57.9 - 0.17X_2$	X_2	.015
	$Y = 59.8 - 0.13X_3$	X_3	.274
	$Y = 63.4 - 1.25X_1 - 0.01X_2$	X_1, X_2	.840
	$Y = 63.4 - 1.23X_1 - 0.01X_3$	X_1, X_3	.841
	$Y = 58.4 + 1.28X_2 - 0.31X_3$	X_2, X_3	.556
	$Y = 63.1 - 1.17X_1 + 0.14X_2 - 0.04X_3$	X_1, X_2, X_3	.842
Loop 12	$Y = 56.4 - 0.65X_1$	X_1	.520
	$Y = 55.9 - 0.43X_2$	X_2	.233
	$Y = 56.4 - 0.13X_3$	X_3	.705
	$Y = 57.9 - 0.61X_1 - 0.36X_2$	X_1, X_2	.678
	$Y = 56.5 - 0.96X_1 - 0.12X_3$	X_1, X_3	.709
	$Y = 56.5 - 0.03X_2 - 0.13X_3$	X_2, X_3	.706
	$Y = 57.1 - 0.23X_1 - 0.14X_2 - 0.09X_3$	X_1, X_2, X_3	.719
Loop 10	$Y = 64.5 - 1.45X_1$	X_1	.644
	$Y = 58.7 - 0.26X_2$	X_2	.019
	$Y = 58.9 - 0.12X_3$	X_3	.130
	$Y = 65.0 - 1.44X_1 - 0.14X_2$	X_1, X_2	.650
	$Y = 64.4 - 1.47X_1 + 0.01X_3$	X_1, X_3	.645
	$Y = 59.0 + 0.78X_2 - 0.24X_3$	X_2, X_3	.193
	$Y = 66.2 - 1.75X_1 - 0.74X_2 + 0.14X_3$	X_1, X_2, X_3	.683
Loop 14	$Y = 60.8 - 0.64X_1$	X_1	.423
	$Y = 60.5 - 0.43X_2$	X_2	.207
	$Y = 60.7 - 0.13X_3$	X_3	.515
	$Y = 62.5 - 0.61X_1 - 0.38X_2$	X_1, X_2	.592
	$Y = 60.9 - 0.22X_1 - 0.10X_3$	X_1, X_3	.533
	$Y = 61.1 - 0.14X_2 - 0.12X_3$	X_2, X_3	.531
	$Y = 62.3 - 0.51X_1 - 0.33X_2 - 0.25X_3$	X_1, X_2, X_3	.596

C. Computer-Sensor System

Figure 5.7 contains the percentage of missing hourly summaries by time-of-day for the time period September 1 through 28, 1969. The hourly summary is reported as missing if the car count is zero, a very unlikely event for State Highway 37 except when the Computer-Sensor System is non-operational. The percentage of hourly summaries with bad car counts $\geq$ 5% by time of day and for the same time period is given in Figure 5.8. A BCC occurs when the Computer-Sensor System senses the passage of a vehicle over the sensor; however, the speed and length is recorded as zero. Several causes for this phenomena are given in Section 4 of Volume II. During the month of September program development for the expanded system and hardware implementation were on-going; in particular, the time periods 1 - 4 o'clock P.M. and 12 - 6 o'clock A.M. were chosen for system shut-down in order to maximize the chances of collecting data at high-accident times. Thus, the percentages at times other than those indicated above provide a reasonable estimate of the system capability with regard to missing reports. Table 5.12 contains the system availability for the 22-week period beginning with June 23, 1969 and terminating with November 23, 1969. System availability is defined as the proportion of the total time that the system is both operational and providing data for which the BCC < 5% of the reported data. Four hours per week are for scheduled maintenance and thus the maximum availability will not exceed 97.6% (164/168) except in unusual weeks when maintenance requirements are less than the four hours. The fact that the system has relatively high availability during several weeks in July and August indicates the potential capability of this system.

Figure 5.7 Percentage of Missing Hourly Summaries by Time of Day

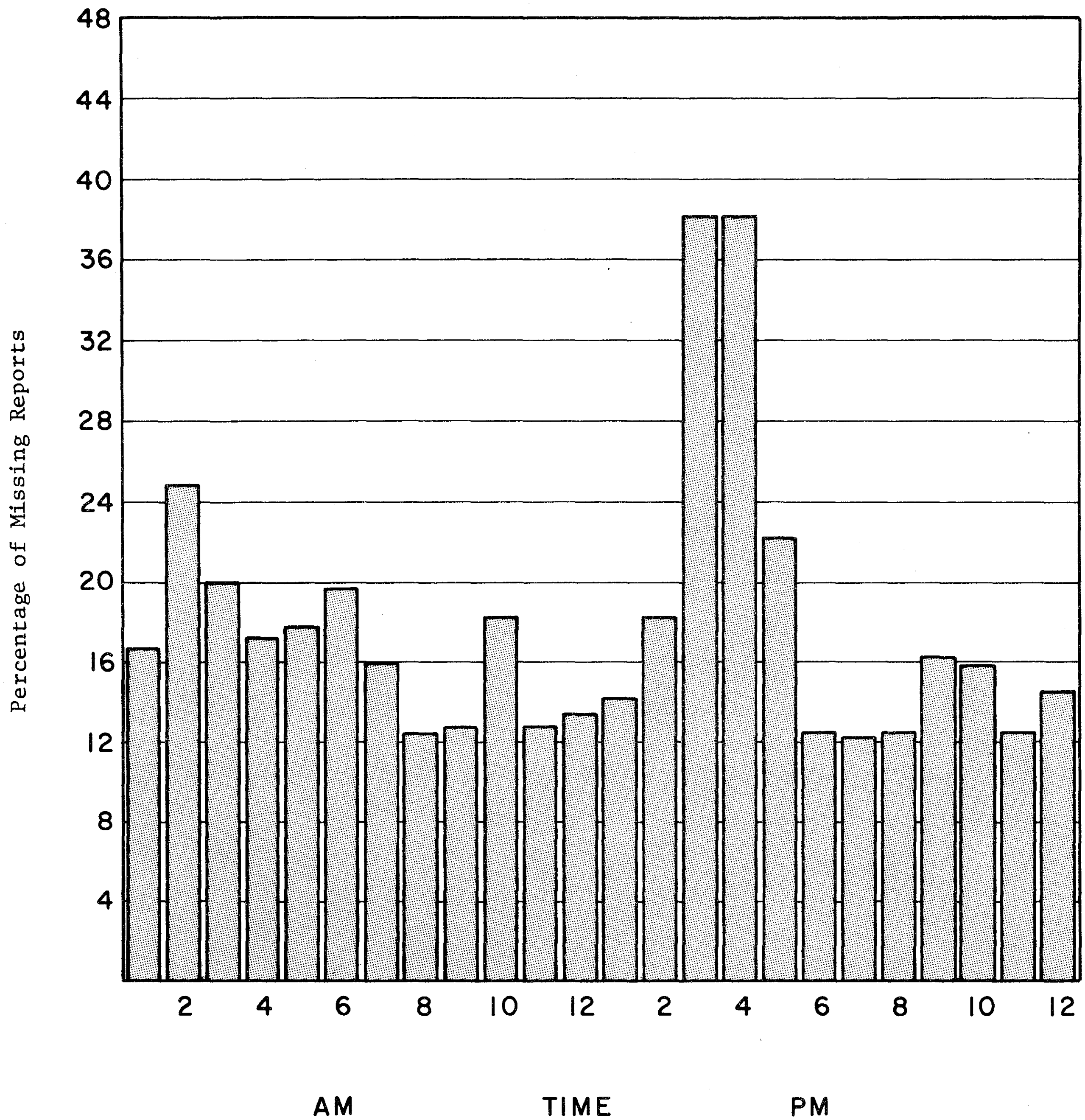

Figure 5.8 Percentage of Hourly Summaries with BCC ≥ 5% by Time of Day

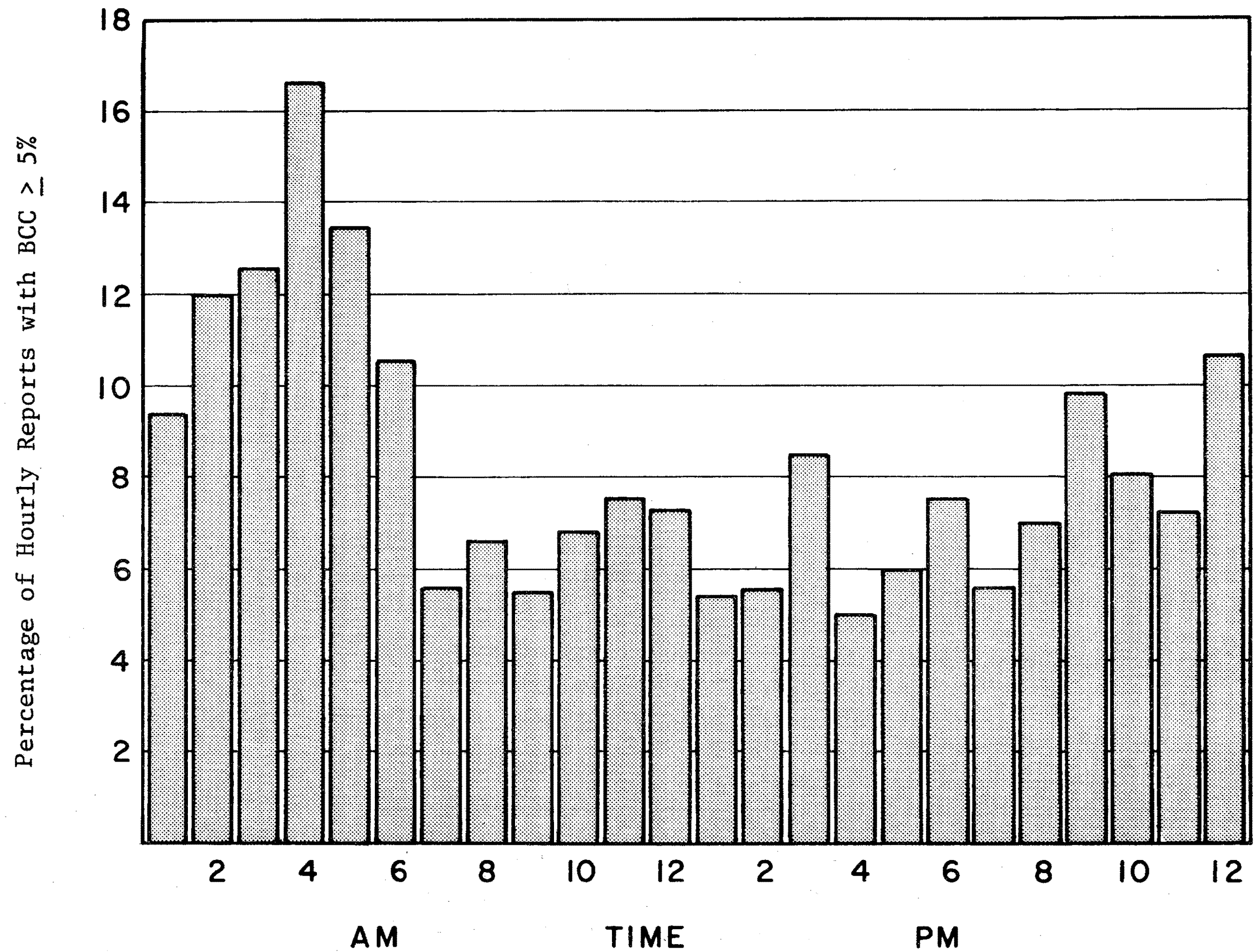

Table 5.12 System Availability (%)*

Time Period

Loop No.	WEEK 1 6/23 – 6/29	WEEK 2 6/30 – 7/6	WEEK 3 7/7 – 7/13	WEEK 4 7/14 – 7/20	WEEK 5 7/21 – 7/27	WEEK 6 7/28 – 8/3	WEEK 7 8/4 – 8/10	WEEK 8 8/11 – 8/17	WEEK 9 8/18 – 8/24	WEEK 10 8/25 – 8/31	WEEK 11 9/1 – 9/7	WEEK 12 9/8 – 9/14	WEEK 13 9/15 – 9/21	WEEK 14 9/22 – 9/28
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0 & 4	70	96	88	92	94	97	94	86	90	96	93	82	42	80
1 & 5	75	96	87	93	95	99	95	88	82	99	95	84	74	86
2 & 6	76	92	88	94	86	98	95	86	83	96	96	86	74	90
3 & 7	75	98	90	90	96	99	89	79	84	99	98	86	76	90
8 & 12	76	96	70	72	96	92	93	84	87	95	89	74	49	70
9 & 13	18	45	44	86	96	90	95	87	91	98	93	70	54	81
10 & 14	36	65	42	54	77	93	94	85	91	99	88	82	73	85
11 & 15	15	25	16	42	69	79	60	64	62	0	27	46	8	0
TOTAL (16 Loops)	55	77	66	78	89	93	89	82	84	85	85	76	56	73

*Scheduled maintenance time of four hours per week of 168 hours reduces the maximum value to 97.6%. Values exceeding 97.6% result from maintenance times shorter than anticipated.

Table 5.12 (Continued)

Loop No.	Time Period WEEK 15 9/29 – 10/5	WEEK 16 10/6 – 10/12	WEEK 17 10/13 – 10/19	WEEK 18 10/20 – 10/26	WEEK 19 10/27 – 11/2	WEEK 20 11/3 – 11/9	WEEK 21 11/10 – 11/16	WEEK 22 11/17 – 11/23
	%	%	%	%	%	%	%	%
0 & 4	68	75	72	70	65	75	80	71
1 & 5	71	78	72	72	68	74	79	90
2 & 6	73	25	52	74	67	72	58	75
3 & 7	73	79	76	75	68	76	58	62
8 & 12	33	0	50	72	63	75	63	66
9 & 13	71	76	72	73	69	76	74	0
10 & 14	63	67	63	62	64	76	70	63
11 & 15	24	31	53	67	61	70	49	64
TOTAL (16 Loops)	60	54	64	71	66	74	66	61

6. REFERENCES

[1] Solomon, D., (1964) "Accidents on Main Rural Highways, Related to Speed, Driver and Vehicle," U.S. Department of Commerce, July, 1964.

[2] RTI and IRPS Staff Members, (1969) "Speed and Accidents - Phase I," Interim Report prepared for the National Highway Safety Bureau under Contract Number FH-11-6965, July 11, 1969, 138pp.

[3] White, S. B., Jr. and Nelson, A. C., Jr., (1970) "Some Effects of Measurement Errors in Estimating Involvement Rate as a Function of Deviation from Mean Traffic Speed," Accepted for publication in June issue of Journal of Safety Research.

[4] NHSB Staff, (1969) "Maximum Safe Speed for Motor Vehicles," Office of Research and Program Synthesis, National Highway Safety Bureau, January 31, 1969, 81pp.

[5] Proceedings of National Highway Safety Bureau Priorities Seminar Held at Fredericksburg, Virginia, July 18-20, 1969: Volume 5, "Speed-Related Accident Countermeasures and Their Priorities," 89pp. (PB - 186 272)