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Accident Analysis and Speed Characteristics

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Accident Analysis and Speed Characteristics

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Operational Route Analysis

BURTON M. RUDY, Highway Associate Engineer, Connecticut State Highway Department

The multitude of data comprising the accident histories of existing highway facilities in Connecticut require the expenditure of considerable man-hours in executing analyses and conducting field investigations of locations with accident concentrations. The mileage of highway network continues to grow and the miles of vehicle travel increase at an even greater rate. As a result, the task of providing efficient accident analyses is becoming of such magnitude as to (a) threaten the quality of the analyses and/or (b) delay identification of accident-prone locations and, therefore, prompt application of remedial measures.

The characteristics of the problem stimulated a review of various processing and investigating techniques with regard to effectiveness, personnel, and equipment involved, and to ease of application. The method selected involves a statistical evaluation of accidents by contrasting the pertinent accident rates against the roadway mean and individual control limits to determine the range of frequency that could be expected to result from chance occurrence.

This application, while monitoring the occurrence levels and distinguishing between the chance events and incidents requiring attention, enables the concentration of personnel in the more critical areas; thereby eliminating the necessity for analyzing all accident data to obtain these sensitive locations.

Results of the test application indicated, without a doubt, that the method employed was effective in pointing out areas requiring special attention, and could be implemented with a minimum number of engineering personnel. Indications are that the bulk of mathematical computations can be accomplished by use of an electronic computer with a relatively simple program.

• TRAFFIC INVESTIGATIONS of specific highway locations result most frequently from requests submitted by municipal authorities, residents of the particular community, and interested motorists. The multitude of such requests necessitates a considerable expenditure of man-hours to visit the site, procure pertinent data, and conduct the analysis.

Some of the reports of alleged undesirable conditions are not substantiated by investigation, and some concern situations where remedial actions are found to be necessary. In the first instance, the value of these efforts is questionable; in the latter instance, it would seem to be remiss not to have discovered the conditions through one's own efforts.

A comprehensive traffic analysis program should reveal "critical" locations before they become apparent by the magnitude and frequency of incidents in the area. This would normally be followed by the institution of such remedial measures as are considered necessary, improvement in operating conditions, and the diminishing of scattered traffic investigations.

BACKGROUND

A review of the frequency, character, location, and cause of traffic investigations being conducted on state-maintained roads indicated the probability that a general route analysis from an operational standpoint would prove highly beneficial. It appeared that a regulated program would point out the areas requiring special consideration before the pertinent accident frequencies, by their magnitude, promoted numerous individual studies. Further efforts were guided by the premise that a comprehensive and effective analysis, which would monitor the incident levels of locations with respect to the entire facility, would enable the prediction of a trend and indicate areas warranting concentrated study before the accident rate reached a critical level.

Regardless of the approach, previous "spot" studies have been largely influenced by the magnitude, position, and frequency of incidents, as well as the vehicle-miles of travel. Though the emphasis of said techniques appears guided in the right direction, the conclusions obtained neglect to provide a distinction between the number of events that might have occurred as a matter of chance and those incidents exceeding this level. Also, they do not reveal the relationship of the particular section with respect to the entire roadway.

PURPOSE AND SCOPE

The purpose of employing quality control techniques to highway accident data was to determine the method's effectiveness to analyze statistically large quantities of varied information and to delineate sensitive areas while distinguishing chance events.

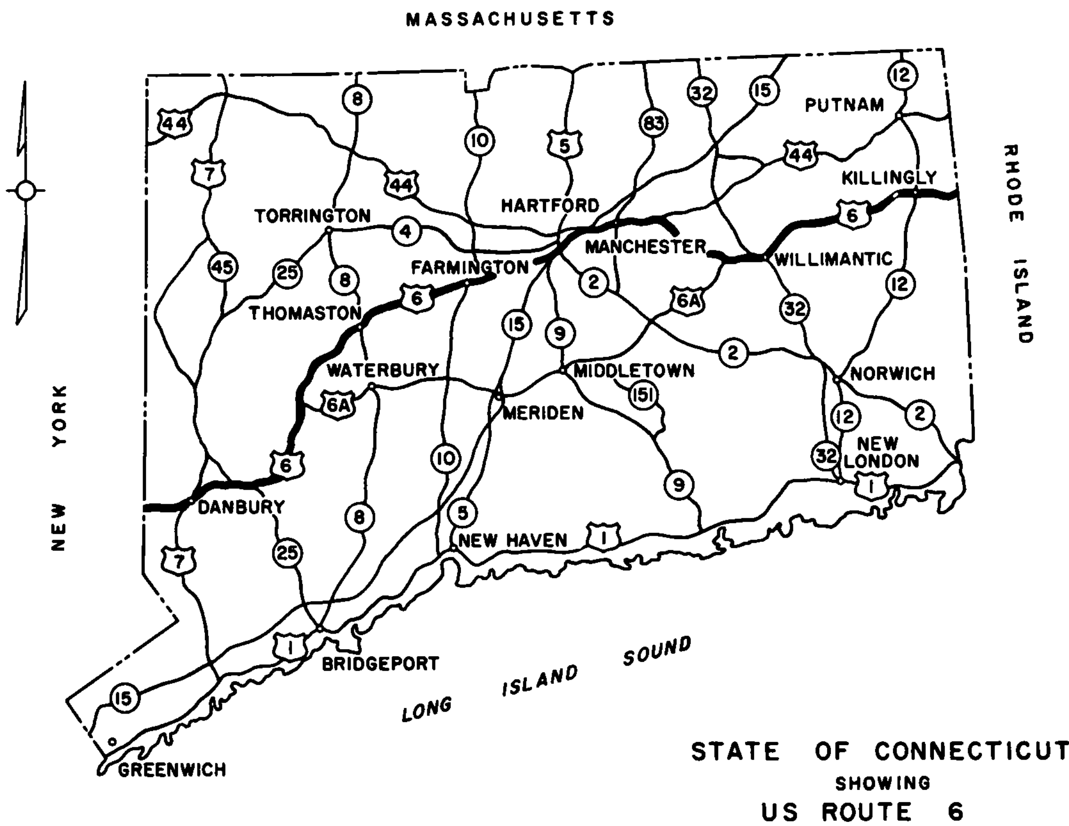

Figure 1. Location of study.

If this were accomplished, it would facilitate accident analysis of individual highways and, consequently, of the entire highway network, noting the effect of enviroment, geometry, and exposure conditions on the frequency of events.

It was believed that the incorporation of this technique as the foundation of a comprehensive traffic analysis program would provide direction of effort and be statistically indicative of remedial applications.

METHOD

The statistical quality control technique was applied to the accident data collected for the number of years considered necessary to provide a sufficient sample. This approach utilized chance or probability concepts to reveal the desired information with clarity and emphasis—the criterion being that while events in a sequence will show a

TABLE 1

ACCIDENT RATE COMPUTATIONS[1]

CONTROL SECTION	ANNUAL FREQUENCY ALL ACCIDENTS	LENGTH (MILES)	AADT	MILES OF TRAVEL 10^8	ACCIDENT RATE PER 10^8 MVM
1	29.00	4.18	4750	.07247	400
2	45.50	7.35	6950	.18645	244
3	15.50	1.50	6825	.03737	415
4	10.50	2.58	6675	.04499	233
5), 6)[a]	3.25	1.55	4550	.01196	272
7	9.75	2.28	3775	.03132	311
8	5.50	1.86	3825	.02597	212
9	14.75	3.02	3675	.04051	364
10	1.25	.50	2750	.00502	249
11	5.00	3.88	2100	.02976	168
12	3.25	1.79	2175	.01421	228
13	10.50	1.04	2100	.00797	1317
14	.50	.40	2350	.00343	146
15	2.50	.75	2200	.00602	415
16	4.75	3.21	2200	.02578	184
17	1.50	.54	7050	.01390	108
18	10.75	.57	10300	.02143	502
19	11 25	1.42	7750	.04018	280
20	4.50	1.26	6125	.02817	159
21	18.00	1.30	8300	03939	457
22	6.50	.49	4950	.00886	734
23	11.75	1.79	6325	.04132	284
24	12.00	.52	7900	.01500	800
25	,5.00	.29	8000	.00847	590
26	6.50	.24	8200	00718	905
27	68.25	2.58	8825	.08311	821
28	22.00	2.57	8400	.07880	279
29), 30)[a]	50.75	5.45	12075	.15614	325
31	38.00	1.50	13800	.07556	503
32	16.00	.39	13300	.01893	845
33	27.00	.98	18000	.06390	419
34	1.50	.52	11700	.02222	68
35	1.75	.19	2500	.00172	1017
36	5.50	.22	5100	.00410	1315
37	11.75	1.26	14775	.06795	173
38	10.25	.71	12025	.03117	329
39	26.25	.74	16625	.04491	583
40	14.50	.48	14500	.02541	571
41	14.75	.81	11375	.03363	439
42	22.00	1.54	12350	.06942	317
43	23.25	1.40	11250	.05689	409
44	20.50	5.27	5150	.09947	206
45	28.75	5.57	3875	.07878	365
46	17.75	1.93	6475	.04561	389
47	5.00	.45	7700	.01265	395
48	4.25	.21	8450	.00648	656
49	4.00	.33	5275	.00635	630
50), 51), 52)[a]	32.75	4.92	9475	.10276	319
53), 54)[a]	14.75	3.18	6300	.03818	386
55	7.75	3.33	2850	.03464	224
56	10.75	3.57	2925	.03812	282
57	30.00	4.06	5750	.08521	352
58	6.25	1.35	4050	.01996	313
59	3.25	.79	3950	.01139	285
60	5.50	.48	3850	.00675	815
61	8.25	2.66	3400	.03301	250
TOTAL	802.25			TOTAL 2.22035	

[1]All data averaged for the 4 years studied

[a]Combined 1951-1954

$$\lambda = \frac{802.25}{2.22035} = 361.31 \text{ accidents}/10^8 \text{ Vehicle Miles}$$

certain degree of chance variation, the variations themselves create a stable pattern as the same percentage of varying points will continue to place within any given set of limits, providing there is in the system no alteration that gives rise to them.

With reference to the problem at hand, the occurrence levels vary on any given highway, but the limits of the variation are stable. In other words, as long as the basic factors affecting accident probability incur only minor changes, the rates will continue to fluctuate within certain limits.

The aforenoted method assists the engineer by focusing his attention on critical locations. It is followed by a thorough analysis of accident reports and field conditions. It is in this phase of the program where the traffic engineer plots the course of future efforts by concentrating analyses where they will effect the greatest benefit.

SITE AND PROCEDURE

The highway selected for the trial application of the technique discussed in this report was US 6. This highway is an important east-west artery running from the New York State Line in the Town of Danbury easterly to the Rhode Island State Line in the Town of Killingly, and passes through the urban areas of Danbury, Bristol, Hartford, Manchester, Willimantic, and Danielson (Fig. 1).

This route encompasses varied geometrical and enviromental conditions and handles from 2,500 to 20,000 vehicles per day. Consequently, it affords an excellent opportunity to study the behavior of the applied technique and the feasibility of operating the analysis program on a statewide basis.

US 6 is comprised of 61 State highway road inventory control sections of varying lengths that represented the integral units of the study system. The integral unit had to be the "control section" rather than equal unit lengths, as the latter method would

TABLE 2

COMPUTATIONS FOR TRIAL CONTROL LIMIT CURVE t_1

$$U.C.L. = \lambda + t_1\sqrt{\frac{\lambda}{m}} + \frac{0.829}{m} + \frac{1}{2m}$$

λ = 361.31

t_1 = 2.576

$$L.C.L. = \lambda - t_1\sqrt{\frac{\lambda}{m}} + \frac{0.829}{m} - \frac{1}{2m}$$

m	$t_1\sqrt{\frac{\lambda}{m}}$	$\frac{0.829}{m}$	$\frac{1}{2m}$	U.C.L.	L.C.L.
.00100	1550.52	828.75	500.00	3240.58	-860.46
.00200	1094.90	414.37	250.00	2120.58	-569.22
.00300	873.62	276.25	166.66	1677.84	-402.72
.00400	774.16	207.18	125.00	1467.65	-330.67
.00500	692.45	165.75	100.00	1391.51	-265.39
.01000	489.62	82.87	50.00	983.80	- 95.44
.01500	399.71	55.25	33.33	849.60	- 16.48
.02000	346.16	41.43	25.00	773.90	31.58
.02500	309.63	33.15	20.00	724.09	64.83
.03000	282.63	27.62	16.66	688.22	89.64
.03500	257.96	23.67	14.28	657.22	112.74
.04000	244.79	20.71	12.50	639.31	124.73
.04500	230.80	18.41	11.11	621.63	137.81
.05000	218.96	16.57	10.00	606.84	148.92
.06000	199.87	13.81	8.33	583.32	166.92
.07000	185.05	11.83	7.14	565.33	180.95
.08000	173.10	10.35	6.25	551.01	192.31
.09000	163.18	9.20	5.55	539.24	201.78
.10000	154.81	8.28	5.00	529.40	209.78
.12000	141.31	6.90	4.16	513.68	222.74
.14000	130.83	5.91	3.57	501.62	232.82
.15000	126.40	5.52	3.33	496.56	237.10
.17000	115.92	4.87	2.94	485.04	247.32
.19000	112.31	4.36	2.63	480.61	250.73
.20000	109.45	4.14	2.50	477.40	253.50

λ = Mean accident rate per 10^8 vehicle miles
m = 10^8 vehicle miles of travel
t_1 = 1% Probability limits
U.C.L. = Upper Control Limit (accidents per 10^8 vehicle miles)
L.C.L. = Lower Control Limit (accidents per 10^8 vehicle miles)

have resulted in a wide range of geometry and traffic flows being incorporated into same. Use of control sections as the basic unit appeared questionable because some were quite short. This was remedied by combining short adjacent sections of the same character and guiding decisions by the fact that an area 1 mi in length, in which 14 to 25 accidents happen each year, is an excellent study interval because the high risk location will stand noticeably revealed. In other instances, it was not possible to effect combinations because of geometric roadway differences and the desire to evaluate the technique with respect to homogeneous units.

A preliminary investigation of field conditions of all the study intervals on US 6 was conducted to aid in effecting the combinations and noting the characteristics of the study intervals.

The quality control method was then applied in the following sequence:

1. To assure an adequate sample, accident and vehicle-mile data were accumulated for a period of four years (1951 through 1954) by control sections and averaged to obtain an annual frequency. This was followed by the computation of accident rates for each control section and the accident rate (trial mean) for the entire road (Table 1).
2. Development of the basic control limits for each study interval using (1)

$$UCL = \lambda + t\sqrt{\frac{\lambda}{m} + \frac{0.829}{m}} + \frac{1}{2m}$$

$$LCL = \lambda - t\sqrt{\frac{\lambda}{m} + \frac{0.829}{m}} - \frac{1}{2m}$$

in which

UCL = upper control limit;
LCL = lower control limit;
λ = mean accident rate per 10^8 vehicle-miles; and
m = 10^8 vehicle-miles of travel for the individual study interval.

It was desired to test the effect of different probabilities of false detection and accordingly the t-value was varied in the previous equations.

t_1 = 2.576 = 1 percent false detection;
t_2 = 1.960 = 5 percent false detection;
t_3 = 1.645 = 10 percent false detection; and
t_4 = 1.440 = 15 percent false detection.

To facilitate computation of control limits, the author computed curves of UCL and LCL vs vehicle-miles for the specific value of λ, as the curves were smooth and continuous and required a relatively small number of calculated points (Table 2). The trial control limits for an interval were determined from these curves based on the exposure of the section, then the individual accident rates were contrasted against the structure noting areas where the rate exceeded the control limit span (Fig. 2).

3. Calculation of final mean (accident rate for entire road) excluding accident and vehicle-mile data pertaining to those study intervals whose rate exceeded the trial limits. As different levels of sensitivity were obtained by varying the t-value, some occurrence levels were noted between the t_1 curve and t_4 curve, and it was necessary to calculate four means. Final control limits were computed following the same procedure as described in Step 2, inserting final means as values for λ.

The results obtained are shown in Figure 3. Although this chart reveals the over-all accident frequencies with respect to the study intervals and the entire route, no comparison is offered between the daylight and nighttime occurrence levels.

Past experience with accident data indicated the necessity for determining whether the event rate was abnormal during daylight and/or during hours of darkness. Inasmuch as a normally operating section of highway should have an identical ratio of occurrences per vehicle-miles of travel regardless of light or dark operation, the magnitude of variance of the ratio would be indicative of the necessity for remedial applications when the control limits were exceeded.

The notes obtained during the preliminary field investigation of the control intervals, and the assembling of accident data focused attention on one particular interval, Control Section 45, which allegedly incorporated certain inefficiencies that were apparently accentuated during the hours of darkness; however, the results obtained from applying the control technique with the combined light and dark data did not reveal the area to be critical. It was thought that perhaps the interval's low daylight rate was responsible for suppressing the high nighttime level. The attempt to prove this theory involved employing light and dark data separately in the control technique. To facilitate computations, one value of t (2.576—1 percent detection) was used and the control limits were computed for Section 45 although the light and dark route means utilized this data for the entire road. Calculations were executed with respect to dark and light accident data, individually, and compared with the conclusions obtained using the combined data. Figure 4 shows the results:

All Data: Limit A. —This depicts the US 6 mean accident rate and control limits for Section 45. The over-all accident rate (light and dark accidents combined) for this interval is little different from the route mean and offers no contrast between the light and dark frequency of events.

Light Accident Data: Limit B. —In this case the US 6 mean accident rate is shown using only daylight events. Accordingly, the occurrence level and control limits for Section 45 were computed using light accident data only. The comparison affected relates to the interval's light frequency ratio with that of the entire route.

Dark Accident Data: Limit C. —This illustrates the same approach as Limit B using dark accident data only. The comparison of events is pertinent to night operation only.

At the termination of these three tests, it was obvious that the presence of the light occurrence data predominated in the interval. This was revealed when the light accident

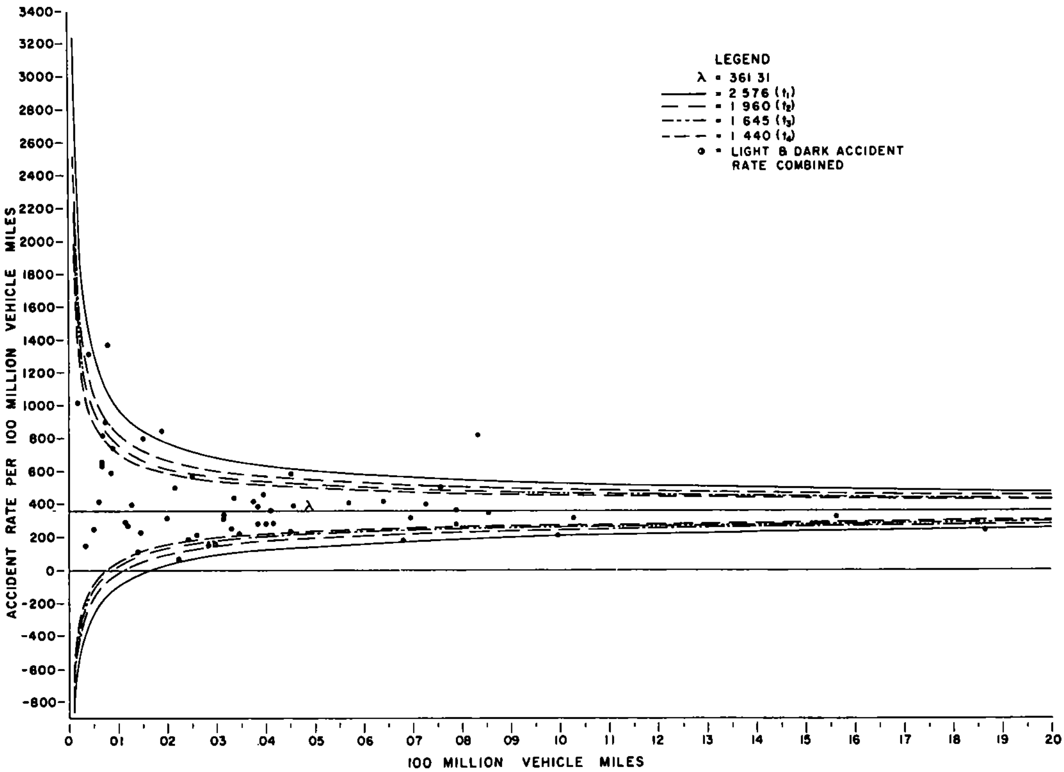

Figure 2. Trial control limit curves.

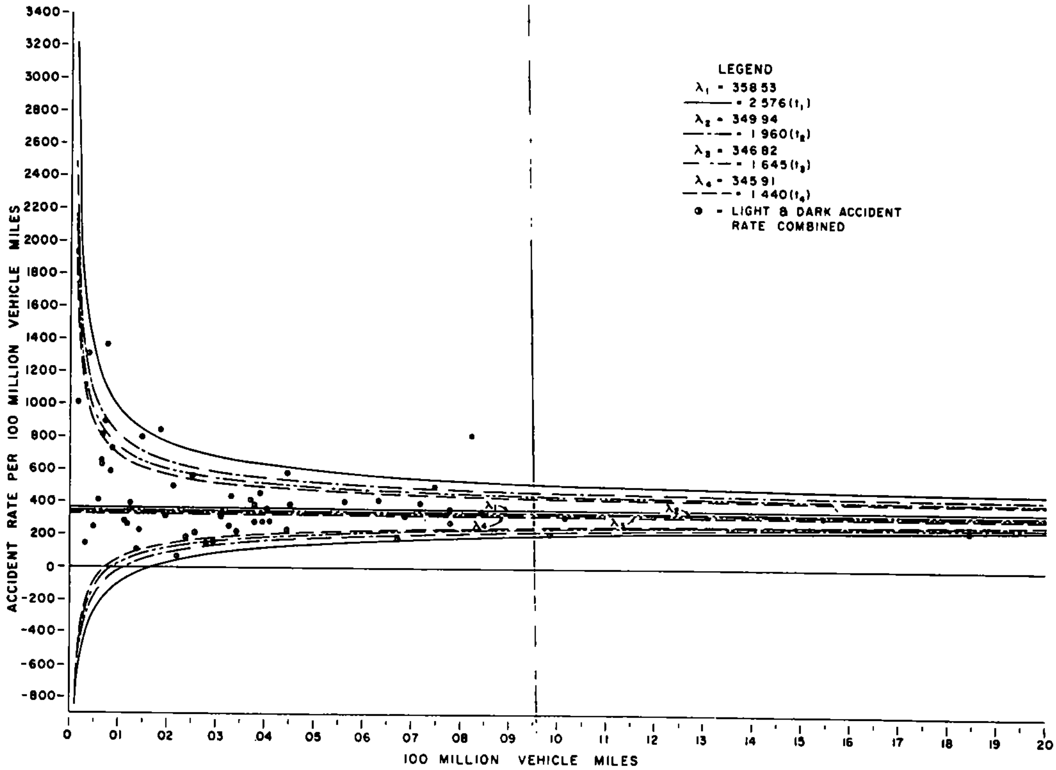

Figure 3. Final control limit curves.

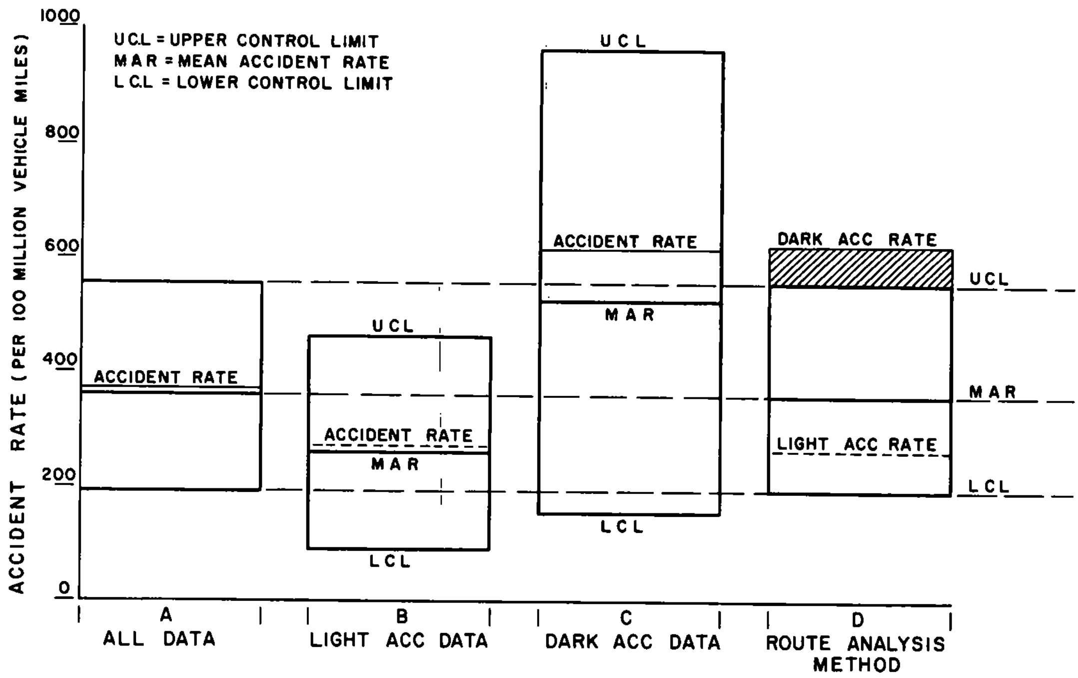

Figure 4. Control Section 45—control limits vs accident rates.

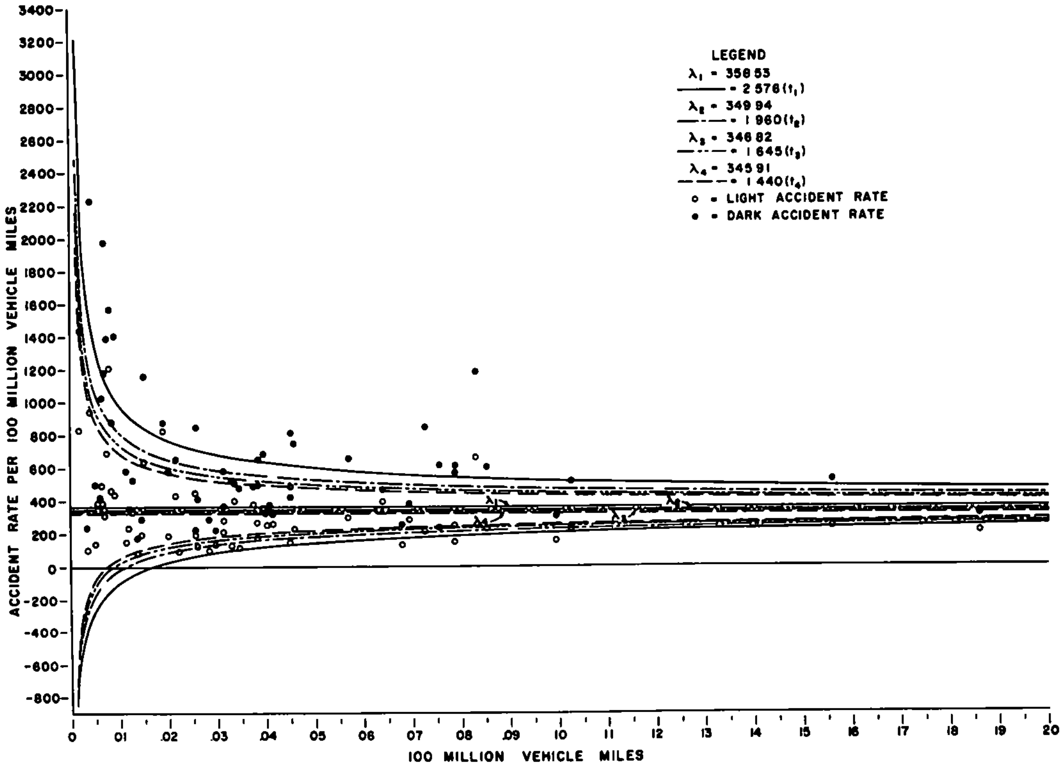

Figure 5. Control limits: route analysis method.

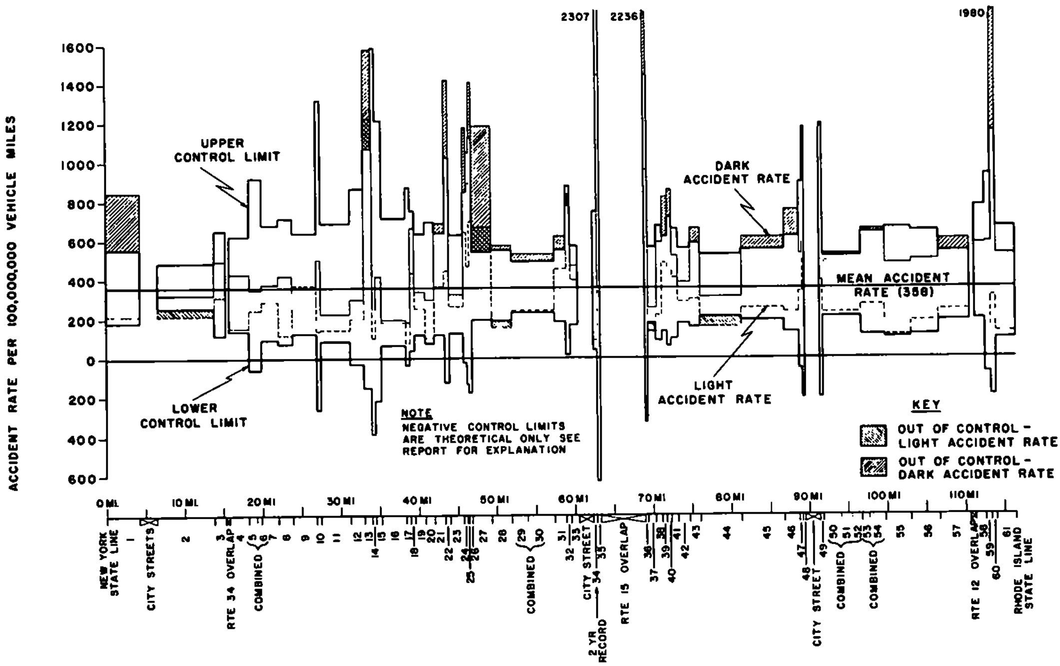

Figure 6. Operational control chart.

data (shown in Limit B) was extracted from the combined data control structure in Limit A. The resultant effect was a downward placement of the entire control structure with a negligible increase in the control limit span. Conversely, when the dark event data (shown in Limit C) was extracted from the combined grouping, it produced a wide span of control limits and a higher mean and event level. These were indicative of a higher frequency of occurrences during hours of darkness than that experienced during daylight hours.

This prompted the initiation of a fourth test, which is based on the premise that a normally operating section of highway should have an identical ratio of events per vehicle-miles of travel regardless of light or dark conditions. If the ratio of occurrences exceeds the allowable limits during light or dark situations, it would be indicative of the nature of traffic control measures warranted. Conversely, if the ratio of events were normal, they would be represented by the combined accident rate and combined route mean, rendering the control limits applicable.

The aforenoted theory was applied to Control Section 45 and represented in Figure 4 as Route Analysis Method D. The high nighttime frequency is delineated when the light and dark ratios are contrasted with the control limits and route mean which utilize combined information drawn from both conditions of traffic operation. The conclusion obtained clearly indicates that remedial traffic measures should be applied with respect to nighttime conditions.

The route analysis method was then applied to the entire study route using the four sensitivity values of t and the mean accident rate determined by the "out of control" combined accident rates. This approach is shown in Figure 5. The magnitude of the frequency ratios are clearly discernible when internally contrasted with the control limits based on their theoretical distribution.

Figure 5 also shows the effect of varying the control limits. In normal applications of this technique, it would be desired to effect study intervals with stable limits, using combinations of same or taking larger samples. The effect of varying the t -value diminishes as the control becomes more stable. The value giving 1 percent false detection was selected because of its negligible difference with the 15 percent control limits in this range, and the increased efficiency rendered with respect to personnel effort.

Figure 7. Control Section 39—roadway surface conditions.

Figure 8. Control Section 40—median openings.

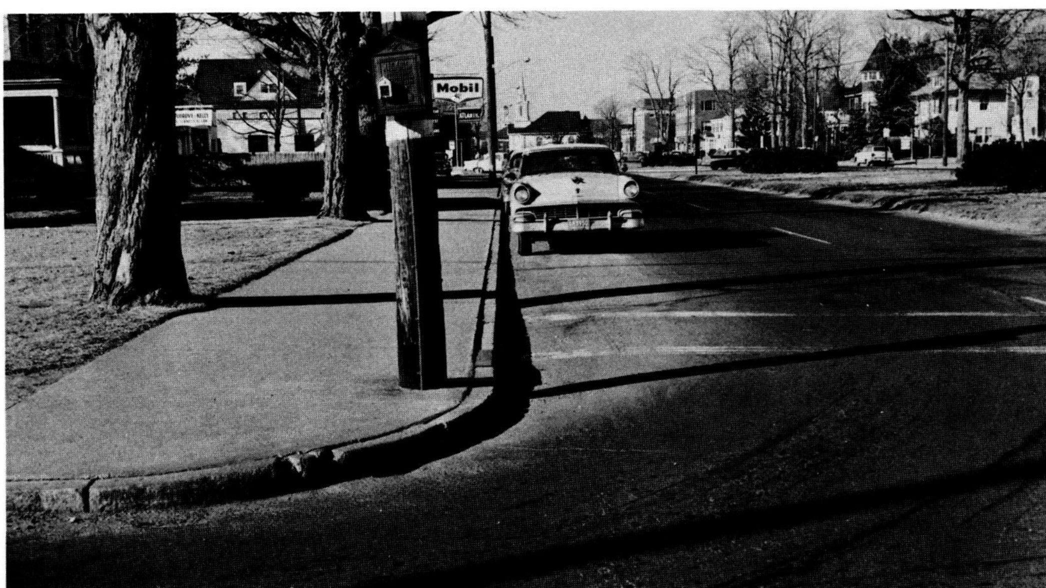

Figure 9. Control Section 40— sight distance at intersection.

Figure 10. Control Section 45—US 6 eastbound approach to intersection of Conn. 87.

Figure 11. Control Section 45—US 6 eastbound approach to intersection of Conn. 87.

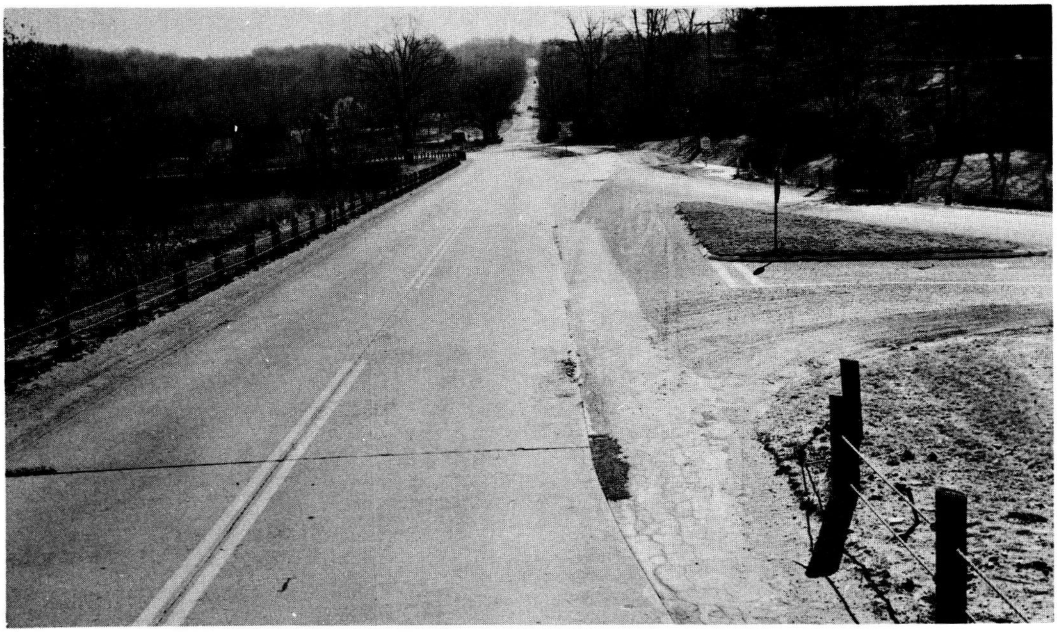

Figure 12. Control Section 45—eastbound on US 6 at intersection of Conn. 87.

Figure 13. Control Section 45—US 6 westbound approach to intersection of Conn. 87.

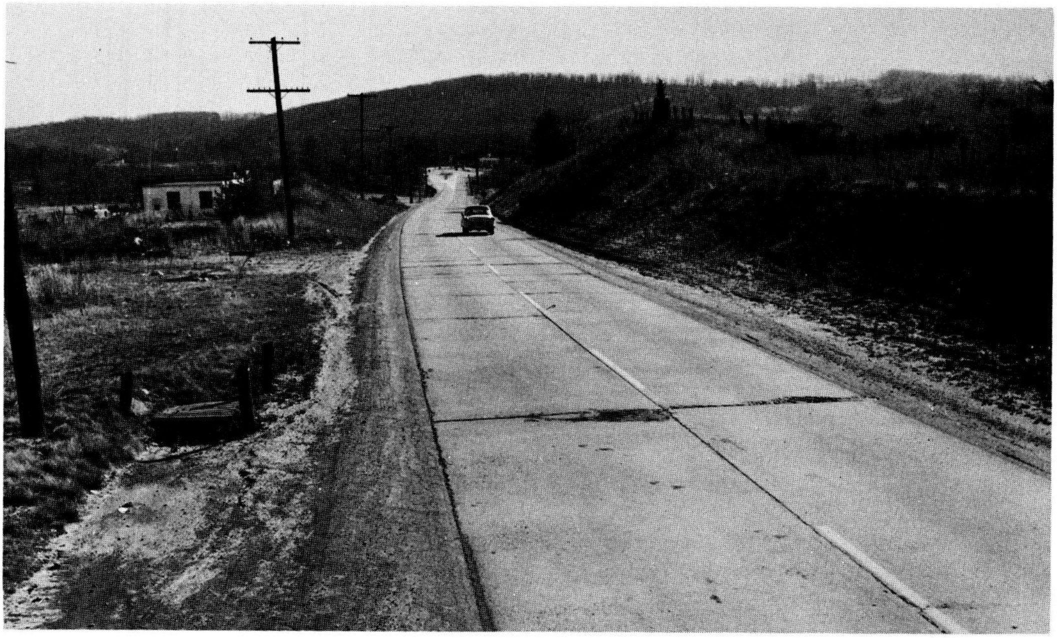

Figure 14. Control Section 45—eastbound on US 6 from Porter Road to intersection of US 6A.

Figure 15. Control Section 45—US 6 eastbound approach to intersection of US 6A.

The information in Figure 5 was transferred to the operational.route chart shown in Figure 6, using the 1 percent control limits.

Some of the lower control limits in Figure 6 are of a negative value. This ambiguous condition is due to the application of the formula to control sections that have extremely low vehicle mileage and where one or two accidents can produce an abnormal change in the accident rate. These negative control limits would be discounted in actual practice, but they were drawn for clarification and illustration.

The previous procedures were then followed by a field inspection of the areas deemed critical by use of the statistical analysis. This involved such items as roadway geometry, roadside culture, traffic devices and controls, travel speeds, and character of traffic. Paralleling this phase was a thorough examination of pertinent accident reports.

To facilitate the completion of this report, the investigation was confined to those critical areas present in the 47-mi segment of the study route which runs from US 15 in Manchester easterly to the Rhode Island State Line in Killingly.

Ten control sections in this area were noted as "out of control" when the statistical analysis had been completed. The field investigation more than adequately emphasized the effectiveness of the technique employed by revealing conditions that warranted improvement.

NIGHT ACCIDENT RATE IN OUT OF CONTROL AREAS

Control Section 36.—This interval runs for 0.22 mi through a rural area in the Town of Manchester and has a relatively low volume of traffic. An analysis of night accident data for the period 1951 to 1956 inclusive revealed that 8 accidents occurred in 1951, but succeeding years have experienced considerably fewer events with an increase in vehicle miles. A check of construction records revealed that this interval was reconstructed early in 1952. From this information, it was concluded that whatever was present in 1951 was subsequently corrected by the reconstruction.

Control Section 39.—This section extends 0.74 mi through an urban area in the Town of Manchester and handles a heavy volume of traffic on a two-lane, two-directional concrete surfaced travelway with 10-ft bituminous shoulders. Field investigation revealed poor surface conditions and the presence of old car tracks that straddle the

Figure 16. Control Section 45—eastbound on US 6 at intersection of US 6A.

centerline for the entire length of the control section (Fig. 7). The combination of these two factors gives drivers the tendency to travel partly on the shoulder or in close proximity to the centerline. The latter is much in evidence as accident records note numerous sideswipe occurrences.

Also, minimum visibility is experienced during nighttime travel due to poor highway illumination.

Control Section 40. —This interval, located in the Town of Manchester, is a four-lane, two-directional, divided roadway, 0.48 mi in length, which accommodates a large volume of traffic and has numerous access roads that necessitate the presence of median openings (Fig. 8).

The accident record for this area notes numerous rear-end events involving vehicles executing left turns. This could be attributed to the absence of left turn slots that would afford protection and allow the left lane through movement to proceed. Also, the median breaks were without traffic control devices which would be of assistance at some intersections as entering side street traffic was fairly heavy.

At one particular location with a heavy accident concentration were parked cars in close proximity to the intersection hindering adequate sight distance (Fig. 9).

Control Section 43. —This interval runs for 1.4 mi through Tolland County, and was shown to warrant attention with respect to nighttime operation. A subsequent check of records disclosed that this area was reconstructed since 1956. A detailed field investigation of this area was considered unnecessary as the analysis employed in this study utilized accidents that occurred before reconstruction.

Control Section 45. —This section extends 5.27 mi through a rural area in the Towns of Andover and Columbia. Examination of night accident experience and a subsequent field investigation revealed the presence of three locations necessitating corrective action.

One location is the approaches and intersection of US 6 and Conn. 87. The eastbound approach (shown in Figs. 10 and 11) provides little indication that the motorist is nearing an intersection. The only visible clue is a single, diamond-shaped sign.

At the intersection itself (Fig. 12) pavement markings were noticeably lacking and destination signing was inadequate. Figure 13 shows the westbound approach to the same intersection; there is no destination signing for this direction of travel at the junction of the two routes.

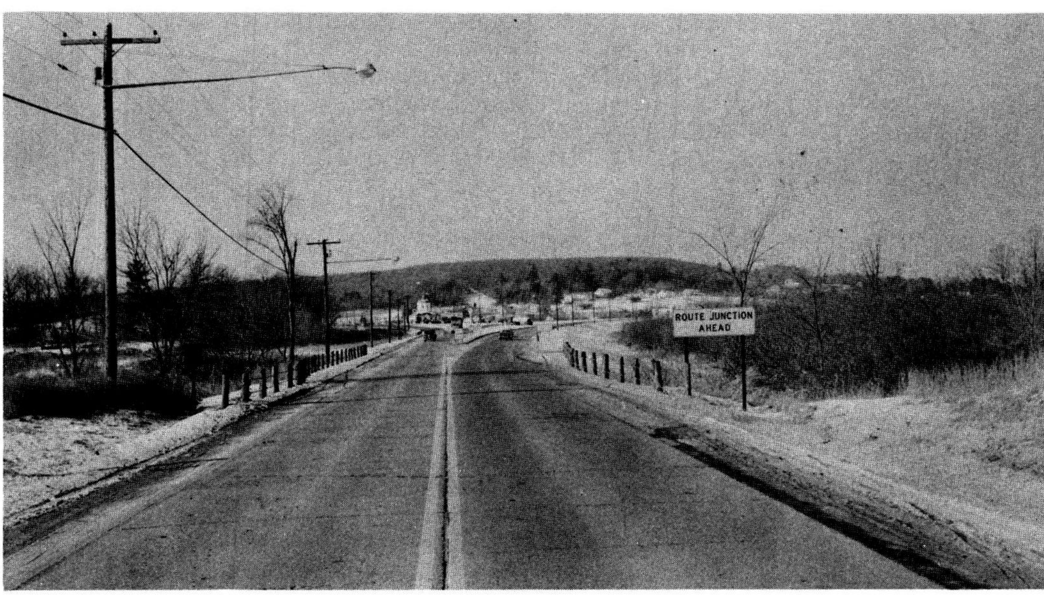

Figure 17. Control Section 45—US 6 westbound approach to intersection of US 6A.

Figure 18. Control Section 45—westbound on US 6 at intersection of US 6A.

On both approaches and at the intersection itself was an absence of highway illumination.

The second location requiring remedial measures is the area from Porter Road east to the intersection of US 6A (Fig. 14) where the lack of highway illumination and the absence of shoulder lines are considered to be contributory to the occurrence of nighttime accidents.

The last location is the intersection of US 6 and US 6A. The advance signing on the eastbound approach to this junction (Fig. 15) does not indicate to the motorist that he is approaching an intersection. The destination signing at the intersection (Fig. 16) is inadequate for the speed of approaching vehicles. Also, there were 8-in. lenses on the traffic control signal where 12-in. lenses would effect better target value.

An examination of accident data revealed that the superior signing of the westbound approaches (Figs. 17 and 18) has resulted in less accidents.

Control Section 46.—This section extends 1.93 mi through an urban area in the Town of Columbia. Field investigation disclosed roadside delineation and/or shoulder lines to be lacking all through this area at locations where they would be of valuable assistance during nighttime travel.

Control Section 49.—This interval, extending 0.33 mi in the Town of Windham, is only slightly "out of control." A field investigation failed to disclose any existing condition warranting corrective measures; therefore, this high dark accident rate can be attributed to the lack of vehicle-mile data and the occurrence of 5 night accidents in 1953. Succeeding years have experienced markedly fewer accidents.

Control Sections 53 and 54.—These intervals, which run for a total of 3.18 mi through the Towns of Chaplin and Hampton, were combined to obtain sufficient accident and vehicle-mile data to satisfy the requirements of the technique. When calculations terminated, these combined areas were "out of control." A subsequent examination of records and a field investigation revealed this area to have undergone recent construction changes, thereby rendering the analysis dated.

Control Section 57.—This section runs for 4.06 mi through an urban area in the Town of Killingly and experiences a heavy volume of traffic. Analysis of accident data and field investigation disclosed an accident-prone location where the road width was insufficient to allow parking on both sides and adequate highway illumination was lacking.

This portion of US 6 came under town jurisdiction following the completion of the analysis. Field observations were mentioned in this instance to illustrate the detective abilitiy of the analysis.

Control Section 61. —This section extends for 2.66 mi in the Town of Killingly. Examination of records and a field investigation disclosed that the area has undergone recent construction changes, thereby rendering this study dated.

CONCLUSION

The statistical evaluation of accident experience eliminates the inconsistencies that result from the individual's analysis of accident frequencies because it distinguishes between the number of events that might have occurred as a matter of chance and those incidents exceeding this level, while revealing the true relationship of the study interval to the over-all route.

It is of even greater importance to the general route analysis as a tool to pinpoint locations that warrant closer inspection and analysis. It should facilitate the institution of a statewide traffic analysis program, which in turn should effect lower accident rates, more efficient use of personnel and monies, and improved public relations.

The methods used in this study were based on the methods described by Dunlap and Associates (1). The techniques described in their report were modified to meet the needs of the present application. Other variations of the methods will be tried to determine which effects the best results compared with the effort required. In the text of this paper, certain levels of probability of a false detection are discussed. Because of the modifications in the methods, these are only nominal probabilities of false detection.

REFERENCE

1. Dunlap and Associates, "Manual for Application of Statistical Control Techniques to Analysis of Highway Accident Data." (1956).

ACKNOWLEDGMENT

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Driver Behavior Study—Influence of Speed Limits On Spot Speed Characteristics in a Series Of Contiguous Rural and Urban Areas

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Expedient and safe operation of traffic on various highways and streets has necessitated regulation of motor vehicle speeds. Before scientific warrants can be developed for determination of proper and reasonable speed limits, driver response to regulatory speed limit signs must be ascertained to evaluate the effectiveness of these traffic control devices in modifying vehicular speeds. This field investigation was designed to measure the influence of speed limits on individual driver's speed characteristics in a series of contiguous rural and urban areas. The roadway traveled by the observed drivers was relatively homogeneous in the rural areas. Uniformity of travel existed in the urban centers with the exception of different posted speed regulations.

Analyses of the speed data by appropriate statistical techniques indicated that speed limit signs had relatively little effect in regulating both the central tendency and the variability of vehicle speeds at urban locations. However, these signs were no doubt effective as a means of advising motorists of prevailing speed conditions. This inference concerning the effectiveness of regulatory speed signs was the result of a before-and-after study made to evaluate the influence of altering speed limits in the urban areas.

There was some uniformity in the speed habits of individual drivers in the five rural areas, but little consistency existed in their speeds of travel in the four urban areas. In addition, no significant relationship existed between the individual driver's speeds in rural and urban areas; that is, a fast driver in rural areas was not necessarily a fast driver in urban areas, and vice versa.

The condition of chronic speeding was not observed to any marked degree as the individual drivers exceeding the urban and rural speed limits varied from one location to another. Finally, results of statistical tests showed that variations of spot speeds with time of day were not consistent with respect to both times of the day and locations along the study route.

• THE VEHICULAR speed regulation project, IHR-53, at the University of Illinois has been charged with the development of scientific warrants for the regulation of vehicular speeds. Before an acceptable criterion can be formulated for the establishment of speed-zoning warrants, driver-behavior characteristics must be fully appraised. It is imperative that particular emphasis be placed on the evaluation of driver observance of posted speed regulations. Therefore, the purpose of this research investigation was to ascertain driver observance of reasonable speed regulations on a relatively homogeneous highway having various speed limits along this traffic route.

The influence of posted speed limits on vehicular speeds has been appraised in past studies that were designed to investigate the modification of spot speed characteristics occasioned by changes in speed limit values. These before-and-after studies are often a routine part of speed zoning programs in many cities and states.

Presence of speed regulations in urban areas apparently has no significant effect on the speeds adopted by drivers. This conclusion was developed in 1948 from speed observations of local and through traffic made in Champaign, Ill., on major streets with no posted speed limits and with posted speed limits of 20, 25, 30, 35, and 40 mph (7).

In New Mexico, where it was found that many communities had established unreasonably low speed regulations, the State highway department conducted an extensive speed zoning investigation based on the 85th percentile speed criterion. This program resulted in the raising of many urban speed limits. Spot speed characteristics were then sampled on these traffic facilities, and it was discerned that the 85th percentile speed values did not increase where the speed limits had been raised. In fact, this percentile measure of the speed distribution often decreased when an unreasonbly low speed limit was increased (1). Similar results were reported for a speed zoning program conducted in the urban centers along US 30 in Nebraska. Speed limit increases of 5 to 20 mph produced no significant changes in the average and 85th percentile speeds (2).

When speed limits were reasonably lowered on rural highways in Wisconsin through properly applied speed zoning, there was generally a substantial reduction in the observed spot speeds of traffic on these roadways (5). From data collected in a comprehensive before-and-after survey of traffic speeds on Illinois highways in 1957 and 1958, reductions in vehicular speeds were observed where new speed zones were established and where existing speed limits were lowered. No changes were apparent in the spot speed characteristics where existing speed limits were raised (3).

Little attention has been devoted to investigating the extent to which individual drivers observe various speed regulations encountered during the course of a trip. A comprehensive study was conducted in New York State over a period of one year in an attempt to relate speeds to both driver and vehicle characteristics. This 1950-51 survey revealed that 46 percent of the speeds over the 85th percentile speed were contributed by the fastest 15 percent of the drivers studied, and further that the driver whose average speed is equal to the over-all average can be expected to exceed the 85th percentile speed about 11 percent of the time (4).

It is evident that additional information is needed on driver behavior in regard to observance of posted speed regulations. This field investigation was uniquely designed to account for the behavioral patterns of individual drivers as they traveled along a relatively homogeneous traffic route having various speed limits posted in the urban areas.

PROCEDURE

Before October 1, 1960, both through and local traffic traveled on US 150 between Urbana and Danville, Ill. Interstate 74, which closely parallels this highway, was opened to traffic on this date. This four-lane, divided facility with controlled access now attracts much of the traffic that formerly used US 150.

US 150 provided an ideal study location for the evaluation of driver observance of posted speed limits. Roadway and traffic features of the highway were practically identical in the rural areas. The environment of the urban centers along US 150 was very similar except for different posted speed regulations in these communities.

Design of Experiment

US 150 is a two-lane, concrete highway with a right-of-way width of 66 ft, a pavement width of 20 ft, and narrow turf shoulders. Alignment of the roadway is mainly straight with a flat profile. Immediately adjacent to one side of the highway is a single-track railroad. The study area is predominantly farmland with very slightly rolling terrain, and "elevator" towns are spaced at frequent intervals along this traffic route. A description of this study route is shown in Figure 1. The 1960 ADT value for this highway section, which was about 16 mi in length, was approximately 4,000 to 5,000 vehicles per day.

Nine speed observation stations were established along US 150. Four of these speed

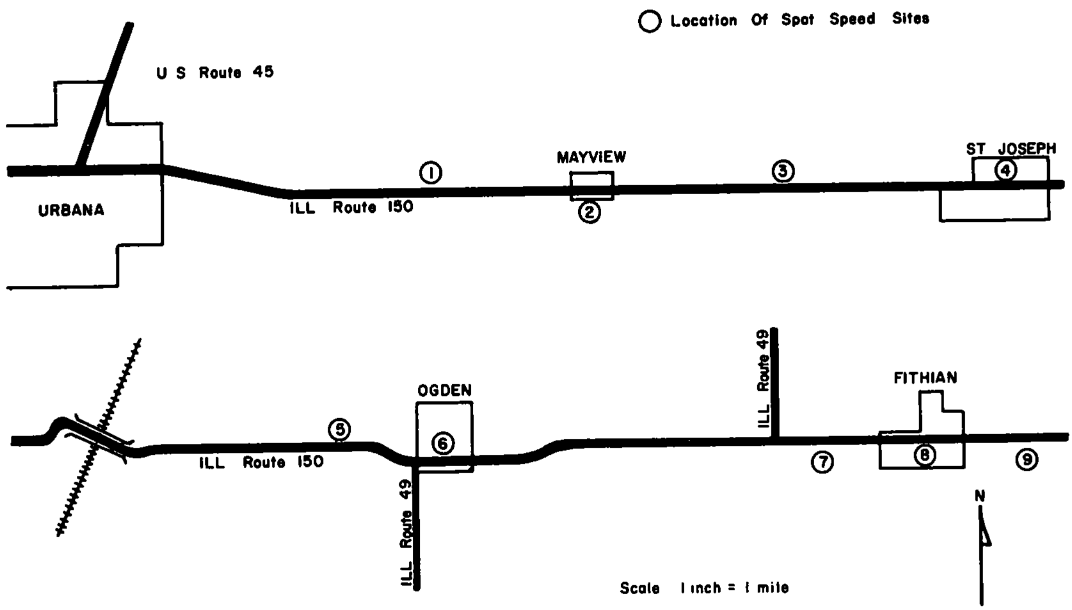

Figure 1. Description of study route.

sites were located in the communities of Mayview, St. Joseph, Ogden, and Fithian with populations of 175, 1,210, 515, and 495, respectively. Roadway and traffic conditions were similar in these towns, but posted speed limits varied among these urban centers. Present speed limits were established on the basis of the 85th percentile speed observed in each community by the Illinois Division of Highways in 1959.

The five remaining speed sites were located in rural areas adjacent to both sides of these towns. Relative positions of these rural and urban study locations are shown in Figure 1. These rural stations were selected on the basis of similarity in roadway and traffic conditions. The regulatory speed limit at each of these rural sites was the absolute 65-mph limit applicable in Illinois.

On September 27, 1960, personnel from the Illinois Division of Highways and the University of Illinois performed this field investigation of driver speed behavior. Two observers were assigned to each speed site. Generally, one observer operated the radar speedmeter, and the other observer acted as recorder. Both personnel and equipment were concealed to the extent permitted by roadside conditions.

Only traffic in the westbound direction was observed for 2½ hr in the morning. As each vehicle passed a site, the following information was noted:

1. Speed in miles per hour,
2. Vehicle type,
3. Last three digits of the license number,
4. Vehicle color, and
5. Time at which the vehicle passed the speed site.

Only the color of the lower portion of the car body and the color of the tractor unit were recorded in cases of multicolored vehicles. This technique of data collection permitted the observed vehicles to be identified individually at the nine study locations.

The same procedure was repeated again for 2½ hr in the afternoon. During this time only eastbound traffic was observed. Starting and stopping times were staggered at individual sites to account for the time required to travel between the respective points of observation. Thus, each through vehicle entering the study section was observed as it passed through the nine check points.

Analysis of Data

Because the purpose of the study was to investigate the relationships between the speeds selected by individual drivers under both rural and urban travel conditions, it was necessary to tabulate the speeds of each vehicle at the nine speed observation stations. Data recorded at each site were matched with data from the other sites on the basis of vehicle classification, last three digits of the license plate number, color of the vehicle, and times at which the vehicle passed the various speed sites.

Approximately 550 vehicles were observed at each site, and of this number 229 vehicles passed all nine sites. Complete records at each site, however, were obtained for only 40 vehicles. The smallness of this sample was mainly due to difficulties encountered in recording the necessary information for vehicles traveling in platoons. Radar speedmeter failures at two study sites for a period of 1 hr also reduced the number of vehicles observed at all nine locations.

In view of the small sample resulting from these operational difficulties, the analysis was confined to those vehicles for which complete information had been recorded at the four urban sites and at a minimum of three rural sites. This procedure yielded a sample size of 160 vehicles.

This sample of 160 vehicles was divided into four groups, indentified as A, B, C, and D. Group A contained those vehicles observed during the first half of the morning study, and Group B represented those vehicles passing the speed sites in the second half of the morning study. Similarly, Groups C and D referred to the first and second halves of the afternoon study. The purpose of this division was to investigate the influences of time of day and direction of travel on the speeds of vehicles observed.

Various statistics, such as mean, standard deviation, and standard error of the mean, were computed at each site to summarize the speed data for time-group samples and total sample. In addition, speeds for the five rural sites were combined for each individual driver to fabricate an average rural condition.

To analyze the speed patterns of each driver at different locations, the following scatter diagrams and correlations were prepared:

1. Individual speeds at each rural site vs individual speeds for the other rural locations,
2. Individual speeds for each urban speed site vs individual speeds at the remaining urban centers, and
3. Individual speeds at each urban location vs the average speed of each vehicle under rural conditions of travel.

This analysis was performed for the total sample and for each time grouping in the

TABLE 1

SUMMARY OF RESULTS

Site	Mean Speed (mph)	85th Percentile Speed (mph)	Speed Limit (mph)	Standard Deviation (mph)	Standard Mean Error (mph)
1. Rural	56.0	63.8	65	7.47	0.72
2. Mayview	39.5	45.7	45	5.94	0.47
3. Rural	56.3	63.4	65	6.87	0.70
4. St. Joseph	31.3	36.5	35	5.01	0.40
5. Rural	55.0	63.0	65	7.73	0.69
6. Ogden	33.3	37.9	35	4.42	0.35
7. Rural	56.4	65.6	65	8.85	0.71
8. Fithian	35.4	40.9	40	5.36	0.42
9. Rural	55.0	62.8	65	7.49	0.58

second and third categories just cited. In the first case, only the complete sample was considered. Speeds of individual drivers were further analyzed at each site to determine the frequency with which each driver exceeded posted speed limits.

TABLE 2

COMPARISON OF BEFORE-AND-AFTER STUDIES

Site	Speed Limit Study, 1959		Driver Behavior Study, 1960		t Statistic
	Speed Limit (mph)	Mean Speed (mph)	Speed Limit (mph)	Mean Speed (mph)	
2. Mayview	45	39.2	45	39.5	0.54
4. St. Joseph	30	30.6	35	31.3	1.42
6. Ogden	40	32.2	35	33.3	2.40[a]
8. Fithian	35	34.9	40	35.3	0.71

[a]Significant at 5 percent level.

TABLE 3

CORRELATION COEFFICIENTS FOR SPEEDS OF INDIVIDUAL DRIVERS AT RURAL SITES

Rural Site	3	5	7	9
1	0.57[a]	0.45[a]	0.43[a]	0.45[a]
3	-	0.77[a]	0.65[a]	0.12
5	-	-	0.62[a]	0.40[a]
7	-	-	-	0.33[a]

[a]Significant at 1 percent level.

TABLE 4

CORRELATION COEFFICIENTS FOR SPEEDS OF INDIVIDUAL DRIVERS AT URBAN SITES

Urban Site	Time Group	4	6	8
2	A	0.32	0.36	-0.01
	B	0.11	0.15	-0.24
	C	0.24	0.34	0.10
	D	0.07	0.25	0.21
	Total	0.14	0.22[a]	0.05
4	A	-	0.43	0.05
	B	-	0.36	0.37
	C	-	0.53[a]	0.11
	D	-	0.31	0.37[a]
	Total	-	0.44[a]	0.27[a]
6	A	-	-	-0.23
	B	-	-	0.36
	C	-	-	-0.28
	D	-	-	0.41[a]
	Total	-	-	0.25[a]

[a]Significant at 1 percent level.

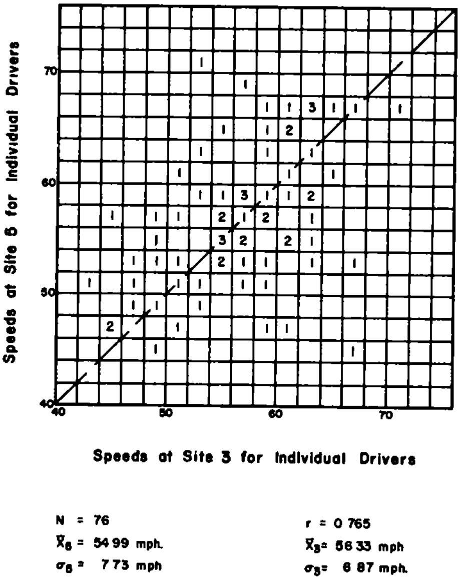

Figure 2. Typical scatter diagram for rural-travel conditions.

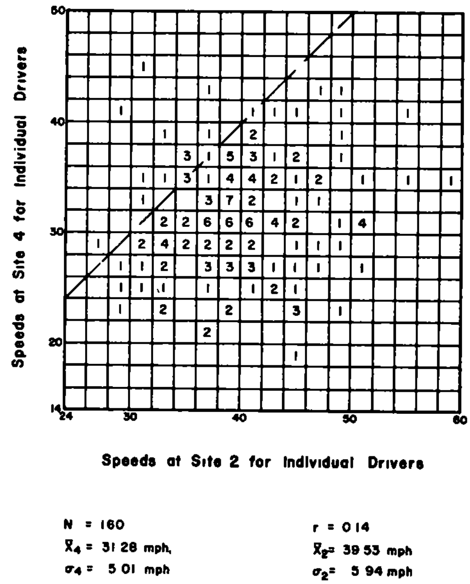

Figure 3. Typical scatter diagram for urban travel conditions.

Several tests of significance were applied to these speed data to make decisions concerning the influence of speed limits on driver behavior and the effect of time of day on spot speed characteristics.

RESULTS

The technique of data collection permitted both macro- and micro-analyses of driver observance of the various speed limits posted along the study route. These investigations were concerned with the over-all observance of speed regulations both before and after speed limit changes and with the speed patterns of individual drivers in the rural and urban areas. In addition, statistical consideration was given to the influences of time of day and direction of travel on vehicular speed characteristics.

Average Speed Characteristics

Various statistics describing the results of this speed survey are given in Table 1.

TABLE 5

CORRELATION COEFFICIENTS FOR SPEEDS OF INDIVIDUAL DRIVERS UNDER RURAL VS URBAN TRAVEL CONDITIONS

Time Group	Average Rural Site vs Urban Site			
	2	4	6	8
A	0.32	0.08	0.24	-0.15
B	0.30	0.22	0.42[a]	0.01
C	0.23	0.14	0.34	0.06
D	0.10	0.17	0.36	0.11
Total	0.31[a]	0.16	0.32[a]	0.03

[a]Significant at 1 percent level.

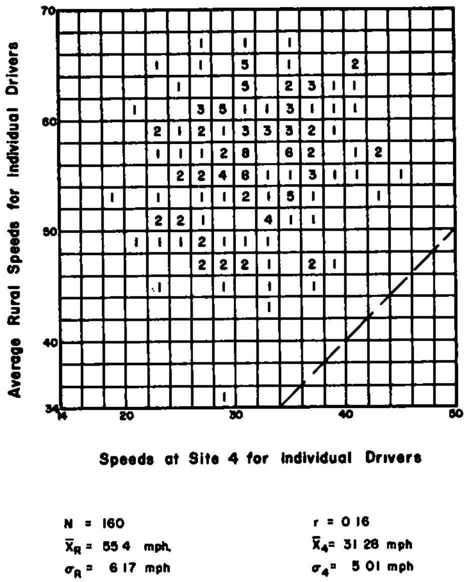

Figure 4. Typical scatter diagram for rural vs urban travel conditions.

The mean speed and the standard deviation represent measures of central tendency and variability, respectively, of vehicular speeds at the nine observation points. The standard error of the mean is indicative of the precision achieved in the experiment. A detailed summary of the study results is given in Appendix A.

The mean speeds for the five rural sites were almost identical. This same relationship also existed among the 85th percentile speeds and among the standard deviations. Thus, similar spot speed characteristics were evidenced in the rural areas. In consideration of the 85th percentile speed as a criterion for speed zoning, a rural speed limit of 65 mph on this highway section appeared to be a realistic and reasonable value.

The average speeds in the urban centers varied considerably from one location to another, although homogeneity of the variance was evident. It was impossible to ascertain the amount of variation in mean speeds attributed to different posted speed limits and that ascribed to confounding variables such as city size and number of commercial establishments.

Speed-Zone Modifications

In the summer of 1959, the Illinois Division of Highways conducted spot speed studies in the towns of Mayview, St. Joseph, Ogden, and Fithian to evaluate the necessity for any modifications in posted speed limits. Based on the results of these speed surveys and the 85th percentile speed as a criterion for speed zoning, the speed limits were left at 45 mph in Mayview, increased from 30 to 35 mph in St. Joseph, decreased from 40 to 35 mph in Ogden, and raised from 35 to 40 mph in Fithian.

Speed data afforded by the speed limit study conducted in 1959 and the driver behavior study performed in 1960 permitted the appraisal of these speed zone modifications

TABLE 6

FREQUENCY OF INDIVIDUAL DRIVERS EXCEEDING THE POSTED SPEED LIMITS (FOR DRIVERS OBSERVED AT ALL SITES)

No. of Speed Limits Exceeded	Drivers		
	No.	Percent	Cumulative Percent
0	19	48	100
1	7	17	52
2	6	15	35
3	6	15	20
4	0	0	5
5	2	5	5
6	0	0	0
7	0	0	0
8	0	0	0
9	0.	0	0

through a before-and-after analysis. The t-test was utilized to ascertain the significance of the difference between the respective mean speeds (6). In this significance testing, a pooled estimate of the variance of the difference between the two means was employed because the Bartlett test for homogeneity of variance led to the general conclusion of homoscedasticity.

TABLE 7

FREQUENCY OF INDIVIDUAL DRIVERS EXCEEDING THE POSTED SPEED LIMITS ACCORDING TO TYPE OF AREA (FOR DRIVERS OBSERVED AT ALL SITES)

No. of Urban Speed Limits Exceeded	No. of Rural Speed Limits Exceeded[a]					
	0	1	2	3	4	5
0	19 (48)	1 (2)	0	0	0	0
1	6 (15)	1 (2)	2 (5)	0	0	0
2	5 (13)	2 (5)	0	1 (2)	0	0
3	2 (5)	0	1 (2)	0	0	0
4	0	0	0	0	0	0

[a]Values in parentheses are percents.

TABLE 8

ANALYSIS OF VARIANCE OF SPEEDS ACCORDING TO TIME OF DAY

Site	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.95}$
1	Total	6,098.92	109	-	-	-
	Between means	342.18	3	114.06	2.10	2.70
	Within groups	5,756.74	106	54.31	-	-
2	Total	5,623.84	159	-	-	-
	Between means	335.43	3	111.81	3.29[a]	2.67
	Within groups	5,288.41	156	33.90	-	-
3	Total	4,661.56	97	-	-	-
	Between means	655.48	3	218.49	5.12[a]	2.71
	Within groups	4,006.08	94	42.62	-	-
4	Total	4,069.90	159	-	-	-
	Between means	126.02	3	42.01	1.66	2.67
	Within groups	3,943.88	156	25.28	-	-
5	Total	7,503.00	125	-	-	-
	Between means	253.38	3	84.46	1.42	2.68
	Within groups	7,249.62	122	59.42	-	-
6	Total	3,102.38	159	-	-	-
	Between means	480.38	3	160.13	9.53[a]	2.67
	Within groups	2,622.00	156	16.80	-	-
7	Total	12,438.45	157	-	-	-
	Between means	1,006.40	3	335.47	4.51[a]	2.67
	Within groups	11,432.05	154	74.23	-	-
8	Total	4,560.10	159	-	-	-
	Between means	230.25	3	76.75	2.76[a]	2.67
	Within groups	4,329.85	156	27.76	-	-
9	Total	7,211.88	128	-	-	-
	Between means	116.65	3	38.88	0.68	2.68
	Within groups	7,095.23	125	56.76	-	-

[a]Significant at 5 percent level.

TABLE 9

COMPARISON OF SPEEDS AS A FUNCTION OF DIRECTION OF TRAVEL

Site	Mean Speed (mph)		t Statistic
	Westbound	Eastbound	
1. Rural	57.09	55.20	1.32
2. Mayview	38.54	40.25	-1.82
3. Rural	58.78	54.56	3.13[a]
4. St. Joseph	32.30	30.55	2.21[a]
5. Rural	54.86	55.08	-0.16
6. Ogden	35.24	31.93	5.07[a]
7. Rural	56.42	56.36	0.04
8. Fithian	36.60	34.45	2.59[a]
9. Rural	55.62	54.55	0.81

[a]Significant at 5 percent level.

Results of this before-and-after study are given in Table 2. Raising the speed limits by 5 mph in the two urban centers produced no significant increase in mean speeds. However, the mean speed in Ogden increased significantly after the speed limit was reduced from 40 to 35 mph. These results served to indicate that speed limits posted in the urban areas had no realistic influence on controlling the rate of traffic movement. The slight increase in the 1960 mean speeds over the corresponding 1959 values can probably be attributed to the annual rise in the speed of motor vehicle operation.

Individual Driver Behavior

Scatter diagrams prepared for the total sample of 160 vehicles indicated that speeds selected by each driver at the five rural sites were consistent to some degree. That is, fast drivers at one site were often fast drivers at the other rural locations, and slow drivers frequently had low speeds on the rural sections of the study route. This observation was further demonstrated by the significant correlation coefficients that were calculated for these scatter plots. These coefficients of correlation for travel in the rural areas are given in Table 3. The average correlation coefficient for the various combinations of rural sites was 0.48 with a standard deviation of 0.18. On the average, approximately 23 percent of the variation among the speeds of individual drivers in rural areas were explained by regression. With one exception, the correlation coefficients were significant at the 1 percent level. No reasonable explanation appeared to exist for the one inconsistency in these results. A scatter diagram, typical of the individual speed patterns among the various rural sites, is shown in Figure 2.

For the case of urban travel, scatter plots were prepared for the total sample of 160 vehicles and for each of the four time groups. Little uniformity was revealed in the speeds selected by individual drivers when traveling through the four urban centers. Correlation coefficients for the urban studies are given in Table 4 according to time groupings. Summary statistics for the various combinations of urban sites were an average correlation coefficient of 0.23 and a standard deviation of 0.13 for these coefficients of correlation. Only the relationship between individual spot speeds observed in St. Joseph (Site 4) and those recorded in Ogden (Site 6) showed moderate values for the product-moment correlation. This repetition of driver behavior in regard to speed of travel occurred in the two communities having posted speed limits of 35 mph. A typical scatter diagram for individual speed behavior in urban areas is shown in Figure 3. In summary, no consistent pattern of speed characteristics was evident among individual drivers traveling in the study communities.

To investigate the relationship between speeds selected by each driver at both urban and rural sites, scatter diagrams were prepared with the average speed of each driver at the rural sites plotted against their respective speeds in each of the four towns. A typical scatter plot is shown in Figure 4 for rural vs urban travel conditions. The speed for an average rural site was calculated by averaging the three to five rural speeds observed for each individual driver. Because significant correlations were evidenced between individual speeds at the five rural study locations, the average rural speed of each driver was considered representative of his speed habits in rural areas.

Correlation coefficients obtained for this comparison of rural vs urban speeds are given in Table 5. As indicated by the low degrees of correlation, it was deduced that individual drivers observed in this speed investigation did not operate their vehicles in a consistent manner in regard to rate of travel under rural and urban conditions. A fast driver in an urban center was not necessarily a fast driver on rural sections of the highway. In like fashion, a slow driver in the one area was not in consequence observed operating at low speeds in the other area. The average correlation coefficient for this comparison of rural versus urban travel was 0 20 with a standard deviation of 0.14.

Speed Limit Violations

An analysis of the speed data was made to ascertain the frequency with which individual drivers exceeded speed limits posted along the study route. The results afforded an interesting insight into driver behavior, particularly in regard to the fact that the 85th-percentile-speed criterion for establishing speed limits is predicated on the assumption that 15 percent of the drivers are violators of speed regulations. These findings are summarized by the individual frequencies of violation in Tables 6 and 7.

If the condition of chronic speeding existed, then approximately 85 percent of the drivers would have exceeded no speed limits, and about 15 percent would have violated all nine speed regulations. However, the data given in Table 6 indicated that 52 percent of the drivers violated at least one speed limit for the nine points of observation. The maximum degree of violation was the case of two drivers who exceeded five speed limits. Only 38 percent of those drivers who were observed traveling faster than the speed limit exceeded more than two speed limits. It was inferred that many drivers exceeded a few speed limits, but few drivers exceeded many speed limits. Similar results were reported by Lefeve (4) in a study of speed habits observed on a rural highway. More than one-half of the drivers who had their speeds measured as many as seven times could be expected to exceed the 85th perentile speed at least once.

To refine this analysis of speed limit violations further, the data in Table 7 were separated according to type of area. This refinement showed that 50 percent of the drivers violated speed limits in the urban centers, whereas only 20 percent exceeded speed limits posted in the rural areas. This discrepancy was explained by the findings of the analysis of individual driver behavior. The high degree of uniformity in operating speeds for the individual drivers in rural areas indicated that few drivers traveled consistently at high speeds and exceeded the rural speed regulations. In comparison, the low correlation for speed habits in urban areas implied that many drivers operated at high speeds in some communities and at low speeds in others. This behavioral pattern resulted in more individuals violating urban speed limits along the study route.

As evidenced by the data compiled in Table 7, the maximum numbers of speed limit violations by an individual driver were three out of five for the rural speed limits and three out of four for the urban regulations. This fact is probably explained by the greater heterogeneity in urban speed patterns as compared to the driver speed behavior in rural areas.

Time of Day

In an attempt to discover any significant variations in vehicular speed characteristics with time of day and/or direction of travel, an analysis of variance was performed to test the hypothesis that the mean speeds of the populations delineated as Time Groups A, B, C, and D were equal (6). A priori knowledge of spot speed characteristics permitted the assumption of normal populations. Results of the Bartlett test for homogeneity of variance were previously reported to indicate the same variance for the four populations. The analysis of variance test is summarized in Table 8.

Average speeds for the four time groups were significantly different at two rural and three urban locations. These findings did not permit the ascertaining of variations in spot speed characteristics according to various time periods of the day. These significant differences in mean speeds for the different times of the day appeared to be sporadic in time and inconsistent with respect to site location. It is quite possible that some confounding variables were in operation at particular times and at certain locations to produce these significant differences in these central measures of the speed distributions.

Direction of Travel

Speed information collected in this research investigation was appraised to assess any modifications in speed statistics occasioned by direction of travel. The t-test was employed to analyze statistically the difference between the mean speeds for the morning and for the afternoon at each study site (6). Again, the nonsignificant results of the Bartlett test for homogeneity of variance allowed the use of a pooled estimate of the population variance for the t-test. Table 9 contains the results of this testing of significance.

Only traffic in the westbound direction was observed in the morning. The speed sample in the afternoon was composed of vehicles traveling in the eastbound direction. The results of the t-test were too varied to justify any generalization on mean speed variations with direction of travel. The westbound and eastbound speeds were significantly different for four sites and not significantly different for the remaining five locations. No doubt, other variables including time of day assisted in producing the observed variations.

CONCLUSIONS

The conclusions inferred from the results of this driver behavior investigation are valid only for the individual drivers sampled on the traffic route studied. However, the real benefits of research are realized through inferences made about the entire population of motor vehicle drivers. This technique is predicated on the assumption that a sample is randomly chosen and representative of the population under study. In this perspective, the following conclusions were drawn from the study results:

1. The presence of speed regulations in urban areas had no significant influence on the central tendency and variability of spot speed characteristics. As a result, posted speed limits were not effective as a traffic control device in regulating the rate of motor vehicle movement through urban centers. This conclusion does not remove the desirability of having advisory speed limits posted along the traffic route to assist unfamiliar drivers.
2. The individual driver had variable speed habits; that is, he was not consistent in his selection of operating speeds. Although the rate of travel for each driver assumed some uniformity in rural areas, no definite speed pattern was discernible for urban travel. In addition, a fast driver in rural areas was not necessarily observed as a fast driver in urban areas. The converse of this finding was also true for slow drivers.
3. At any single location approximately 15 percent of the drivers exceeded the posted speed limit; however, over 50 percent of the observed road users violated the speed regulations at one or more of the nine study sites. Therefore, enforcement activities designed to apprehend the fastest 15 percent of the drivers would not be realistic in curtailing the operation of motor vehicles at speeds in excess of the posted speed limit.
4. Chronic speeding was not evident among the drivers sampled. In most instances, the violation of an urban speed limit seemed to be a chance event, and few drivers exceeded the speed regulations posted in rural areas. Only 20 percent of the motor-vehicle operators exceeded more than two of the nine speed limits. The two individuals who exceeded five of the nine speed regulations represented the maximum degree of speed limit violation.
5. More drivers violated speed limits in urban centers than in rural areas. Uniformity of traffic operations in urban areas is difficult to achieve because not only do

drivers vary among themselves but each individual driver is subject to considerable variation in his urban speed habits.

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Appendix

COMPLETE SUMMARY OF RESULTS

Site	Time Period A				Time Period B				Time Period C				Time Period D				Total Sample			
	N	$\bar{X}$	S	S E	N	$\bar{X}$	S	S E	N	$\bar{X}$	S	S E	N	$\bar{X}$	S	S E	N	$\bar{X}$	S	S E
1	19	59 79	5 51	1 30	26	55 12	9 29	1 86	30	54 83	7 23	1 34	35	55 51	6 29	1 08	110	55 97	7 47	0 72
2	31	39 65	5 06	0 92	36	37 58	6 95	1 17	44	41 59	5 13	0 78	49	39 04	5 71	0 82	160	39 53	5 94	0 47
3	21	61 09	6 25	1 40	20	56 35	7 11	1 63	27	54 48	5 06	0 99	30	54 63	7 10	1 32	98	56 33	6 87	0 70
4	31	32 45	4 74	0 87	36	32 14	5 58	0 94	44	30 84	5 12	0 78	49	30 29	4 44	0 64	160	31 28	5 01	0 40
5	21	57 48	8 15	1 82	31	53 10	8 19	1 50	40	55 45	7 80	1 25	34	54 65	6 19	1 08	126	54 99	7 73	0 69
6	31	35 42	3 68	0 67	36	35 08	4 75	0 80	44	32 70	3 95	0 60	49	31 22	3 88	0 56	160	33 31	4 42	0 35
7	31	57 65	7 99	1 46	36	55 36	8 92	1 51	43	59 72	9 41	1 45	48	53 35	7 64	1 11	158	56 39	8 85	0 71
8	31	37 10	5 78	1 06	36	36 17	6 99	1 18	44	33 80	3 81	0 58	49	35 02	4 16	0 60	160	35 35	5 36	0 42
9	27	56 81	5 92	1 16	31	54 58	9 74	1 78	33	54 91	6 29	1 10	38	54 24	7 08	1 16	129	55 03	7 49	0 58
Avg Rural	31	57 77	5 34	0 97	36	54 53	7 16	1 21	44	56 05	6 41	0 98	49	54 12	5 05	0.73	160	55 45	6 17	0 49

A Study of Factors Influencing Traffic Speeds

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The over-all objectives of the research project were (a) to evaluate the effectiveness of speed limits established by present practices and (b) to develop new or more substantial criteria for the establishment of speed zones. The results of the first phase of the research were reported previously. This report covers the second phase of the research and deals specifically with an evaluation of factors influencing the drivers' selection of speed

The first part deals with a study of factors that influence traffic speeds in areas of transition from rural to urban conditions Two study techniques were used to measure speeds in transition areas: (a) measurement of the average speed of each vehicle through each of several sectors of the transition zone, and (b) continuous measurement of the speed of a test car through the transition zone. The studies pointed up several roadway and development characteristics that influenced traffic speeds, including horizontal and vertical curves, sight distance, changes in roadway cross-section, commercial development, and appearance of residential development.

Several studies involving 12- and 24-hr speed observations were conducted to determine the influence of changing traffic conditions on traffic speeds. These studies showed that speeds were subject to only minor variations during the hours of normal traffic operation

Other studies were concerned with the influence of radar enforcement operations on traffic speeds. These studies showed that enforcement operations caused appreciable speed reductions, but the influence did not extend beyond four miles on either side of the enforcement unit.

• IN 1958 THE TEXAS Transportation Institute initiated a research project aimed at providing data for the development of new or more substantial criteria for the establishment of speed zones. The project, which was sponsored by the Texas Highway Department, was conducted in two phases. The first phase consisted of an evaluation of the effectiveness of speed limits established on the basis of 85-percentile speeds. The results of the first phase have been reported previously (1)

In the first phase of the research project, comparative before-and-after studies were conducted in 186 spot speed study locations to determine the effect of speed limit signs on traffic speeds. This large number of studies permitted an analysis of data for conditions when the speed limits were changed from 60 down to 30 mph, and from 30 up to 55 mph in increments of 5 mph. The results of this study indicated that speed limit signs actually had very little influence on the drivers' choice of speed. Figure 1 shows results typical of the study. The only notable influence on traffic speeds was a slight decrease in the over-all dispersion of traffic speeds. A summary of the results is given in Table 1.

These findings should not be construed to mean that speed zoning serves no worthwhile purpose Speed zoning is necessary to provide the needed flexibility in the general speed laws, so that traffic speeds can legally conform to the desirable operational characteristics of the roadway.

This report covers the second phase of the research which dealt with an evaluation of factors influencing the drivers' selection of speed.

The speed of an individual vehicle is subject to considerable variation throughout a given section of roadway. This is particularly true if the section of roadway is in an area of transition from rural to urban conditions. The factors causing the variation in speed are innumerable. They may be physical or psychological; tangible or intangible. However, it is presupposed that variations or changes in the speed of a vehicle are functions of the driver's evaluation of the existing conditions ahead.

Most of the tangible or measurable factors can be categorized into three basic groups: (a) roadway geometrics, (b) characteristics of development, and (c) traffic conditions. In transition from rural to urban conditions these factors rarely occur independently, but rather in complex combinations. Also, successive occurrences of the various factors involved cause speed changes to occur almost continuously throughout the transition area.

In the second phase of the research, studies were conducted to evaluate the specific factors influencing individual speeds in transition areas (rural to urban). In the studies, primary consideration was given to geometric and roadside development characteristics. The influence of traffic conditions was reduced as much as possible by selecting free-flow vehicles for the main consideration in the analysis.

The influence of traffic conditions was given greater consideration in additional studies conducted to determine the variations in traffic speeds throughout the day. These studies consisted of evaluation of all speeds during 12- and 24-hr speed observations on three different types of roadways.

Studies were also conducted to evaluate the influence of radar enforcement practices on traffic speeds. These studies were made to determine the effects of enforcement on

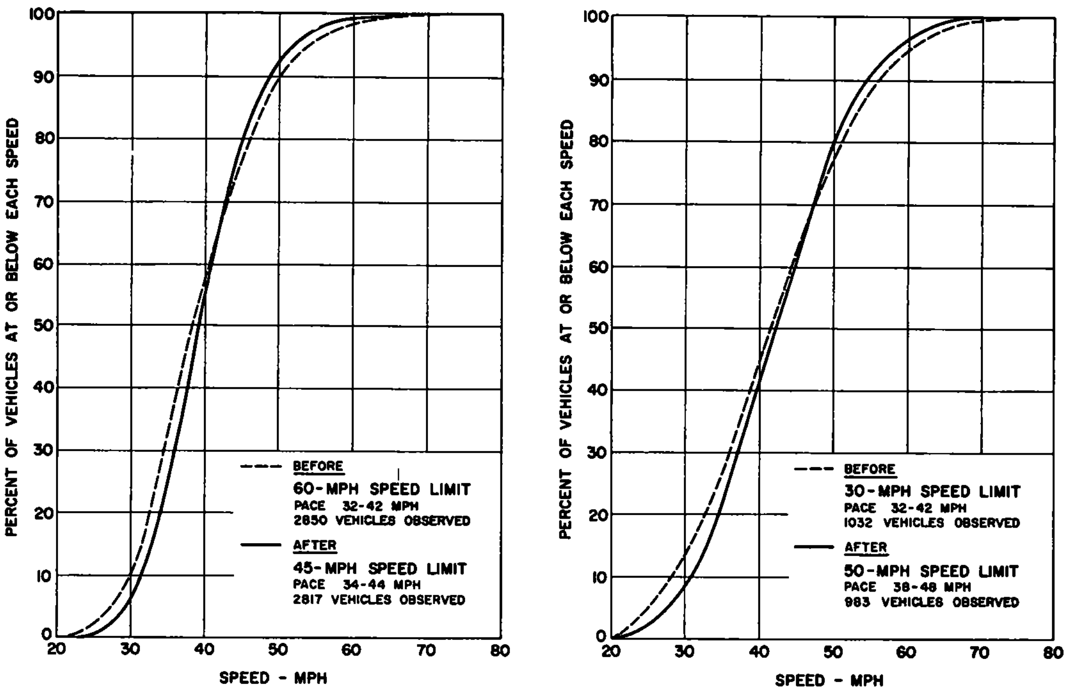


Figure 1. Typical speed distribution curves for before-and-after conditions of speed zoning.

traffic speed in the immediate vicinity of the radar unit and the distance along the roadway to which the influence extended.

FACTORS IN TRANSITION AREAS

In an effort to identify various influencing factors and evaluate their effects, studies were conducted in several transition areas where significant speed changes occurred Two study techniques were used:

1. Individual vehicle speed study method. —Measurement of the average speed of each individual vehicle through each of several control sections or sectors of the transition zone.
2. Test car method. —Continuous measurement of the speed of selected drivers in a test car for several trips through the transition zone.

Study Locations

The major problems of speed zoning in Texas have been encountered in the transition sections to small towns on two-lane highways. For this reason, five study locations were selected to provide a good representation of the various conditions normally encountered. Table 2 summarizes very briefly the general characteristics of each of the five study locations. The study sections were approximately one mile in length.

TABLE 1

RESULTS OF BEFORE-AND-AFTER STUDIES TO DETERMINE EFFECT OF POSTED SPEED LIMITS ON TRAFFIC SPEEDS

District	Speed Limit (mph)		No of Vehicles	Speed (mph)				Pace (mph)	Std Dev (mph)
	Before	After		85-Percent	15-Percent	Differential	Average		
12 (Houston	60	-	1,518	59 4	42 0	17 4	51 68	48-58	8 61
	-	60	1,564	58 7	41 7	17 0	51 33	48-58	8 62
	60	-	2,783	55.5	37 5	18 0	47 33	40-50	8 77
	-	55	3,099	55 0	38 3	16 7	47 62	42-52	8 06
	60	-	2,930	53 7	35 5	18 2	45 64	38-48	8 80
	-	50	2,976	52.0	35 1	16 9	44 54	38-48	7 92
	60	-	2,850	47 3	31 2	16 1	40.27	32-42	8 00
	-	45	2,817	46 4	32 6	13 8	40 59	34-44	6 93
	60	-	524	41 5	28 3	13 2	35 74	28-38	6 21
	-	40	481	39 9	28 5	11 4	35 41	30-40	5 56
	60	-	1,807	40 2	25 6	14 6	33 70	26-36	7 30
	-	35	2,052	38 9	24 3	14 6	32 77	26-36	7 27
	60	-	531	31 2	21.3	9 9	27 53	22-32	4 98
	-	30	571	33 2	23 3	9 9	29 23	22-32	4 83
1 (Paris)	60	-	5,452	57 0	33 8	23 2	46 22	40-50	10 90
	-	60	4,902	56.6	35.0	21 6	46 85	40-50	10 09
	60	-	407	55 2	35 1	20 1	45 55	38-48	9.09
	-	55	614	51 2	33 5	17 7	43 86	40-50	8 62
	60	-	2,611	51 5	29 3	22 2	41 74	32-42	10 45
	-	50	2,010	50 9	30 7	20 2	42 06	38-48	10 09
	60	-	954	47 6	23 4	24 2	36 72	24-34	11 41
	-	45	658	43 9	26 3	17 6	36 07	28-38	8 21
	60	-	431	40.4	22 8	17 6	33 17	28-38	8 57
	-	40	338	38 6	24 7	13 9	32 98	28-38	6 64
	30	-	4,584	53 2	30 7	22 5	26 83	38-48	7 10
	-	55	3,596	50 5	33 5	17 0	27 99	38-48	6 96
	30	-	1,103	52 6	30 4	22 2	30 18	32-42	7 19
	-	50	832	51 3	32 5	18 8	31 41	38-48	7 51
	30	-	4,742	45 4	28 1	17 3	33 68	30-40	7 97
	-	45	4,156	45 2	28 8	16 4	34 61	32-42	8 12
	30	-	2,678	40 3	24 4	15 9	37 50	28-38	8 25
	-	40	2,165	42 0	25 2	16 8	37 89	28-38	7 91
	30	-	1,032	36 8	21 4	15 4	42 64	24-34	10 61
	-	35	983	38 4	23 0	15 4	42 97	24-34	9 06
	30	-	322	33 5	18 3	15 2	43-33	20-30	10 77
	-	30	400	34 1	19 5	14 6	43 22	22-32	7 96

TABLE 2

GENERAL DESCRIPTION OF STUDY LOCATIONS

Study No.	Location (town)	Hwy. No.	Road Class.	Predom. Develop.	Study Section Length (ft)	No. of Sectors	ADT[a]	Pop.[b]
I	Waller	US 290	Primary[c]	Commer.	4,958	6	5,940	1,000
II	Madisonville	Texas 21	Secondary	Resid.	6,585	7	1,330	3,000
III	Cameron	US 77	Primary	Mixed	5,898	5	2,200	5,052
IV	Bremond	Texas 6	Primary	Mixed	5,492	9	1,980	1,141
V	Oakwood	US 79	Primary	Commer. and Resid. (segregated)	5,978	8	1,600	759

[a]Rural, within 4 mi of city limits.
[b]1960 census.
[c]Truck route.

The ADT values on these roadways ranged from 1,330 to 5,940 vehicles per day. Development in the study sections ranged from predominantly residential to predominantly commercial. The geographic location of the study sites is shown in Figure 2.

A number of variables were eliminated or controlled through careful selection of study sites. Care was exercised to avoid roadway sections that contained the following:

1. Traffic signals or control devices other than flashing amber beacons.
2. Horizontal and vertical curves that severely limited traffic speeds.
3. Major intersections presenting complex traffic problems.
4. Serious pavement surface irregularities.

In general, an attempt was made to select study sections in which the factors affecting vehicle speeds could be categorized into roadway geometrics, development characteristics, and traffic conditions.

Study Methods

Individual Vehicle Speed Study Method.—A comprehensive survey was used to collect traffic data in each of the study locations. The survey consisted of four components: (a) measurement of individual vehicle speeds throughout various sectors of the study section, (b) concurrent measurement of individual vehicle speeds in an adjacent rural section, (c) observation of all passing, turning, or crossing traffic, and (d) a study of the development and roadway geometrics in the study section.

To develop a profile of individual vehicle speeds through the transition zone, the section of roadway selected for study was divided into control sections, referred to as sectors. The limits of these sectors were determined by changes in development and by physical changes in the roadway geometry. The average speed of each vehicle was measured through each of the designated sectors.

An event recorder was used in the measurement of individual vehicle speeds in the urban areas. This recorder (a 20-pen ink-type recorder) was used with a series of road tubes and air switches to measure the time required for a vehicle to travel the length of each of the sectors. To measure the time increments, the road tubes and air switches were placed at the limits of each of the sectors, as shown in Figure 3. By means of field telephone cable each air switch was connected to a pre-selected pen in the 20-pen recorder. As a vehicle passed through the study section, a "blip" was recorded by each corresponding pen as the vehicle crossed each of the road tubes. Because the chart in the recorder moved at a constant, predetermined speed, the distance between successive "blips" was proportional to the time required for the vehicle to travel between the road tubes. An example of the chart record is also shown in Figure 3.

To identify the direction in which the vehicles were traveling, two different road tube arrangements were used. The arrangement most commonly used resembled the

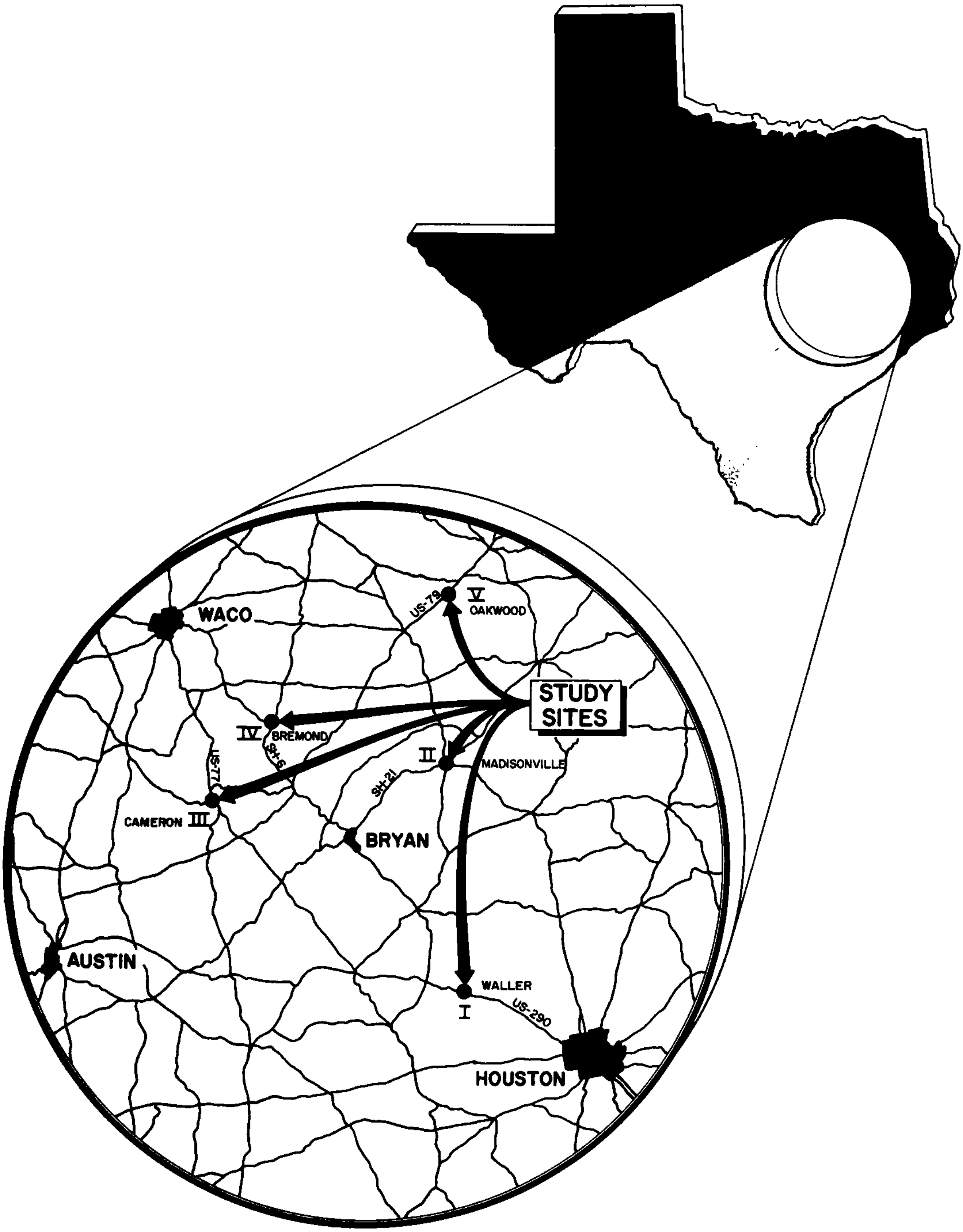


Figure 2. Location of study sites.

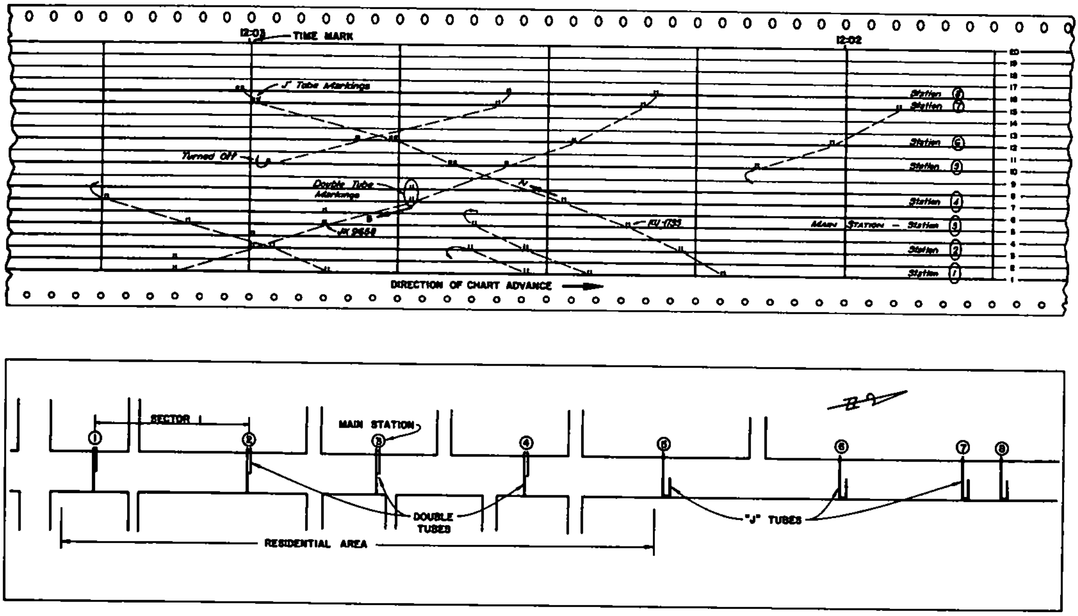


Figure 3. Example of 20-pen recorder chart resulting from road tubes located as shown at study site.

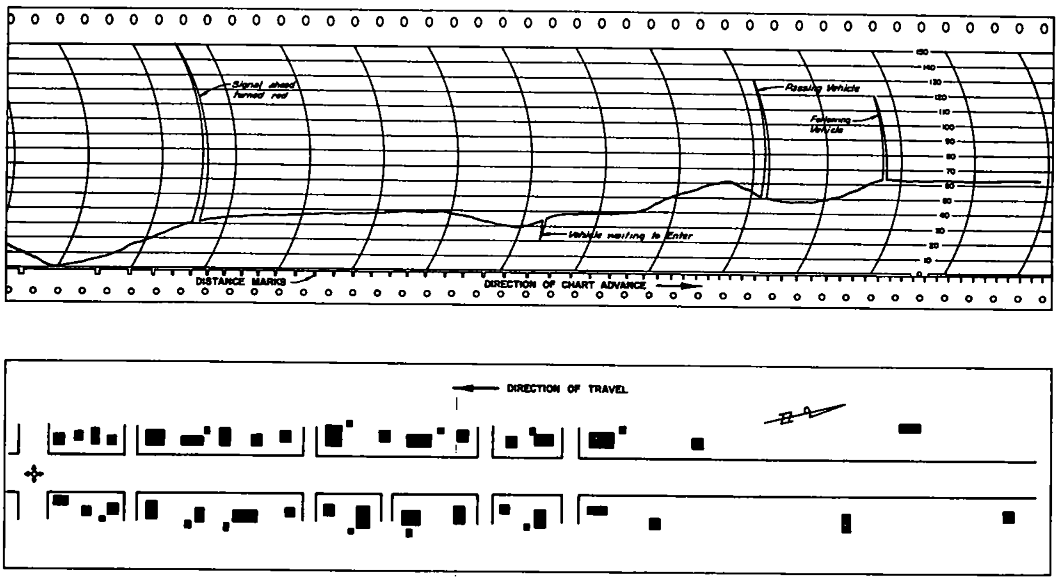


Figure 4. Example of recording speedometer chart and study site comparison.

letter "J" as shown in Figure 3. To form this arrangement, the road tube was extended from the centerline to one edge of the pavement, then along the pavement edge for approximately 15 ft (about 1½ times the normal wheelbase of a passenger car), and then across both lanes to the air switch. This arrangement provided two "blips" on the chart for 2-axle vehicles in one direction and four "blips" for 2-axle vehicles traveling in the other direction.

A more positive means of simultaneously indicating direction of travel and identifying vehicles with three or more axles was provided by the double road tube arrangement, also shown in Figure 3. In this system, two road tubes were placed side by side and connected to two separate air switches. One of the tubes extended only to the centerline of the roadway. Vehicles traveling in one direction crossed the long road tube and actuated one pen in the recorder, whereas vehicles traveling in the opposite direction crossed both road tubes and simultaneously actuated two pens in the recorder. With this arrangement, the number of "blips" in a group on the chart always represented the actual number of axles of the vehicles.

At a station near the center of the study area each vehicle was identified by its license number and the direction of travel as it crossed one of the double road tube arrangements. The information was recorded on a portable voice recorder in chronological order. In addition, frequent time indications were recorded on the voice

TABLE 3

COMPARISON OF COMMERCIAL WITH ALL FREE-FLOW VEHICLE SPEEDS

Study	Sector	Northbound-Outbound				Southbound-Inbound			
		Commercial		Free-Flow		Commercial		Free-Flow	
		No of Veh	Avg Speed (mph)	No of Veh.	Avg Speed (mph)	No of Veh	Avg. Speed (mph)	No of Veh	Avg Speed (mph)
I	1	15	47 0	51	39.4	6	42 3	27	46 2
	2	15	39 5	51	37 6	6	37 3	27	40 2
	3	15	35 7	51	33 4	6	33.2	27	38 4
	4	15	34 3	51	34 6	6	32.7	27	37 6
	5	15	37 8	51	38 7	6	34 9	27	41.0
	6	15	38 6	51	47 0	6	38 4	27	44 9
II	1	19	27 0	159	32 6	12	34.5	143	35 6
	2	19	33 1	159	37 7	12	38 3	143	38 5
	3	19	33 5	159	38 2	12	39 6	143	41.5
	4	19	34 3	159	40 2	12	41 0	143	43.0
	5	19	36.4	159	40 6	12	40 6	143	42 6
	6	19	39.6	159	45.5	12	42 3	143	44.4
	7	19	38.9	159	45.1	12	45 8	143	46.5
III	1	8	28.9	140	30.9	12	30 6	140	32 6
	2	8	29 3	140	31 4	12	30.4	140	32 2
	3	8	31 5	140	33.5	12	35.7	140	35 1
	4	8	33.4	140	37 3	12	39.7	140	40.4
	5	8	36 7	140	42.6	12	40.8	140	42 9
IV	1	14	25.3	100	32 7	24	30 9	112	33.8
	2	14	31 7	100	37 1	24	35 7	112	37.2
	3	14	35 0	100	39 2	24	39.0	112	39.2
	4	14	38.9	100	43 9	24	46.1	112	45.8
	5	14	39.4	100	43 9	24	44.4	112	45 7
	6	14	44.6	100	47 6	24	49.8	112	51 0
	7	14	44.0	100	48 0	24	50 0	112	53.5
	8	14	43.3	100	48.8	24	53.5	112	55.4
	9	14	43.2	100	49.9	24	51.6	112	55.1
V	1	17	45.7	127	51 5	19	37 2	171	43 6
	2	17	42.6	127	47.4	19	38 5	171	44.5
	3	17	37 2	127	40 1	19	35.2	171	38.2
	4	17	33 0	127	33 8	19	32.0	171	32.8
	5	17	36.5	127	38 7	19	36 8	171	39.2
	6	17	39.4	127	44.8	19	43 0	171	47.1
	7	17	41.6	127	48 1	19	45.7	171	54 0
	8	17	42 4	127	49 5	19	47 5	171	56.1

TABLE 4

SPEED CHARACTERISTICS OF SECTORS IN STUDY SECTION I

Sector	Characteristic	Northbound			Southbound		
		All Veh.	Through Vehicles	Free-Flow Vehicles	All Veh.	Through Vehicles	Free-Flow Vehicles
1	No. veh	205	129	51	111	81	27
	Speed (mph)·						
	Avg.	39.9	40.1	39.4	43.8	45.0	46.2
	85-percent.	47 5	48.0	47 0	48.5	52.5	56.5
	15-percent.	31.0	32.5	31.5	34.5	36 0	35.5
	Diff.	16.5	15.5	15.5	14.0	16.5	21.0
	Pace (mph)	33-43	33-43	33-43	39-49	39-49	35-45
	Std. dev. (mph)	8.86	8.07	8.30	7.15	7.56	8 98
2	No veh.	236	129	51	129	81	27
	Speed (mph)·						
	Avg.	35.6	37.4	37.6	38 5	37.9	40.2
	85-percent.	41 0	42.0	44 0	43.5	44.5	52.0
	15-percent.	28 0	31.0	30.0	31.0	29.0	31.0
	Diff.	13.0	11.0	14.0	12.5	15.5	21.0
	Pace (mph)	29-39	33-43	33-43	31-41	33-43	31-41
	Std dev. (mph)	6 45	5.90	6.69	7.14	7.82	8.75
3	No. veh.	220	129	51	116	81	27
	Speed (mph)						
	Avg.	31.6	33.0	33.4	34.4	35.1	38.4
	85-percent	36 0	37.0	38.5	39.5	40 0	46.5
	15-percent.	25.0	27.0	27.0	26.5	28.5	28 0
	Diff.	11.0	10 0	11.5	13.0	11 5	18.0
	Pace (mph)	27-37	27-37	27-37	29-39	29-39	29-39
	Std dev. (mph)	6.14	5.91	6.30	7.01	7.97	11.11
4	No. veh	210	129	51	120	81	27
	Speed (mph)						
	Avg	32 3	32 7	34.6	33 3	35.9	37.6
	85-percent	37.5	37.5	39.0	38.0	40.5	42.0
	15-percent	25.5	26 0	28.0	27.0	28.0	28.5
	Diff.	12.0	11.5	11 0	11 0	12.5	13.5
	Pace (mph)	25-35	27-37	31-41	27-37	31-41	31-41
	Std. dev. (mph)	6.40	6.10	6.59	6.60	6.49	7.78
5	No. veh	225	129	51	120	81	27
	Speed (mph):						
	Avg.	36 8	37.9	38.7	36.9	39.9	41.0
	85-percent.	42.0	43.5	44.0	42.5	43.5	46.5
	15-percent.	29.0	29.5	31.0	29.0	32.5	31.5
	Diff	13.0	14.0	13 0	13.5	11.0	15.0
	Pace (mph)	31-41	35-45	35-45	33-43	33-43	35-45
	Std. dev. (mph)	7.06	6.76	6.66	7.42	7.04	9.06
6	No. veh.	230	129	51	137	81	27
	Speed (mph)						
	Avg.	45 9	47 2	47.0	43 3	43.9	44.9
	85-percent.	51.5	52.0	52.5	50.0	49.5	53 5
	15-percent.	38 0	39.0	38.5	34 5	35.6	35.6
	Diff.	13.5	13.0	14.0	15.5	13.9	17.9
	Pace (mph)	41-51	41-51	41-51	37-47	39-49	39-49
	Std. dev. (mph)	7.04	6.74	6.80	7.69	7.06	8.77

TABLE 5

SPEED CHARACTERISTICS OF SECTORS IN STUDY SECTION II

Sector	Characteristic	Outbound			Inbound		
		All Veh.	Through Vehicles	Free-Flow Vehicles	All Veh.	Through Vehicles	Free-Flow Vehicles
1	No. veh.	422	237	159	374	219	143
	Speed (mph)·						
	Avg.	33.0	32.6	32.6	34 8	35.0	35.6
	85-percent.	39.0	39.0	38 5	40.0	40 0	41.0
	15-percent.	24.5	24.0	24.0	27.0	27.5	28.0
	Diff.	14 5	15.0	14.5	13 0	12.5	13 0
	Pace (mph)	27-37	27-37	27-37	31-41	29-39	29-39
	Std. dev. (mph)	7.62	7.41	7.25	7.40	7.61	7.75
2	No. veh.	347	237	159	323	219	143
	Speed (mph)·						
	Avg.	37 0	37 4	37.7	38.0	38.8	38.5
	85-percent.	44.5	45.0	43.0	44.0	44.0	45.0
	15-percent.	28.0	28.0	29 0	30.0	31 0	30 5
	Diff.	16.5	17 0	14 0	14.0	13 0	14.5
	Pace (mph)	31-41	31-41	31-41	31-41	33-43	33-43
	Std dev. (mph)	8.22	8.11	7 62	7.47	6.67	6.77
3	No. veh	355	237	159	315	219	143
	Speed (mph)						
	Avg	38 1	38.0	38.2	40 0	41.4	41.5
	85-percent.	47.0	47.0	46.0	47.5	49.0	49.5
	15-percent.	27 5	28 5	29.5	30.0	31.5	31 0
	Diff.	19.5	18 5	16.5	17.5	17.5	18 5
	Pace (mph)	31-41	33-43	31-41	35-45	35-45	35-45
	Std. dev (mph)	9.32	9.22	8.30	8.91	8 30	8.54
4	No. veh.	377	237	159	303	219	143
	Speed (mph)·						
	Avg.	39 5	39 8	40 2	41.8	43 0	43.0
	85-percent	47 5	48 0	47 5	49 0	50 0	50.0
	15-percent.	30 0	30 0	31 0	32 5	34 5	34.0
	Diff.	17.5	18.0	16 5	16 5	15 5	16 0
	Pace (mph)	33-43	35-45	35-45	37-47	37-47	37-47
	Std dev. (mph)	8.96	9.12	8.58	8 41	7.75	7 60
5	No. veh.	274	237	159	262	219	143
	Speed (mph)						
	Avg.	39.8	40.2	40.6	41.3	42.1	42 6
	85-percent.	47.5	48 0	48 5	49.0	49.5	50.0
	15-percent.	30.0	30 5	31.0	31.5	32 0	33.0
	Diff.	17.5	17 5	17.5	17 5	17 5	17.0
	Pace (mph)	35-45	35-45	35-45	35-45	35-45	35-45
	Std. dev. (mph)	9.26	8.81	8.85	8 98	8.32	8 15
6	No. veh	280	237	159	261	219	143
	Speed (mph)·						
	Avg.	43.8	45.1	45 5	43 5	44.7	44.4
	85-percent.	53 5	54.0	54.5	53 5	53 5	54.0
	15-percent.	32.0	34.0	34.5	32.5	34.0	34 5
	Diff.	21.5	20.0	20 0	21.0	19 5	19 5
	Pace (mph)	39-49	39-49	41-51	41-51	41-51	37-47
	Std. dev (mph)	10 83	10 52	10 64	10.26	9.37	9 10
7	No. veh.	271	237	159	248	219	143
	Speed (mph)·						
	Avg.	43 8	44 5	45.1	46.0	46 8	46.5
	85-percent.	52.0	52.5	53 0	54.5	55.0	55.5
	15-percent.	33.0	34.0	35.0	35.5	36.5	36.0
	Diff.	19.0	18.5	18 0	19.0	18.5	19.5
	Pace (mph)	41-51	41-51	41-51	43-53	43-53	43-53
	Std. dev. (mph)	9.79	9.78	9.25	9.72	9.30	9.76

recorder and the event recorder simultaneously to facilitate later identification of vehicles.

To record turning, crossing, and passing movements in each sector, a sufficient number of observers were stationed at vantage points throughout the study section. All entrance, exit, and passing maneuvers were recorded as to the exact time of occurrence to facilitate later interpretation of the 20-pen recorder charts.

A development or land-use survey was conducted at each study location. From the survey, strip maps were prepared showing roadway dimensions, driveway and building locations, the size and use of the buildings, and the type and extent of access to the main roadway.

This method of measuring vehicle speeds was subject to certain limitations. The study method could only be used satisfactorily on two-lane roadways. The increased freedom to maneuver on multi-lane facilities would make it almost impossible to trace

TABLE 6

SPEED CHARACTERISTICS OF SECTORS IN STUDY SECTION III

Sector	Characteristic	Outbound			Inbound		
		All Veh.	Through Vehicles	Free-Flow Vehicles	All Veh.	Through Vehicles	Free-Flow Vehicles
1	No. veh.	469	208	140	344	200	140
	Speed (mph):						
	Avg.	30.4	30.9	30.9	31.2	32.2	32.6
	85-percent.	35.5	35.0	35.0	35.5	36.0	37.0
	15-percent.	24.5	25.0	25.5	25.5	26.5	27.0
	Diff.	11.0	10.0	9.5	10.0	9.5	10.0
	Pace (mph)	25-35	27-37	27-37	25-35	25-35	27-37
	Std. dev. (mph)	5.57	5.72	5.03	5.34	5.14	5.11
2	No. veh.	422	208	140	321	200	140
	Speed (mph):						
	Avg.	31.2	31.1	31.4	31.2	31.6	32.2
	85-percent.	35.5	35.0	35.5	35.0	36.0	36.5
	15-percent.	24.0	24.5	25.0	25.0	25.0	25.5
	Diff.	11.5	10.5	10.5	10.0	11.0	11.0
	Pace (mph)	25-35	29-39	27-37	25-35	25-35	25-35
	Std. dev. (mph)	6.41	5.96	5.97	5.65	5.92	5.41
3	No. veh.	350	208	140	269	200	140
	Speed (mph):						
	Avg.	32.8	32.7	33.5	34.3	35.0	35.1
	85-percent.	37.5	37.5	38.5	39.5	39.5	39.0
	15-percent.	26.5	26.5	27.0	27.5	28.0	29.0
	Diff.	11.0	11.0	11.5	12.0	11.5	10.0
	Pace (mph)	27-37	27-37	27-37	29-39	29-39	29-39
	Std. dev. (mph)	7.02	6.35	5.39	7.04	6.06	5.79
4	No. veh.	360	208	140	281	200	140
	Speed (mph)						
	Avg.	36.3	36.5	37.3	39.3	40.1	40.4
	85-percent.	42.0	42.0	43.0	46.5	46.0	46.0
	15-percent.	29.0	28.5	29.5	30.5	33.0	33.5
	Diff.	13.0	13.5	13.5	16.0	13.0	12.5
	Pace (mph)	29-39	33-43	33-43	35-45	35-45	35-45
	Std. dev. (mph)	6.66	6.86	7.00	7.61	6.81	6.48
5	No. veh.	268	208	140	250	200	140
	Speed (mph):						
	Avg.	41.0	41.2	42.6	44.0	43.3	42.9
	85-percent.	49.0	49.0	50.5	51.0	49.5	49.5
	15-percent.	33.0	33.0	34.0	34.5	35.0	34.5
	Diff.	16.0	16.0	16.5	16.5	14.5	15.0
	Pace (mph)	33-43	33-43	37-47	39-49	39-49	37-47
	Std. dev. (mph)	7.92	8.22	7.93	9.10	7.57	7.59

TABLE 7

SPEED CHARACTERISTICS OF SECTORS IN STUDY SECTION IV

Sector	Characteristic	Outbound			Inbound		
		All Veh	Through Vehicles	Free-Flow Vehicles	All Veh	Through Vehicles	Free-Flow Vehicles
1	No veh	204	128	100	237	161	112
	Speed (mph)						
	Avg	30 6	32 1	32 7	32 2	33 2	33 8
	85-percent	37 5	38 5	39 0	36 5	38 0	38 5
	15-percent	22 0	23 5	24 0	25 5	26 5	27 0
	Diff	15 5	15 0	15 0	11 0	11 5	11 5
	Pace (mph)	25-35	27-37	31-41	27-37	27-37	27-37
	Std dev (mph)	7 61	7 10	7 16	6 84	6 07	5 74
2	No veh	237	128	100	246	161	112
	Speed (mph)						
	Avg	34 6	36 9	37 1	35 0	36 7	37 2
	85-percent	41 5	43 0	43 0	40 5	42 0	42 5
	15-percent	26 0	29 0	29 0	27 5	29 0	29 5
	Diff	15 5	14 0	14 0	13 0	13 0	13 0
	Pace (mph)	29-39	31-41	31-41	29-39	29-39	33-43
	Std dev (mph)	7 86	8 01	7 92	6 80	6 43	6 36
3	No veh	246	128	100	273	161	112
	Speed (mph)						
	Avg	35 4	38 9	39 2	36 0	38 8	39 2
	85-percent	43 0	44 5	45 0	42 5	44 0	44 0
	15-percent	26 5	30 5	30 5	28 5	31 0	31 5
	Diff	16 5	14 0	14 5	14 0	13 0	12 5
	Pace (mph)	29-39	37-47	37-47	29-39	33-43	33-43
	Std dev (mph)	8 02	7 01	6 95	7 14	6 33	6 34
4	No veh	208	128	100	243	161	112
	Speed (mph)						
	Avg	41 6	43 5	43 9	42 1	44 3	45 8
	85-percent	49 0	50 5	50 5	50 0	50 5	51 5
	15-percent	31 5	33 5	33 5	32 5	35 5	37 0
	Diff	17 5	17 0	17 0	17 5	15 0	14 5
	Pace (mph)	37-47	39-49	37-47	37-47	39-49	43-53
	Std dev (mph)	8 56	8 12	8 29	8 61	7 94	7 53
5	No veh	174	128	100	209	161	122
	Speed (mph)						
	Avg	42 3	43 2	43 9	43 5	44 2	45 7
	85-percent	49 0	49 0	49 5	49 5	49 0	50 0
	15-percent	34 5	34 5	35 0	35 5	36 0	37 0
	Diff	14 5	14 5	14 5	14 0	13 0	13 0
	Pace (mph)	39-49	41-51	41-51	41-51	41-51	41-51
	Std dev (mph)	7 66	7 55	7 71	8 90	8 61	7 78
6	No veh	179	128	100	225	161	112
	Speed (mph)						
	Avg	48 0	47 4	47 6	48 5	50 3	51 0
	85-percent	54 5	54 5	55 0	55 5	57 0	57 5
	15-percent	36 0	38 5	38 5	39 5	41 0	41 5
	Diff	18 5	16 0	16 5	16 0	16 0	16 0
	Pace (mph)	43-53	43-53	43-53	41-51	45-55	45-55
	Std dev (mph)	8 99	8 20	8 57	8 35	7 77	8 09
7	No veh	177	128	100	215	161	112
	Speed (mph)						
	Avg	46 9	48 3	48 0	51 3	53 0	53 5
	85-percent	55 5	55 0	54 0	60 0	61 0	61 5
	15-percent	37 0	38 5	38 0	42 0	44 0	43 5
	Diff	18 5	16 5	16 0	18 0	17 0	18 0
	Pace (mph)	45-55	45-55	45-55	45-55	45-55	47-57
	Std dev (mph)	9 34	8 53	8 34	8 29	8 19	8 84
8	No veh	176	128	100	215	161	112
	Speed (mph)						
	Avg	48 1	47 6	48 8	52 8	54 2	55 4
	85-percent	56 5	55 5	57 0	61 0	62 5	63 0
	15-percent	37 0	36 5	37 5	43 5	44 0	44 0
	Diff	19 5	19 0	19 5	17 5	18 5	19 0
	Pace (mph)	45-55	43-53	45-55	47-57	47-57	49-59
	Std dev (mph)	9 70	9 58	9 28	8 61	8 44	9 06
9	No veh	172	128	100	214	161	112
	Speed (mph)						
	Avg	49 3	49 8	49 9	53 2	54 3	55 1
	85-percent	58 0	58 0	58 0	62 0	64 0	64 0
	15-percent	38 0	37 5	37 5	43 5	44 5	44 5
	Diff	20 0	20 5	20 5	18 5	19 5	19 5
	Pace (mph)	47-57	47-57	49-59	45-55	45-55	49-59
	Std dev (mph)	10 02	9 84	9 90	8 61	9 00	9 65

a vehicle through the study section, and the greater density which is usually present on this type of facility would further complicate the procedure.

In order that a direct correlation could be made of individual vehicle speeds under rural and urban conditions, rural traffic speeds were observed concurrently with the urban study at a station located two to four miles from the urban study section. A radar speed meter with graphic recorder was used for the rural speed observations. The unit was concealed in a mailbox-type camouflage, and the recorder was removed to an inconspicuous position. The license number, type of vehicle, and the direction of travel for each vehicle were written directly on the speed recorder chart.

Test Car Study Method. —In addition to the studies involving the observation of individual vehicle speed, a "test car" method was devised and utilized in four of the five selected study locations. Selected drivers operating the test car made a series of runs through transition zones. The test car was equipped with a recording speedometer to

TABLE 8

SPEED CHARACTERISTICS OF SECTORS IN STUDY SECTION V

Sector	Characteristic	Northbound			Southbound		
		All Veh.	Through Vehicles	Free-Flow Vehicles	All Veh.	Through Vehicles	Free-Flow Vehicles
1	No. veh.	266	172	127	318	212	171
	Speed (mph):						
	Avg.	48.3	51.4	51.5	41.8	43.5	43.6
	85-percent.	57.0	58.5	59.0	50.0	51.0	51.0
	15-percent.	36.0	43.0	42.0	31.0	35.0	35.0
	Diff.	21.0	15.5	17.0	19.0	16.0	16.0
	Pace (mph)	47-57	47-57	49-59	37-47	41-51	41-51
	Std. dev. (mph)	10.15	8.53	8.32	9.08	8.13	8.20
2	No. veh.	286	172	127	318	212	171
	Speed (mph):						
	Avg.	45.1	47.3	47.4	42.5	44.4	44.5
	85-percent.	53.5	55.0	55.0	50.5	50.0	51.0
	15-percent.	35.0	38.5	38.0	31.5	35.0	35.0
	Diff.	18.5	16.5	17.0	19.0	15.0	16.0
	Pace (mph)	39-49	41-51	41-51	39-49	41-51	41-51
	Std. dev. (mph)	9.22	7.85	7.57	9.14	7.97	8.03
3	No. veh.	270	172	127	325	212	171
	Speed (mph):						
	Avg.	36.8	39.9	40.1	35.1	38.2	38.2
	85-percent.	53.5	55.0	55.0	50.5	50.5	51.0
	15-percent.	35.0	38.5	38.0	31.5	35.0	35.0
	Diff.	16.5	15.5	16.0	17.0	15.0	14.5
	Pace (mph)	31-41	31-41	33-43	27-37	31-41	31-41
	Std. dev. (mph)	8.59	7.59	7.31	8.35	7.34	7.44
4	No. veh.	217	172	127	278	212	171
	Speed (mph):						
	Avg.	33.5	33.7	33.8	31.7	32.8	32.8
	85-percent.	39.5	39.5	39.0	39.0	38.5	39.0
	15-percent.	25.0	26.5	26.0	23.0	25.0	25.0
	Diff.	14.5	13.0	13.0	16.0	13.5	14.0
	Pace (mph)	27-37	27-37	29-39	25-35	25-35	25-35
	Std. dev. (mph)	9.40	6.76	6.30	8.08	6.72	6.61
5	No. veh.	257	172	127	306	212	171
	Speed (mph):						
	Avg.	37.5	38.7	38.7	38.0	39.1	39.2
	85-percent.	45.0	44.5	45.0	45.5	45.5	45.5
	15-percent.	29.5	31.0	31.5	29.5	31.5	31.5
	Diff.	15.5	13.5	13.5	16.0	14.0	14.0
	Pace (mph)	31-41	31-41	31-41	31-41	31-41	31-41
	Std. Dev. (mph)	8.04	7.05	7.09	7.73	7.03	7.14

provide a continuous record of the vehicle speed. An example of the speed chart is shown in Figure 4. To record the traffic conditions confronting the driver, the vehicle was equipped with a sequence camera actuated by the distance marker on the speed recorder.

The test car method of study was developed to provide, under controlled conditions, an evaluation of the relationships between vehicle speeds and the factors influencing speeds. The method provided a continuous speed indication, whereas the previously described method was a point-to-point type of survey measuring average speeds within sectors. It was anticipated that this study method would indicate points of reaction that may not necessarily be reflected in the individual vehicle speed studies using the average sector speed approach.

The study method was used to conduct limited studies in three of the selected study locations, and a comprehensive study in a fourth location. This study method was not used in the fifth location because the roadway in the test section was reconstructed to a four-lane facility. In the limited studies at the three locations, two drivers were used to make four test car runs in each direction. The results of these studies were used merely to determine more specifically the true shape of the speed profile through the section.

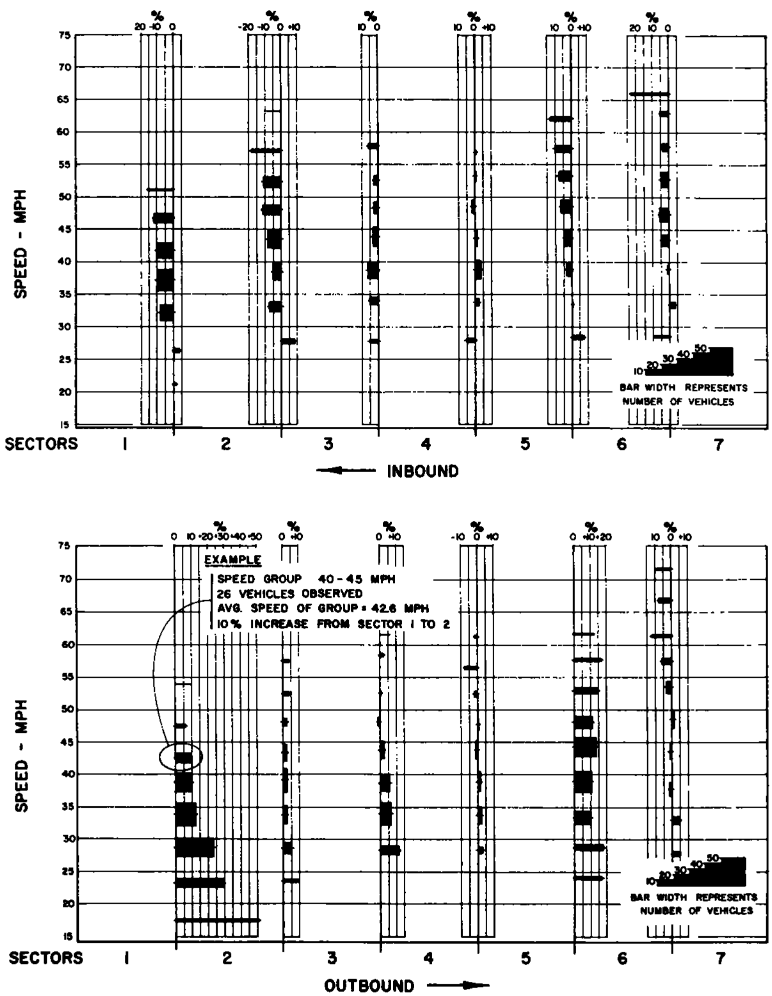


Figure 5. Study II, percent change in speed of 5-mph groups, Madisonville, Texas.

The comprehensive study, using the test car method, was conducted in one of the selected locations to provide data on specific reaction patterns of drivers. In this study, ten drivers made four test car runs in each direction. The experimental design and the results of the study are reported in a later section of the report.

Individual Vehicle Speed Studies

Analysis of Data. —Because of the large volume of data collected in the individual vehicle speed studies, electronic data-processing equipment was utilized to a great extent in the analysis. After interpreting the recorder charts, the linear time measurements for each vehicle and other supplemental data were transferred to IBM punch cards. The various computations involved were then made by electronic computer.

Figure 6. Site of individual speed study I.

The speed parameters used in the evaluations were average speeds, 85-percentile speed, 15-percentile speed, and the speed differential. These parameters were considered as most representative of the speed distributions observed. The pace was also used in the initial stages of the analysis but was later ruled out because of its apparent oversensitivity. An analysis showed that the pace could fluctuate greatly over the straight portion of the speed distribution curve when the speed differential was large. In other words, the pace was considered reliable only when it closely approximated the speed differential.

The traffic speeds observed in each of the studies were divided into three groups, depending on traffic flow conditions: all vehicles, through vehicles, and free-flow vehicles. In this report, "all vehicles" represents all the vehicles observed in each sector during the study period regardless of trip length or flow conditions; "through vehicles" indicates the vehicles that traveled throughout the entire length of the study section; and "free-flow vehicles" describes only the portion of "through vehicles" that was not influenced by slower-moving vehicles in the traffic stream. The condition of free flow was ascertained from interpretation of the recorder charts, where queueing and the rate of closure were readily discernible.

The speed parameter values for free-flow vehicles in each of the studies were plotted in relation to roadway geometry, development, and traffic movement, as shown in

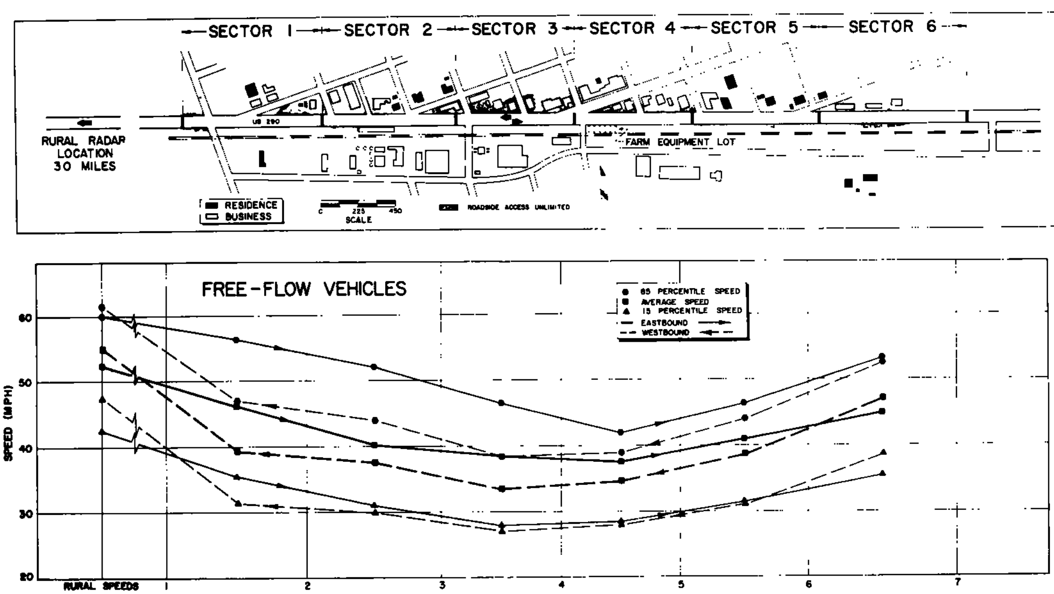


Figure 7. Individual vehicle speed study I, US 290, Waller, Texas.

TABLE 9

DESCRIPTION OF STUDY SECTION I, WALLER

Sector No	Sector Length (ft)	Pavem Width (ft)	Shoulder Type	Horiz Curves (deg)	Flashing Amber Signal	Type of Develop	Resid Units (No)	Commer Units (No)	Driveways (No)	Percent with Unlimited Access	Inter-secting Streets (No)	Sight Distance[a]	
												Northbound	Southbound
1	886	24	Gravel	-	-	Commer	1	5	0	75	2	No	No
2	842	24	Gravel	-	-	Commer	3	4	0	100	3	No	No
3	752	24	Paved one side	-	-	Commer	1	6	0	100	3	No	No
4	749	24	Paved one side	-	*	Commer	0	8	0	100	3	No	No
5	796	24	Gravel	-	-	Commer	4	1	0	100	3	No	No
6	933	24	Gravel	-	-	Commer	1	3	0	50[b]	0	No	No

[a]Less than 1,000 ft at any point within sector
[b]50 percent unlimited, 50 percent rural

subsequent figures. By using free-flow vehicle speeds, the influence of traffic conditions was reduced to the psychological effects of anticipated conflicts. The traffic volumes observed during the study are expressed in terms of average hourly volume and maximum hourly volume at each road tube station. Also, the average and maximum hourly turning movements are indicated within the sector in which they occurred. A detailed description of each study location is given in Tables 9 through 13.

The measurement of individual vehicle speeds through each of the sectors in a study made it possible to examine speed changes in relation to the speed in the previous sector. Figure 5, which typically represents these relationships, shows the percent change in speed between any two sectors for inbound and outbound traffic. These changes in speed can best be illustrated by example. The first graph in the lower half of the figure shows speed changes between Sectors 1 and 2 in the outbound direction. The third bar in this graph shows 26 vehicles (width of bar) were in the 40- to 45-mph group in Sector 1, and their average speed in that sector was 42.6 mph. The change

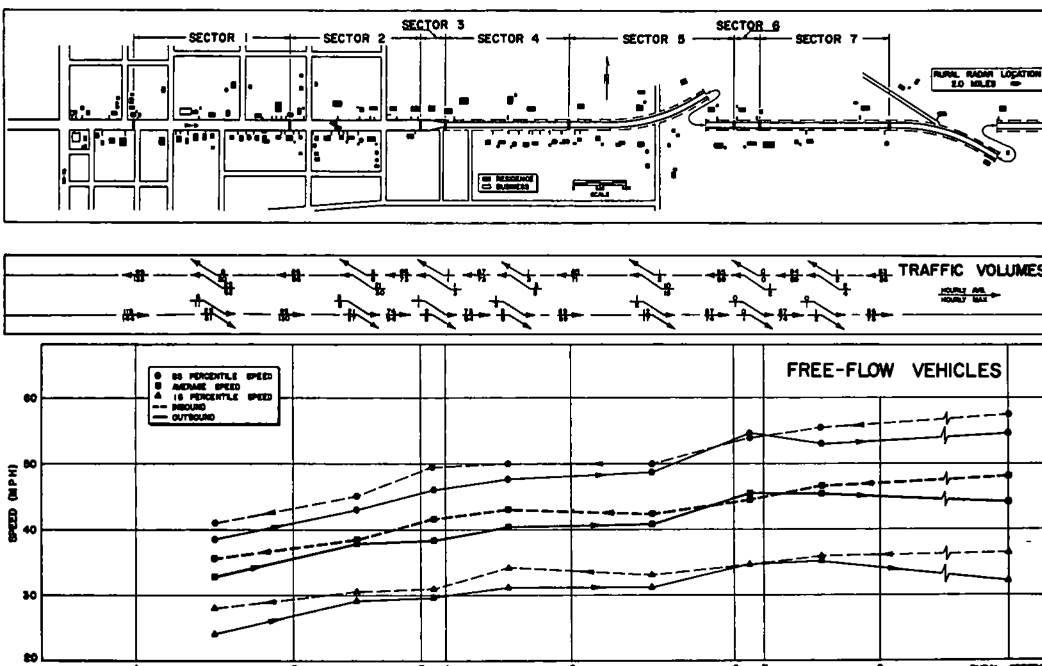


Figure 8. Individual vehicle speed study II, Texas 21, Madisonville.

TABLE 10

DESCRIPTION OF STUDY SECTION II, MADISONVILLE

Sector No	Sector Length (ft)	Pavt Width (ft)	Shoulder Type	Horiz Curves (deg)	Type of Develop	Resid Units (No)	Driveways (No.)	Percent with Unlimited Access	Inter-secting Streets (No)	Sight Distance[a] Inbound	Sight Distance[a] Outbound
1	1,353	40	Curb	-	Resid	19	17	0	4	Yes	Yes
2	1,140	40	Curb	-	Resid	15	17	0	2	Yes	Yes
3	211	-[b]	-[b]	-	Resid	1	0	0	1	No	No
4	1,187	20	Grass	-	Resid	11	10	0	1	No	Yes
5	1,365	20	Grass	4	Resid	9	6	0	1	Yes	Yes
6	230	20	Grass	-	Resid.	2	2	0	0	Yes	No
7	1,099	20	Grass	-	Resid	7	3	0	0	Yes	Yes

[a]Less than 1,000 ft at any point within sector
[b]Transition

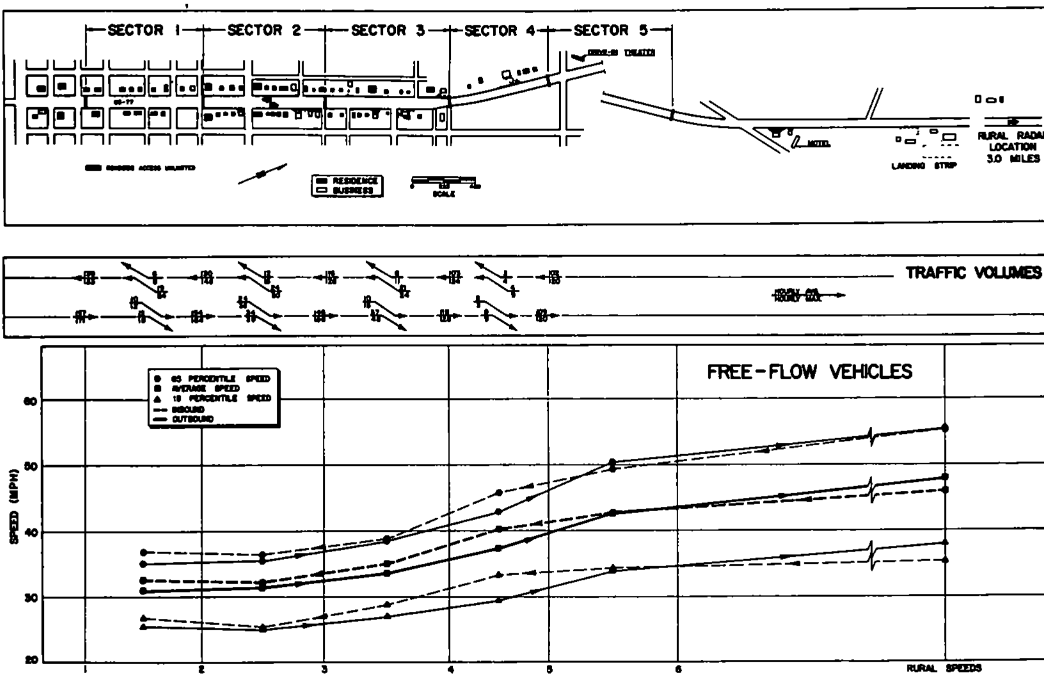


Figure 9. Individual vehicle speed study III, US 77, Cameron, Texas.

in speed of this group between Sector 1 and 2 was 10 percent of their average speed in Sector 1. The other bars in the first graph represent speed changes for the various 5-mph speed groups. The width of each bar (vertical dimension) represents the number of vehicles in the group, the center of the bar indicates the average speed of the group, and the bar length (horizontal dimension) indicates the percent change in speed between the two sectors for the same manner, the other graphs represent speed changes between the sectors indicated.

In the final analysis there was no distinction made between commercial and pasenger vehicles because the number of commercial vehicles in each study was too small to be treated separately with any statistical reliability. The comparison of the average truck speeds with average speeds of the composite free-flow traffic stream is given in Table 3.

A complete listing of the results of the studies is given in Tables 4 through 8.

Discussion of Results. —The results of the individual vehicle speed studies repeatedly pointed up several factors of roadway geometrics and roadside development that directly affected traffic speeds. However, the sequence in which these factors occurred in the test section determined to a great extent their effect on speeds. In other words, the influence of certain factors was dependent on the conditions that the driver had expe-

TABLE 11

DESCRIPTION OF STUDY SECTION III, CAMERON

Sector No	Sector Length (ft)	Pavt Width (ft)	Shoulder Type	Horiz Curves (deg)	Flashing Amber Signal	Type of Develop	Resid Units (No)	Commer Units (No)	Driveways (No)	Percent with Uncontrolled Access	Inter-secting Streets (No)	Sight Distance[a] Inbound	Sight Distance[a] Outbound
1	1,167	40	Curb	-	-	Resid	13	1	4	0	4	No	No
2	1,207	40	Curb	-	*	Mixed	20	5	12	5	3	Yes	Yes
3	1,230	40	Curb	-	-	Mixed	15	6	13	10	5	Yes	Yes
4	1,012	40	Gravel	2 (approx)	-	Mixed	5	1	7	5	0	Yes	Yes
5	1,282	40	Gravel	-	-	Mixed	1	0	0	0	1	Yes	Yes

[a]Less than 1,000 ft at any point within sector

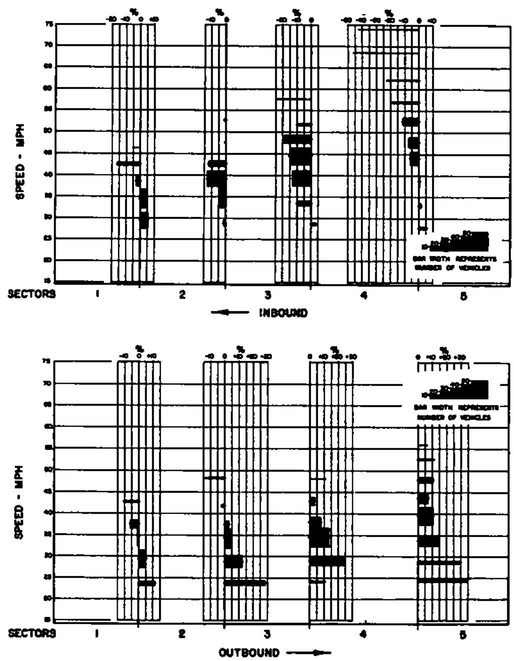


Figure 10. Study III, percent change in speed of 5-mph groups, Cameron, Texas.

rienced in previous portions of the test section. Each study is discussed individually so that previous influences will be accounted for in the evaluation of specific variables or combinations.

Study I. —This preliminary study was conducted primarily to evaluate study techniques and to determine if the data would reflect the extent of influence from the various factors. A site was selected for this preliminary study for which the general speed pattern was known, and which had few variations in conditions throughout the section. The traffic volume through this section was higher than desired, but this afforded a better check on the operation of the equipment and the study techniques being tested. This test was conducted just before the reconstruction of the study section to a four-lane facility. Therefore, additional studies could not be conducted.

As shown in Figures 6 and 7, the test section was composed almost entirely of commercial development. This development was limited to the north side of the roadway because of the proximity of the railroad tracks on the south side. Ingress and egress to the various businesses were provided by a continuous paved shoulder. The roadway

TABLE 12

DESCRIPTION OF STUDY SECTION IV, BREMOND

Sector No	Sector Length (ft)	Pavt Width (ft)	Shoulder Type	Horiz Curves (deg)	Flashing Amber Signal	Type of Develop	Resid Units (No)	Commer Units (No)	Driveways (No)	Percent with Uncontrolled Access	Inter-secting Streets (No)	Sight Distance[a]	
												Inbound	Outbound
1	432	20	-[b]	-	-	Resid	7	0	2	0	1	No	No
2	687	20	-[b]	-	-	Mixed	8	3	2	30	2	No	No
3	333	20	-[b]	-	-	Resid	5	0	1	0	1	No	Yes
4	916	20	-[b]	-	-	Resid	10	1	4	5	3	No	Yes
5	1,080	20	-[b]	-	-	Commer	7	5	4	50	1	Yes	No
6	304	20	-[b]	-	-	Rural	0	0	0	0	0	Yes	No
7	678	20	-[b]	2	-	Rural	0	0	0	0	1	No	Yes
8	820	20	-[b]	2	-	Rural	3	0	0	0	1	Yes	No
9	718	20	-[b]	-	-	Rural	0	0	0	0	1	Yes	No

[a]Less than 1,000 ft at any point within sector
[b]Grass and/or gravel

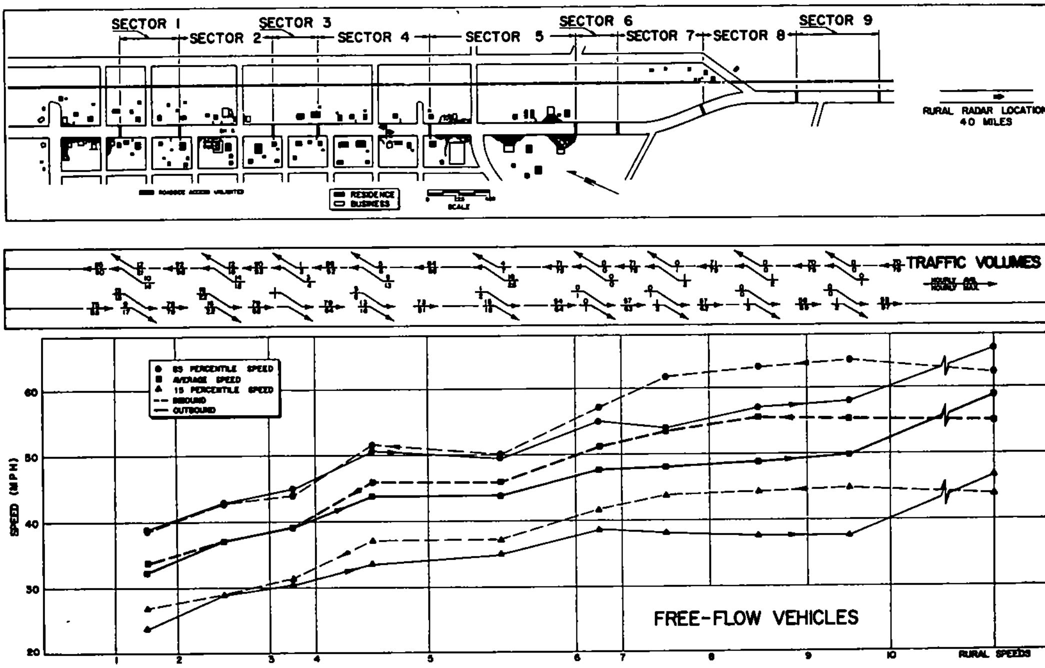


Figure 11. Individual vehicle speed study IV, Texas 6, Bremond.

was straight throughout the test section and adjacent areas, and the grades were negligible; therefore, no sight distance problems were encountered. The cross-section of the roadway was the same throughout the study area with the exception of the paved shoulder provided next to the development. A detailed description of the study section is given in Table 9.

The speed profiles in Figure 7 show that traffic speeds in the rural areas were essentially the same for both directions of travel. As the vehicles entered the developed area in the eastbound direction, their speeds reduced gradually, reaching a minimum in Sector 4. At this point the speeds began to increase gradually because the drivers could clearly see the end of the developed area. In the westbound direction speeds were reduced gradually as traffic entered the developed area, reaching a minimum in Sectors 4 and 3. Again, speeds gradually increased until the vehicles had passed through the developed area in Sector 1. The westbound traffic did not attain rural speeds within the test section.

The speeds on the developed side of the roadway were significantly lower than the speeds on the undeveloped side.

TABLE 13

DESCRIPTION OF STUDY SECTION V, OAKWOOD

Sector No	Sector Length (ft)	Pavt Width (ft)	Shoulder Type	Horiz Curves (deg)	Flashing Amber Signal	Type of Develop	Resid Units (No)	Commer Units (No)	Driveways (No)	Percent with Uncontrolled Access	Inter-secting Streets (No)	Sight Distance[a] Northbound	Sight Distance[a] Southbound
1	300	20	-[b]	-	-	Resid	3	0	4	0	1	No	No
2	1,000	20	-[b]	-	-	Resid	8	0	9	0	1	No	No
3	754	20	-[b]	-	-	Resid	6	3	2	5	2	Yes	No
4	716	20	-[b]	-	*	Commer	5	4	0	100	2	Yes	Yes
5	756	20	-[b]	-	-	Commer	4	3	2	35	1	Yes	Yes
6	1,366	20	-[b]	4	-	Resid	7	0	1	5	1	No	Yes
7	300	20	-[b]	-	-	Rural	0	0	0	0	0	No	No
8	300	20	-[b]	-	-	Rural	0	0	0	0	0	No	No

[a]Less than 1,000 ft at any point within sector
[b]Grass and/or gravel

Study II. —The location for Study II was selected to afford an analysis of the influence of purely residential development. A strip map of the study section is shown in Figure 8, and a detailed description is given in Table 10. In the first two sectors, the roadway was a curbed street with parking permitted on both sides. In Sector 3, the cross-section changed to a two-lane rural type highway with grass shoulders. A 4-deg horizontal curve was located in Sector 5, and a second 4-deg curve was located just outside Sector 7. Sight distance was restricted in certain portions of the test section by the horizontal curves and by the slightly rolling profile through the test section.

The speed profiles for inbound traffic indicated a general deceleration pattern throughout the study section. Deviations from a constant deceleration pattern could be directly related to features of the roadway and the appearance of the development. The abrupt reduction in speed in Sector 5 was caused by the sight distance restrictions imposed on the driver by the horizontal curve in that sector. The speed change relationships between Sectors 6 and 5, shown in Figure 5, indicated that these conditions caused a proportionately greater reduction in the higher speed ranges.

A second abrupt reduction in the speed of the inbound traffic was observed as the roadway cross-section changed from a rural to a curbed urban section (Sector 3). This

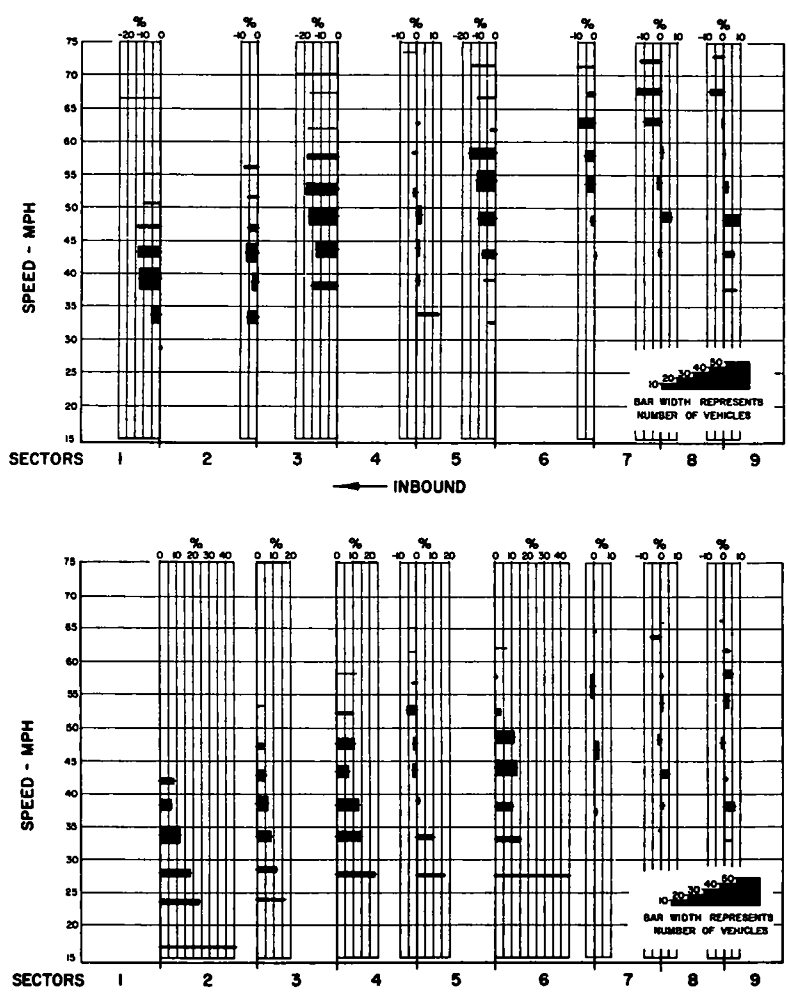


Figure 12. Study IV, percent change in speed of 5-mph groups, Bremond, Texas.

reduction was not altogether due to the change in cross-section. There was a significant change in the development in the general area of the speed change. The development in the urban section differed from that in the rural section by extensive planting of trees and shrubbery near the curbline. Again the speed change relationships in Figure 5 show the higher speed ranges to have been most severely affected between Sectors 3 and 2, where the change in development occurred.

The speeds of the outbound traffic indicated the same general tendency to follow a constant speed change pattern except where deviations were caused by horizontal curves and the sight distance restrictions imposed by the curves. This effect was observed in Sector 5 and again in Sector 7. Figure 5 shows a marked reduction in the higher speed ranges, whereas the lower speeds were affected to a lesser degree.

Study III. —The location for Study III was selected to permit an analysis of traffic speed patterns in relation to mixed development. The study site consisted of a transition section with intermittent commercial and residential development followed by a continuously developed city street of extended length as shown in Figure 9. In Sectors 1, 2, and 3, the roadway was a curbed street with parking permitted on both sides. A flashing amber beacon was located within Sector 2. Between Sectors 3 and 4 the roadway cross-section changed to a two-lane rural highway with grass shoulders.

The centerline profile through the study section was slightly rolling with crest vertical curves located in Sectors 2, 3, and 4. Also a sag type vertical curve was located within the horizontal curve in Sector 4. A detailed description of the study section is given in Table 11.

The speed profile in Figure 9 shows that the major speed changes of inbound traffic occurred between Sectors 3 and 5. It was noted that intermittent development outside the study section had caused a slight reduction in the speed of inbound traffic before it entered the study section. However, limited test car studies indicated that part of this reduction was due to sight distance restrictions imposed on the inbound traffic by a crest vertical curve located in the vicinity of Station 5.

The speed reduction observed between Sectors 5 and 4 was due to the re-introduction of development and critical sight distance restrictions imposed on the driver by the

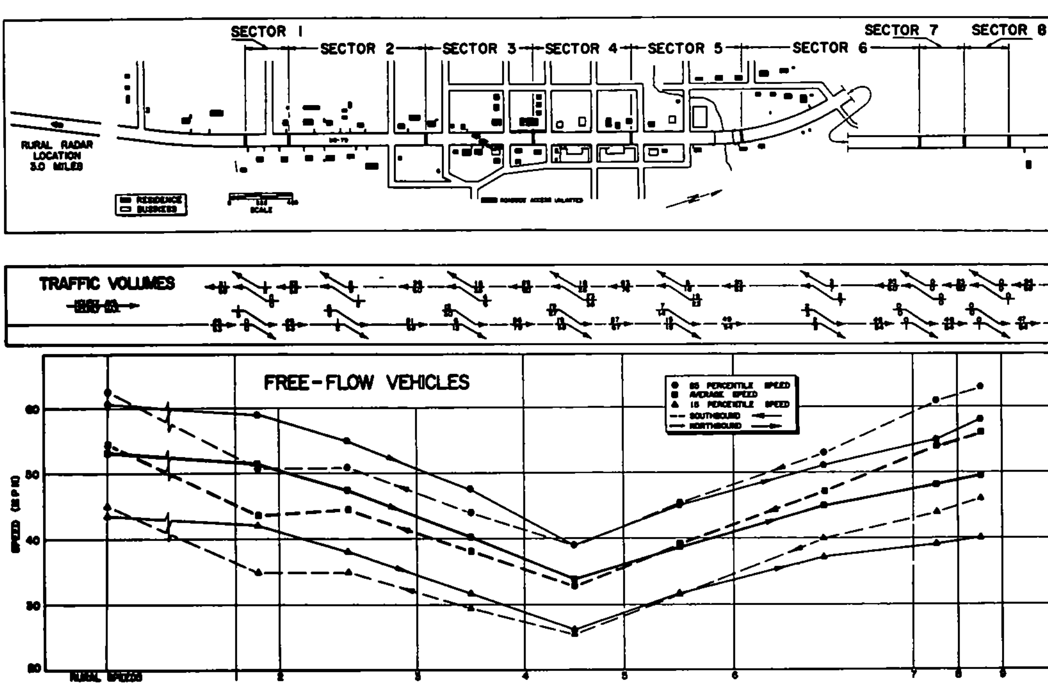


Figure 13. Individual vehicle speed study V, US 79, Oakwood, Texas.

combination of horizontal and vertical curvature, which occurred in Sector 4. Figure 10 shows the greatest reduction to have occurred in the higher speed ranges.

The greatest reduction in speeds of the inbound traffic was observed between Sectors 4 and 3. This reduction was the result of a combination of factors including the change in cross-section, an increase in the proportion of commercial development, and restrictive sight distance due to a crest vertical curve in Sector 3. The commercial development in the area generated frequent traffic conflicts.

Speeds were essentially constant through Sectors 1 and 2 where the drivers were confronted with a continuously developed city street section. However, the limited test car studies indicated an internal reaction in Sector 2 where there was an important intersection controlled by a flashing amber beacon. Also, sight distance was restricted by a crest vertical curve near the intersection. The reaction was a slight depression in the test car speed profile immediately preceding and within the intersection area. The reduction was only slightly reflected in the average sector speeds.

TABLE 14

COMPARISON OF AVERAGE SPEEDS OF LOCAL AND NONLOCAL VEHICLE TRIPS

Study	Sector No.	Northbound-Inbound			Southbound-Outbound		
		Avg. Speed of Veh. (mph)		Speed Diff.	Avg. Speed of Veh. (mph)		Speed Diff.
		Nonlocal	Local		Nonlocal	Local	
I	1	40.1	38.8	-1.3	45.0	40.6	-4.4
	2	37.4	33.3	-4.1	37.9	36.0	-1.9
	3	33.0	29.6	-3.4	35.1	31.2	-3.9
	4	32.7	30.5	-2.2	35.9	30.6	-5.3
	5	37.9	35.2	-2.7	39.9	34.9	-5.0
	6	47.2	43.8	-3.4	43.9	40.8	-3.1
II	1	32.6	33.7	+1.1	35.0	34.5	-0.5
	2	37.4	36.9	-0.5	38.8	36.7	-2.1
	3	38.0	37.3	-0.7	41.4	39.0	-2.4
	4	39.8	39.1	-0.7	43.0	38.6	-4.4
	5	40.2	38.7	-1.5	42.1	37.5	-4.6
	6	45.1	37.9	-7.2	44.7	37.4	-7.3
	7	44.5	40.2	-4.3	46.8	41.9	-4.9
III	1	30.9	29.4	-1.5	32.2	29.8	-2.4
	2	31.1	31.1	0	31.6	30.6	-1.0
	3	32.7	33.0	+0.3	35.0	32.2	-2.8
	4	36.5	36.0	-0.5	40.1	36.5	-3.6
	5	41.2	40.8	-0.4	43.3	43.5	+0.2
IV	1	32.1	29.0	-3.1	33.2	29.9	-3.3
	2	36.9	31.5	-5.4	36.7	31.4	-5.3
	3	38.9	32.4	-6.5	38.8	32.1	-6.7
	4	43.5	39.5	-4.0	44.3	37.6	-6.7
	5	43.2	40.1	-3.1	44.2	41.6	-2.6
	6	47.4	42.5	-4.9	50.3	43.8	-6.5
	7	48.3	43.7	-4.6	53.0	47.6	-5.4
	8	47.6	42.0	-5.6	54.2	47.9	-6.3
	9	49.8	45.9	-3.9	54.3	49.2	-5.1
V	1	51.4	44.1	-7.3	43.5	38.5	-5.0
	2	47.3	42.3	-5.0	44.4	38.7	-5.7
	3	39.9	32.4	-7.5	38.2	30.7	-7.5
	4	33.7	29.8	-3.9	32.8	25.7	-7.1
	5	38.7	33.3	-5.4	39.1	35.4	-3.7
	6	45.0	40.1	-5.9	47.3	44.1	-3.2
	7	48.1	42.3	-5.8	53.9	48.6	-5.3
	8	49.7	43.8	-5.9	55.6	50.5	-5.1

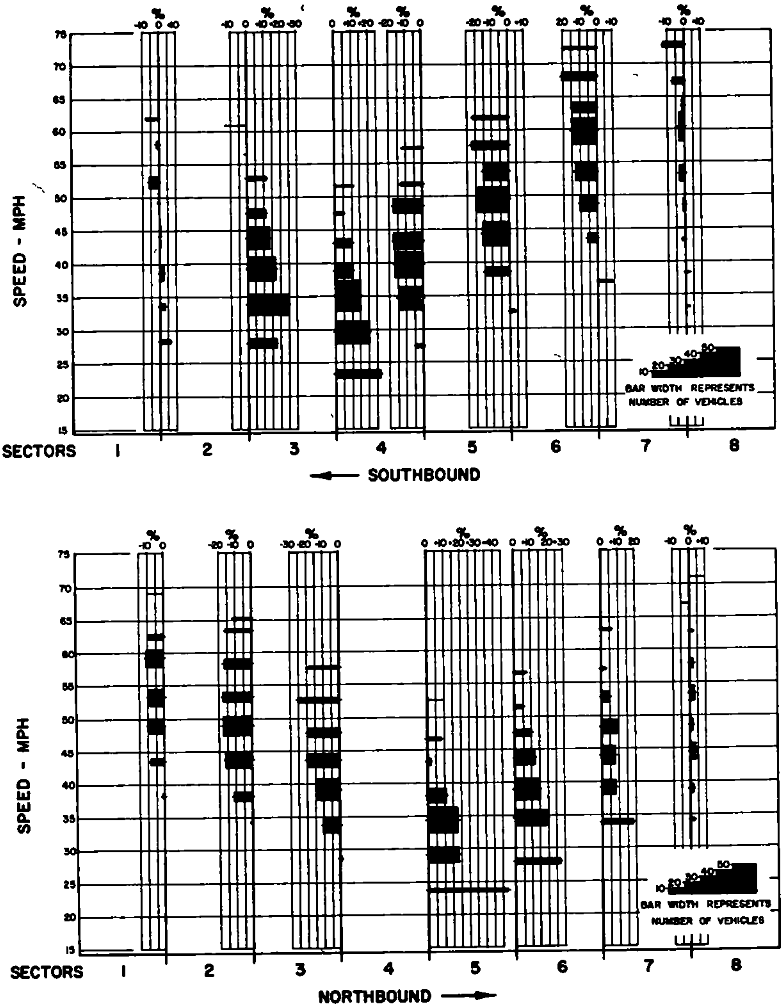


Figure 14. Study V, percent change in speed of 5-mph groups, Oakwood, Texas.

TABLE 15

COMPARISON OF TEST CAR SPEEDS WITH NORMAL TRAFFIC SPEEDS

Sector No.	Speed (mph)					
	Inbound			Outbound		
	Test Car[a]	Normal Traffic[b]	Diff.	Test Car[a]	Normal Traffic[b]	Diff.
1	50.0	41.0	9.0	46.2	38.5	7.7
2	55.9	45.0	10.9	52.4	43.0	9.4
3	60.3	49.5	10.8	54.9	46.0	8.9
4	61.3	50.0	11.3	57.3	47.5	9.8
5	61.1	50.0	11.1	57.7	48.5	9.2
6	63.6	54.0	9.6	61.4	54.5	6.9
7	65.5	55.5	10.0	64.0	53.0	11.0

[a]Average speed for 10 drivers.
[b]85-percentile speed (from individual vehicle speed study II).

In the outbound direction, traffic speeds exhibited many of the same characteristics as previously pointed out for the inbound traffic. Speeds were fairly constant through Sectors 1 and 2, where the roadway did not portray the characteristics of a transition area. As in the inbound direction, the major transitional speed change occurred between Sectors 3 and 5.

Study IV. —The location for Study IV was selected to provide data for an analysis of the influence of mixed development on traffic speed patterns in a relatively short

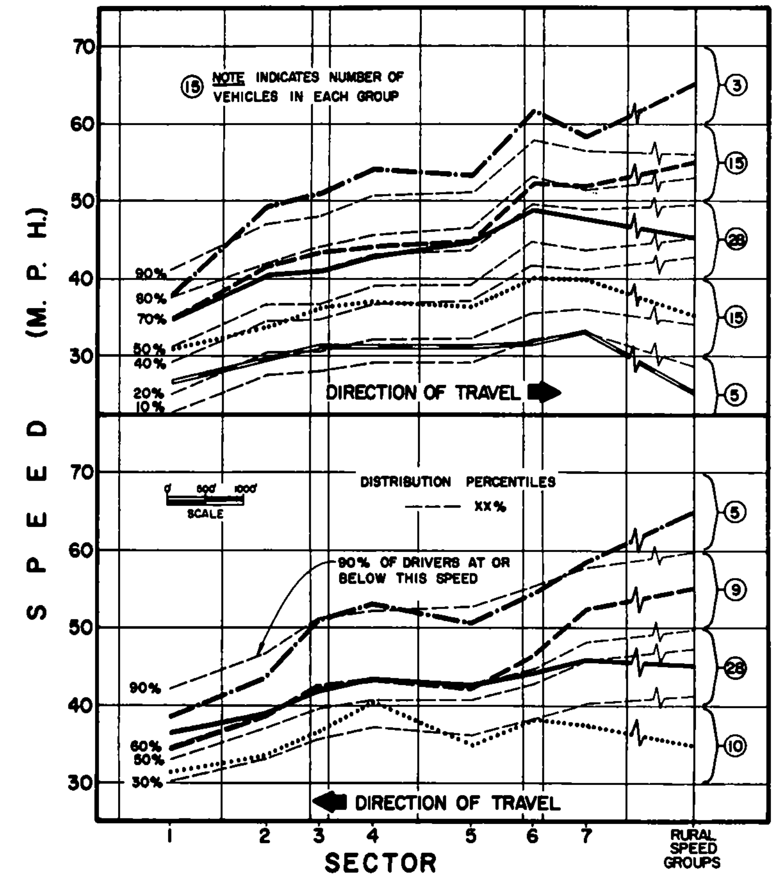


Figure 15. Average speeds through urban sectors compared to rural speeds, Study II.

TABLE 16

COMPARISON OF TRAFFIC SPEEDS FOR CONDITIONS OF RADAR ENFORCEMENT AND NO ENFORCEMENT

Direction of Travel	Study Loc	Radar Enforcement							No Enforcement						
		Veh Obs (No)	Speed (mph) Avg	85-Percent	15-Percent	Diff	Percent Exceeding 55 mph	Std Dev	Veh Obs (No)	Speed (mph) Avg	85-Percent	15-Percent	Diff	Percent Exceeding 55 mph[a]	Std Dev
Enforced	1	239	50 3	56 5	41 6	14 9	24 7	6 95	471	52 2	58 1	44 3	13 8	35 0	6 80
	2	446	52 8	57 6	45 7	11 9	35 7	6 26	272	54 6	60 2	47 4	12 8	44 5	7 11
	3	176	50 7	57 0	42 2	14 8	29 5	7 40	404	51 0	56 9	43 3	13 6	27 0	6 36
	4	195	55 3	62 0	47 2	14 8	49 7	7 54	67	52 2	60 0	42 4	17 6	43 3	8 68
Opposing	1	262	45 3	49 6	38 4	11 2	4 6	5 55	402	50 3	56 0	42 7	13 3	21 6	6 48
	2	228	48 5	54 3	41 3	13 0	15 8	6 69	128	52 3	60 9	43 3	17 6	35 2	9 65
	3	202	45 0	49 7	37 3	12 4	2 4	5 67	259	51 2	56 7	43 3	13 4	29 7	6 30
	4	76	48 7	54 5	41 3	13 2	17 1	8 03	133	54 7	61 5	45 7	15 8	46 6	8 24

[a]Speed limit

transition area. A detailed description of the study section is given in Table 12. A rural-type two-lane highway cross-section with grass or gravel shoulders was continuous throughout the study section. Traffic volumes were low, and there were few intersecting streets of any significance.

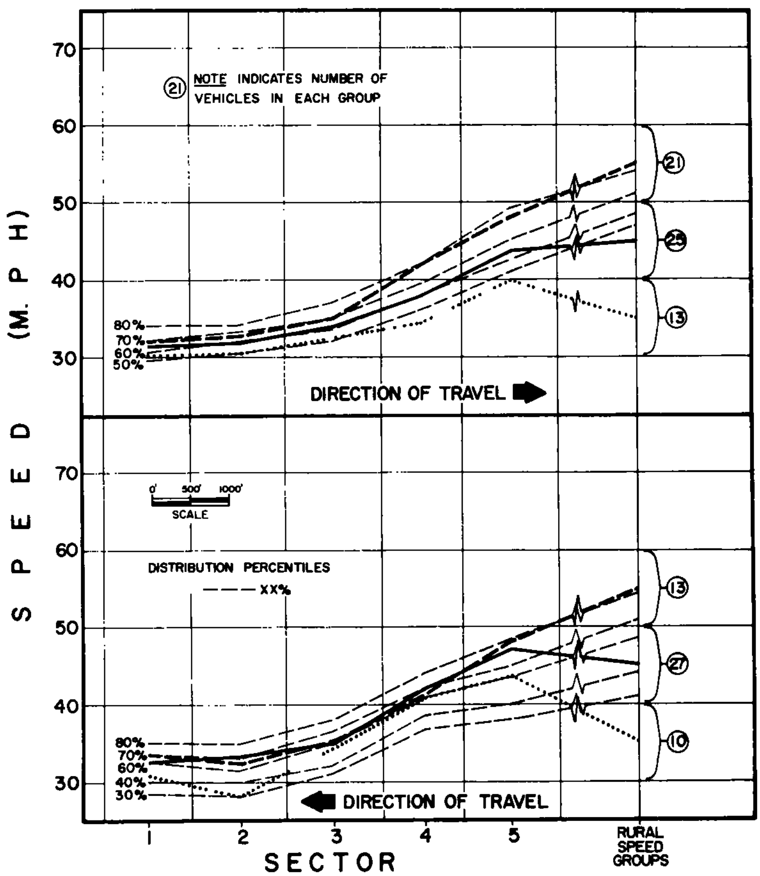


Figure 16. Average speeds through urban sectors compared to rural speeds, Study III.

TABLE 17

COMPARISON OF TRUCK SPEEDS FOR DAYTIME, NIGHTTIME AND RADAR ENFORCEMENT CONDITIONS

Time	Condition	Direc of Travel	Veh Obs (No)	Speed (mph) Avg	85-Percent	15-Percent	Diff	Percent Exceeding 45 mph[a]	55 mph	Std Dev
Day	Normal[b]	Combined	191	49 4	57	42	15	73 4	22 5	7 47
Night	Normal[c]	Combined	146	49 9	54	44	10	82 2	15 8	5 82
	Radar Enforcem [d]	Enforced	155	46 7	52	40	12	55 5	9 0	6 21
		Opposing	126	42 9	47	36	11	28 6	4 0	5 92

[a]Speed limit

[b]Observations by concealed research unit, 4 locations Waller, US 290 West, Oakwood US 79 West, Madisonville, Texas 21 East (2)

[c]Observations by concealed research unit, 4 locations Navasota, Texas 6 North, College Station, Texas 6 South, Bryan, Texas 6 North, Bryan Texas 21 East

[d]6 locations Navasota, Texas 6 North (2), College Station, Texas 6 South, Bryan, Texas 6 North, Bryan, Texas 21, East, Calvert, Texas 6 North

The transition section was preceded by two 2-deg horizontal curves as shown in Figure 11. With regard to horizontal alignment, this location was similar to Study II, where the transition section involved two 4-deg curves. However, no direct comparison could be made because the curves in Study IV did not impose the same sight distance restrictions and there was no associated development.

In evaluating the results of this study, the first reduction in speed of the inbound traffic was noted in Sector 6 (Fig. 11) and the deceleration was continued into Sector 5. This substantial reduction was due to a combination of circumstances which confronted the driver. The extent of the concentrated commercial development in Sector 5 (see strip map, Fig. 11) became apparent to the driver as he entered Sector 6, and his sight distance was restricted by a vertical curve in the approximate vicinity of Station 5. The speed-change relationships in Figure 12 show that the greatest speed reductions between Sectors 6 and 5 occurred in the higher ranges.

As the inbound traffic left the area of concentrated commercial development, there was a tendency toward a slight increase in speed. In the area where the increase occurred, there was also an increase in the sight distance afforded the driver, and the development had assumed a residential appearance. The sudden change in conditions acted as a vacuum and encouraged higher speeds. However, the recurrence of commercial development again caused a reduction in speed in Sector 3. The development causing the reduction was actually located in Sector 2, but it came into prominent view just before the vehicles entered Sector 3.

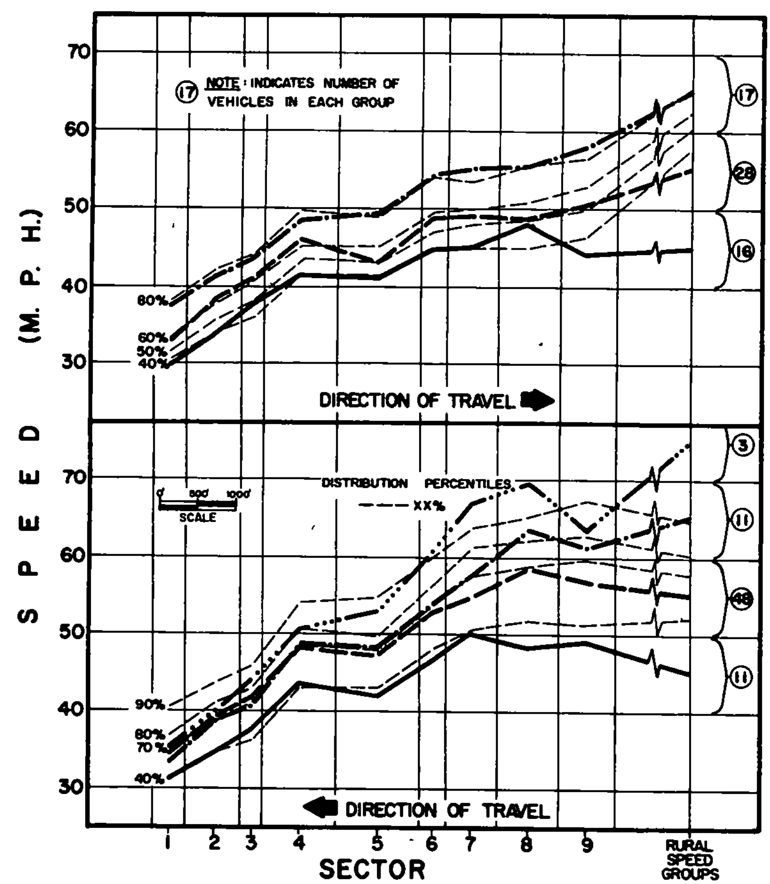


Figure 17. Average speeds through urban sectors compared to rural speeds, Study IV.

Traffic speeds in the outbound direction exhibited essentially the same characteristics as the inbound speeds. A general acceleration pattern was followed by the traffic throughout the study section except for deviations occurring in Sectors 4 and 5. A significant increase in speed occurred in Sector 4 as the traffic passed from a commercial area into an area which was predominantly residential. In Sector 5, a reduction in speed was due to the concentrated commercial development in that sector. Also, there was a slight reduction in speed noted in Sector 7. Figure 12 shows this reduction to have occurred only in the higher ranges of speeds. At this point the drivers were confronted by a horizontal curve superimposed on a sag vertical curve, a condition that presented a deceptive appearance.

Study V. —The location for Study V was selected to afford an analysis of traffic speed patterns in relation to segregated but adjacent areas of commercial and residential development. The developed area was composed of a concentrated business area surrounded by a tightly grouped zone of residential development, all of which was centered on a single main highway (Fig. 13). The roadway through the test section was a two-lane rural-type highway with grass or gravel shoulders. The gravel shoulders provided continuous access throughout the business area. A detailed description of the study section is given in Table 13.

In view of the general conditions just outlined, it was possible to include all of the developed area in the study section and thus obtain speed data on vehicles passing through the entire town. This condition is shown in Figure 13.

Two studies were conducted in this location because volumes were low during the

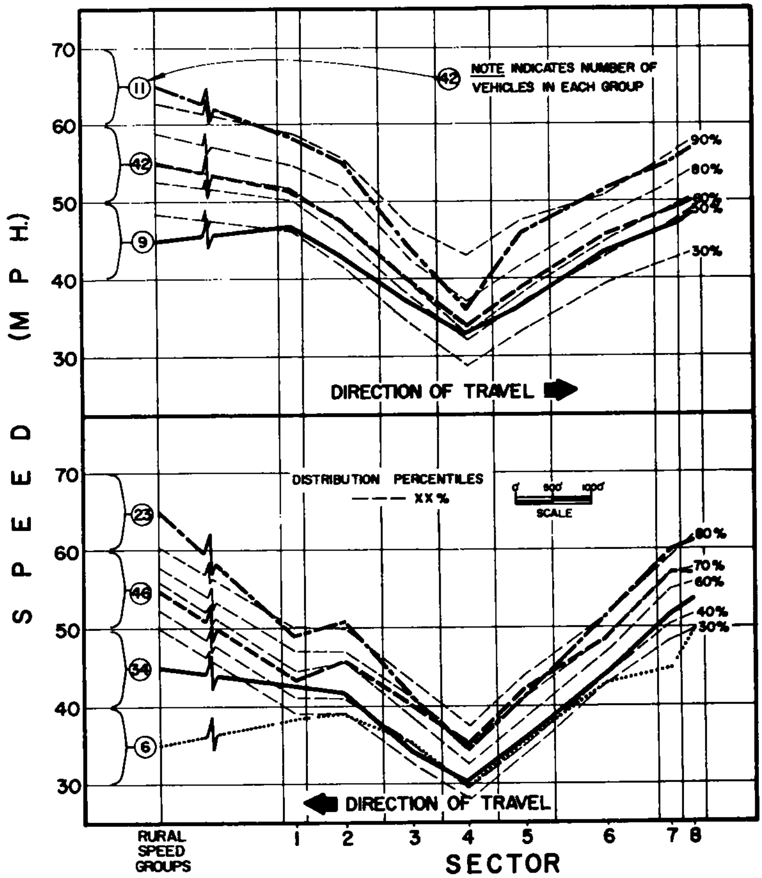


Figure 18. Average speeds through urban sectors compared to rural speeds, Study V.

periods of observation. The studies were first analyzed independently. Because the results of the two studies were very similar, they were combined to provide a more reliable sample.

In this study, the effects of horizontal and vertical alignment were very limited. There was a slight vertical curve which crested at Station 4 and hid the business district

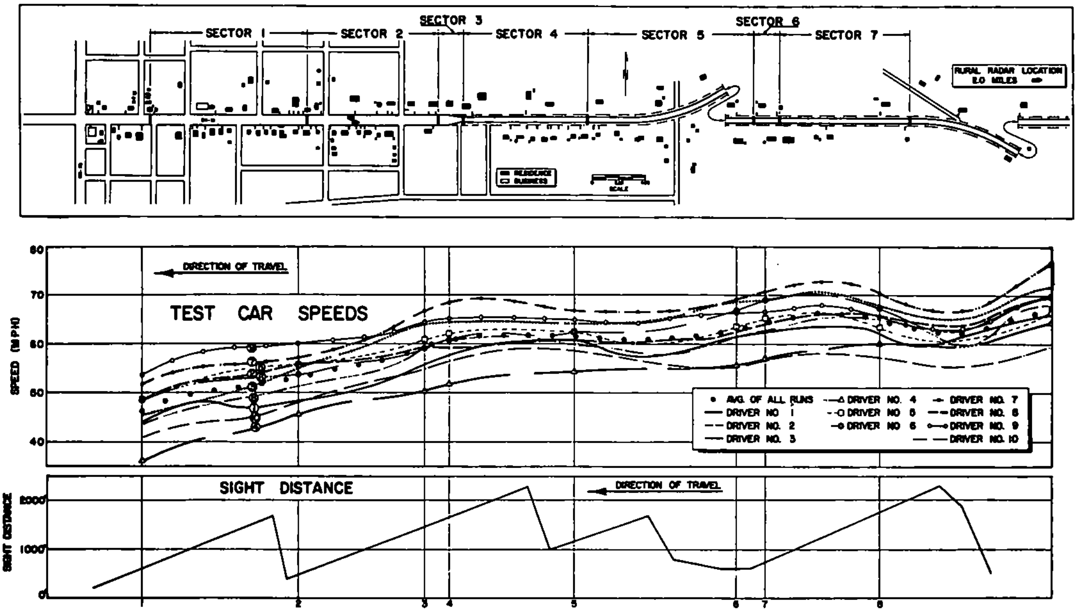


Figure 19. Inbound direction of travel, test car study, Texas 21, Madisonville.

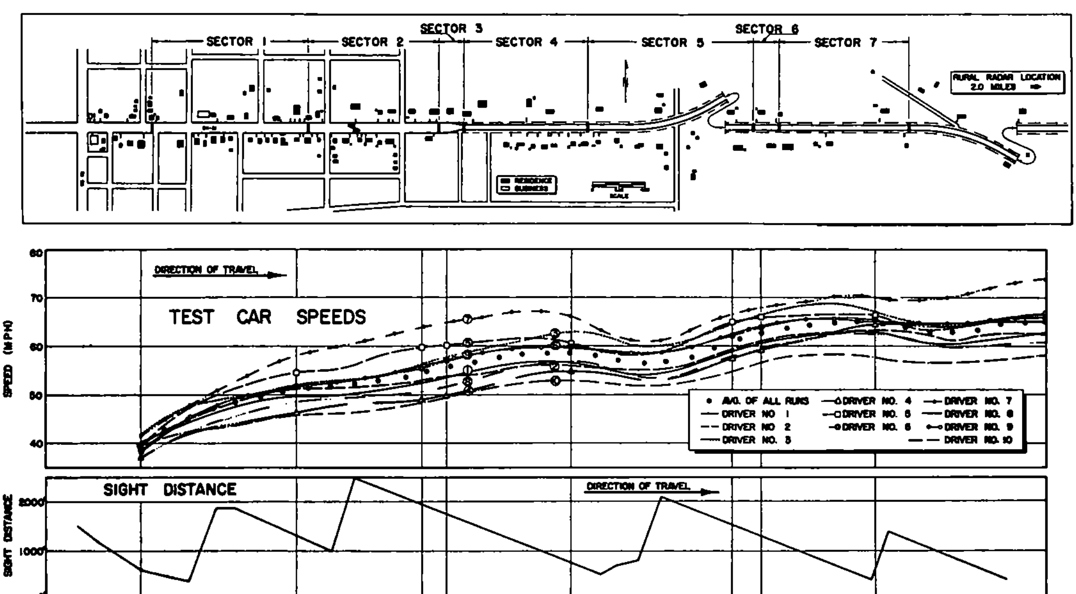


Figure 20. Outbound direction of travel, test car study, Texas 21, Madisonville.

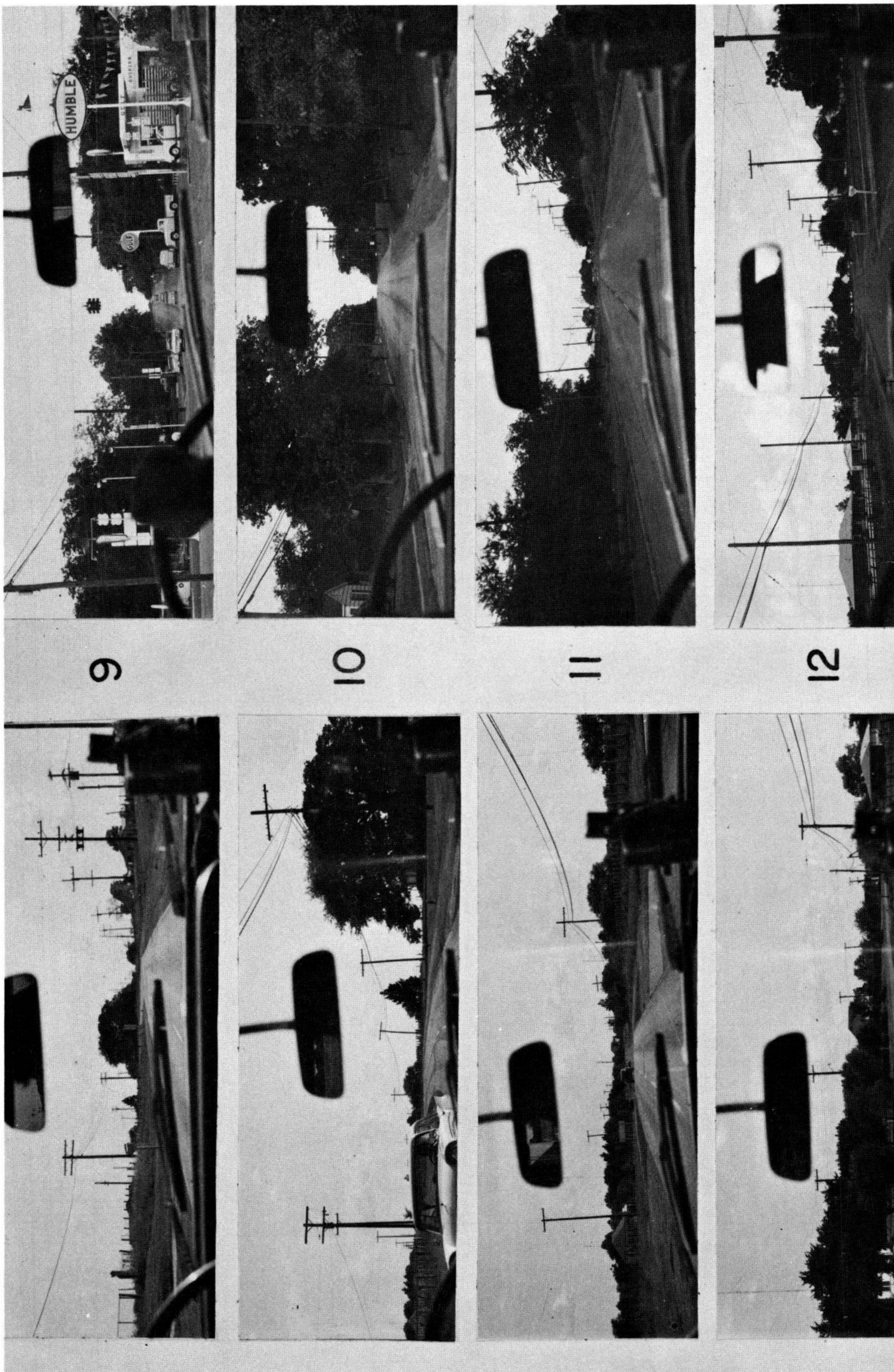
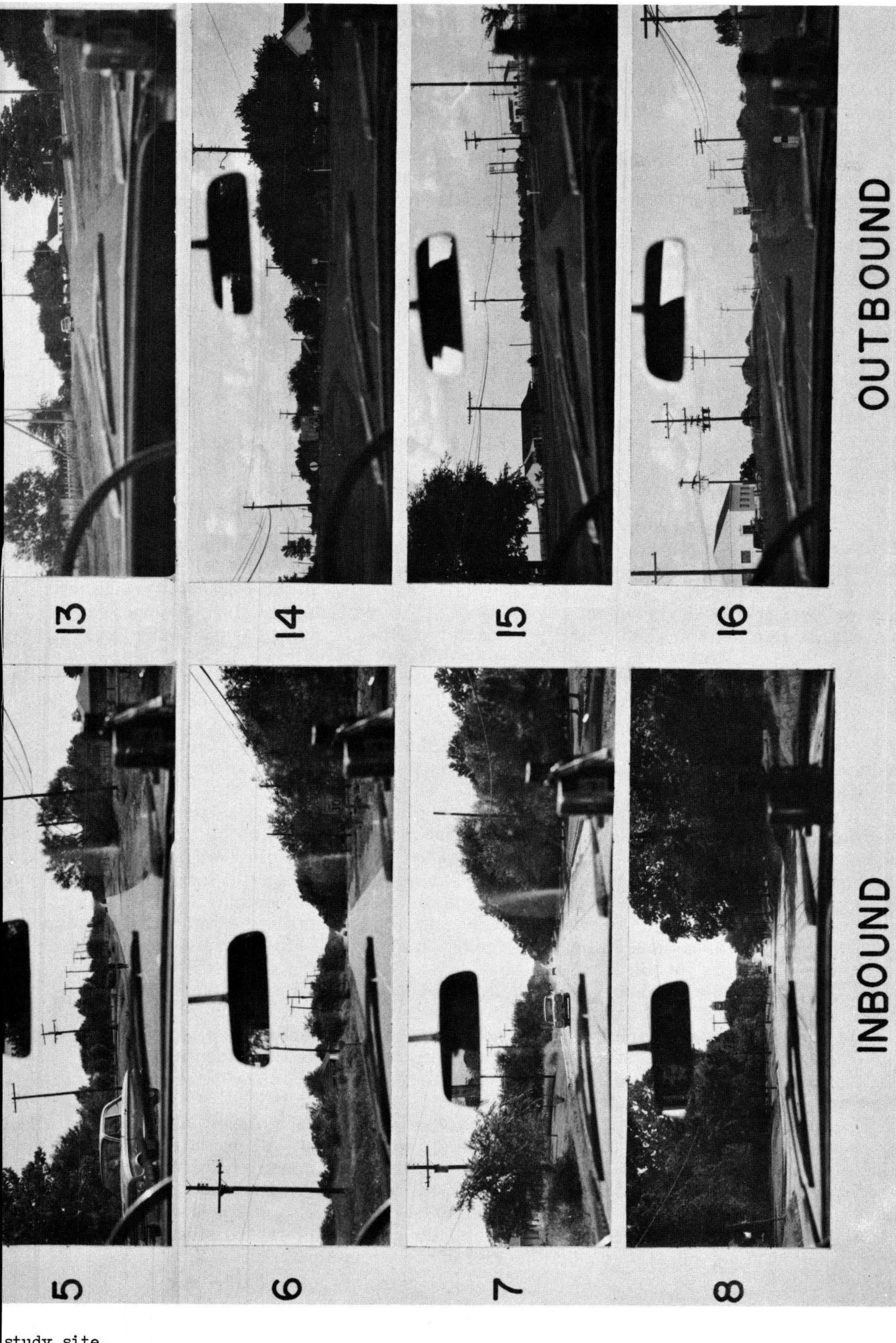


Figure 21.



study site.

from traffic approaching in the northbound direction. There was a 4-deg horizontal curve contained in Sector 6 which restricted the approaching southbound driver's view of the business district until he reached the approximate center of the curve. Although the immediate effect of these elements was not readily discernible in average sector speeds, the limited test car study indicated very definite driver reactions. At these points the drivers assumed a more rapid deceleration rate which continued into the business area.

The speed profiles in Figure 13 show that the traffic entering and leaving the developed area followed a linear speed-change pattern. This pattern occurred in short, compact transition sections which were virtually free from isolated influences of commercial development and critical geometric elements. However, southbound traffic speeds did not completely conform to this general pattern in Sector 1. Furthermore, there was no obvious explanation for the deviation. It occurred on the fringe of development and there were no sight restrictions, although there was a 1-deg curve ahead. Although this deviation did not occur in the limited test car studies, it was evident in both of the individual vehicle speed studies.

As in other studies, a general divergence was noted between inbound and outbound speeds. However, the magnitude of divergence in this study was greater than that observed in the other studies and was attributed primarily to the short, compact characteristics of the transition sections.

Summary of Findings. —The results of each of the individual vehicle speed studies repeatedly pointed up several factors of roadway and development characteristics that influenced traffic speeds. The most significant were as follows:

1. Roadway Geometry and Sight Distance. —The two most common elements of roadway geometry that were found to influence speeds were horizontal and vertical curves. These elements not only imposed physical limitations on vehicle operation but generally imposed limitations on sight distance, or the distance ahead at which the roadway and related development were visible. The visibility relationship appeared to be of most significance when traffic speeds were below the design speed of the geometric elements. However, restricted sight distance did not materially influence speeds unless associated with development. Apparently its effect on speed was the result of the driver's anticipation of traffic conflicts beyond the limits of his vision.

2. Cross-Section. —In the two studies where there were changes in cross-section, there were corresponding changes in speed. Although these factors could not be isolated for evaluation because of other factors, it was apparent that they contributed to an urbanized appearance.

3. Commercial Development. —In several of the studies, concentrated commercial development appeared to have a substantial influence on speed. Its full impact was demonstrated in Study IV by the increase in speeds observed as the traffic passed from the commercial area into a predominantly residential area of equal or greater density. However, it is recognized that restricted sight distance in the commercial area was also a contributing factor. The second occurrence of concentrated commercial development in the study also caused a marked reduction in speeds. In this case there were no additional factors involved.

4. Residential Development. —Residential development did not indicate the same level of importance as did commercial development. This may be due to its lower traffic generation characteristics. The appearance of residential development determined to a great extent its level of influence on traffic speeds. Residential areas having good lateral clearances had far less influence on speeds than those where shrubbery and trees were planted near the curbline.

5. Density of Development. —The density of residential development expressed as a percent of occupancy did not appear to correlate with speeds, except in its extreme ranges. Areas of residential development having the same density had entirely different appearances to the driver, and as pointed out previously, the appearance of development seemed to have a great influence on the driver's selection of speed.

6. Deceleration Pattern. —In some of the individual vehicle speed studies, traffic speeds followed a generally constant deceleration pattern in transition from rural to

urban conditions. In other studies, deviations from a constant deceleration line were directly related to certain characteristics of the roadway and development.

7. Divergence of Speeds.—In the studies involving short transition sections (Studies I and IV) the inbound and outbound speed patterns were significantly different. A general divergence between the speed profiles of the two directions was noted. This characteristic was observed in the other studies where transition sections were longer, but the divergence was much smaller.

Rural vs Urban Speed Relationships

The individual vehicle speed data were analyzed to evaluate the consistency of drivers to travel at approximately the same percentile speed throughout the rural and urban areas. The free-flow vehicles that traveled throughout the urban and rural test section were selected for this analysis. Their speeds at the rural observation stations were grouped in 10-mph increments, and the average speed of each of these groups was computed for each of the sectors in the urban sections. These values were plotted for comparison as shown in Figures 15 to 18. Also, percentile bands were plotted to show the relationship of these speed groups to the distribution of free-flow vehicles traveling throughout the urban section. However, the percentile bands plotted at the rural stations represent the entire traffic stream because free-flow vehicles were not separated at that point.

Figures 15 to 18 show there was a general tendency for the speed groups to maintain their same relative position in the over-all distribution throughout the rural and urban areas. In other words, the faster drivers in rural areas were generally the faster drivers throughout the transition areas. However, the speed groups merged under city street traffic conditions as indicated in Sectors 1, 2, and 3 of Study III. Also, there was more consistency in the distribution of the speed groups in the outbound direction than in the inbound direction.

Local vs Nonlocal Speed Characteristics

The individual vehicle speed study data were used to evaluate the differences in

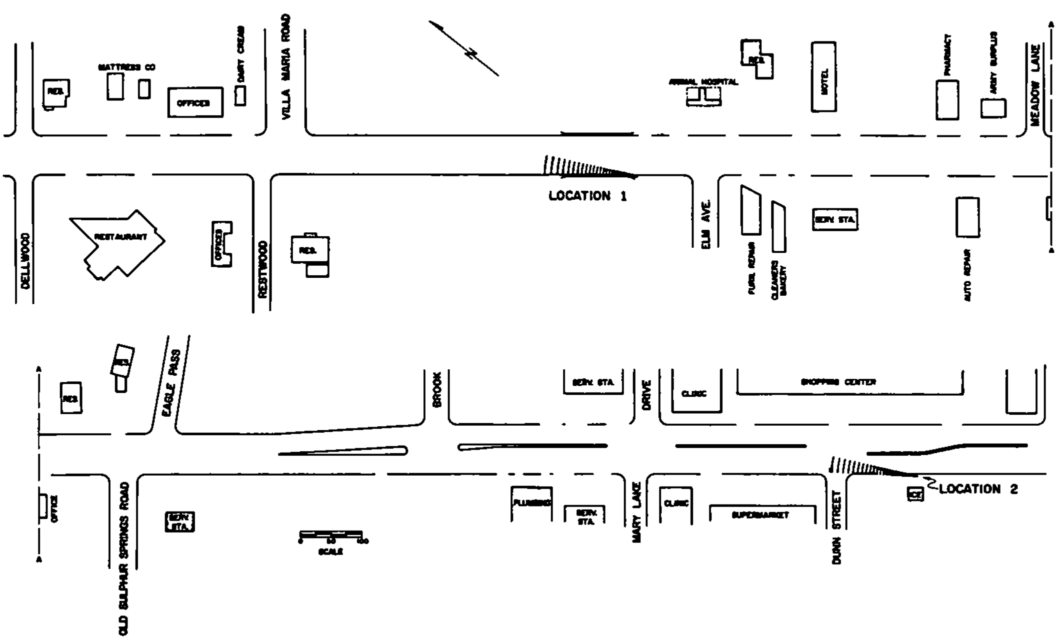


Figure 22. 24-hr speed study locations.

speeds of local and nonlocal vehicle trips. The speeds of the vehicles that traveled the entire length of the urban study section were separated from the total sample and designated as nonlocal vehicle speeds. The remaining portion of the sample, those that traveled through only part of the study section, were designated as local trips. The average speeds of each of these two groups of vehicles were computed for each of the sectors in the study sections. The results are given in Table 14.

A comparison of the two groups shows that the average speeds of nonlocal vehicles were higher than those of local vehicles, almost without exception.

Test Car Study

The test car study method was used to conduct a comprehensive study at one of the previously selected study locations. This location, which was the same as for Study II of the individual speed studies, was selected because of the several geometric influences it presented, and because of the singularity in the type of development (purely residential) in the area. In general, the study site provided a number of influential factors that could be separated for intensive study.

In planning the study, ten drivers were selected to operate the test car on a prescribed route which included the test section selected. The total length of the route was approximately 5 miles, including about 3 miles of rural highway outside the study section. Each of the ten drivers was required to drive the prescribed route in an alternating inbound-outbound pattern until he had completed four acceptable runs in each direction.

The ten drivers selected were students at Texas A & M College, between the ages of 21 and 28. Although they were part-time employees of the Texas Transportation Institute on other projects, they were not familiar with the objectives or survey techniques of this study. Before beginning the test runs, each driver was instructed to drive the prescribed route repetitively. Each driver continued to drive the route until the observer

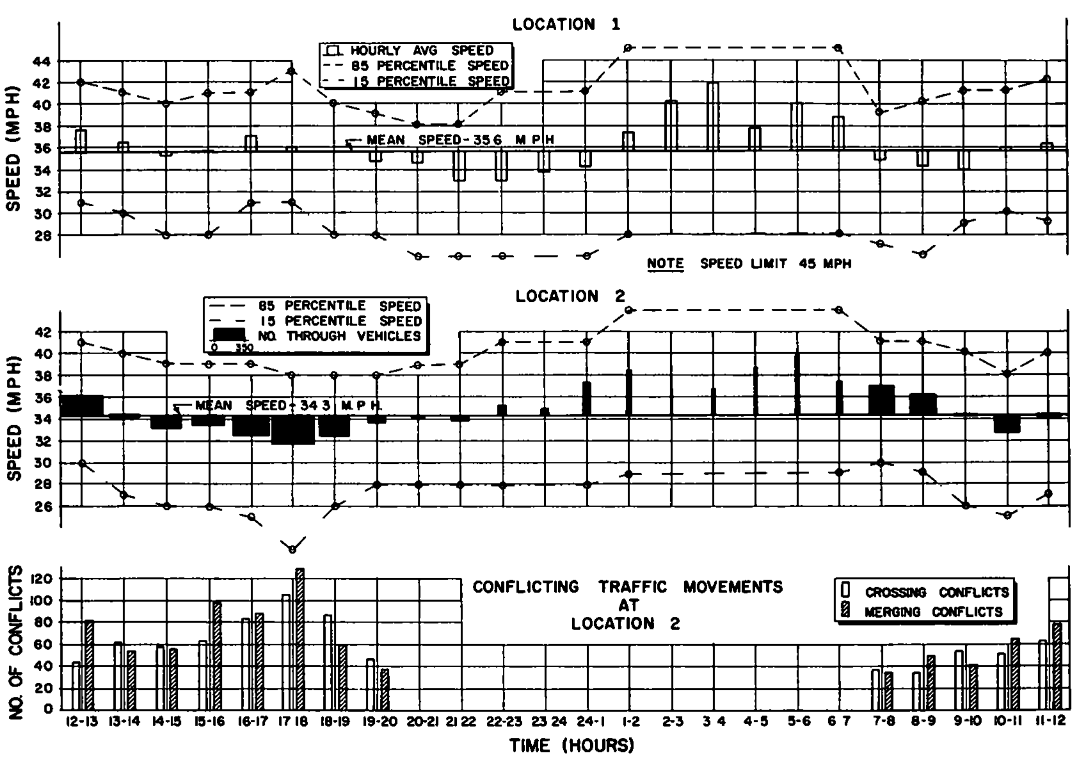


Figure 23. Hourly variations in traffic speeds.

had determined that he had made four runs in each direction without interference from other vehicles.

During the study, the existing speed limit signs were completely covered with paper to eliminate any possible influence on the driver. Also all test equipment except the sequence camera was placed in the rear of the station wagon to simulate as nearly as possible normal driving conditions.

It is probable that the test driver was more alert and more attentive to his driving than a normal driver. The fact that he was employed for the specific purpose of driving the test car is fairly substantial justification for this assumption. However, if most reactions to factors influencing speeds are of a subconscious nature, the test driver should react in much the same manner as the normal driver. This was fairly well substantiated by a comparison of the test car speeds with 85-percentile speeds from the individual vehicle speed study (Table 15). The test car speeds were 9 to 11 mph higher except in Sectors 1 and 6. These differences may have resulted from vehicle performance characteristics. The two sectors in which they occurred were acceleration areas; and the test vehicle, a 1961 six-cylinder station wagon with automatic transmission, had less-than-average acceleration characteristics.

Test car runs were plotted so that the individual runs of each driver could be compared. Because this comparison showed that each driver's runs were very similar in reaction pattern, an average run was plotted for each driver. The average runs for all the drivers are compared in subsequent figures.

The comparison of individual test car runs for each of the drivers indicated a slight increase in speeds in the order in which the runs were made. This trend probably resulted from increased familiarity with the roadway.

To facilitate a comparison of the test car speeds with roadway and development conditions, a strip map of the study section and a plot of sight distance are provided in proper proportion with the speed plots (Figs. 19 and 20). A detailed description of the study section is given in Table 10.

In Figure 21, a series of photographs taken from the test car shows the general characteristics of the roadway as viewed by the driver. These photographs were selected from a more complete series of snapshots taken during one of the travel runs. They provide an acceptable representation of the conditions confronting the drivers during the test runs.

In the evaluation of the results, primary consideration was given to a visual comparison of the speed profile with the existent conditions of roadway geometrics and development characteristics. This comparison pointed up several influencing factors and indicated the point and extent of reaction to these factors.

Results. —Evaluation of the test runs in the inbound direction showed the drivers were decelerating when they entered the test section (Fig. 19). This deceleration continued until a point was reached within the first 4-deg curve. Because these speeds were in excess of the design value of the curve, most of the reduction in speed was attributed to the drivers' evaluation of the physical limitations of the curve. However, due consideration should be given to the fact that sight distance was rapidly decreasing in the presence of limited development as the drivers were nearing the curve, and increased suddenly to more than 2,000 ft at the point where speeds began to increase. (The term "sight distance" describes the distance ahead in which the driver could see the roadway and related development.)

On leaving the first curve, the drivers continued to accelerate until reaching a point where sight distance was reduced to approximately 1,100 ft. From this point, they followed a constant deceleration pattern into the second 4-deg curve. The general appearance of the area in which the deceleration occurred is shown in photo 3 in Figure 21.

Test car speeds were more or less constant in the second curve, but increased slightly on leaving it, even though the density of development was greater than that preceding the curve. However, the sight distance had increased, and as shown in sequence photo 5, the development in the area confronting the driver did not impose any undue lateral sight restrictions. Also, access to the individual residential units was provided by culverts, and very little shrubbery was planted near the roadway.

The next significant change in test car speed was observed when the transition from rural to urban cross-section came into view. At this point, the drivers entered a distinct deceleration pattern that continued to a point approximately 400 ft beyond the transition section. The rapid change in speed was attributed to the change in cross-section accompanied by a significant change in development characteristics. Although the density of the residential units was essentially the same as the drivers had previously experienced in the test section, the appearance was completely different, as shown in sequence photo 7. The change in appearance was caused by extensive planting of trees and shrubbery up to the property line, giving the driver a feeling of lateral restriction. The change in appearance of the development and the change in cross-section combined to give the drivers a feeling of urban conditions, and resulted in a significant speed change.

A less pronounced rate of deceleration was observed following the influence of the transition to urban conditions. The rate of deceleration was comparable to that observed in the approach to the second curve. Sight distance conditions in the two sections were also comparable. In both cases, the drivers were subjected to sight distances less than 1,000 to 1,100 ft.

As the drivers continued in the inbound direction, their speeds became constant when sight distance was again restored. However, they assumed another similar deceleration pattern at approximately 1,000 ft from the intersection of US 75. This intersection was 600 ft outside the test section. The deceleration patterns outside the test section were highly variable depending on the signal at the major highway intersection.

The test car runs in the outbound direction were very similar in many respects to the inbound runs. However, several differences were considered worthy of discussion. Figure 20 shows that the drivers were still accelerating quite rapidly as they entered the test section, 600 ft beyond the signalized intersection. The rate of acceleration decreased slowly as the drivers slowly approached a speed commensurate with the existing conditions. As indicated by the sight distance plot, the drivers were confronted with a crest vertical curve just inside the test section. However, the restricted sight distance imposed by the vertical curve did not appear to influence the speeds because the drivers were still in the process of accelerating to what they considered a normal speed for the existing conditions.

Once the drivers had negotiated the first vertical curve, they were immediately confronted by a second vertical curve completely within the urban section. When sight distance was reduced to approximately 1,200 ft, some of the drivers altered their rate of acceleration. Once sight distance was restored, their speeds increased uniformly. Actually the major change in the speed profile occurred approximately 200 ft from the transition to urban cross-section. Sequence photo 11 shows the roadway ahead of the driver at the point of change.

The next major change in speed occurred in the approach to the first horizontal curve in the outbound direction. The drivers assumed a deceleration pattern when sight distance was reduced to 1,000 ft, and continued to decelerate into the curve until adequate sight distance was restored.

When sight distance was restored, the roadway and surrounding area had assumed an appearance of rural conditions. As a result, the drivers accelerated rapidly, approaching their normal rural speeds. As the drivers approached the second curve in the outbound direction, their sight distance was once more reduced below 1,000 ft, and a slight reduction in speed was observed. This reduction was considered primarily a reaction to the curve, because speeds returned to normal as the drivers passed from the curve into a completely rural section, as shown in sequence photo 16.

Although the sight distance was less than 1,000 ft at the end of the curve, the speed profile indicated a slight increase in speeds. Apparently the drivers did not consider sight distance as important outside the developed areas.

Summary of Findings.—The average test car speeds in each of the sectors were consistently 9 to 11 mph higher than corresponding 85-percentile speeds of the normal drivers. This over-all difference was attributed to the characteristics of the age group of the test car drivers, 21 to 28 years, and their knowledge of being tested.

Through the use of the test car technique it was possible to isolate certain variables for specific evaluation. Because of the continuous speed record, the point of reaction related to a certain variable could often be detected.

The test car study served to substantiate further many of the findings of the individual vehicle speed studies. Of most significance was the influence of sight distance on speeds. In practically every situation where horizontal or vertical curves limited

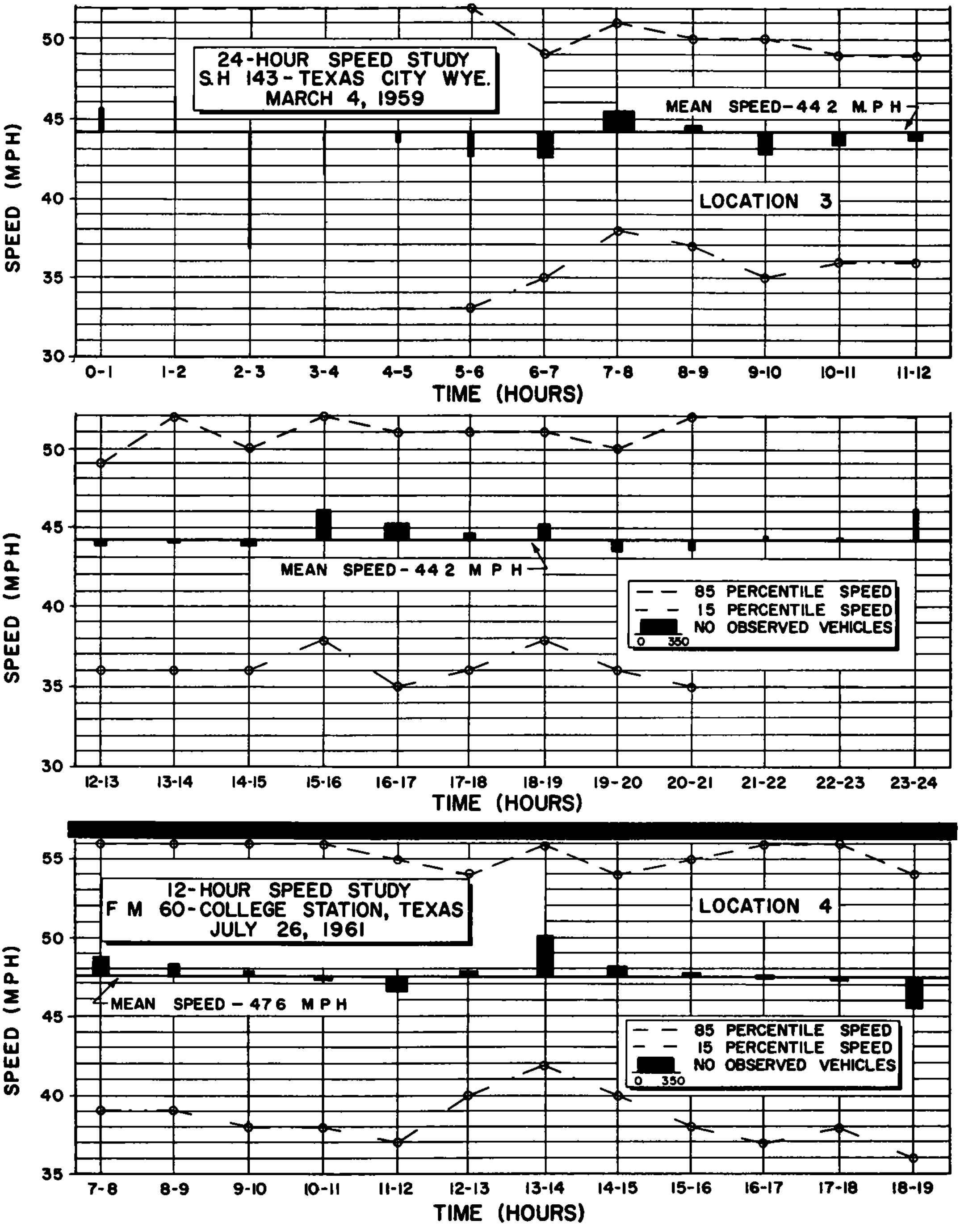


Figure 24. Hourly variations in traffic speeds.

sight distances to less than 1,000 to 1,200 ft, there was a distinct reduction in speeds. The drivers began to decelerate or to decelerate more rapidly each time sight distance became restrictive.

Although the influence of restrictive sight distance was demonstrated in the developed areas, it was apparently of little or no significance in the rural or undeveloped areas.

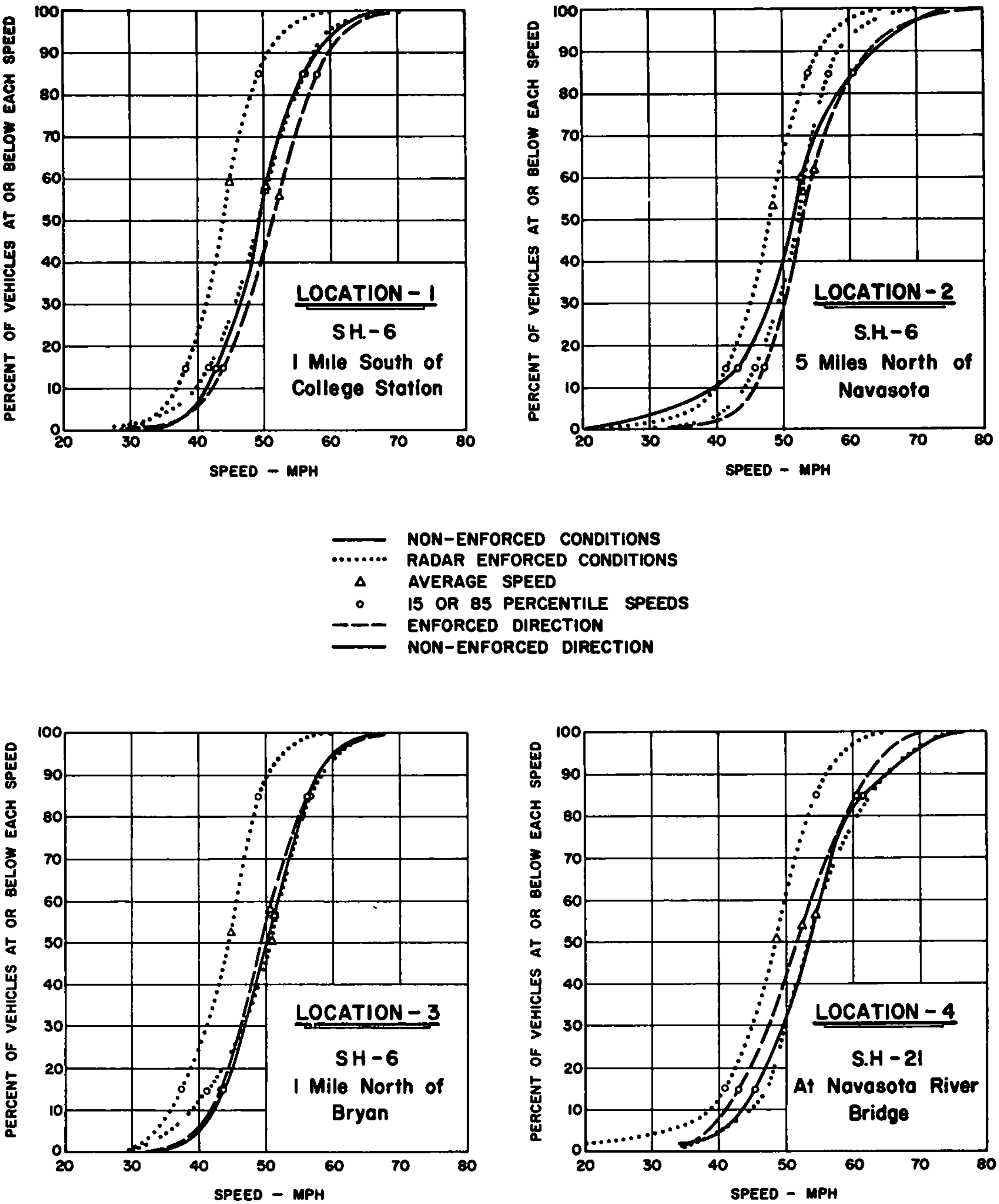


Figure 25. Distribution of traffic speeds operating under non-enforced conditions vs routine radar enforcement.

The influence of the appearance of development and roadway cross-section was also demonstrated in the test car study. The drivers decelerated rapidly over a section extending 400 ft on each side of the transition from rural to urban cross-section. In this same area there was also a significant change in the appearance of the development, caused by extensive shrubbery and trees near the roadway. This combination of factors caused a sudden change from rural to urban appearance.

HOURLY VARIATIONS

Previous research has established that variations in traffic speeds generally exist over a 24-hr period (2). For this reason, it was felt that studies should be conducted to establish a possible relationship between traffic speeds and variations in traffic conditions.

The studies were conducted at four sites to provide data on the variations of speeds throughout the day. Speeds were observed for all vehicles during a 24-hr period at three locations and for a 12-hr period at the fourth location. Concealed radar units equipped with graphic recorders were used to measure speeds.

Study Locations

The studies were conducted at four locations on three different types of roadways:

Location 1.—A midblock location on a four-lane undivided major street that also served as a primary highway route.

Location 2. —An intersection location in a shopping center area on a four-lane, channelized major street (same facility as Location 1) (Fig. 22).

Location 3. —A rural section of a four-lane divided State highway serving an industrial area.

Location 4. —A two-lane secondary highway carrying a rather high volume of traffic for this type of roadway.

Location 1 was a midblock section virtually free from turning movements, whereas Location 2 was at an intersection in a shopping center complex. The studies at these

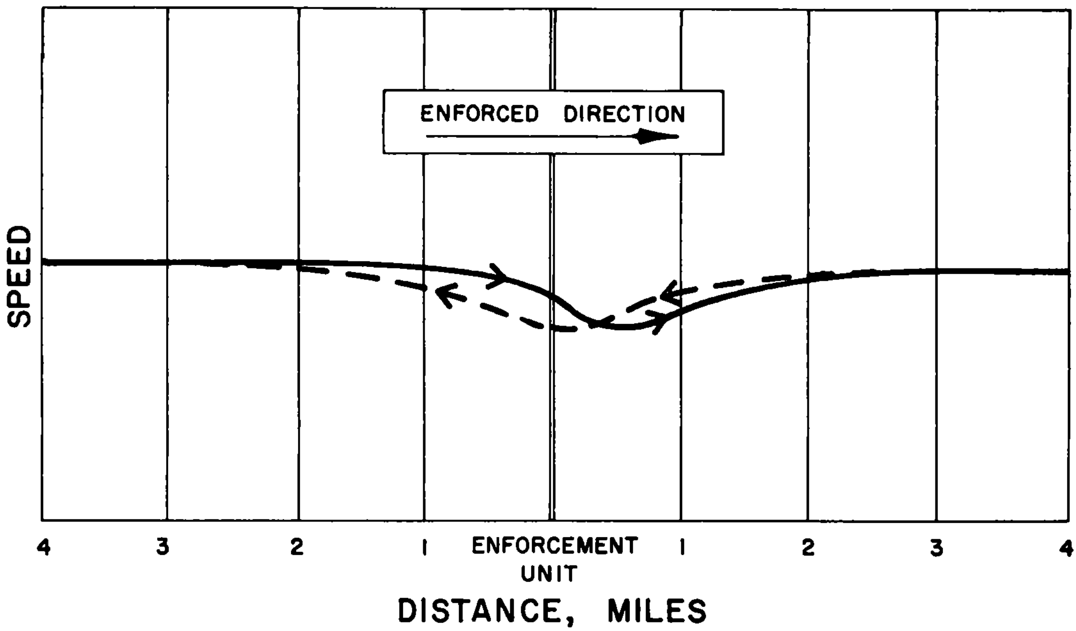


Figure 26. Speed profiles in area of enforcement.

locations were conducted concurrently to provide a comparative evaluation of the effects of turning movements on traffic speeds. At Location 2, observers recorded all turning movements in the intersection area and counted the number of through vehicles in the southbound direction during the business hours. Because of the excessive width of the street and high traffic volumes, speeds were observed in the southbound direction only.

At Location 3, speeds were observed in only one direction of travel, because the facility was a four-lane divided highway.

At Location 4, the study was conducted over a 12-hr period during the daylight hours. Speeds were observed in both directions of travel, and because a graphic recorder was used unattended, the speeds could not be separated according to direction.

Analysis of Data

In each of the studies, the hourly average speed was compared to the mean speed for the entire study, as shown in Figures 23 and 24. The 85- and 15-percentile speeds for those hours having sufficient volume were plotted as an envelope about the mean speed. In the night and early morning hours when volumes were low, hourly speed observations were combined to yield statistically reliable percentile values for the group. This appears as a horizontal line joining two far-removed data points.

On the chart in Figure 23 the number of "through" vehicles for each hour is indicated by the width of the bar. These values, as well as the conflicting movements shown in the lower chart, were determined by manual counting. Because the volumes at Location 1 and 2 were essentially the same, no attempt was made to obtain an actual count at Location 1.

The volumes indicated on the charts for Locations 3 and 4 were determined through interpretation of the speed recorder charts and are therefore subject to a small amount of error due to the normal difficulties involved in measuring speeds of two lanes of traffic simultaneously.

Results

The studies at Locations 1 and 2 provided data for the evaluation of variations in speeds on a typical major street where moderately high volumes and heavy traffic conflicts are experienced. Under these conditions, the maximum deviation from the mean of any hourly average speed was approximately 3 mph, as shown in Figure 23. Larger deviations were noted only in the early morning hours when traffic conflicts were essentially nonexistent. Except for the early morning hours, the 85-percentile speeds varied over a 5-mph range at Location 1 and a 3-mph range at Location 2.

With the exception of the early morning hours, the maximum deviations in average speed occurred during the peak hours. These deviations were not always below the mean as might be expected. At Location 2, the average speeds during the morning and noon peaks ranged from 2 to 3 mph above the mean, even in the presence of moderate conflicts at the intersection. These higher speeds can be explained by considering that the majority of the drivers were under the compulsion of a tight schedule. The concept of the influence of compulsion on the part of the driver is further substantiated by noting the low average speeds at both locations during the off-peak hours (10 to 11 and 14 to 15 hr). At these times the traffic stream was composed largely of shoppers and others who were not influenced by rigid schedules.

The effect of large numbers of conflicts can be realized through a comparison of average speeds at Locations 1 and 2 during the afternoon peaks (17 to 18 hr). The average speed at Location 1 was slightly above the mean, whereas the average speed at Location 2, where the large number of conflicts occurred, was approximately 2.5 mph below the mean (Fig. 23).

There was an apparent difference in the average speeds at Locations 1 and 2 during the morning peaks. This difference was the result of a large number of vehicles entering Texas Avenue from Villa Maria Road (Fig. 22) during this period and had not yet attained normal operating speeds before entering the range of the radar unit at Location 1. Similar differences were observed during the late evening hours (21 to 01). These differences were caused by traffic entering Texas Avenue from a drive-in theater on Villa Maria Road and from a restaurant and drive-in cafe in the general area (Fig. 22). Again, this traffic had not yet attained full operating speeds before entering the range of the radar unit.

The study at Location 3 provided data for the evaluation of the variations in speeds on a high-type facility that primarily served industrial commuter traffic. This service was provided under comparatively low volume conditions and essentially no traffic conflicts.

The peak periods observed in the study reflected the shift changes at refineries and chemical plants in the general area. These shift changes normally occurred in two cycles: 7:00 AM-3:00 PM-11:00 PM; and 8:00 AM-4:00 PM-midnight. The study shows (Fig. 24) that average speeds observed during the shift changes were generally above the mean of the entire study. This further substantiates the previous ideas regarding the relationship between speeds and the pressure of a rigid schedule.

The study at Location 4 was conducted to provide data on variations in speeds on a two-lane secondary type roadway. In addition to serving the rural area, it also provided access to a small commercial airport and to limited facilities for some agricultural research and extension services.

The speeds were observed at a point approximately ½ mile outside the College Station city limit. Although the area was primarily rural, there were widely scattered residences in the general area.

Evaluation of the results showed the maximum deviation in hourly average speeds was approximately 3 mph (Fig. 24). However, deviations were less than 1 mph during 8 of the 12 hours of observation. The greatest variation in the 85-percentile speeds was 2 mph.

Summary of Findings

In each of the four studies, hourly average speeds did not differ greatly throughout the daylight and evening hours. Even smaller variations were noted in the 85-percentile speeds during these periods.

The higher traffic speeds were observed during (a) extremely low volume conditions in the late evening and early morning hours, and (b) rush-hour periods when the driver was operating on a tight schedule. A large number of traffic conflicts resulted in a reduction in traffic speeds.

The result of these studies indicates that traffic speeds varied little throughout daylight hours. The 85-percentile, mean, and 15-percentile speeds during any hour were representative of the speeds during the remainder of the daylight hours. During the peak "rush" hours, increased intersection conflicts caused a reduction in speeds in the vicinity of the intersection. At none of the sites studied was the volume sufficiently close to the capacity of the roadway to cause a significant reduction in speed from the volume of traffic alone.

These studies indicated that for a spot speed study to be representative of a certain section of roadway, the selection of the specific site for the study is an important consideration.

EFFECT OF RADAR ENFORCEMENT

The first phase of the project on effect of radar enforcement on traffic speeds showed that without rigid enforcement drivers generally disregard speed limit signs and select driving speeds according to their judgment of prevailing roadway and traffic conditions. However, little is known of the driver's reaction to efforts aimed at the enforcement of speed limits. From observation, it is evident that the presence of enforcement officials and equipment will reduce traffic speeds, but the extent of the effect in the enforced area and in adjacent sections is not fully known.

A study was undertaken in cooperation with the local highway patrol unit of the Texas Department of Public Safety to determine the effects of routine radar enforcement practices on traffic speeds. The study was designed to indicate changes in speed characteristics in the immediate area of the radar unit and to determine the distance from the radar unit that speeds were affected.

TABLE 18

COMPARISON OF AVERAGE SPEEDS AND PERCENTAGES OF TRAFFIC EXCEEDING SPEED LIMIT

Direction of Travel →
Enforced Direction

Study		4 miles	3 miles	2 miles	1 mile	Enforcement Unit	1.25 miles	2 miles	3 miles	4 miles
Area One	Average Speed, MPH Percent Exceeding Speed Limit	54.1 40*				51.6 30	49.8 12			
Area Two	Average Speed, MPH Percent Exceeding Speed Limit			54.3 43		52.9 32			50.3 19	
Area Three	Average Speed, MPH Percent Exceeding Speed Limit				** 51.8 26	53.4 34		50.0 15		
Area Four	Average Speed, MPH Percent Exceeding Speed Limit					50.8 25		50.2 14		52.1 31

* Speed Limit - 55 MPH
** Slight Effect of Grade

← Direction of Travel
Non-Enforced Direction

Study		4 miles	3 miles	2 miles	1 mile	Enforcement Unit	1.25 miles	2 miles	3 miles	4 miles
Area One	Average Speed, MPH Percent Exceeding Speed Limit	53.8 40				46.6 6	49.7 18			
Area Two	Average Speed, MPH Percent Exceeding Speed Limit			51.6 22		47.8 7				
Area Three	Average Speed, MPH Percent Exceeding Speed Limit				51.6 26	44.6 2		52.0 32		
Area Four	Average Speed, MPH Percent Exceeding Speed Limit					48.4 10		51.7 21		53.3 38

Enforcement Procedure

In routine enforcement operations, the patrol unit used a radar speed meter mounted on a tripod at the shoulder of the roadway. There was no attempt to conceal the unit; however, during the hours of darkness, the radar unit was not readily discernible by the driver until he had entered its range of operation.

During the operation, a patrolman observed speeds from an official vehicle parked 150 to 200 ft beyond the radar unit. He identified speeding vehicles and relayed the information to awaiting patrolmen at the pick-up station normally ¼ to ½ mi beyond the radar unit. Whenever possible, the pick-up station was located within the view of the patrolman observing speeds so that violators could be more positively identified and apprehended. This method of operation limited the apprehension of violators to only one direction of traffic, commonly referred to as the enforced direction.

Study Procedure

Studies to evaluate the effects of enforcement were conducted in two phases. The first phase consisted of studies conducted at isolated locations (a) to record traffic speeds in each direction of travel at the enforcement radar unit during enforcement operations and (b) to observe traffic speeds with a concealed radar unit at the same locations without the presence of enforcement officials. In the second phase, studies were conducted to determine how far the effect of enforcement extended along the roadway on each side of the enforcement unit. To accomplish this aim, concealed radar units were used to observe traffic speeds during enforcement operations in an "area" which extended 4 mi on either side of the enforcement unit.

Study Locations

The locations selected for all studies were in general conformance with the convenience and best interests of the enforcement officials. They were normally situated in sections of roadway where speeds were not governed by geometrics. The locations for speed studies in the first phase, the point survey, were as follows:

Location 1.—Texas 6, 1 mi south of College Station.
Location 2.—Texas 6, 5 mi north of Navasota.
Location 3.—Texas 6, 1 mi north of Bryan.
Location 4.—Texas 21, Navasota River Bridge.

In the second phase which consisted of the "area" enforcement studies, an exact number of study locations could not be predetermined. With the two radar units available for research purposes, it was necessary to conduct studies on four different occasions to obtain sufficient data for the analysis. These four studies were not conducted at the same location because it was thought that repeat drivers would have begun to anticipate radar operations. The locations at which the area studies were conducted are as follows:

Area 1.—Texas 6, south of College Station. Research radar units located 4 mi in advance and 1.25 mi beyond enforcement unit.

Area 2.—Texas 6, south of College Station. Research radar units located 2 mi in advance and 3 mi beyond enforcement unit.

Area 3.—Texas 36, north of Caldwell. Research radar units located 1 mi in advance and 2 mi beyond enforcement unit.

Area 4.—Texas 6, south of College Station. Research radar units located 2 mi in advance and 4 mi beyond enforcement unit.

Analysis of Data

The analysis of data from the enforcement studies was aimed at evaluating by comparison any differences in traffic speeds or their distribution resulting from radar enforcement operations. To facilitate this comparison, the speed characteristics given in Tables 16 to 18 were calculated, and the speed distribution curves were plotted.

TABLE 19

SUMMARY OF RESULTS, AREA ENFORCEMENT STUDY

AREA ONE

State Highway 6 - 4 Miles South of College Station

E - Enforced Direction
O - Opposing Direction

Location A ○ — 4 Miles — ■ Enforcement Unit — 1.25 Miles — ○ Location D

	Location A Research Unit		Enforcement Unit Enforced Direction →		Location D Research Unit	
	E	O	E	O	E	O
Total No. of Vehicles	303	186	283	158	308	160
Average Speed, MPH	54.1	53.8	51.6	46.6	49.8	49.7
85-Percentile Speed, MPH	59	60	57	51	54	56
15-Percentile Speed, MPH	48	46	44	39	44	42
Speed Differential, MPH	11	14	13	12	10	14
Percent Exceeding 55 MPH	39.6	40.0	30.0	6.3	12.3	18.1
Percent Exceeding 60 MPH	13.5	14.5	7.8	1.8	2.0	3.5
Standard Deviation, S	6.75	7.15	6.90	6.32	4.83	6.89

AREA TWO

State Highway 6 - 11 Miles South of College Station

E - Enforced Direction
O - Opposing Direction

Location B ○ — 2 Miles — ■ Enforcement Unit — 3 Miles — ○ Location G

	Location B Research Unit		Enforcement Unit Enforcement Direction →		Location G Research Unit	
	E	O	E	O	E	O
Total No. of Vehicles	204	191	207	164	220	
Average Speed, MPH	54.3	51.6	52.9	47.8	50.3	
85-Percentile Speed, MPH	60	56	58	52	55	
15-Percentile Speed, MPH	48	45	46	41	45	
Speed Differential, MPH	12	11	12	11	10	
Percent Exceeding 55 MPH	43.1	22.5	31.9	6.7	18.6	
Percent Exceeding 60 MPH	14.2	4.7	8.7	1.8	0.9	
Standard Deviation, S	6.07	6.23	6.20	5.41	5.50	

AREA THREE

State Highway 36 - 7 Miles North of Caldwell

E - Enforced Direction
O - Opposing Direction

Location C ○ — 1 mile — ■ Enforcement Unit — 2 miles — ○ Location E

	Location C Research Unit		Enforcement Unit Enforced Direction →		Location E Research Unit	
	E	O	E	O	E	O
Total No. of Vehicles	179	89	160	79	182	84
Average Speed, MPH	51.8	51.6	53.4	44.6	50.0	52.0
85-Percentile Speed, MPH	58	56	61	48	54	59
15-Percentile Speed, MPH	45	45	45	39	43	43
Speed Differential, MPH	13	11	16	9	11	16
Percent Exceeding 55 MPH	26.3	25.9	34.3	2.5	15.4	32.2
Percent Exceeding 60 MPH	7.8	3.4	16.8	1.3	0	9.5
Standard Deviation, S	6.50	5.84	7.46	5.41	4.88	7.39

AREA FOUR

State Highway 6 - 9 Miles South of College Station

E - Enforced Direction
O - Opposing Direction

■ Enforcement Unit — 2 miles — ○ Location F — 4 miles — ○ Location H

	Enforcement Unit Enforced Direction →		Location F Research Unit		Location H Research Unit	
	E	O	E	O	E	O
Total No. of Vehicles	215	117	263	158	280	169
Average Speed, MPH	50.8	48.4	50.2	51.7	52.1	53.3
85-Percentile Speed, MPH	57	53	54	56	57	59
15-Percentile Speed, MPH	44	41	44	45	45	46
Speed Differential, MPH	13	12	10	11	12	13
Percent Exceeding 55 MPH	25.1	10.3	13.7	20.9	31.4	37.9
Percent Exceeding 60 MPH	5.6	0.9	1.2	7.0	5.0	13.0
Standard Deviation, S	6.70	5.64	5.00	5.82	6.15	7.38

In the analysis, the speeds of trucks and buses were separated from passenger car speeds and given special consideration.

Results

Phase I, Studies With and Without Enforcement. —Evaluation of the results of studies conducted at the four locations with and without enforcement activity showed enforcement caused a reduction of traffic speeds in the direction opposite to the enforced direction (Fig. 25). This reduction was attributable to enforcement activity because there was no significant difference in speeds by direction of travel when observed under conditions of no enforcement. The difference observed under enforced conditions was largely attributable to the presence of the pick-up unit, which the drivers in the opposing direction had observed shortly before arriving at the radar unit.

Comparison of the average speeds given in Table 16 shows the magnitude of the speed differences resulting from enforcement ranged from 5.0 to 6.6 mph. Comparison of other speed characteristics indicates similar differences.

Although the 4-hr periods of speed observation at each study location provided good sampling of passenger cars, no one study provided a reliable sample of truck speeds. For this reason, truck speeds of all studies conducted with the enforcement unit were combined with respect to their direction of travel. In the studies with no enforcement, truck speeds for all locations were combined to form one large sample. This was considered permissible because an analysis showed no appreciable difference in speeds by direction of travel in the studies with no enforcement.

For further comparison, truck speeds from spot speed studies made during daylight hours in the four locations given in Table 17 were combined to form a sample. These studies were conducted on weekday afternoons using the concealed research radar unit.

Table 17 shows the various combinations of data made it possible to compare truck speeds under four different conditions:

1. Normal operation during daylight hours.
2. Normal operation during night hours.
3. During enforcement at night in the enforced direction.
4. During enforcement at night in the opposing direction.

The results indicated that truck speeds were essentially the same for day and night conditions in the absence of enforcement operations. Although the speed limit for trucks was 45 mph, the average speeds under each of the two conditions were 49.4 and 49.9 mph, respectively. It is notable that approximately three-fourths of the trucks were exceeding the speed limit.

The comparison of truck speeds at night under conditions of enforcement and no enforcement shows a decrease in the average speed from 49.9 to 46.7 mph in the enforced direction. This decrease was probably the result of "passing the word" among the truck drivers, a practice which seemed to be much more prevalent with truck drivers than with passenger car drivers.

The most significant reduction in truck speeds was observed in the opposing direction of travel, where the vehicles passed the pick-up unit before arriving at the enforcement radar unit.

Phase II, Area Studies. —The results of the "area" enforcement studies indicate that the influence of enforcement operations loses significance within approximately 4 mi on either side of the enforcement unit. However, these studies do not show and were not intended to show the far-reaching effects of the over-all enforcement program. To provide this evaluation it would be necessary to study the speed characteristics of a roadway before the initiation of an enforcement program in comparison with the speed characteristics of the roadway after the enforcement program was established.

The extent to which enforcement affects speeds in areas adjacent to the enforcement unit can be ascertained through a careful study of the speed characteristics of the "area" studies given in Table 19. To permit an easier evaluation of the results of the studies, the average speeds and percent of vehicles exceeding the speed limit have been extracted and are given in Table 18. This summary of results shows that speeds in both directions were essentially the same and were apparently unaffected by enforcement at a point 4 mi in front of the enforcement unit. However, in this same study a significant reduction in the average speed of traffic in the enforced direction had occurred when the traffic arrived at the enforcement unit. A further reduction was observed at a point 1.25 mi beyond the unit. Very substantial reductions were observed in the percent of vehicles exceeding the speed limit.

In the area 2 study, traffic speeds in the enforced direction at a point 2 mi in front of the enforcement unit apparently were not yet affected by the enforcement activity. When the traffic arrived at the enforcement unit, the average speed and the percent of traffic exceeding the speed limit had decreased. Further reductions were observed 3 mi beyond the unit.

In the area 3 study, the radar unit placed 1 mi in front of the enforcement unit was located on an upgrade to the traffic in the enforced direction. Although the grade was not recognized as a speed deterrent at the time of the study, the results showed that speeds at this point were lower than at the enforcement unit. Also, low volume conditions on the roadway reduced the effect of "passing the word" by drivers that had observed the enforcement activity.

A comparison of the speeds in the enforced direction at the enforcement unit and at a point 2 mi beyond, showed a substantial reduction in average speed and the percent of traffic exceeding the speed limit.

In area 4 the research units were located 2 mi beyond the enforcement unit. This study indicated only a slight reduction in average speeds between the enforcement unit and a point 2 mi beyond. However, the traffic exceeding the speed limit had decreased significantly.

At a point 4 mi beyond the enforcement unit, traffic speeds had not completely returned to normal when compared with speeds in the opposing direction. However, the differences in speed at that point were minor.

A general comparison of speeds within the area of enforcement operations has shown that traffic in the enforced direction began to reduce speed at some point within 2 mi in front of the enforcement unit. This reduction was apparent at the enforcement unit, but possessed greater significance at points 1 to 3 mi beyond the unit. The traffic speeds had, for all practical purposes, returned to normal at a distance of 4 mi beyond the enforcement unit.

A similar comparison of speeds in the opposing or nonenforced direction showed that traffic had begun to reduce speed at a distance of 2 mi from the enforcement unit. Again this influence was attributed to "passing the word." From the point at 2 mi, speeds in the nonenforced direction continued to decrease, reaching a minimum at the enforcement unit. The significant reduction in speed at the enforcement unit was the result of drivers' having just passed the pick-up unit. From observation, it appeared that drivers inherently reacted to the presence of a patrol officer regardless of the speed at which they were traveling.

Traffic speeds in the opposing direction did not completely return to normal immediately after passing the enforcement unit. The influence was still evident 2 mi from the enforcement unit but had dissipated at 4 mi.

In comparing speeds by the direction of travel at the enforcement unit, the studies in areas 1, 2, and 3 show differences in average speed of 5.0 to 6.8 mph, whereas area 4 shows a difference of only 2.4 mph. In the latter study, the pick-up unit was located approximately ½ mi from the enforcement unit as compared with approximately ¼ mi in the other three studies. This comparison suggests that the pick-up unit was the primary cause of the speed reductions.

Figure 26 shows the general influence of radar enforcement on traffic speeds. The speed profiles show the minimum speed to be in the vicinity of the pick-up unit. Although speeds were not measured at the pick-up unit for practical reasons, field observation showed that the maximum speed reduction occurred in that general area.

CONCLUSIONS

The following conclusions have been drawn from the results of this research:

1. Substantial speed reductions occurred when sight distance was below 1,000 to

1,200 ft. This sight distance, defined as the distance ahead in which the driver could see the roadway and related development, appeared to alter the driver's choice of speed only in developed areas where there were potential traffic conflicts.

2. The introduction of a curbed urban street cross-section had an effect on the speed pattern.

3. Continuous residential development caused a reduction in traffic speeds. The extent of this reduction was more dependent on the lateral restrictions it imposed than on the relative density of development. Extensive planting of trees and shrubbery near the roadway contributed greatly to this result.

4. Concentrated commercial development in transition areas caused substantial reductions in traffic speeds.

5. The faster drivers in the rural areas were generally the faster drivers throughout the transition areas. Generally, the speed groups remained in the same relative position in the over-all distribution throughout the rural and urban areas.

6. The speeds of vehicles making trips entirely within the developed area were consistently slower than vehicles traveling through the developed area.

7. The test car technique is a reliable means of predicting normal driver reactions to factors influencing traffic speeds.

8. In the 24-hr speed studies, there were no substantial differences in hourly average speeds within the hours of normal traffic operation. Even smaller variations were observed in the 85-percentile speeds.

9. Traffic speeds were reduced in the immediate vicinity of radar enforcement activity. The localized influence of enforcement had essentially dissipated at 4 mi on either side of the radar unit.

RECOMMENDATIONS

The results of this research have shown that traffic responds to changing conditions on the roadway and surrounding area in a manner that is definitely in the interests of safety. Therefore, it is logical that speed limits be established using as a basis the characteristics of traffic speeds observed on the roadway. Any method or procedure of speed zoning that truly represents the speed characteristics of the traffic is acceptable.

It is reasonable that the speed characteristic chosen as a basis for speed zoning be representative of the majority of the traffic on the roadway. This majority is best defined by a speed value on a cumulative speed distribution curve above which the higher speed values are associated with rapidly decreasing percentages of vehicles; i.e., the breakpoint of the curve. Numerous observations have shown that this breakpoint is closely approximated by the 85-percentile speed.

It is recognized that traffic volumes on many secondary roadways are often too low to provide adequate samples of spot speed data within a reasonable length of time. Under such conditions it appears reasonable that methods of predicting traffic speed characteristics based on prevailing conditions would be much more economical and equally or more reliable than the small speed samples obtainable. However, based on this research, numerical values cannot be assigned to factors influencing speeds because each of the factors most frequently occurs in combination with other factors. These factors are believed to impose variable influences, depending on the specific combination, and on their sequence of occurrence within the developed area.

It is possible that a straight line relationship could be used to predict with reasonable accuracy speed characteristics in short, compact transition sections in small towns. However, fixing the end points of the line would depend on good engineering judgment. Generally, the rural speed limit could be used at the beginning of concentrated development. The urban end could be fixed by a reliable spot speed study at the inbound end of the transition section.

In longer transition sections where the straight line relationship does not necessarily apply, the test car method could be used in conjunction with a very limited number of reliable spot speed studies to predict the traffic speed characteristics continuously throughout the transition area.

This research has shown that traffic operation on a facility is directly related to its geometric design and the character of development along the roadway. Therefore, if proper consideration is given to the influence of geometric elements and future development, it is possible to predict the level of service afforded throughout the design life of the facility.

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A Theory on Vehicular Speed Regulation

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This conceptual study resulted in the theoretical development of a rational technique designed to ascertain scientific warrants for the regulation of vehicular speeds. The investigation was predicated on the need for an engineering approach to an important problem in the operation of the highway transportation system—proper speed limits.

Speed regulations can be developed for any given highway or street location by using the following procedure: (a) the optimal speed that minimizes the cost of highway transportation is first selected; (b) the adjusted speed is derived from the optimal speed by subtracting the reduction in speed occasioned by those driver, vehicle, roadway, traffic, and environmental variables that significantly modify vehicular speeds (this technique accounts for those conditions that differ from the ideal travel conditions for which the optimal speed is determined); and (c) statistical relationships between the upper and lower speed limits and the adjusted speed produce the posted speed regulations. The actual mean speed of the traffic stream should conform to the adjusted speed as the result of proper enforcement and driver education. Statewide speed limits can be evolved from the first and third steps for different vehicle types during daytime or nighttime travel on various roadway facilities in different areas of traffic operation. A technique employing all three steps permits the designation of speed limits (regulatory or advisory) for highway and street locations where various physical and environmental factors influence traffic-stream conditions.

• THE EFFECTIVE operation and control of traffic on various highways and streets necessitates the regulation of speeds of motor vehicles. To control vehicular speeds on these roadway facilities properly, an acceptable criterion must be developed to serve as the foundation for speed-zoning warrants.

Highway and traffic engineers are frequently confronted with this problem of speed regulation in an attempt to accommodate the ever-increasing volumes of vehicular traffic with their demands for inexpensive, safe, rapid, and comfortable travel. However, no concept or theory presently exists for the rational determination of vehicular speed limits. In several instances, qualitative ideas have been advanced as the desirable benefits that should accrue from the application of vehicular speed regulations, but no practical speed warrants have been developed from these ideas. The determination of speed controls is ascertained either by arbitrary selection of speed limits (such as statewide speed limits in specific land-use areas) or by designation of speed limits that correspond to some speed measure of the existing traffic (such as 85th-percentile speed or 10-mph pace). It is quite evident that existing techniques and warrants for speed control are not predicated on a scientific basis.

The Vehicular Speed Regulation Project IHR-53 at the University of Illinois has been charged with the development of scientific warrants for the regulation of vehicular speeds. The purpose of this report was to conceive and develop a rational criterion for the scientific determination of warrants for vehicular speed-zoning. An engineering approach to the basic necessity of providing efficient and economical highway transportation provided the basis for the establishment of a theory for vehicular speed regulation.

THEORY

The general functions of a highway facility are to provide the necessary physical plant for the expedient movement of relatively large volumes of highway motor vehicles between desired origins and destinations and/or to provide access to various forms of land use. It is essential that both of these purposes be accomplished with a high degree of safety and acceptable levels of comfort and convenience.

The transportation of persons and goods on highway and street systems is a branch of industry that consumes a considerable portion of national resources, both natural and human. The consumption of resources in promoting place and time utilities through highway transportation can be analyzed according to the following categories:

1. Economics of vehicle operation,
2. Values of time to drivers and passengers,
3. Safety of travel, and
4. Travel comfort and convenience.

To produce the maximum benefits and services for a given investment of capital, labor, land, managerial ability, and technical innovation in any branch of industry, proper allocation of these resources must be made among various alternate uses. Thus, the most efficient allocation of resources (input) to and within the highway transportation industry is essential to the realization of the optimum production (output) of benefits and services in the highway transportation system.

The effective operation of the economic system requires that highway transportation services of high quality be provided at a minimum cost. Therefore, a criterion for the establishment of regulations controlling the speeds of highway motor vehicles was formulated on the premise that maximum and minimum speed limits should be established to minimize the costs of highway transportation. This involves the establishment of speed limits that result in a majority of the highway traffic moving at that desirable speed which minimizes the consumption of those resources that are a function of vehicular speed. To permit the evaluation of these resource expenditures in their proper proportions, it is necessary to measure them on a quantitative scale that is admissible to arithmetic operations. This was accomplished by basing the following categories on the expenditure of resources per mile of travel:

1. Operation cost,
2. Time cost,
3. Accident cost, and
4. Service (comfort and convenience) cost.

Graphical relationships of these cost factors and the total costs for various speeds can be developed from macro-economic studies of vehicular travel on various types of highways (two-lane and multilane) in different types of traffic areas (rural, intermediate, residential, and business). These cost curves can be further refined for daytime and nighttime travel conditions and for different types of highway motor vehicles (passenger car and commercial vehicle).

According to this concept, the speed at which vehicles must travel to minimize the cost of highway transportation can be selected from the minimum point on the total cost curve. This speed value is defined as the "optimal speed" for the specified conditions for which the curves are developed. To validate this reference point, these cost curves must be representative of motor vehicle travel for roadway and traffic conditions that are nearly ideal; that is, the speed of operation is not limited by the characteristics of physical and environmental factors. Optimal speeds evaluated from economic analyses for various highway types, traffic areas, and vehicle types for daytime and nighttime travel under ideal conditions are the desired operating speeds for statewide or area-wide speed-zoning. However, speeds of highway motor vehicles are not uniform but represent an approximately normal distribution. The optimal speed must represent the central value of this distribution. In other words, this optimal speed should conform to the mean or 50-percentile speed of the highway traffic. The optimal speed is less than the upper speed limit and is greater than the lower speed limit.

In the development of vehicular speed regulations, it is necessary to consider those highway and street locations whose physical and/or environmental conditions do not coincide with the ideal travel conditions on which the economic analyses are evaluated. Because of certain physical restrictions (such as high-volume flows, restricted pavement widths, restricted lateral clearances, and critical alignment) and environmental restrictions (such as inclement weather, slippery pavement, and reduced visibility), relationships between optimal speeds of vehicular travel and significant influences of these factors on vehicular speeds must be measured. By the use of statistical procedures and the collection of speed data by proper sampling techniques, relationships can be developed for these restraining conditions.

It would be improper to specify a maximum or minimum speed limit based on information obtained from economic analyses for ideal roadway and traffic conditions where these speeds are not feasible because of physical and/or environmental limitations imposed on the traffic streams. However, the optimal speed is first specified by the economic considerations of highway travel. For those highway and street sections whose conditions are not similar to the ideal travel conditions on which the optimal speed is warranted, this speed is modified by the physical and/or environmental effects on vehicular speeds.

This procedure is similar to the technique utilized in the computation of capacities for highways and intersections. This microanalysis of roadway sections is employed in the selection of desirable speeds for regulatory or advisory speed-zoning where the travel speed is modified by physical and environmental factors existing on these roadway sections. After the optimal speed is adjusted for these restrictions on traffic-

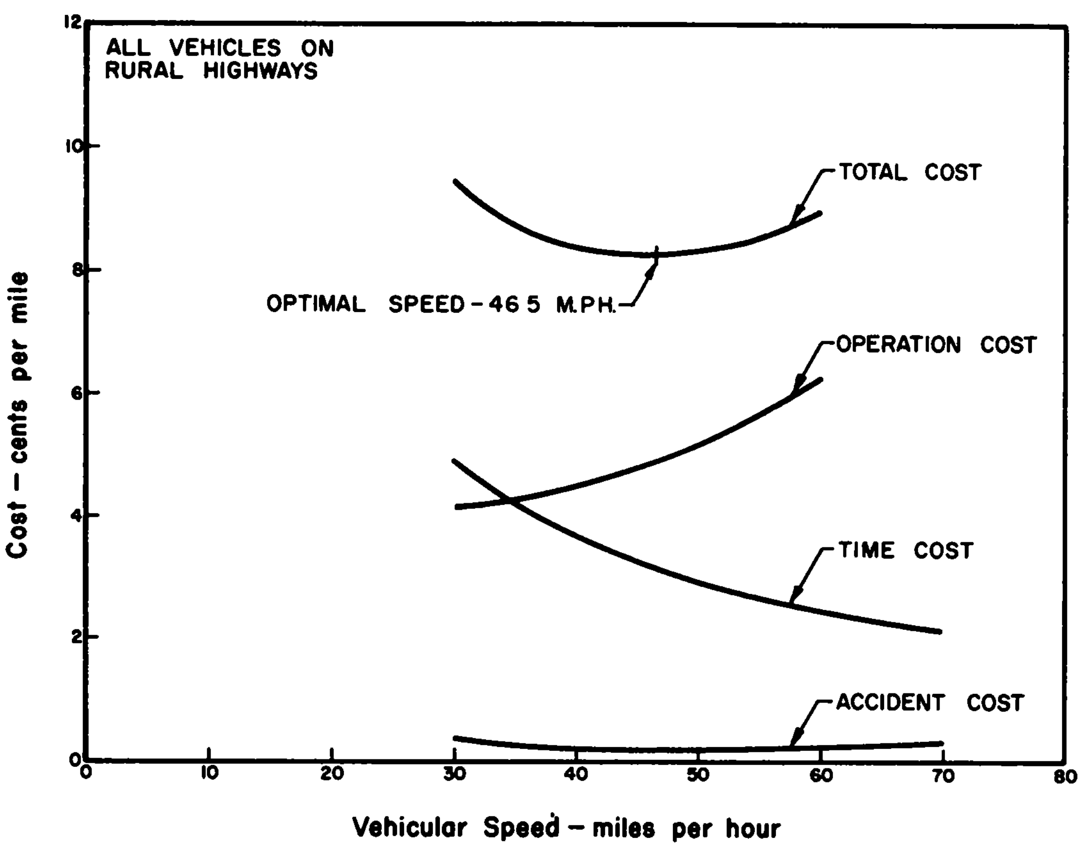

Figure 1. Cost of highway transportation vs vehicular speed—two-lane, daytime.

stream flow, the new speed value is defined as the "adjusted speed." Again, upper and lower speed limits are selected in such a manner that the average speed of travel on the roadway section being speed-zoned coincides with the adjusted speed.

The resulting speed distribution produces traffic-stream characteristics that not only minimize the cost of highway transportation but further maximize the efficiency of the highway or street facility by having vehicles traveling at a more nearly uniform speed.

ANALYSIS

Quantitative analysis of the theory outlined in the preceding section must be undertaken to evaluate speed-zoning warrants. This section considers and appraises the reduction of the conceptual model to a working procedure capable of determining upper and lower speed limits that are feasible for the regulation of vehicular speeds.

Optimal Speed

A macroanalysis of the cost components of highway transportation provides a determination of the optimal speed. At present, only cost information for various operating speeds is available for the elements of operation, time, and accidents. The service (comfort and convenience) costs are relatively intangible quantitites to which it is difficult to assign monetary values. However, it can be assumed that this cost item increases at low speeds (driver impatience) and at high speeds (driver tension), whereas at intermediate speeds the service cost is minimized in the region of driver satisfaction (7).

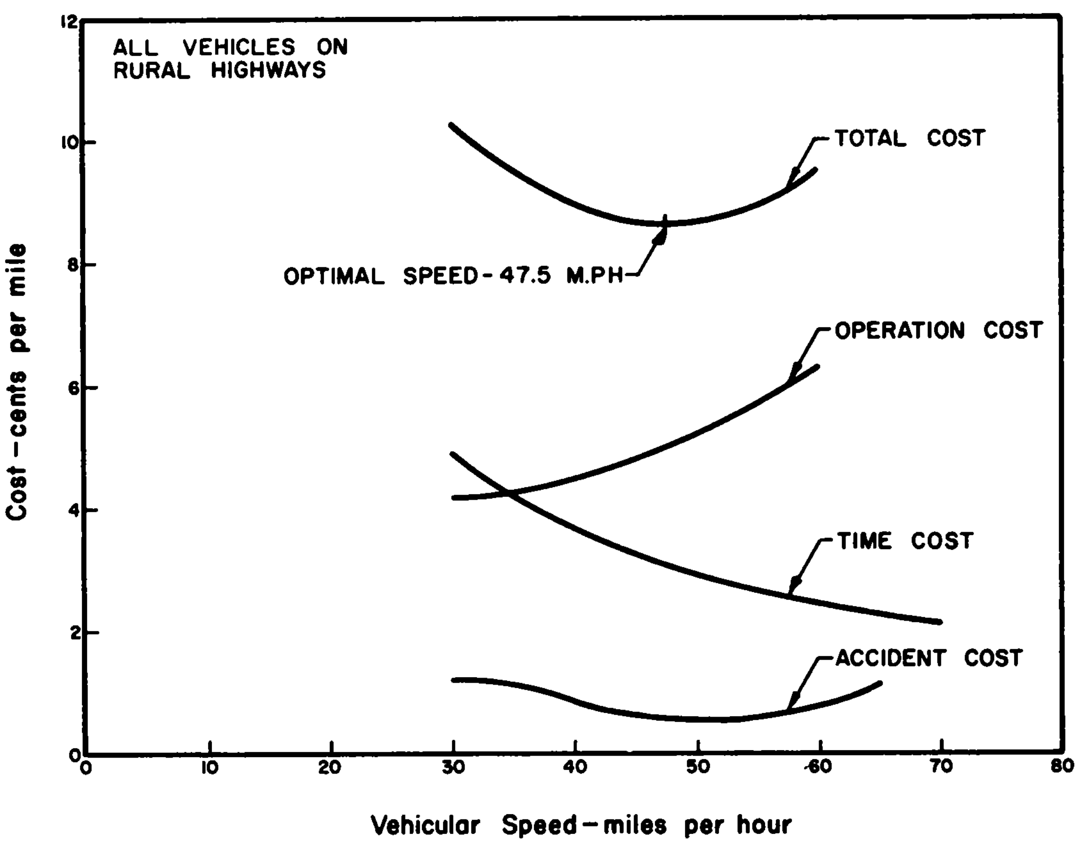

Figure 2. Cost of highway transportation vs vehicular speed—two-lane, nighttime.

Analyses of the costs of highway transportation are shown in Figures 1 to 4. These figures show how each individual item and the total cost vary with speed of travel for all vehicles on rural highways. The economics of travel on two-lane facilities are shown in Figure 1 for daytime operation and in Figure 2 for nighttime operation. Corresponding analyses for four-lane highways are shown in Figures 3 and 4 for daytime and nighttime conditions, respectively. The minimal point on the total cost curve defines the optimal speed for the specified conditions of the economic analysis. From data available, optimal speeds were determined for all vehicles representing 81.0 percent passenger cars, 10.0 percent light trucks, 6.4 percent single-unit trucks, and 2.6 percent combination trucks on rural highways as follows:

1. Two-lane, daytime 46.5 mph,
2. Two-lane, nighttime 47.5 mph,
3. Four-lane, daytime 50.0 mph, and
4. Four-lane, nighttime 51.0 mph.

This technique is valid where speed-zoning regulations apply uniformly to the entire traffic movement. If speed limits are to be developed for different classes of vehicles (passenger car, truck, etc.), then the optimal speed for each class can be ascertained from highway transportation costs differentiated according to vehicle type.

The element of traffic safety has often been advanced as the primary objective of speed regulation. The development of accident costs (antithesis of safety) concerns both the rate of involvement in traffic accidents (8) and the severity per involvement at different travel speeds and attempts to maximize safety by minimizing the cost of

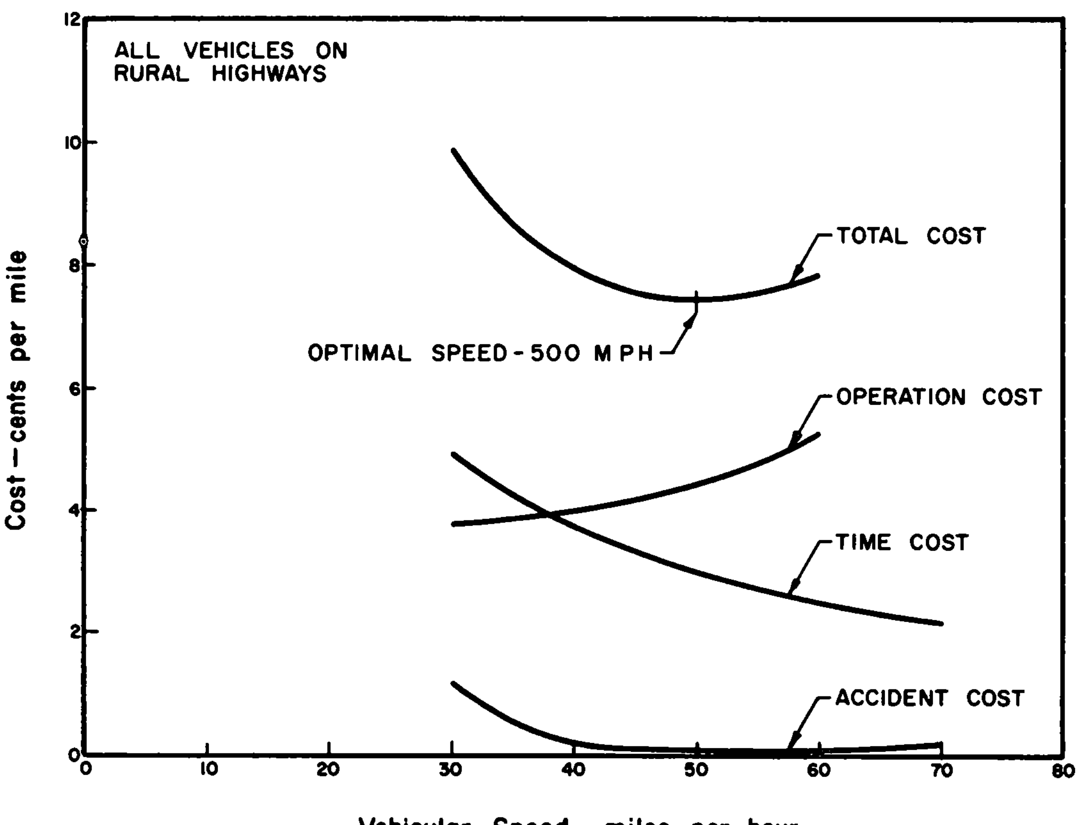

Figure 3. Cost of highway transportation vs vehicular speed—four-lane, daytime.

accidents. The accident cost for a given speed is the product of the severity at that speed and the involvement rate at the same speed. Rather high involvement rates at low speeds are shown in Figures 5 and 6, whereas in Figures 7 and 8 the severity per involvement is shown to increase with higher operating speeds. It is evident that the optimal speed is not appreciably altered when safety is considered as the sole element for speed-zone warrants. Thus, this theory tends to maximize safety by selecting an optimal speed that minimizes the combination of traffic accident involvements and the degree of accident severity per involvement.

When sufficient economic data on highway transportation costs become available, then the optimal speed for any given vehicle type on any given roadway facility in any given traffic area for daytime or nighttime travel can readily be determined for ideal roadway and traffic conditions. This engineering approach to vehicular speed regulation optimizes the operation of motor vehicles in the highway transportation system.

Adjusted Speed and Modifying Factors

Before an acceptable criterion can be formulated for the establishment of speed-zoning warrants, a comprehensive investigation of the characteristics of vehicular speeds must be undertaken. The evaluation of speed characteristics necessitates the appraisal of those driver, vehicle, roadway, traffic, and environmental conditions that determine or significantly modify vehicular speeds.

When the speed of motor vehicle operation is not limited by these travel variables, the individual driver has relatively free operational conditions and can select his desired speed of travel. When conditions permit road users to travel at their desired

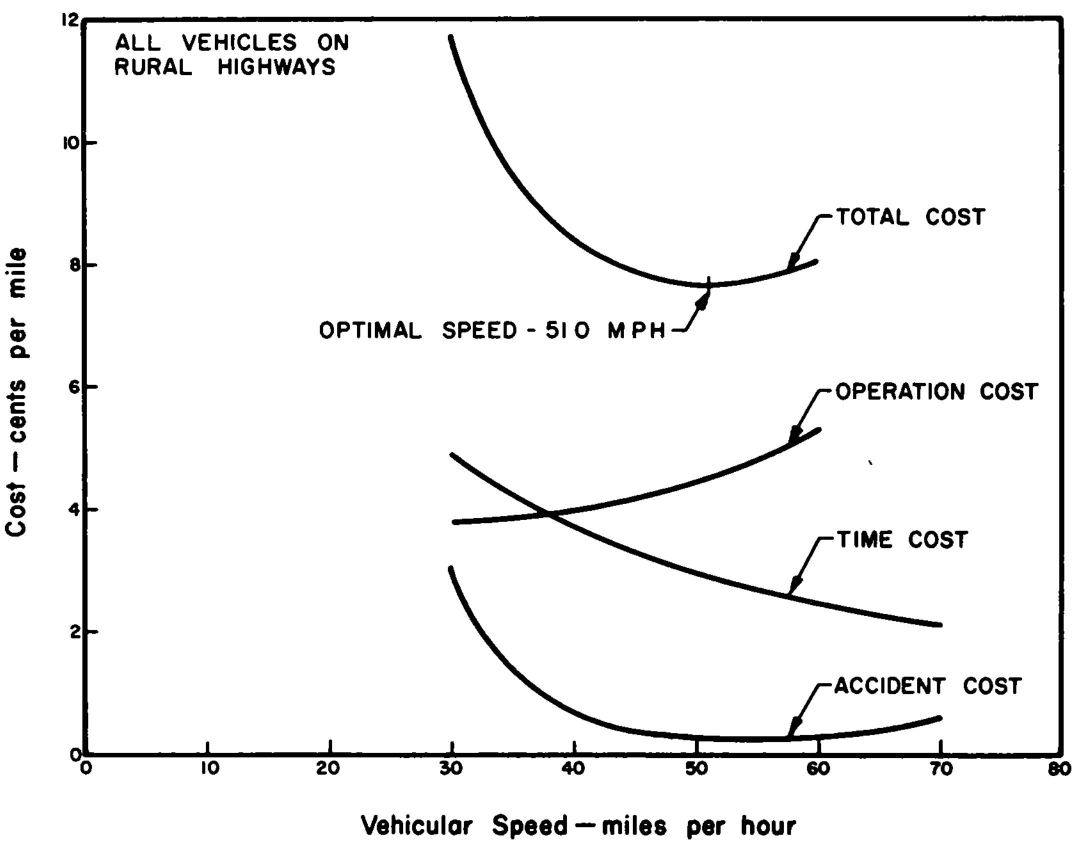

Figure 4. Cost of highway transportation vs vehicular speed—four-lane, nighttime.

speeds, there is a wide range in speeds at which various operators drive their motor vehicles (1). However, research investigations have shown that various restrictions to the flow of traffic produce average speeds of the non-free-flowing traffic that are less than those speed values for free-flowing conditions (4). In many instances, the relationship between average speed and a specific traffic-stream restriction, with all other variables maintained constant, is approximately linear with a negative slope.

Because of the influence of traffic density on vehicular speed, the relationship between average speed and traffic volume is an important consideration in the evaluation of traffic-stream characteristics (3). Investigations conducted on an extensive scale have concluded that the speed-volume relations for a given type of roadway facility in a specific traffic area are represented by a straight-line function when all other modifying factors are identical. Thus, these speed-volume relations describe the controlling influence of traffic volume or density on the average speed of travel As the volume on a traffic facility increases, the average speed decreases approximately linearly until the traffic volume has reached the possible capacity of the particular facility under prevailing roadway and traffic conditions.

Research investigations of traffic flow show that other variables (such as speed limits, adequate passing sections on two-lane roads, lateral clearances, percentages of commercial vehicles, and widths of traffic lanes) tend to affect speed patterns (5). The qualitative analysis illustrated previously indicates that the normal speed-volume relation is modified by various traffic-flow restrictions that control the average speed of vehicle movement at a roadway location. The degree of this modification is dependent on types, combinations, and levels of restrictive variables, highway type, and traffic area.

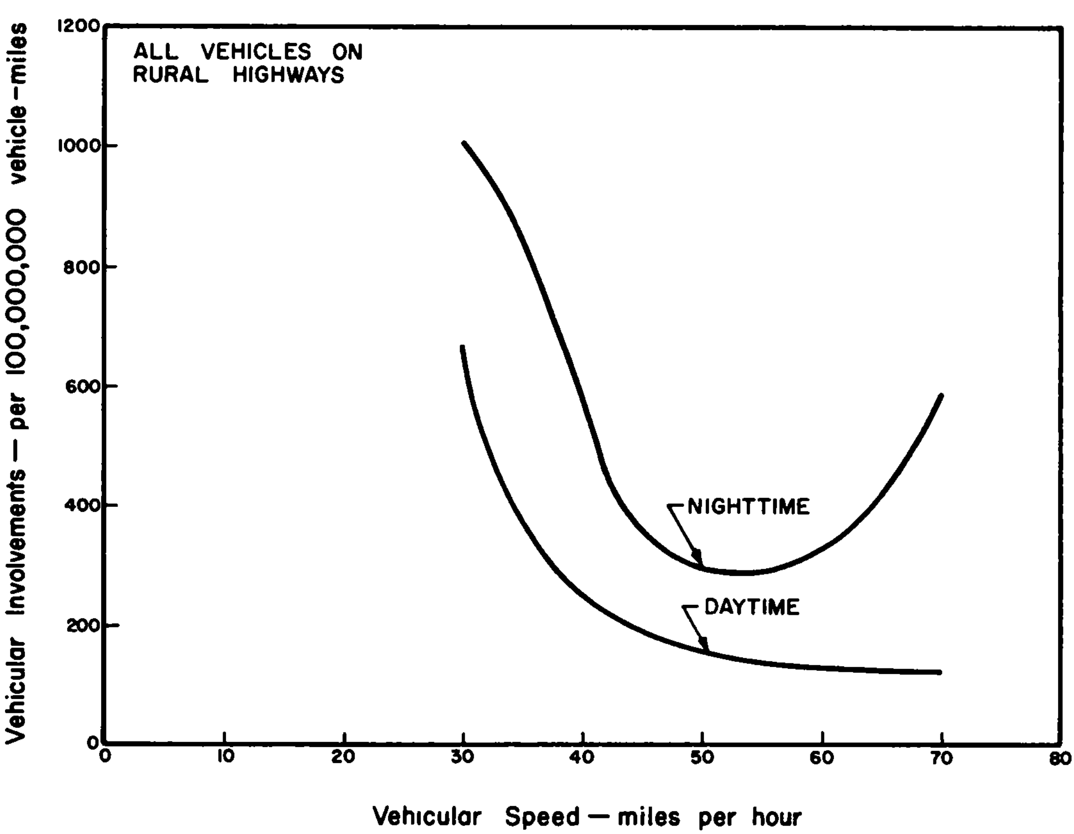

Figure 5. Vehicular involvements vs vehicular speed—two-lane.

This conceptual model is summarized as the statistical estimation of the functional relationships between average spot speed and those travel variables that significantly control the rate of traffic movement. The description of this concept as a mathematical model for the estimation of vehicular speeds suggests equations for multiple estimating (2). This inference problem is best formulated as the following two multiple linear regression equations (6):

$$\bar{S}_1 = c_1 F_1 + c_2 F_2 + \ldots + c_m F_m + c U \qquad (1)$$

in which

$\bar{S}_1$ = average spot speed,
c_j = common factor loading (j = 1, 2, ..., m),
F_j = $d_j + \sum_1^n d_{ij} x_i + g_i$ = common factor
(i = 1, 2, ..., n; j = 1, 2, ..., m),
d_j = intercept for factor score (j = 1, 2, ..., m),
e_{ij} = net regression coefficient for j-th factor score (i = 1, 2, ..., n),
x_i = independent variable (i = 1, 2, ..., n),
g_i = residual variable (j = 1, 2, ..., m),
c^1 = unique factor loading,
U = unique factor,
m = number of common factors, and
n = number of independent variables.

$$\bar{S}_2 = a + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n + h \qquad (2)$$

in which

$\bar{S}_2$ = average spot speed,
a = intercept,
b_i = net regression coefficient (i = 1, 2, ..., n),
x_i = independent variable (i = 1, 2, ..., n),
h = residual variable, and
n = number of independent variables.

The average spot speeds in these regression models are defined as dependent variables which are functionally related to generated factors in the first equation and to travel restriction variables in the second relationship.

Consideration of the knowledge of traffic-stream characteristics presently limits the analysis to linear relations. Also, the selection of the independent variables is predicated on the assumption of linearity in both the parameters and the variables.

From a priori considerations, the following are the various travel conditions to be considered as independent variables in the evaluation of these mathematical models:

1. Driver variations and desires,
2. Vehicle characteristics,
3. Roadway features,
4. Traffic conditions, and
5. Environmental variables.

Each category contains many items that appear to influence the rate of traffic movement. For a particular highway type in a given traffic area, certain restrictions may exert various significant degrees of controlling influence on vehicular speeds, while different travel variables may be significant for other highway-type and traffic-area combinations.

A comprehensive sampling operation must be conducted to permit the estimation of the functional relations between average speeds and the significant driver, vehicle, roadway, traffic, and environmental variables. A parsimonious description of traffic flow in terms of generated factors is developed by employing the technique of factor analysis, which also determines a multiple linear regression equation in terms of these factors. Thus, statistical procedures are available to evaluate those travel variables that significantly modify vehicular speeds. For each type of highway or street in each traffic area, vehicular spot-speed studies must be performed to measure the average speeds for different levels of the various travel conditions. It is quite evident that the proposed sampling operation is an extremely complex and intricate study. However, it is essential for the complete and accurate evaluation of the proposed mathematical models.

Solutions to the proposed mathematical models permit the development of modifying factors (either in tabular or graphical form) that facilitate the reduction of the optimal speed to the adjusted speed. These factors are the differences between average speeds obtained from the multiple regression equations for actual roadway conditions and average speeds computed from the same expressions for ideal conditions. This modification depends on the degree to which the various conditions existing on the roadway facility being speed-zoned alter the operating speeds that would occur under ideal conditions. Thus, a rational technique is available to compute the adjusted speed from the optimal speed where the various physical and/or environmental conditions differ from the ideal for which the optimal speed is evaluated.

To illustrate the adjustment of the optimal speed, it is assumed that a two-lane, rural highway being posted with speed limits has a curved horizontal alinement, a restricted lateral clearance, and a traffic volume that reduce the average speed by 2.3, 1.4, and 3.0 mph, respectively, below the mean speed that would occur under ideal roadway and traffic conditions. The total influence of the individual roadway

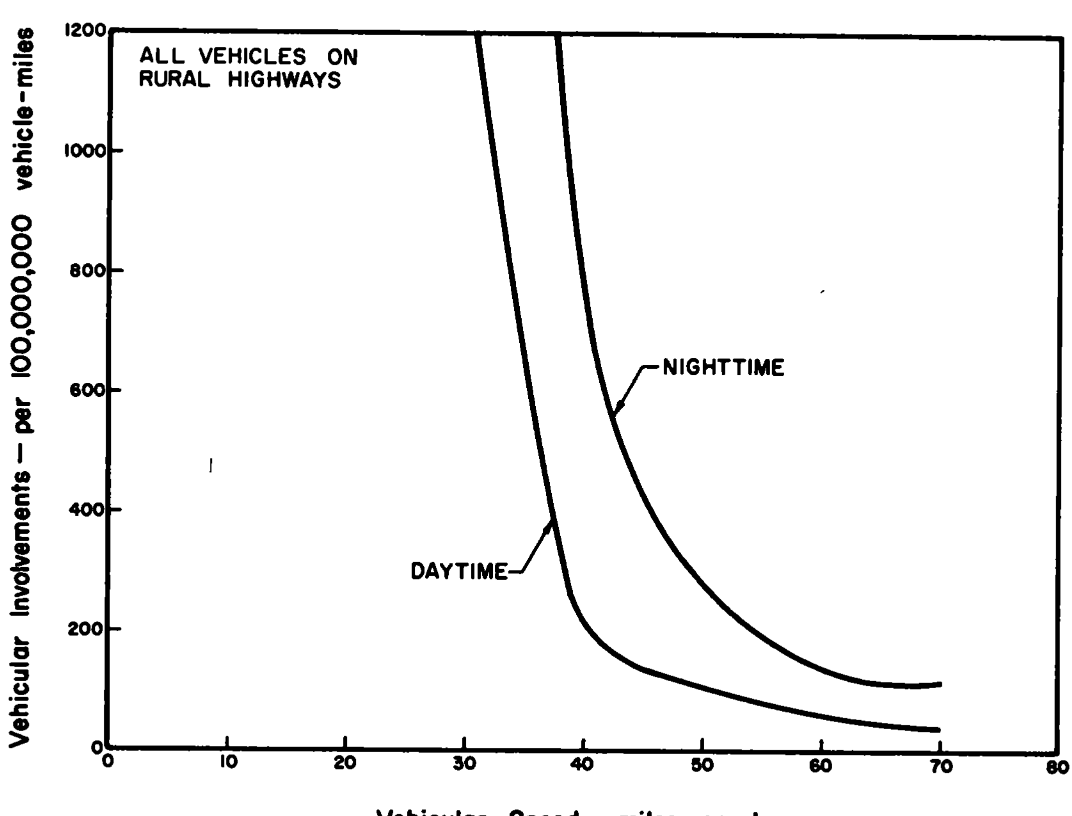

Figure 6. Vehicular involvements vs vehicular speed—four-lane.

restrictions, 6.7 mph, is subtracted from the optimal speed for daytime travel, 46.5 mph, to produce an adjusted speed of 39.8 mph.

Speed Limits

Resultant speeds on that portion of the highway which is being speed-zoned should have the adjusted speed as their measure of central tendency. Also, the proper introduction of both upper and lower speed limits should reduce the variability of vehicular speeds and make individual speeds more nearly equal to this desired value. The hypothetical relationship between these various speed values is shown in Figure 9.

A field study designed to measure mean speeds for various posted upper and lower speed limits should indicate the number of standard deviations that the upper speed limit is above the mean speed and the number of standard deviations that the lower speed limit is below the mean speed. The upper speed limit can be calculated by adding the adjusted speed to the product of the standard deviation of vehicular speeds for the roadway facility being zoned and the corresponding normal deviate (ratio of the difference between the upper speed limit and the mean speed to the standard deviation) obtained from the field investigation. The lower speed limit is computed in a similar manner, except that the product of the standard deviation and the normal deviate representing the lower speed limit is subtracted from the adjusted speed to yield the lower speed limit. This final procedure produces upper and lower speed limits that result in an actual mean spot speed which is approximately equal to the adjusted speed.

To continue with the example previously presented, it is assumed that the speed variability of all vehicles on the two-lane, rural highway is represented by a standard

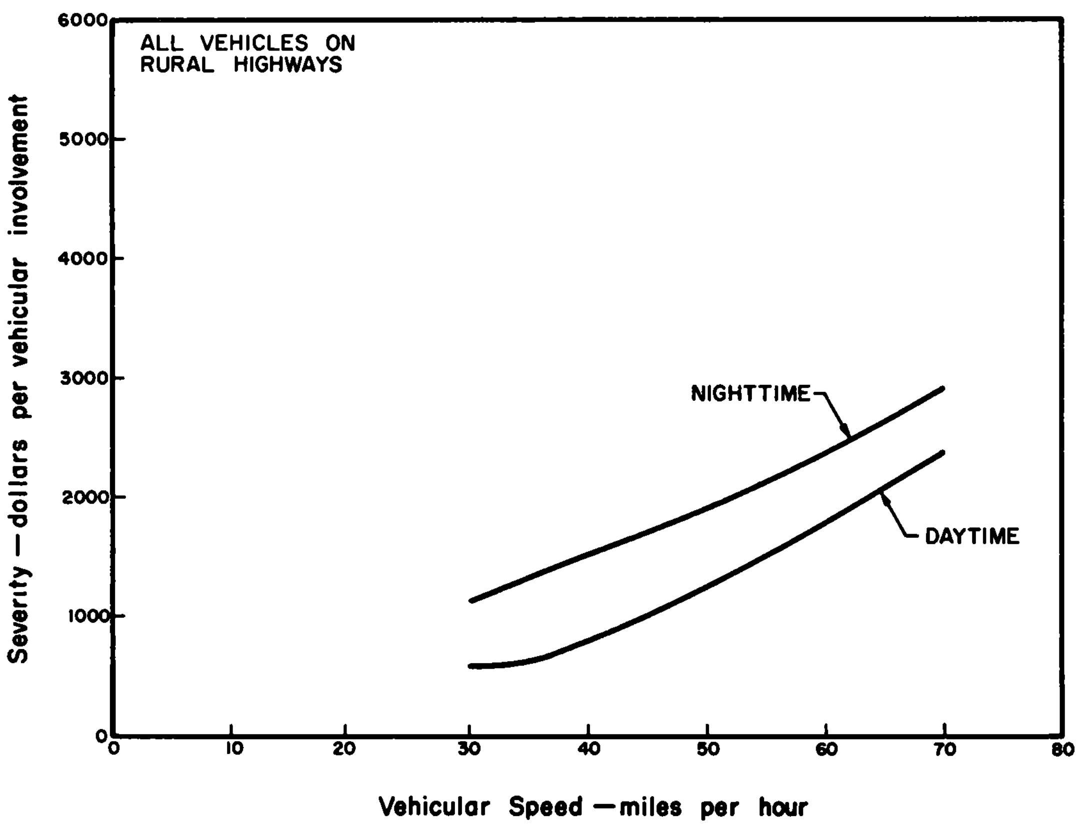

Figure 7. Severity vs vehicular speed—two-lane.

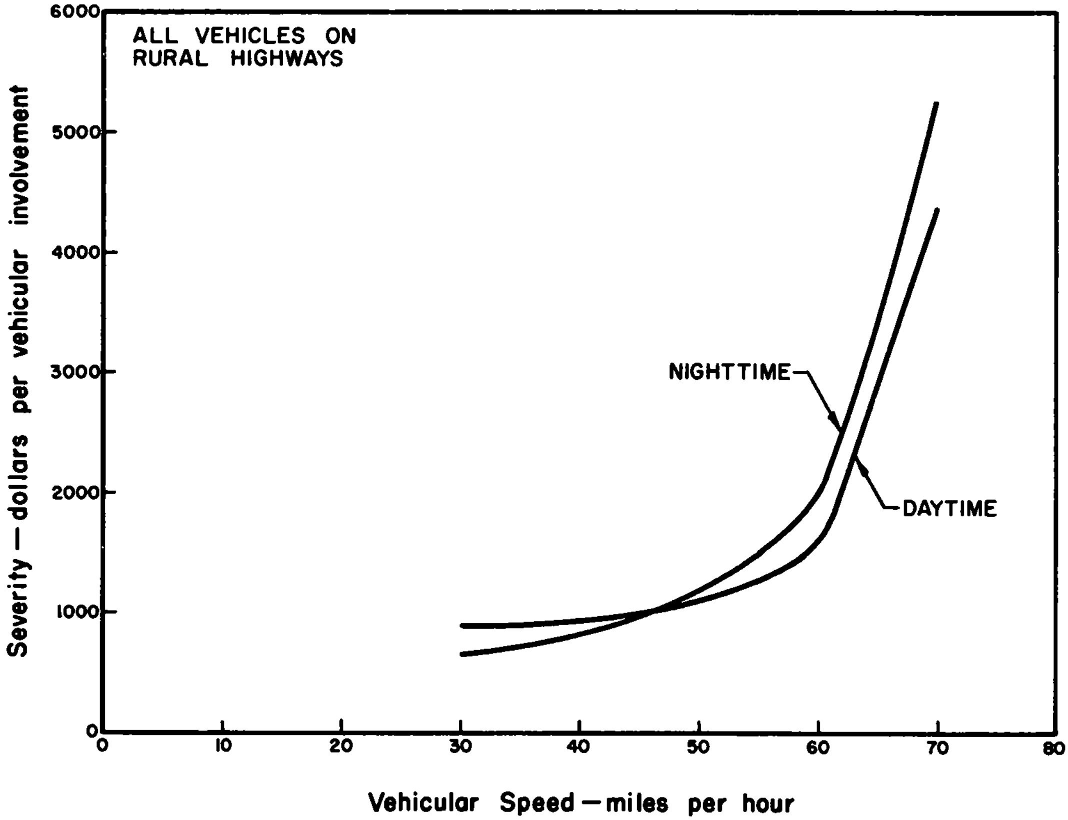

Figure 8. Severity vs vehicular speed—four-lane.

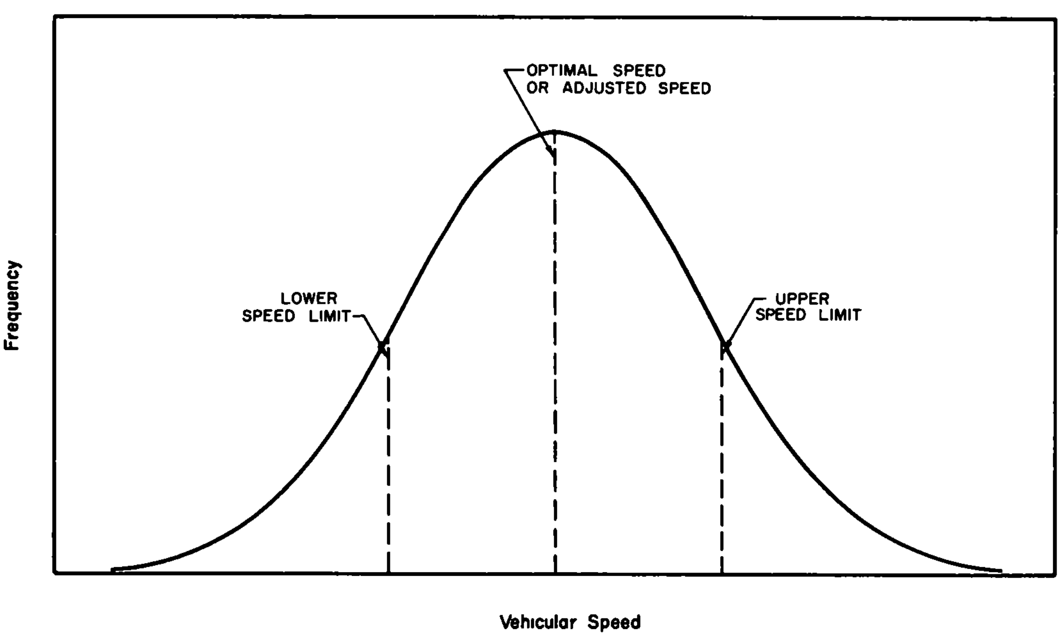

Figure 9. Frequency distribution for vehicular speeds.

deviation of 8.4 mph. Hypothetical values for the normal deviates are 1.6 for the upper speed limit and 1.4 for the lower speed limit. The upper speed limit is equal to 39.8 + 8.4 × 1.6 or 53.2 mph, and the lower speed limit is 39.8 - 8.4 × 1.4 or 28.0 mph. Therefore, an upper speed limit of 55 mph and a lower speed limit of 30 mph would be posted to regulate all vehicles on this two-lane highway having restricted travel conditions.

SUMMARY

The preceding discussion has been the development of a theory or concept for a scientific method to establish speed-zoning warrants. The basic principle of this theory involves the regulation of speeds of highway motor vehicles at that speed which most nearly minimizes the cost of highway transportation. This analysis optimized three resource expenditures incurred in highway transportation—economics of vehicle operation, value of time, and safety of travel. However, it is realized that various physical and environmental features of a highway or street location provide restrictions on the speed at which the individual driver can operate his motor vehicle. The second item of this theory involves a determination of the influences of these significant features on spot-speed characteristics. By comparing them with the ideal travel conditions for which the economic analyses are performed, the optimal speed can be modified by these reduction factors to obtain the adjusted speed at the given roadway location. Finally, the natural distribution of vehicular speeds must be considered in the selection of upper and lower speed limits. This necessitates a consideration of the properties of the normal curve and the selection of upper and lower speed-limit values so that the resulting average speed of the highway traffic coincides with the previously determined adjusted speed.

This analysis is a theory for the regulation of vehicular speeds; it is presently being quantitatively evaluated for actual field conditions. It represents an attempt to develop a scientific procedure for determining the regulation of vehicular speeds and not merely the establishment of speed limits that conform to some existing percentile speed of vehicles at a given highway or street location.

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Appendix

The data utilized in this report for the determination of optimal speeds for the specified conditions of two-lane and four-lane rural highways during daytime and nighttime operation are given in Tables 1 to 4. Operation costs were obtained from information developed by Winfrey (9), and time-cost data were compiled from several sources (7).

The rates of involvements in traffic accidents and the severity of traffic accidents at various operating speeds for the previously mentioned conditions are given in Tables 5 and 6 and Tables 7 and 8, respectively. Involvement rates were determined from the results of research studies conducted by the Bureau of Public Roads (8). The development of accident severities was accomplished by evaluating traffic accident statistics (7).

TABLE 1

COST OF HIGHWAY TRANSPORTATION, ALL VEHICLES ON RURAL HIGHWAYS—TWO-LANE, DAYTIME

Speed (mph)	Cost (dollar/mi)			
	Operation	Time	Accident	Total
30	0.04167	0.04922	0.00384	0.09473
35	0.04286	0.04218	0.00230	0.08734
40	0.04482	0.03691	0.00199	0.08372
45	0.04765	0.03281	0.00200	0.08246
50	0.05147	0.02953	0.00211	0.08311
55	0.05645	0.02685	0.00218	0.08545
60	0.06281	0.02461	0.00234	0.08976
65	-	0.02272	0.00255	-
70	-	0.02109	0.00287	-

TABLE 2

COST OF HIGHWAY TRANSPORTATION, ALL VEHICLES ON RURAL HIGHWAYS—TWO-LANE, NIGHTTIME

Speed (mph)	Cost (dollar/mi)			
	Operation	Time	Accident	Total
30	0.04167	0.04922	0.01174	0.10263
35	0.04286	0.04218	0.01116	0.09620
40	0.04482	0.03691	0.00869	0.09042
45	0.04765	0.03281	0.00618	0.08664
50	0.05147	0.02953	0.00569	0.08669
55	0.05645	0.02685	0.00614	0.08944
60	0.05281	0.02461	0.00780	0.09522
65	-	0.02272	0.01111	-
70	-	0.02109	0.01719	-

TABLE 3

COST OF HIGHWAY TRANSPORTATION, ALL VEHICLES ON RURAL HIGHWAYS—FOUR-LANE, DAYTIME

Speed (mph)	Cost (dollar/mi)			
	Operation	Time	Accident	Total
30	0.03796	0.04922	0 01162	0.09880
35	0.03868	0.04218	0.00591	0.08677
40	0.04037	0.03691	0.00195	0.07923
45	0.04164	0.03281	0.00137	0.07582
50	0.04413	0.02953	0.00109	0.07475
55	0.04789	0.02685	0.00095	0.07569
60	0.05280	0.02461	0.00092	0.07833
65	-	0.02272	0.00131	-
70	-	0.02109	0.00166	-

TABLE 4

COST OF HIGHWAY TRANSPORTATION, ALL VEHICLES ON RURAL HIGHWAYS—FOUR-LANE, NIGHTTIME

Speed (mph)	Cost (dollar/mi)			
	Operation	Time	Accident	Total
30	0.03796	0.04922	0.03017	0.11735
35	0.03868	0.04218	0.01435	0.09521
40	0.04037	0.03691	0.00639	0.08366
45	0.04164	0.03281	0.00408	0.07853
50	0.04413	0.02953	0.00324	0.07690
55	0.04789	0.02685	0.00277	0.07751
60	0.05280	0.02461	0.00271	0.08012
65	-	0.02272	0.00381	-
70	-	0.02109	0.00612	-

TABLE 5

VEHICULAR ACCIDENT INVOLVEMENTS, ALL VEHICLES ON RURAL HIGHWAYS—TWO-LANE

Speed (mph)	Vehicular Involvements (rate per 10^8 vehicle-miles)	
	Daytime	Nighttime
30	663	1,046
35	378	849
40	248	575
45	196	361
50	167	296
55	144	287
60	131	328
65	123	421
70	121	590

TABLE 6

VEHICULAR ACCIDENT INVOLVEMENTS, ALL VEHICLES ON RURAL HIGHWAYS—FOUR-LANE

Speed (mph)	Vehicular Involvements (rate per 10^8 vehicle-miles)	
	Daytime	Nighttime
30	1,320	4,620
35	662	1,980
40	211	777
45	138	425
50	100	276
55	76	188
60	58	137
65	44	111
70	38	115

TABLE 7

ACCIDENT SEVERITY, ALL VEHICLES ON RURAL HIGHWAYS—TWO-LANE

Speed (mph)	Severity (dollars per vehicular involvement)	
	Daytime	Nighttime
30	579	1,122
35	608	1,315
40	801	1,512
45	1,021	1,713
50	1,264	1,922
55	1,516	2,140
60	1,790	2,377
65	2,077	2,639
70	2,376	2,914

TABLE 8

ACCIDENT SEVERITY, ALL VEHICLES ON RURAL HIGHWAYS—FOUR-LANE

Speed (mph)	Severity (dollars per vehicular involvement)	
	Daytime	Nighttime
30	880	653
35	893	725
40	925	822
45	991	960
50	1,094	1,174
55	1,253	1,474
60	1,590	1,978
65	2,971	3,434
70	4,372	5,324

A Practical Method for Improving the Accuracy Of Vehicular Speed Distribution Measurements

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A formula connecting the speed distribution measured in time with the speed distribution measured in space is derived and applied to the cases of (a) Pearson type III distributions, and (b) lognormal distributions. In the first case, conversion tables from time to space measurements are provided both for the mean and variance and for the percentage of cars going more slowly than some fixed speed.

• IT IS APPARENTLY a fixed characteristic of drivers that they are unwilling to sacrifice their use of the road network for the sake of scientific research. Perhaps they are justified in this attitude; nevertheless, it introduces experimental difficulties that have no counterpart in the laboratory. The quantities available to the traffic engineer (and to the traffic theorist) are those that can be obtained without hindrance or substantial inconvenience to the driver. In these circumstances, it is natural that a large proportion of available data relates to the behavior of vehicles as recorded by various kinds of road tapes. Some drivers object even to these inoffensive sources of information and regard with apprehension the possibility of their driving characteristics being recorded. But the majority are sufficiently inured to road tapes and vaguely aware of their harmless or even useful nature, so that information of this sort is widely available.

However, road tape information (no matter which particular variable it records) presents to the research worker only a silhouette of the true traffic picture; namely, variation in time at a fixed point in space. Aerial photography gives the dual silhouette: variation in space at a fixed time. For some purposes it is better to regard the latter as the "true" picture.

For example, if a collection of vehicles moves around a circular track an aerial photograph would record all of them and consequently give equal weight to each, whereas a tape at one point in the track would receive the imprints of faster cars more frequently than slower ones and give biased results.

The foregoing remarks apply to a greater or lesser extent depending on the quantity being measured. Three basic quantities are considered :

1. Flow or volume, in cars per time; interarrival time, in time per car.
2. Density, concentration or gap, in cars per distance or distance per car.
3. Velocity, in distance per time.

Each of these is measureable (for an individual car) by either of the two methods. There is, for example, a time speed distribution (so often obtained) and a space speed distribution (which seems impossible to obtain). It is the purpose of this paper to show how certain properties of the space speed distribution can be obtained from the time speed distribution, if a few assumptions are made.

Before leaving these general questions, however, it is worthwhile to point out that the corresponding relationship between the time gap distribution and the space gap distribution is at present unknown. Even in the simplest situation, where every car travels in a linear space-time trajectory without interference from any other car, the connection between the two gap distributions eludes mathematical solution. Geometrically, the problem may be expressed as follows: given a set of points on one of the coordinate axes, with an arbitrary distribution of the distances between consecutive points, and given a distribution of slopes of lines through these points, to find the distribution of the gaps that these lines produce on the other coordinate axis.

TIME SPEED AND SPACE SPEED DISTRIBUTIONS

Table 1 gives notation for speed distributions.

TABLE 1

Item	Time Distribution	Space Distribution
Density function	f(x)	F(x)
LaPlace transform	g(t)	G(t)
Arithmetic mean	m	M
Harmonic mean	μ	-
Variance	v	V
kth moment about the origin	a_k	A_k

To obtain the relationship between f(x) and F(x), a case that is intermediate between time and space is considered. If an airplane of constant speed z flies over the roadway, forming a distribution of speeds of all vehicles that it passes over, the resulting distribution $h_z(x)$ will be related to the time and space speed distributions as follows: If the plane goes infinitely fast, the space distribution will be obtained; i.e., $H_\infty(x) = F(x)$, and if the plane hovers, the time distribution will be obtained; i.e., $h_0(x) = f(x)$.

Now, assuming the true probabilities of speeds to be F(x), the probabilities observed by the plane will be proportional to F(x), but weighted with the relative speed of the plane $|z - x|$. In other words,

$$h_z(x) = C\ |z - x|\ F(x),$$

in which C is a constant to be determined so that $\int_0^\infty h_z(x)\,dx = 1$. Putting in the constant,

$$h_z(x) = \frac{|z - x|\ F(x)}{\int_0^\infty |z - x|\ F(x)\,dx} \tag{1}$$

The probability of the plane observing a car of speed z is zero, as is expected, and letting z approach infinity, the formula $h_\infty(x) = F(x)$ is confirmed. The formula on which this paper is based comes from setting z = 0; namely,

$$M\,f(x) = x\,F(x) \tag{2}$$

No doubt a more rigorous proof of Eq. 2 could be devised, but for the purposes of the present paper, it is enough that the formula is true in all circumstances of practical interest. The corresponding relationship between the LaPlace transformations is still simpler,

$$M\,g(t) + dG(t)/dt = 0 \tag{3}$$

and from this, or direct integration of Eq. 2, the formula connecting the moments can be written down as

$$A_k = \mu\,a_{k-1} \tag{4}$$

This equation involves the harmonic mean of the time distribution, but that too can be found easily by integrating $Mf/x = F$; the result is

$$\mu = M \qquad (5)$$

Similarly, the space variance is given in terms of time arithmetic and harmonic means as

$$V = \mu m - \mu^2 \qquad (6)$$

which is always positive by virtue of the fact that the harmonic mean is less than the arithmetic mean.

TYPE III DISTRIBUTIONS

A Pearson type III distribution, defined over $0 < x < \infty$, is specified by the density function

$$\frac{p^q}{(q-1)!} e^{-px} x^{q-1} \qquad (7)$$

in which p and q are parameters easily expressible in terms of the mean and variance. Such distributions, with appropriate choice of parameters, can be made to fit a wide variety of data, ranging from a simple exponential pe^{-px}, for $q = 1$, to near normality for large values of p and q. In case time speed measurements are satisfactorily fitted to a type III distribution with parameters p and q, then an application of Eq. 2 yields the fact that the space speed distribution is also type III, but with parameters p and $q - 1$.

The mean of a type III distribution with parameters p and q is q/p, its harmonic mean is $(q-1)/p$ and its variance is q/p^2. Using these facts with Eqs. 5 and 6 the space mean and variance can be written in terms of the time mean and variance:

$$M = \frac{m^2 - v}{m}, \quad V = \frac{m^2 v - v^2}{m^2} \qquad (8)$$

Another quantity of some interest in speed measurements is the proportion of cars traveling more slowly than some fixed speed, for example, the speed limit. If L is any fixed speed, then this proportion can be expressed in the two cases as

$$r = \int_o^L f(x)\,dx \text{ and } R = \int_o^L F(x)\,dx \qquad (9)$$

Substituting the value of f(x) from Eq. 7 and integrating by parts, the first part of Eq. 9 yields exactly R for the residual integral, where F(x) is also given by Eq. 7, but with q replaced by q - 1. The expression is

$$r = -\frac{p^{q-1}}{(q-1)!} L^{q-1} e^{-pL} + R$$

Therefore, replacing p and q by their values m/v and m^2/v, respectively, the value of R can be found by adding a correction term to r:

$$\frac{(m/v)^{(m^2/v)-1}}{[(m^2/v) - 1]!} L^{(m^2 - v)/v} e^{-mL/v} \qquad (10)$$

The 85th percentile speed is of interest in finding the proper speed limit for a given section of roadway. To determine the true (space distributed) 85th percentile, Eq. 9 is evaluated for L with R set equal to 0.85. As before, F(x) is given by Eq. 7 where q is replaced by q - 1. On substitution into Eq. 9 the resulting expression to be evaluated is

$$0.85 = \frac{p^{q-1}}{\Gamma(q-1)} \int_o^L e^{-px} x^{q-1}\,dx$$

or on substitution of $px = y$,

$$0.85 = \frac{1}{\Gamma(q-1)} \int_0^{pL} e^{-q(y)} (q-1) \, dy = \frac{\gamma(q-1, pL)}{\Gamma(q-1)} \qquad (11)$$

in which

$p = m/v$, and

$q = m^2/v$.

If in Eq. 11 q is replaced by q+1 the time distributed 85th percentile can be evaluated.

LOGNORMAL DISTRIBUTIONS

Apart from the Pearson type III, the only other well-known statistical distribution with the correct domain of definition which would apply to speed measurements is the lognormal. In this case the result is particularly simple and should be easy to apply without tables. If the logarithm of the space-measured speed is normally distributed with mean n and variance w, then the logarithm of the time-measured speed is also normally distributed with mean n + w and variance w. The converse is also true: in passing from time to space measurements, if logarithms are taken, the variance is unaltered and the mean is reduced by an amount equal to the variance.

The proof of these facts is nearly the same and depends on simple statistical calculations. For assumed space distribution, it is assumed that

x = speed measured in space;
X = log x;
y = speed measured in time; and
Y = log y.

Then, by hypothesis, the density function for X is

$$C \exp\left[-\frac{(X-n)^2}{2w}\right], \qquad -\infty < X < \infty$$

in which

$$C (2\pi w)^{1/2} = 1$$

Using the transformation X = log x, the density function of x becomes

$$C \frac{1}{x} \exp\left[-\frac{(\log x - n)^2}{2w}\right], \qquad 0 < x < \infty$$

with mean value

$$M = \exp\left(n + \frac{1}{2} w\right)$$

Using Eq. 2, the distribution of y is

$$C \exp\left[-\frac{(\log y - n)^2}{2w} - m - \frac{1}{2} w\right], \qquad 0 < y < \infty$$

and that of Y = log y is

$$C \exp\left[-\frac{(Y-n)^2}{2w} - m - \frac{1}{2} w + Y\right]$$

$$= C \exp\left[-\frac{(Y - m - w)^2}{2w}\right], \qquad -\infty < Y < \infty$$

which is normal with mean m + w and variance w.

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Appendix

NUMERICAL TABLES

Eq. 8 has been evaluated for m = 5(5)—70 and v = 1(1)—15, (5)—90(10)—230, (Tables 2-4; Eq. 10 for L = 5(5)—70, m = 5(5)—70 and v = 1(1)—15, (5)—90, (10)—230, (Tables 5-18); and Eq. 11 for both space (5) and time (T) distributed 85th percentile speeds by m = 5(5)—70 and v = 1(1)—15, (5)—90, (10)—230 (Tables 19-21).

TABLE 2

MEAN AND VARIANCE OF SPACE DISTRIBUTED VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN		5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	M=	4.8	9.9	14.9	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
	V=	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	M=	4.6	9.8	14.9	19.9	24.9	29.9	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
	V=	1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	M=	4.4	9.7	14.8	19.9	24.9	29.9	34.9	39.9	44.9	49.9	55.0	60.0	65.0	70.0
	V=	2.6	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
4	M=	4.2	9.6	14.7	19.8	24.8	29.9	34.9	39.9	44.9	49.9	54.9	59.9	64.9	70.0
	V=	3.4	3.9	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
5	M=	4.0	9.5	14.7	19.8	24.8	29.8	34.9	39.9	44.9	49.9	54.9	59.9	64.9	69.9
	V=	4.0	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	M=	3.8	9.4	14.6	19.7	24.8	29.8	34.8	39.9	44.9	49.9	54.9	59.9	64.9	69.9
	V=	4.6	5.6	5.8	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
7	M=	3.6	9.3	14.5	19.7	24.7	29.8	34.8	39.8	44.9	49.9	54.9	59.9	64.9	69.9
	V=	5.0	6.5	6.8	6.9	6.9	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
8	M=	3.4	9.2	14.5	19.6	24.7	29.7	34.8	39.8	44.8	49.8	54.9	59.9	64.9	69.9
	V=	5.4	7.4	7.7	7.8	7.9	7.9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
9	M=	3.2	9.1	14.4	19.6	24.6	29.7	34.8	39.8	44.8	49.8	54.8	59.9	64.9	69.9
	V=	5.8	8.2	8.6	8.8	8.9	8.9	8.9	9.0	9.0	9.0	9.0	9.0	9.0	9.0
10	M=	3.0	9.0	14.3	19.5	24.6	29.7	34.7	39.8	44.8	49.8	54.8	59.8	64.9	69.9
	V=	6.0	9.0	9.6	9.6	9.8	9.9	9.9	9.9	10.0	10.0	10.0	10.0	10.0	10.0
11	M=	2.8	8.9	14.3	19.5	24.6	29.6	34.7	39.7	44.8	49.8	54.8	59.8	64.8	69.9
	V=	6.2	9.9	10.5	10.7	10.8	10.9	10.9	10.9	11.0	11.0	11.0	11.0	11.0	11.0
12	M=	2.6	8.8	14.2	19.4	24.5	29.6	34.7	39.7	44.7	49.8	54.8	59.8	64.8	69.8
	V=	6.2	10.6	11.4	11.6	11.8	11.8	11.9	11.9	11.9	12.0	12.0	12.0	12.0	12.0
13	M=		8.7	14.1	19.4	24.5	29.6	34.6	39.7	44.7	49.7	54.8	59.8	64.8	69.8
	V=		11.3	12.3	12.6	12.7	12.8	12.9	12.9	12.9	12.9	13.0	13.0	13.0	13.0
14	M=		8.6	14.1	19.3	24.4	29.5	34.6	39.7	44.7	49.7	54.8	59.8	64.8	69.8
	V=		12.0	13.1	13.5	13.7	13.8	13.8	13.9	13.9	13.9	13.9	14.0	14.0	14.0
15	M=		8.5	14.0	19.3	24.4	29.5	34.6	39.6	44.7	49.7	54.7	59.8	64.8	69.8
	V=		12.8	14.0	14.4	14.6	14.6	14.8	14.9	14.9	14.9	14.9	14.9	15.0	15.0

TABLE 3

MEAN AND VARIANCE OF SPACE DISTRIBUTED VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
20		M= 8.0	M= 13.7	M= 19.0	M= 24.2	M= 29.3	M= 34.4	M= 39.5	M= 44.6	M= 49.6	M= 54.6	M= 59.7	M= 64.7	M= 69.7
		V= 16.0	V= 18.2	V= 19.0	V= 19.4	V= 19.6	V= 19.7	V= 19.8	V= 19.8	V= 19.8	V= 19.9	V= 19.9	V= 19.9	V= 19.9
25		M= 7.5	M= 13.3	M= 18.8	M= 24.0	M= 29.2	M= 34.3	M= 39.4	M= 44.5	M= 49.5	M= 54.6	M= 59.6	M= 64.6	M= 69.7
		V= 18.8	V= 22.2	V= 23.4	V= 24.0	V= 24.3	V= 24.5	V= 24.6	V= 24.7	V= 24.8	V= 24.8	V= 24.8	V= 24.9	V= 24.9
30		M= 7.0	M= 13.0	M= 18.5	M= 23.8	M= 29.0	M= 34.2	M= 39.3	M= 44.3	M= 49.4	M= 54.5	M= 59.5	M= 64.5	M= 69.6
		V= 21.0	V= 26.0	V= 27.8	V= 28.6	V= 29.0	V= 29.3	V= 29.4	V= 29.6	V= 29.6	V= 29.7	V= 29.8	V= 29.8	V= 29.8
35		M= 6.5	M= 12.7	M= 18.3	M= 23.6	M= 28.8	M= 34.0	M= 39.1	M= 44.2	M= 49.3	M= 54.4	M= 59.4	M= 64.5	M= 69.5
		V= 22.8	V= 29.6	V= 31.9	V= 33.0	V= 33.6	V= 34.0	V= 34.2	V= 34.4	V= 34.5	V= 34.6	V= 34.7	V= 34.7	V= 34.8
40		M= 6.0	M= 12.3	M= 18.0	M= 23.4	M= 28.7	M= 33.9	M= 39.0	M= 44.1	M= 49.2	M= 54.3	M= 59.3	M= 64.4	M= 69.4
		V= 24.0	V= 32.9	V= 36.0	V= 37.4	V= 38.2	V= 38.7	V= 39.0	V= 39.2	V= 39.4	V= 39.5	V= 39.6	V= 39.6	V= 39.7
45		M= 5.5	M= 12.0	M= 17.8	M= 23.2	M= 28.5	M= 33.7	M= 38.9	M= 44.0	M= 49.1	M= 54.2	M= 59.3	M= 64.3	M= 69.4
		V= 24.8	V= 36.0	V= 39.9	V= 41.8	V= 42.8	V= 43.4	V= 43.7	V= 44.0	V= 44.2	V= 44.3	V= 44.4	V= 44.5	V= 44.6
50		M= 5.0	M= 11.7	M= 17.5	M= 23.0	M= 28.3	M= 33.6	M= 38.8	M= 43.9	M= 49.0	M= 54.1	M= 59.2	M= 64.2	M= 69.3
		V= 25.0	V= 38.9	V= 43.8	V= 46.0	V= 47.2	V= 48.0	V= 48.4	V= 48.8	V= 49.0	V= 49.2	V= 49.3	V= 49.4	V= 49.5
55			M= 11.3	M= 17.3	M= 22.8	M= 28.2	M= 33.4	M= 38.6	M= 43.8	M= 48.9	M= 54.0	M= 59.1	M= 64.2	M= 69.2
			V= 41.6	V= 47.4	V= 50.2	V= 51.6	V= 52.5	V= 53.1	V= 53.5	V= 53.8	V= 54.0	V= 54.2	V= 54.3	V= 54.4
60			M= 11.0	M= 17.0	M= 22.6	M= 28.0	M= 33.3	M= 38.5	M= 43.7	M= 48.8	M= 53.9	M= 59.0	M= 64.1	M= 69.2
			V= 44.0	V= 51.0	V= 54.2	V= 56.0	V= 57.1	V= 57.8	V= 58.2	V= 58.6	V= 58.8	V= 59.0	V= 59.2	V= 59.3
65			M= 10.7	M= 16.8	M= 22.4	M= 27.8	M= 33.2	M= 38.4	M= 43.6	M= 48.7	M= 53.8	M= 58.9	M= 64.0	M= 69.1
			V= 46.2	V= 54.4	V= 58.2	V= 60.3	V= 61.6	V= 62.4	V= 62.9	V= 63.3	V= 63.6	V= 63.8	V= 64.0	V= 64.1
70			M= 10.3	M= 16.5	M= 22.2	M= 27.7	M= 33.0	M= 38.3	M= 43.5	M= 48.6	M= 53.7	M= 58.8	M= 63.9	M= 69.0
			V= 48.2	V= 57.8	V= 62.2	V= 64.6	V= 66.0	V= 66.9	V= 67.6	V= 68.0	V= 68.4	V= 68.6	V= 68.9	V= 69.0
75			M= 10.0	M= 16.3	M= 22.0	M= 27.5	M= 32.9	M= 38.1	M= 43.3	M= 48.5	M= 53.6	M= 58.8	M= 63.9	M= 68.9
			V= 50.0	V= 60.9	V= 66.0	V= 68.8	V= 70.4	V= 71.5	V= 72.2	V= 72.8	V= 73.2	V= 73.4	V= 73.7	V= 73.9
80			M= 9.7	M= 16.0	M= 21.8	M= 27.3	M= 32.7	M= 38.0	M= 43.2	M= 48.4	M= 53.6	M= 58.7	M= 63.8	M= 68.9
			V= 51.6	V= 64.0	V= 69.8	V= 72.9	V= 74.8	V= 76.0	V= 76.8	V= 77.4	V= 77.9	V= 78.2	V= 78.5	V= 78.7
85			M= 9.3	M= 15.8	M= 21.6	M= 27.2	M= 32.6	M= 37.9	M= 43.1	M= 48.3	M= 53.5	M= 58.6	M= 63.7	M= 68.8
			V= 52.9	V= 66.9	V= 73.4	V= 77.0	V= 79.1	V= 80.5	V= 81.4	V= 82.1	V= 82.6	V= 83.0	V= 83.3	V= 83.5
90			M= 9.0	M= 15.5	M= 21.4	M= 27.0	M= 32.4	M= 37.8	M= 43.0	M= 48.2	M= 53.4	M= 58.5	M= 63.6	M= 68.7
			V= 54.0	V= 69.8	V= 77.0	V= 81.0	V= 83.4	V= 84.9	V= 86.0	V= 86.8	V= 87.3	V= 87.8	V= 88.1	V= 88.4

TABLE 4

MEAN AND VARIANCE OF SPACE DISTRIBUTED VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
100			M= 8.3 V= 55.6	M= 15.0 V= 75.0	M= 21.0 V= 84.0	M= 26.7 V= 88.9	M= 32.2 V= 91.8	M= 37.5 V= 93.8	M= 42.8 V= 95.1	M= 48.0 V= 96.0	M= 53.2 V= 96.7	M= 58.3 V= 97.2	M= 63.5 V= 97.6	M= 68.6 V= 98.0
110			M= 7.7 V= 56.2	M= 14.5 V= 79.8	M= 20.6 V= 90.6	M= 26.3 V= 96.6	M= 31.9 V=100.1	M= 37.3 V=102.4	M= 42.6 V=104.0	M= 47.8 V=105.2	M= 53.0 V=106.0	M= 58.2 V=106.6	M= 63.3 V=107.1	M= 68.4 V=107.5
120			M= 7.0 V= 56.0	M= 14.0 V= 84.0	M= 20.2 V= 97.0	M= 26.5 V=104.0	M= 31.6 V=108.3	M= 37.0 V=111.0	M= 42.3 V=112.9	M= 47.6 V=114.2	M= 52.8 V=115.2	M= 58.0 V=116.0	M= 63.2 V=116.6	M= 68.3 V=117.1
130				M= 13.5 V= 87.8	M= 19.8 V=103.0	M= 25.7 V=111.2	M= 31.3 V=116.2	M= 36.8 V=119.4	M= 42.1 V=121.7	M= 47.4 V=123.2	M= 52.6 V=124.4	M= 57.8 V=125.3	M= 63.0 V=126.0	M= 68.2 V=126.6
140				M= 13.0 V= 91.0	M= 19.4 V=108.6	M= 25.3 V=118.2	M= 31.0 V=124.0	M= 36.5 V=127.8	M= 41.9 V=130.3	M= 47.2 V=132.2	M= 52.5 V=133.5	M= 57.7 V=134.6	M= 62.9 V=135.4	M= 68.0 V=136.0
150				M= 12.5 V= 93.8	M= 19.0 V=114.0	M= 25.0 V=125.0	M= 30.7 V=131.6	M= 36.3 V=135.9	M= 41.7 V=138.9	M= 47.0 V=141.0	M= 52.3 V=142.6	M= 57.5 V=143.8	M= 62.7 V=144.7	M= 67.9 V=145.4
160				M= 12.0 V= 96.0	M= 18.6 V=119.0	M= 24.7 V=131.6	M= 30.4 V=139.1	M= 36.0 V=144.0	M= 41.5 V=147.4	M= 46.8 V=149.8	M= 52.1 V=151.5	M= 57.3 V=152.9	M= 62.5 V=154.0	M= 67.7 V=154.8
170				M= 11.5 V= 97.8	M= 18.2 V=123.8	M= 24.3 V=137.9	M= 30.2 V=146.4	M= 35.8 V=151.9	M= 41.2 V=155.7	M= 46.6 V=158.4	M= 51.9 V=160.5	M= 57.2 V=162.0	M= 62.4 V=163.2	M= 67.6 V=164.1
180				M= 11.0 V= 99.0	M= 17.8 V=128.2	M= 24.0 V=144.0	M= 29.9 V=153.6	M= 35.5 V=159.8	M= 41.0 V=164.0	M= 46.4 V=167.0	M= 51.7 V=169.3	M= 57.0 V=171.0	M= 62.2 V=172.3	M= 67.4 V=173.4
190				M= 10.5 V= 99.8	M= 17.4 V=132.2	M= 23.7 V=149.9	M= 29.6 V=160.5	M= 35.3 V=167.4	M= 40.8 V=172.2	M= 46.2 V=175.6	M= 51.6 V=178.1	M= 56.8 V=180.0	M= 62.1 V=181.5	M= 67.3 V=182.6
200				M= 10.0 V=100.0	M= 17.0 V=136.0	M= 23.3 V=155.6	M= 29.3 V=167.4	M= 35.0 V=175.0	M= 40.6 V=180.3	M= 46.0 V=184.0	M= 51.4 V=186.8	M= 56.7 V=188.9	M= 61.9 V=190.5	M= 67.2 V=191.8
210					M= 16.6 V=139.4	M= 23.0 V=161.0	M= 29.0 V=174.0	M= 34.8 V=182.4	M= 40.3 V=188.2	M= 45.8 V=192.4	M= 51.2 V=195.4	M= 56.5 V=197.8	M= 61.8 V=199.6	M= 67.0 V=201.0
220					M= 16.2 V=142.6	M= 22.7 V=166.2	M= 28.7 V=180.5	M= 34.5 V=189.8	M= 40.1 V=196.1	M= 45.6 V-200.6	M= 51.0 V=204.0	M= 56.3 V=206.6	M= 61.6 V=208.6	M= 66.9 V=210.1
230					M= 15.8 V=145.4	M= 22.3 V=171.2	M= 28.4 V=186.8	M= 34.3 V=196.9	M= 39.9 V=203.9	M= 45.4 V=208.8	M= 50.8 V=212.5	M= 56.2 V=215.3	M= 61.5 V=217.5	M= 66.7 V=219.2
240					M= 15.4 V=147.8	M= 22.0 V=176.0	M= 28.2 V=193.0	M= 34.0 V=204.0	M= 39.7 V=211.6	M= 45.2 V=217.0	M= 50.6 V=221.0	M= 56.0 V=224.0	M= 61.3 V=226.4	M= 66.6 V=228.3

TABLE 5

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 5 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.080	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.113	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.138	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.160	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.179	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.197	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.213	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.228	P=.020	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.243	P=.028	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.258	P=.037	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.272	P=.046	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.286	P=.055	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.065	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.075	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.085	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.136	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.186	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.232	P=.017	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
35		P=.276	P=.029	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
40		P=.318	P=.045	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
45		P=.359	P=.062	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
50		P=.399	P=.081	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
55			P=.102	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
60			P=.123	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
65			P=.146	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
70			P=.168	P=.018	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
75			P=.192	P=.023	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
80			P=.215	P=.030	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
85			P=.239	P=.037	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
90			P=.263	P=.045	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
100			P=.311	P=.063	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
110			P=.359	P=.083	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
120			P=.408	P=.106	P=.013	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
130				P=.130	P=.019	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
140				P=.156	P=.026	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
150				P=.182	P=.034	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
160				P=.210	P=.043	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
170				P=.239	P=.054	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
180				P=.268	P=.065	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
190				P=.298	P=.078	P=.012	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
200				P=.329	P=.091	P=.015	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
210					P=.105	P=.019	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
220					P=.121	P=.024	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
230					P=.137	P=.029	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000

TABLE 6

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 10 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ X MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1 X	P=.000	P=.040	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2 X	P=.001	P=.056	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3 X	P=.005	P=.069	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4 X	P=.012	P=.080	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5 X	P=.019	P=.089	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6 X	P=.027	P=.098	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7 X	P=.036	P=.106	P=.010	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8 X	P=.044	P=.113	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9 X	P=.052	P=.120	P=.020	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10 X	P=.060	P=.126	P=.025	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11 X	P=.068	P=.132	P=.030	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12 X	P=.076	P=.138	P=.036	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13 X		P=.144	P=.041	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14 X		P=.150	P=.047	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15 X		P=.155	P=.052	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20 X		P=.179	P=.079	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25 X		P=.201	P=.104	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30 X		P=.221	P=.127	P=.017	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
35 X		P=.240	P=.149	P=.026	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
40 X		P=.258	P=.169	P=.037	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
45 X		P=.276	P=.187	P=.048	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
50 X		P=.294	P=.205	P=.060	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
55 X			P=.222	P=.073	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
60 X			P=.238	P=.085	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
65 X			P=.253	P=.098	P=.015	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
70 X			P=.268	P=.111	P=.020	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
75 X			P=.282	P=.124	P=.025	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
80 X			P=.296	P=.136	P=.030	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
85 X			P=.310	P=.149	P=.036	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
90 X			P=.323	P=.161	P=.042	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
100 X			P=.349	P=.186	P=.055	P=.008	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
110 X			P=.375	P=.209	P=.070	P=.012	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
120 X			P=.400	P=.232	P=.084	P=.017	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
130 X				P=.254	P=.100	P=.023	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
140 X				P=.276	P=.116	P=.029	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
150 X				P=.297	P=.132	P=.037	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
160 X				P=.318	P=.148	P=.045	P=.008	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
170 X				P=.339	P=.164	P=.053	P=.011	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
180 X				P=.359	P=.180	P=.062	P=.014	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
190 X				P=.379	P=.196	P=.071	P=.017	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
200 X				P=.399	P=.213	P=.081	P=.021	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
210 X					P=.229	P=.091	P=.025	P=.005	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
220 X					P=.245	P=.102	P=.030	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
230 X					P=.261	P=.112	P=.034	P=.007	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000

TABLE 7

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 15 MPH
(ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.027	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.038	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.002	P=.046	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.005	P=.053	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.001	P=.009	P=.059	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.002	P=.013	P=.065	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.003	P=.018	P=.070	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.005	P=.023	P=.075	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.007	P=.028	P=.080	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.009	P=.033	P=.084	P=.019	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.012	P=.037	P=.088	P=.022	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.015	P=.042	P=.092	P=.026	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.046	P=.096	P=.030	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.051	P=.100	P=.034	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.055	P=.103	P=.038	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.074	P=.119	P=.056	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.092	P=.133	P=.073	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.107	P=.146	P=.088	P=.014	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
35		P=.122	P=.158	P=.102	P=.022	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
40		P=.136	P=.169	P=.116	P=.030	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
45		P=.149	P=.179	P=.128	P=.038	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
50		P=.162	P=.189	P=.139	P=.047	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
55			P=.199	P=.150	P=.056	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
60			P=.208	P=.161	P=.065	P=.011	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
65			P=.217	P=.170	P=.074	P=.015	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
70			P=.225	P=.180	P=.083	P=.019	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
75			P=.233	P=.189	P=.092	P=.023	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
80			P=.242	P=.198	P=.100	P=.027	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
85			P=.250	P=.206	P=.109	P=.032	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
90			P=.258	P=.215	P=.117	P=.037	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
100			P=.274	P=.230	P=.133	P=.047	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
110			P=.290	P=.245	P=.149	P=.058	P=.013	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
120			P=.306	P=.260	P=.164	P=.069	P=.017	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
130				P=.274	P=.179	P=.080	P=.023	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
140				P=.287	P=.193	P=.091	P=.028	P=.005	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
150				P=.300	P=.207	P=.103	P=.034	P=.007	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
160				P=.313	P=.220	P=.114	P=.041	P=.010	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
170				P=.326	P=.233	P=.125	P=.048	P=.012	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000
180				P=.339	P=.245	P=.136	P=.055	P=.015	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
190				P=.350	P=.257	P=.148	P=.062	P=.018	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000
200				P=.363	P=.269	P=.159	P=.070	P=.022	P=.005	P=.001	P=.000	P=.000	P=.000	P=.000
210					P=.281	P=.169	P=.077	P=.026	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000
220					P=.292	P=.180	P=.085	P=.030	P=.007	P=.001	P=.000	P=.000	P=.000	P=.000
230					P=.304	P=.191	P=.093	P=.034	P=.009	P=.002	P=.000	P=.000	P=.000	P=.000

TABLE 8

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 20 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ X MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.020	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.028	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.001	P=.035	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.003	P=.040	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.006	P=.045	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.009	P=.049	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.001	P=.012	P=.053	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.001	P=.016	P=.056	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.001	P=.002	P=.019	P=.060	P=.012	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.001	P=.003	P=.023	P=.063	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.002	P=.004	P=.026	P=.066	P=.018	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.002	P=.005	P=.029	P=.069	P=.021	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.007	P=.033	P=.072	P=.024	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.008	P=.036	P=.075	P=.027	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.010	P=.039	P=.077	P=.029	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.019	P=.053	P=.089	P=.043	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.029	P=.066	P=.100	P=.056	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.040	P=.078	P=.109	P=.067	P=.013	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
35		P=.050	P=.088	P=.118	P=.078	P=.018	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
40		P=.060	P=.098	P=.126	P=.088	P=.025	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
45		P=.070	P=.107	P=.134	P=.097	P=.032	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
50		P=.079	P=.115	P=.141	P=.106	P=.039	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
55			P=.124	P=.148	P=.114	P=.045	P=.008	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
60			P=.131	P=.155	P=.122	P=.052	P=.011	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
65			P=.139	P=.161	P=.129	P=.059	P=.014	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
70			P=.146	P=.167	P=.136	P=.066	P=.017	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
75			P=.153	P=.173	P=.143	P=.073	P=.020	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
80			P=.159	P=.179	P=.149	P=.079	P=.024	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
85			P=.166	P=.185	P=.155	P=.086	P=.028	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
90			P=.173	P=.190	P=.161	P=.092	P=.032	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
100			P=.185	P=.201	P=.173	P=.104	P=.040	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
110			P=.198	P=.211	P=.184	P=.116	P=.049	P=.013	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000
120			P=.210	P=.221	P=.194	P=.127	P=.057	P=.017	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
130				P=.230	P=.204	P=.138	P=.066	P=.021	P=.004	P=.001	P=.000	P=.000	P=.000	P=.000
140				P=.240	P=.214	P=.149	P=.075	P=.026	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000
150				P=.249	P=.223	P=.159	P=.084	P=.031	P=.008	P=.001	P=.000	P=.000	P=.000	P=.000
160				P=.259	P=.232	P=.169	P=.093	P=.037	P=.010	P=.002	P=.000	P=.000	P=.000	P=.000
170				P=.267	P=.241	P=.178	P=.101	P=.042	P=.012	P=.002	P=.000	P=.000	P=.000	P=.000
180				P=.276	P=.249	P=.187	P=.110	P=.048	P=.015	P=.003	P=.000	P=.000	P=.000	P=.000
190				P=.285	P=.258	P=.196	P=.118	P=.054	P=.018	P=.004	P=.001	P=.000	P=.000	P=.000
200				P=.294	P=.266	P=.205	P=.127	P=.060	P=.021	P=.005	P=.001	P=.000	P=.000	P=.000
210					P=.274	P=.213	P=.135	P=.066	P=.025	P=.007	P=.001	P=.000	P=.000	P=.000
220					P=.281	P=.222	P=.143	P=.073	P=.028	P=.008	P=.002	P=.000	P=.000	P=.000
230					P=.289	P=.230	P=.151	P=.079	P=.032	P=.010	P=.002	P=.000	P=.000	P=.000

TABLE 9

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 25 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ X MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.016	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.023	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.001	P=.028	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.002	P=.032	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.004	P=.036	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.007	P=.039	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.009	P=.042	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.001	P=.012	P=.045	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.001	P=.015	P=.048	P=.010	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.002	P=.017	P=.050	P=.012	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.002	P=.020	P=.053	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.003	P=.023	P=.055	P=.017	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.001	P=.004	P=.025	P=.058	P=.019	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.001	P=.005	P=.028	P=.060	P=.022	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.001	P=.006	P=.030	P=.062	P=.024	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.004	P=.012	P=.042	P=.071	P=.035	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.008	P=.020	P=.052	P=.080	P=.045	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.013	P=.027	P=.061	P=.087	P=.055	P=.011	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
35		P=.018	P=.035	P=.070	P=.094	P=.063	P=.016	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
40		P=.024	P=.042	P=.077	P=.101	P=.071	P=.021	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
45		P=.030	P=.049	P=.084	P=.107	P=.078	P=.027	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
50		P=.037	P=.056	P=.091	P=.113	P=.085	P=.033	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
55			P=.063	P=.098	P=.118	P=.092	P=.038	P=.007	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
60			P=.069	P=.104	P=.124	P=.098	P=.044	P=.010	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
65			P=.076	P=.109	P=.129	P=.104	P=.049	P=.012	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
70			P=.082	P=.115	P=.134	P=.109	P=.055	P=.015	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000
75			P=.088	P=.120	P=.138	P=.115	P=.060	P=.018	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
80			P=.094	P=.125	P=.143	P=.120	P=.066	P=.021	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000
85			P=.099	P=.130	P=.147	P=.125	P=.071	P=.025	P=.005	P=.001	P=.000	P=.000	P=.000	P=.000
90			P=.105	P=.135	P=.152	P=.130	P=.076	P=.028	P=.006	P=.001	P=.000	P=.000	P=.000	P=.000
100			P=.116	P=.144	P=.160	P=.139	P=.086	P=.035	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000
110			P=.126	P=.153	P=.168	P=.147	P=.095	P=.042	P=.012	P=.002	P=.000	P=.000	P=.000	P=.000
120			P=.137	P=.162	P=.175	P=.156	P=.104	P=.049	P=.016	P=.003	P=.000	P=.000	P=.000	P=.000
130				P=.170	P=.183	P=.164	P=.113	P=.057	P=.020	P=.004	P=.001	P=.000	P=.000	P=.000
140				P=.178	P=.190	P=.171	P=.121	P=.064	P=.024	P=.006	P=.001	P=.000	P=.000	P=.000
150				P=.185	P=.197	P=.178	P=.129	P=.071	P=.028	P=.008	P=.001	P=.000	P=.000	P=.000
160				P=.193	P=.203	P=.185	P=.137	P=.078	P=.033	P=.010	P=.002	P=.000	P=.000	P=.000
170				P=.200	P=.210	P=.192	P=.145	P=.085	P=.038	P=.012	P=.003	P=.000	P=.000	P=.000
180				P=.208	P=.216	P=.199	P=.152	P=.092	P=.043	P=.015	P=.004	P=.001	P=.000	P=.000
190				P=.215	P=.222	P=.205	P=.159	P=.099	P=.048	P=.017	P=.005	P=.001	P=.000	P=.000
200				P=.223	P=.228	P=.211	P=.166	P=.106	P=.053	P=.020	P=.006	P=.001	P=.000	P=.000
210					P=.234	P=.218	P=.172	P=.112	P=.058	P=.023	P=.007	P=.002	P=.000	P=.000
220					P=.240	P=.223	P=.179	P=.119	P=.063	P=.026	P=.008	P=.002	P=.000	P=.000
230					P=.246	P=.229	P=.185	P=.125	P=.069	P=.030	P=.010	P=.003	P=.000	P=.000

TABLE 10

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 30 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.019	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.001	P=.023	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.002	P=.027	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.003	P=.030	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.005	P=.033	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.007	P=.035	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.009	P=.038	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.001	P=.012	P=.040	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.001	P=.014	P=.042	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.001	P=.016	P=.044	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.002	P=.018	P=.046	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.000	P=.000	P=.003	P=.020	P=.048	P=.017	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.000	P=.000	P=.003	P=.023	P=.050	P=.019	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.000	P=.001	P=.004	P=.025	P=.052	P=.020	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.001	P=.002	P=.009	P=.034	P=.059	P=.030	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.002	P=.004	P=.015	P=.043	P=.066	P=.038	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.004	P=.007	P=.021	P=.050	P=.073	P=.046	P=.010	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
35		P=.006	P=.011	P=.027	P=.057	P=.079	P=.053	P=.014	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
40		P=.009	P=.015	P=.033	P=.064	P=.084	P=.060	P=.019	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000
45		P=.012	P=.019	P=.039	P=.070	P=.089	P=.066	P=.023	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
50		P=.014	P=.024	P=.044	P=.075	P=.094	P=.071	P=.028	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000
55			P=.028	P=.050	P=.081	P=.099	P=.077	P=.033	P=.007	P=.001	P=.000	P=.000	P=.000	P=.000
60			P=.033	P=.055	P=.086	P=.103	P=.082	P=.038	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000
65			P=.037	P=.060	P=.091	P=.107	P=.087	P=.042	P=.011	P=.002	P=.000	P=.000	P=.000	P=.000
70			P=.042	P=.065	P=.095	P=.111	P=.091	P=.047	P=.014	P=.002	P=.000	P=.000	P=.000	P=.000
75			P=.047	P=.070	P=.100	P=.115	P=.096	P=.052	P=.016	P=.003	P=.000	P=.000	P=.000	P=.000
80			P=.051	P=.074	P=.104	P=.119	P=.100	P=.056	P=.019	P=.004	P=.000	P=.000	P=.000	P=.000
85			P=.055	P=.079	P=.108	P=.123	P=.104	P=.060	P=.022	P=.005	P=.001	P=.000	P=.000	P=.000
90			P=.060	P=.083	P=.112	P=.126	P=.108	P=.065	P=.025	P=.006	P=.001	P=.000	P=.000	P=.000
100			P=.069	P=.092	P=.119	P=.133	P=.116	P=.073	P=.031	P=.008	P=.001	P=.000	P=.000	P=.000
110			P=.077	P=.100	P=.127	P=.140	P=.123	P=.081	P=.037	P=.011	P=.002	P=.000	P=.000	P=.000
120			P=.086	P=.107	P=.133	P=.146	P=.130	P=.088	P=.043	P=.014	P=.003	P=.000	P=.000	P=.000
130				P=.115	P=.140	P=.152	P=.136	P=.095	P=.049	P=.018	P=.004	P=.001	P=.000	P=.000
140				P=.122	P=.146	P=.158	P=.143	P=.102	P=.055	P=.022	P=.006	P=.001	P=.000	P=.000
150				P=.129	P=.152	P=.163	P=.149	P=.109	P=.062	P=.026	P=.008	P=.002	P=.000	P=.000
160				P=.136	P=.158	P=.169	P=.155	P=.116	P=.068	P=.030	P=.010	P=.002	P=.000	P=.000
170				P=.142	P=.164	P=.174	P=.160	P=.122	P=.073	P=.034	P=.012	P=.003	P=.001	P=.000
180				P=.149	P=.169	P=.179	P=.166	P=.128	P=.079	P=.038	P=.014	P=.004	P=.001	P=.000
190				P=.155	P=.175	P=.184	P=.171	P=.134	P=.085	P=.043	P=.016	P=.005	P=.001	P=.000
200				P=.162	P=.180	P=.189	P=.176	P=.139	P=.091	P=.047	P=.019	P=.006	P=.001	P=.000
210					P=.185	P=.194	P=.181	P=.145	P=.096	P=.052	P=.022	P=.007	P=.002	P=.000
220					P=.191	P=.199	P=.186	P=.150	P=.102	P=.056	P=.025	P=.008	P=.002	P=.000
230					P=.196	P=.203	P=.191	P=.155	P=.107	P=.061	P=.027	P=.010	P=.003	P=.001

TABLE 11

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 35 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.016	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.020	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.023	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.025	P=.002	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.028	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.030	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.032	P=.006	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.010	P=.034	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.036	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.001	P=.014	P=.038	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.001	P=.015	P=.039	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.000	P=.000	P=.000	P=.002	P=.017	P=.041	P=.014	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.000	P=.000	P=.000	P=.003	P=.019	P=.043	P=.016	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
15		P=.000	P=.000	P=.000	P=.003	P=.021	P=.044	P=.018	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
20		P=.000	P=.000	P=.001	P=.007	P=.029	P=.051	P=.026	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
25		P=.000	P=.001	P=.003	P=.012	P=.036	P=.057	P=.033	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000
30		P=.001	P=.002	P=.005	P=.017	P=.043	P=.062	P=.040	P=.009	P=.001	P=.000	P=.000	P=.000	P=.000
35		P=.002	P=.003	P=.008	P=.022	P=.049	P=.067	P=.046	P=.013	P=.001	P=.000	P=.000	P=.000	P=.000
40		P=.003	P=.005	P=.011	P=.027	P=.054	P=.072	P=.051	P=.017	P=.002	P=.000	P=.000	P=.000	P=.000
45		P=.005	P=.007	P=.014	P=.032	P=.060	P=.076	P=.056	P=.021	P=.003	P=.000	P=.000	P=.000	P=.000
50		P=.007	P=.009	P=.018	P=.036	P=.064	P=.081	P=.061	P=.025	P=.005	P=.000	P=.000	P=.000	P=.000
55			P=.012	P=.021	P=.041	P=.069	P=.085	P=.066	P=.029	P=.006	P=.001	P=.000	P=.000	P=.000
60			P=.014	P=.025	P=.046	P=.073	P=.088	P=.070	P=.033	P=.008	P=.001	P=.000	P=.000	P=.000
65			P=.017	P=.029	P=.050	P=.077	P=.092	P=.075	P=.037	P=.010	P=.002	P=.000	P=.000	P=.000
70			P=.020	P=.032	P=.054	P=.081	P=.095	P=.078	P=.041	P=.013	P=.002	P=.000	P=.000	P=.000
75			P=.023	P=.036	P=.058	P=.085	P=.099	P=.082	P=.045	P=.015	P=.003	P=.000	P=.000	P=.000
80			P=.026	P=.040	P=.062	P=.089	P=.102	P=.086	P=.049	P=.017	P=.004	P=.000	P=.000	P=.000
85			P=.030	P=.043	P=.066	P=.092	P=.105	P=.090	P=.053	P=.020	P=.005	P=.001	P=.000	P=.000
90			P=.033	P=.047	P=.070	P=.096	P=.108	P=.093	P=.056	P=.022	P=.006	P=.001	P=.000	P=.000
100			P=.039	P=.054	P=.077	P=.102	P=.114	P=.099	P=.063	P=.028	P=.008	P=.001	P=.000	P=.000
110			P=.046	P=.060	P=.084	P=.108	P=.120	P=.106	P=.070	P=.033	P=.011	P=.002	P=.000	P=.000
120			P=.053	P=.067	P=.090	P=.114	P=.125	P=.111	P=.076	P=.038	P=.013	P=.003	P=.000	P=.000
130				P=.073	P=.096	P=.119	P=.130	P=.117	P=.083	P=.044	P=.017	P=.004	P=.001	P=.000
140				P=.079	P=.102	P=.125	P=.135	P=.122	P=.089	P=.049	P=.020	P=.006	P=.001	P=.000
150				P=.086	P=.108	P=.130	P=.140	P=.128	P=.094	P=.054	P=.024	P=.007	P=.002	P=.000
160				P=.092	P=.113	P=.135	P=.144	P=.133	P=.100	P=.059	P=.027	P=.009	P=.002	P=.000
170				P=.097	P=.119	P=.140	P=.149	P=.137	P=.105	P=.065	P=.031	P=.011	P=.003	P=.001
180				P=.103	P=.124	P=.144	P=.153	P=.142	P=.110	P=.070	P=.035	P=.013	P=.004	P=.001
190				P=.109	P=.129	P=.149	P=.157	P=.146	P=.115	P=.075	P=.039	P=.015	P=.005	P=.001
200				P=.115	P=.134	P=.153	P=.162	P=.151	P=.120	P=.079	P=.042	P=.018	P=.006	P=.001
210					P=.139	P=.157	P=.166	P=.155	P=.125	P=.084	P=.046	P=.020	P=.007	P=.002
220					P=.143	P=.162	P=.170	P=.159	P=.129	P=.089	P=.050	P=.023	P=.008	P=.002
230					P=.148	P=.166	P=.173	P=.163	P=.134	P=.093	P=.054	P=.025	P=.010	P=.003

TABLE 12

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 40 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.010	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.014	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.017	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.020	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.022	P=.001	P=.000	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.024	P=.003	P=.000	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.026	P=.004	P=.000	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.028	P=.005	P=.000	P=.000	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.030	P=.007	P=.000	P=.000	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.032	P=.008	P=.000	P=.000	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.033	P=.010	P=.000	P=.000	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.013	P=.035	P=.011	P=.000	P=.000	P=.000	P=.000	P=.000
13		P=.000	P=.000	P=.000	P=.000	P=.002	P=.015	P=.036	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000
14		P=.000	P=.000	P=.000	P=.000	P=.002	P=.017	P=.037	P=.014	P=.001	P=.000	P=.000	P=.000	P=.000
15		P=.000	P=.000	P=.000	P=.000	P=.002	P=.018	P=.039	P=.016	P=.001	P=.000	P=.000	P=.000	P=.000
20		P=.000	P=.000	P=.000	P=.001	P=.006	P=.025	P=.045	P=.023	P=.002	P=.000	P=.000	P=.000	P=.000
25		P=.000	P=.000	P=.000	P=.002	P=.010	P=.032	P=.050	P=.029	P=.005	P=.000	P=.000	P=.000	P=.000
30		P=.000	P=.000	P=.001	P=.004	P=.014	P=.037	P=.055	P=.035	P=.008	P=.001	P=.000	P=.000	P=.000
35		P=.001	P=.001	P=.002	P=.006	P=.018	P=.043	P=.059	P=.040	P=.011	P=.001	P=.000	P=.000	P=.000
40		P=.001	P=.001	P=.003	P=.008	P=.023	P=.047	P=.063	P=.045	P=.015	P=.002	P=.000	P=.000	P=.000
45		P=.002	P=.002	P=.004	P=.011	P=.027	P=.052	P=.067	P=.050	P=.018	P=.003	P=.000	P=.000	P=.000
50		P=.003	P=.003	P=.006	P=.014	P=.031	P=.056	P=.071	P=.054	P=.022	P=.004	P=.000	P=.000	P=.000
55			P=.005	P=.0[illegible]	P=.017	P=.035	P=.060	P=.074	P=.058	P=.026	P=.006	P=.001	P=.000	P=.000
60			P=.006	P=.010	P=.020	P=.039	P=.064	P=.077	P=.062	P=.029	P=.008	P=.001	P=.000	P=.000
65			P=.008	P=.012	P=.023	P=.043	P=.067	P=.080	P=.065	P=.033	P=.010	P=.001	P=.000	P=.000
70			P=.009	P=.014	P=.026	P=.046	P=.071	P=.083	P=.069	P=.037	P=.012	P=.002	P=.000	P=.000
75			P=.011	P=.017	P=.029	P=.050	P=.074	P=.086	P=.072	P=.040	P=.014	P=.003	P=.000	P=.000
80			P=.013	P=.019	P=.032	P=.053	P=.077	P=.089	P=.075	P=.043	P=.016	P=.003	P=.000	P=.000
85			P=.015	P=.022	P=.035	P=.057	P=.080	P=.092	P=.078	P=.047	P=.018	P=.004	P=.001	P=.000
90			P=.017	P=.024	P=.038	P=.060	P=.083	P=.095	P=.081	P=.050	P=.020	P=.005	P=.001	P=.000
100			P=.022	P=.029	P=.044	P=.066	P=.089	P=.100	P=.087	P=.056	P=.025	P=.007	P=.001	P=.000
110			P=.027	P=.033	P=.050	P=.072	P=.094	P=.105	P=.093	P=.062	P=.030	P=.010	P=.002	P=.000
120			P=.032	P=.040	P=.055	P=.076	P=.099	P=.109	P=.098	P=.067	P=.035	P=.013	P=.003	P=.001
130				P=.045	P=.061	P=.083	P=.104	P=.114	P=.103	P=.073	P=.039	P=.015	P=.004	P=.001
140				P=.050	P=.066	P=.088	P=.109	P=.118	P=.107	P=.078	P=.044	P=.018	P=.006	P=.001
150				P=.055	P=.072	P=.093	P=.113	P=.122	P=.112	P=.083	P=.049	P=.022	P=.007	P=.002
160				P=.060	P=.076	P=.098	P=.118	P=.126	P=.116	P=.088	P=.053	P=.025	P=.009	P=.002
170				P=.065	P=.081	P=.102	P=.122	P=.130	P=.120	P=.093	P=.058	P=.028	P=.011	P=.003
180				P=.070	P=.086	P=.107	P=.126	P=.134	P=.124	P=.097	P=.062	P=.032	P=.013	P=.004
190				P=.075	P=.091	P=.111	P=.130	P=.138	P=.128	P=.101	P=.066	P=.035	P=.015	P=.005
200				P=.079	P=.095	P=.115	P=.134	P=.141	P=.132	P=.106	P=.071	P=.039	P=.017	P=.006
210					P=.100	P=.120	P=.137	P=.145	P=.136	P=.110	P=.075	P=.042	P=.019	P=.007
220					P=.104	P=.124	P=.141	P=.148	P=.139	P=.114	P=.079	P=.045	P=.021	P=.008
230					P=.108	P=.127	P=.144	P=.152	P=.143	P=.118	P=.083	P=.049	P=.024	P=.009

TABLE 13

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 45 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.009	P=.000	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.013	P=.000	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.015	P=.000	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.018	P=.001	P=.000	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.020	P=.001	P=.000	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.022	P=.002	P=.000	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.023	P=.003	P=.000	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.025	P=.005	P=.000	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.027	P=.006	P=.000	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.009	P=.028	P=.007	P=.000	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.029	P=.009	P=.000	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.031	P=.010	P=.000	P=.000	P=.000	P=.000
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.013	P=.032	P=.011	P=.000	P=.000	P=.000	P=.000
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.015	P=.033	P=.013	P=.001	P=.000	P=.000	P=.000
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.016	P=.034	P=.014	P=.001	P=.000	P=.000	P=.000
20		P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.022	P=.040	P=.020	P=.002	P=.000	P=.000	P=.000
25		P=.000	P=.000	P=.000	P=.000	P=.001	P=.008	P=.028	P=.044	P=.026	P=.005	P=.000	P=.000	P=.000
30		P=.000	P=.000	P=.000	P=.001	P=.003	P=.012	P=.033	P=.049	P=.031	P=.007	P=.001	P=.000	P=.000
35		P=.000	P=.000	P=.000	P=.001	P=.005	P=.016	P=.036	P=.052	P=.036	P=.010	P=.001	P=.000	P=.000
40		P=.000	P=.000	P=.001	P=.002	P=.007	P=.020	P=.042	P=.056	P=.040	P=.013	P=.002	P=.000	P=.000
45		P=.001	P=.001	P=.001	P=.003	P=.009	P=.023	P=.046	P=.059	P=.044	P=.017	P=.003	P=.000	P=.000
50		P=.001	P=.001	P=.002	P=.004	P=.011	P=.027	P=.050	P=.063	P=.048	P=.020	P=.004	P=.000	P=.000
55			P=.002	P=.003	P=.006	P=.014	P=.031	P=.053	P=.066	P=.052	P=.023	P=.006	P=.001	P=.000
60			P=.002	P=.004	P=.008	P=.017	P=.034	P=.057	P=.069	P=.055	P=.027	P=.007	P=.001	P=.000
65			P=.003	P=.005	P=.009	P=.019	P=.037	P=.060	P=.071	P=.058	P=.030	P=.009	P=.001	P=.000
70			P=.004	P=.006	P=.011	P=.022	P=.041	P=.063	P=.074	P=.061	P=.033	P=.011	P=.002	P=.000
75			P=.005	P=.007	P=.013	P=.025	P=.044	P=.066	P=.077	P=.064	P=.036	P=.013	P=.003	P=.000
80			P=.006	P=.009	P=.015	P=.027	P=.047	P=.069	P=.079	P=.067	P=.039	P=.015	P=.003	P=.000
85			P=.008	P=.010	P=.017	P=.030	P=.050	P=.071	P=.082	P=.070	P=.042	P=.017	P=.004	P=.001
90			P=.009	P=.012	P=.019	P=.033	P=.053	P=.074	P=.084	P=.072	P=.045	P=.019	P=.005	P=.001
100			P=.012	P=.015	P=.024	P=.038	P=.058	P=.079	P=.089	P=.078	P=.050	P=.023	P=.007	P=.001
110			P=.015	P=.019	P=.028	P=.043	P=.063	P=.084	P=.093	P=.082	P=.055	P=.027	P=.009	P=.002
120			P=.019	P=.023	P=.032	P=.049	P=.068	P=.088	P=.097	P=.087	P=.060	P=.031	P=.012	P=.003
130				P=.027	P=.037	P=.053	P=.073	P=.093	P=.101	P=.091	P=.065	P=.036	P=.014	P=.004
140				P=.030	P=.041	P=.057	P=.078	P=.097	P=.105	P=.095	P=.070	P=.040	P=.017	P=.005
150				P=.034	P=.045	P=.062	P=.082	P=.101	P=.109	P=.099	P=.074	P=.044	P=.020	P=.007
160				P=.038	P=.049	P=.066	P=.086	P=.104	P=.112	P=.103	P=.079	P=.048	P=.023	P=.008
170				P=.042	P=.053	P=.070	P=.090	P=.108	P=.116	P=.107	P=.083	P=.052	P=.026	P=.010
180				P=.046	P=.057	P=.074	P=.094	P=.112	P=.119	P=.110	P=.087	P=.056	P=.029	P=.012
190				P=.050	P=.061	P=.078	P=.098	P=.115	P=.122	P=.114	P=.091	P=.060	P=.032	P=.014
200				P=.054	P=.065	P=.082	P=.102	P=.119	P=.125	P=.117	P=.094	P=.064	P=.035	P=.016
210					P=.069	P=.086	P=.105	P=.122	P=.129	P=.121	P=.098	P=.067	P=.038	P=.018
220					P=.073	P=.090	P=.109	P=.125	P=.132	P=.124	P=.102	P=.071	P=.042	P=.020
230					P=.077	P=.094	P=.112	P=.128	P=.135	P=.1[illegible]7	P=.105	P=.075	P=.045	P=.022

TABLE 14

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 50 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.000	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.011	P=.000	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.014	P=.000	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.016	P=.001	P=.000	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.018	P=.001	P=.000	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.020	P=.002	P=.000	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.021	P=.003	P=.000	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.023	P=.004	P=.000	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.024	P=.005	P=.000	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.025	P=.007	P=.000	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.009	P=.026	P=.008	P=.000	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.028	P=.009	P=.000	P=.000	P=.000
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.029	P=.010	P=.000	P=.000	P=.000
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.013	P=.030	P=.012	P=.001	P=.000	P=.000
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.014	P=.031	P=.013	P=.001	P=.000	P=.000
20		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.020	P=.036	P=.018	P=.002	P=.000	P=.000
25		P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.007	P=.025	P=.040	P=.023	P=.004	P=.000	P=.000
30		P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.010	P=.030	P=.044	P=.028	P=.007	P=.001	P=.000
35		P=.000	P=.000	P=.000	P=.000	P=.001	P=.004	P=.014	P=.034	P=.047	P=.032	P=.009	P=.001	P=.000
40		P=.000	P=.000	P=.000	P=.000	P=.002	P=.006	P=.017	P=.038	P=.050	P=.036	P=.012	P=.002	P=.000
45		P=.000	P=.000	P=.000	P=.001	P=.002	P=.008	P=.021	P=.041	P=.054	P=.040	P=.015	P=.003	P=.000
50		P=.000	P=.000	P=.001	P=.001	P=.003	P=.010	P=.024	P=.045	P=.056	P=.043	P=.018	P=.004	P=.000
55			P=.001	P=.001	P=.002	P=.005	P=.012	P=.027	P=.048	P=.059	P=.046	P=.021	P=.005	P=.001
60			P=.001	P=.001	P=.003	P=.006	P=.014	P=.030	P=.051	P=.062	P=.050	P=.024	P=.007	P=.001
65			P=.001	P=.002	P=.003	P=.007	P=.017	P=.033	P=.054	P=.064	P=.052	P=.027	P=.008	P=.001
70			P=.002	P=.002	P=.004	P=.009	P=.019	P=.036	P=.057	P=.067	P=.055	P=.030	P=.010	P=.002
75			P=.002	P=.003	P=.005	P=.011	P=.021	P=.039	P=.059	P=.069	P=.058	P=.033	P=.012	P=.003
80			P=.003	P=.004	P=.007	P=.012	P=.024	P=.042	P=.062	P=.071	P=.060	P=.035	P=.013	P=.003
85			P=.004	P=.005	P=.008	P=.014	P=.026	P=.044	P=.064	P=.074	P=.063	P=.038	P=.015	P=.004
90			P=.005	P=.006	P=.009	P=.016	P=.028	P=.047	P=.067	P=.076	P=.065	P=.040	P=.017	P=.005
100			P=.006	P=.008	P=.012	P=.020	P=.033	P=.052	P=.071	P=.080	P=.070	P=.045	P=.021	P=.007
110			P=.009	P=.010	P=.015	P=.023	P=.038	P=.057	P=.075	P=.084	P=.074	P=.050	P=.025	P=.009
120			P=.011	P=.013	P=.018	P=.027	P=.042	P=.061	P=.079	P=.087	P=.078	P=.055	P=.029	P=.011
130				P=.015	P=.021	P=.031	P=.046	P=.065	P=.083	P=.091	P=.082	P=.059	P=.033	P=.013
140				P=.018	P=.024	P=.035	P=.050	P=.070	P=.087	P=.094	P=.086	P=.063	P=.036	P=.016
150				P=.021	P=.027	P=.038	P=.054	P=.073	P=.090	P=.098	P=.089	P=.067	P=.040	P=.019
160				P=.024	P=.031	P=.042	P=.058	P=.077	P=.094	P=.101	P=.093	P=.071	P=.044	P=.021
170				P=.027	P=.034	P=.046	P=.062	P=.081	P=.097	P=.104	P=.096	P=.075	P=.047	P=.024
180				P=.030	P=.037	P=.049	P=.066	P=.084	P=.100	P=.107	P=.099	P=.078	P=.051	P=.027
190				P=.033	P=.041	P=.053	P=.069	P=.088	P=.104	P=.110	P=.103	P=.082	P=.054	P=.030
200				P=.037	P=.044	P=.056	P=.073	P=.091	P=.107	P=.113	P=.106	P=.085	P=.058	P=.033
210					P=.047	P=.060	P=.076	P=.094	P=.109	P=.116	P=.109	P=.088	P=.061	P=.035
220					P=.050	P=.063	P=.080	P=.098	P=.112	P=.118	P=.111	P=.092	P=.065	P=.038
230					P=.053	P=.066	P=.083	P=.101	P=.115	P=.121	P=.114	P=.095	P=.068	P=.041

TABLE 15

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 55 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.000	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.010	P=.000	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.013	P=.000	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.015	P=.001	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.016	P=.001	P=.000	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.018	P=.002	P=.000	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.019	P=.003	P=.000	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.021	P=.004	P=.000	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.022	P=.005	P=.000	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.023	P=.006	P=.000	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.024	P=.007	P=.000	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.009	P=.025	P=.008	P=.000	P=.000
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.011	P=.026	P=.009	P=.000	P=.000
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.027	P=.011	P=.001	P=.000
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.013	P=.028	P=.012	P=.001	P=.000
20		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.018	P=.032	P=.017	P=.002	P=.000
25		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.006	P=.023	P=.036	P=.021	P=.004	P=.000
30		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.009	P=.027	P=.040	P=.026	P=.006	P=.000
35		P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.012	P=.031	P=.043	P=.029	P=.009	P=.001
40		P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.015	P=.034	P=.046	P=.033	P=.011	P=.002
45		P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.007	P=.018	P=.037	P=.049	P=.036	P=.014	P=.003
50		P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.008	P=.021	P=.041	P=.051	P=.039	P=.017	P=.004
55			P=.000	P=.000	P=.001	P=.001	P=.004	P=.010	P=.024	P=.043	P=.054	P=.042	P=.020	P=.005
60			P=.000	P=.000	P=.001	P=.002	P=.005	P=.012	P=.027	P=.046	P=.056	P=.045	P=.022	P=.006
65			P=.001	P=.001	P=.001	P=.003	P=.006	P=.015	P=.030	P=.049	P=.058	P=.048	P=.025	P=.008
70			P=.001	P=.001	P=.002	P=.003	P=.008	P=.017	P=.033	P=.051	P=.061	P=.050	P=.027	P=.009
75			P=.001	P=.001	P=.002	P=.004	P=.009	P=.019	P=.035	P=.054	P=.063	P=.053	P=.030	P=.011
80			P=.001	P=.002	P=.003	P=.005	P=.010	P=.021	P=.038	P=.056	P=.065	P=.055	P=.032	P=.013
85			P=.002	P=.002	P=.003	P=.006	P=.012	P=.023	P=.040	P=.058	P=.067	P=.057	P=.035	P=.014
90			P=.002	P=.003	P=.004	P=.007	P=.014	P=.025	P=.042	P=.060	P=.069	P=.059	P=.037	P=.016
100			P=.003	P=.004	P=.006	P=.009	P=.017	P=.029	P=.047	P=.065	P=.073	P=.064	P=.042	P=.019
110			P=.005	P=.005	P=.007	P=.012	P=.020	P=.033	P=.051	P=.068	P=.076	P=.067	P=.046	P=.023
120			P=.006	P=.007	P=.009	P=.014	P=.023	P=.037	P=.055	P=.072	P=.079	P=.071	P=.050	P=.027
130				P=.009	P=.011	P=.017	P=.027	P=.041	P=.059	P=.076	P=.083	P=.075	P=.054	P=.030
140				P=.011	P=.014	P=.020	P=.030	P=.045	P=.063	P=.079	P=.086	P=.078	P=.058	P=.034
150				P=.013	P=.016	P=.023	P=.034	P=.049	P=.066	P=.082	P=.089	P=.081	P=.061	P=.037
160				P=.015	P=.019	P=.026	P=.037	P=.052	P=.070	P=.085	P=.092	P=.084	P=.065	P=.040
170				P=.017	P=.021	P=.029	P=.040	P=.056	P=.073	P=.088	P=.095	P=.086	P=.068	P=.044
180				P=.019	P=.024	P=.031	P=.043	P=.059	P=.076	P=.091	P=.097	P=.090	P=.071	P=.047
190				P=.022	P=.026	P=.034	P=.046	P=.062	P=.080	P=.094	P=.100	P=.093	P=.075	P=.050
200				P=.024	P=.029	P=.037	P=.049	P=.065	P=.083	P=.097	P=.103	P=.096	P=.078	P=.053
210					P=.031	P=.040	P=.053	P=.068	P=.085	P=.099	P=.105	P=.099	P=.081	P=.056
220					P=.034	P=.043	P=.056	P=.071	P=.088	P=.102	P=.108	P=.101	P=.084	P=.059
230					P=.037	P=.046	P=.058	P=.074	P=.091	P=.105	P=.110	P=.104	P=.086	P=.062

TABLE 16

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 60 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ X MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.000	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.009	P=.000	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.012	P=.000	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.013	P=.000	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.015	P=.001	P=.000
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.016	P=.002	P=.000
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.018	P=.003	P=.000
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.019	P=.004	P=.000
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.020	P=.005	P=.000
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.021	P=.006	P=.000
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008	P=.022	P=.007	P=.000
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.009	P=.023	P=.008	P=.000
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.024	P=.009	P=.000
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.011	P=.025	P=.010	P=.000
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.026	P=.011	P=.001
20		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.016	P=.030	P=.015	P=.002
25		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.006	P=.021	P=.033	P=.020	P=.004
30		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.008	P=.025	P=.036	P=.023	P=.006
35		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.011	P=.028	P=.039	P=.027	P=.008
40		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.004	P=.014	P=.031	P=.042	P=.030	P=.011
45		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.006	P=.017	P=.034	P=.045	P=.033	P=.013
50		P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.007	P=.019	P=.037	P=.047	P=.036	P=.016
55			P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.009	P=.022	P=.040	P=.049	P=.039	P=.018
60			P=.000	P=.000	P=.000	P=.001	P=.001	P=.004	P=.011	P=.025	P=.042	P=.052	P=.041	P=.020
65			P=.000	P=.000	P=.000	P=.001	P=.002	P=.005	P=.013	P=.027	P=.045	P=.054	P=.044	P=.023
70			P=.000	P=.000	P=.001	P=.001	P=.003	P=.006	P=.015	P=.030	P=.047	P=.056	P=.046	P=.025
75			P=.000	P=.000	P=.001	P=.001	P=.003	P=.008	P=.017	P=.032	P=.049	P=.058	P=.048	P=.028
80			P=.001	P=.001	P=.001	P=.002	P=.004	P=.009	P=.019	P=.034	P=.051	P=.059	P=.050	P=.030
85			P=.001	P=.001	P=.001	P=.002	P=.005	P=.010	P=.021	P=.036	P=.053	P=.061	P=.052	P=.032
90			P=.001	P=.001	P=.002	P=.003	P=.006	P=.012	P=.023	P=.039	P=.055	P=.063	P=.054	P=.034
100			P=.002	P=.002	P=.003	P=.004	P=.008	P=.015	P=.026	P=.043	P=.059	P=.066	P=.058	P=.038
110			P=.003	P=.003	P=.004	P=.006	P=.010	P=.018	P=.030	P=.047	P=.063	P=.070	P=.062	P=.042
120			P=.004	P=.004	P=.005	P=.007	P=.012	P=.021	P=.034	P=.050	P=.066	P=.073	P=.065	P=.046
130				P=.005	P=.006	P=.009	P=.015	P=.024	P=.037	P=.054	P=.069	P=.076	P=.069	P=.050
140				P=.006	P=.008	P=.011	P=.017	P=.027	P=.041	P=.057	P=.072	P=.079	P=.072	P=.053
150				P=.007	P=.009	P=.013	P=.019	P=.030	P=.044	P=.061	P=.075	P=.081	P=.075	P=.056
160				P=.009	P=.011	P=.015	P=.022	P=.033	P=.047	P=.064	P=.078	P=.084	P=.077	P=.060
170				P=.011	P=.013	P=.017	P=.025	P=.036	P=.050	P=.067	P=.081	P=.087	P=.080	P=.063
180				P=.012	P=.015	P=.019	P=.027	P=.039	P=.053	P=.070	P=.084	P=.089	P=.083	P=.066
190				P=.014	P=.017	P=.022	P=.030	P=.041	P=.056	P=.073	P=.086	P=.092	P=.086	P=.069
200				P=.016	P=.018	P=.024	P=.032	P=.044	P=.059	P=.075	P=.089	P=.094	P=.088	P=.071
210					P=.021	P=.026	P=.035	P=.047	P=.062	P=.078	P=.091	P=.096	P=.091	P=.074
220					P=.023	P=.028	P=.037	P=.050	P=.065	P=.081	P=.094	P=.099	P=.093	P=.077
230					P=.025	P=.031	P=.040	P=.052	P=.068	P=.083	P=.096	P=.101	P=.095	P=.079

TABLE 17

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 65 MPH (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.000
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.009	P=.000
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.011	P=.000
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.012	P=.000
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.014	P=.001
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.015	P=.002
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.016	P=.002
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.017	P=.003
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.018	P=.004
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.019	P=.005
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.020	P=.006
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.008	P=.021	P=.007
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.009	P=.022	P=.008
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.023	P=.009
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.011	P=.024	P=.010
20		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.015	P=.027	P=.014
25		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.019	P=.031	P=.018
30		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.008	P=.023	P=.034	P=.022
35		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.010	P=.026	P=.036	P=.025
40		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.004	P=.013	P=.029	P=.039	P=.028
45		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.015	P=.032	P=.041	P=.031
50		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.007	P=.018	P=.034	P=.043	P=.033
55			P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.008	P=.020	P=.037	P=.046	P=.036
60			P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.004	P=.010	P=.023	P=.039	P=.048	P=.038
65			P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.005	P=.012	P=.025	P=.041	P=.049	P=.040
70			P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.006	P=.013	P=.027	P=.043	P=.051	P=.043
75			P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.007	P=.015	P=.029	P=.045	P=.053	P=.045
80			P=.000	P=.000	P=.000	P=.001	P=.001	P=.003	P=.008	P=.017	P=.031	P=.047	P=.055	P=.047
85			P=.000	P=.000	P=.000	P=.001	P=.002	P=.004	P=.009	P=.019	P=.033	P=.049	P=.057	P=.048
90			P=.001	P=.001	P=.001	P=.001	P=.002	P=.005	P=.010	P=.020	P=.035	P=.051	P=.058	P=.050
100			P=.001	P=.001	P=.001	P=.002	P=.003	P=.007	P=.013	P=.024	P=.039	P=.055	P=.061	P=.054
110			P=.001	P=.001	P=.002	P=.003	P=.005	P=.008	P=.016	P=.027	P=.043	P=.058	P=.064	P=.057
120			P=.002	P=.002	P=.002	P=.004	P=.006	P=.010	P=.018	P=.031	P=.046	P=.061	P=.067	P=.060
130				P=.003	P=.003	P=.005	P=.007	P=.013	P=.021	P=.034	P=.050	P=.064	P=.070	P=.063
140				P=.003	P=.004	P=.006	P=.009	P=.015	P=.024	P=.037	P=.053	P=.067	P=.073	P=.066
150				P=.004	P=.005	P=.007	P=.011	P=.017	P=.027	P=.040	P=.056	P=.069	P=.075	P=.069
160				P=.005	P=.006	P=.009	P=.013	P=.019	P=.029	P=.043	P=.059	P=.072	P=.078	P=.072
170				P=.007	P=.008	P=.010	P=.014	P=.022	P=.032	P=.046	P=.062	P=.075	P=.080	P=.074
180				P=.008	P=.009	P=.012	P=.016	P=.024	P=.035	P=.049	P=.064	P=.077	P=.082	P=.077
190				P=.009	P=.010	P=.013	P=.018	P=.026	P=.037	P=.052	P=.067	P=.080	P=.085	P=.079
200				P=.011	P=.012	P=.015	P=.020	P=.028	P=.040	P=.054	P=.069	P=.082	P=.087	P=.081
210					P=.013	P=.017	P=.022	P=.031	P=.042	P=.057	P=.072	P=.084	P=.089	P=.084
220					P=.015	P=.018	P=.024	P=.033	P=.045	P=.059	P=.074	P=.086	P=.091	P=.086
230					P=.016	P=.020	P=.026	P=.035	P=.047	P=.062	P=.077	P=.088	P=.093	P=.088

CORRECTION FACTORS AS A FUNCTION OF MEAN AND VARIANCE THIS TABLE IS FOR A SPEED OF 70 MPH (ASSUMING TYPE III DISTRIBUTIONS)

X MEAN / VAR	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006
2	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.008
3	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.010
4	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.011
5	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.013
6	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.014
7	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.015
8	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.004	P=.016
9	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.017
10	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.005	P=.018
11	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.006	P=.019
12	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.007	P=.020
13		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.008	P=.021
14		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.009	P=.021
15		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.010	P=.022
20		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.003	P=.014	P=.025
25		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.018	P=.028
30		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.007	P=.021	P=.031
35		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.009	P=.024	P=.034
40		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.012	P=.027	P=.036
45		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.005	P=.014	P=.029	P=.038
50		P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.002	P=.006	P=.016	P=.032	P=.040
55			P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.007	P=.019	P=.034	P=.042
60			P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.009	P=.021	P=.036	P=.044
65			P=.000	P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.004	P=.011	P=.023	P=.038	P=.046
70			P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.005	P=.012	P=.025	P=.040	P=.048
75			P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.006	P=.014	P=.027	P=.042	P=.049
80			P=.000	P=.000	P=.000	P=.000	P=.000	P=.001	P=.003	P=.007	P=.015	P=.029	P=.044	P=.051
85			P=.000	P=.000	P=.000	P=.000	P=.001	P=.001	P=.003	P=.008	P=.017	P=.031	P=.046	P=.053
90			P=.000	P=.000	P=.000	P=.000	P=.001	P=.002	P=.004	P=.009	P=.019	P=.033	P=.047	P=.054
100			P=.000	P=.000	P=.000	P=.001	P=.001	P=.003	P=.006	P=.012	P=.022	P=.036	P=.051	P=.057
110			P=.001	P=.001	P=.001	P=.001	P=.002	P=.004	P=.007	P=.014	P=.025	P=.040	P=.054	P=.060
120			P=.001	P=.001	P=.001	P=.002	P=.003	P=.005	P=.009	P=.017	P=.028	P=.043	P=.057	P=.062
130				P=.001	P=.002	P=.002	P=.004	P=.006	P=.011	P=.019	P=.031	P=.046	P=.059	P=.065
140				P=.002	P=.002	P=.003	P=.005	P=.008	P=.013	P=.022	P=.034	P=.049	P=.062	P=.067
150				P=.003	P=.003	P=.004	P=.006	P=.009	P=.015	P=.024	P=.037	P=.052	P=.064	P=.070
160				P=.003	P=.004	P=.005	P=.007	P=.011	P=.017	P=.027	P=.040	P=.054	P=.067	P=.072
170				P=.004	P=.004	P=.006	P=.008	P=.012	P=.019	P=.029	P=.042	P=.057	P=.069	P=.074
180				P=.005	P=.005	P=.007	P=.009	P=.014	P=.021	P=.032	P=.045	P=.060	P=.072	P=.076
190				P=.006	P=.006	P=.008	P=.011	P=.016	P=.023	P=.034	P=.048	P=.062	P=.074	P=.079
200				P=.007	P=.007	P=.009	P=.012	P=.018	P=.026	P=.036	P=.050	P=.064	P=.076	P=.081
210					P=.008	P=.010	P=.014	P=.019	P=.028	P=.039	P=.052	P=.067	P=.078	P=.083
220					P=.010	P=.012	P=.015	P=.021	P=.030	P=.041	P=.055	P=.069	P=.080	P=.085
230					P=.011	P=.013	P=.017	P=.023	P=.032	P=.043	P=.057	P=.071	P=.082	P=.086

TABLE 19

85TH PERCENTILE SPACE DISTRIBUTED (S) AND TIME DISTRIBUTED (T) VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN		5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	S	5.8	10.9	16.0	21.0	26.0	31.0	36.0	41.0	46.0	51.0	56.0	61.0	66.0	71.0
	T	6.0	11.0	16.0	21.0	26.0	31.0	36.0	41.0	46.0	51.0	56.0	61.0	66.0	71.0
2	S	6.0	11.3	16.3	21.4	26.4	31.4	36.4	41.4	46.4	51.4	56.4	61.4	66.4	71.4
	T	6.5	11.5	16.5	21.5	26.5	31.5	36.5	41.5	46.5	51.5	56.5	61.5	66.5	71.5
3	S	6.1	11.5	16.6	21.6	26.7	31.7	36.7	41.7	46.7	51.7	56.7	61.8	66.8	71.8
	T	6.8	11.8	16.8	21.8	26.8	31.8	36.8	41.8	46.8	51.8	56.8	61.8	66.8	71.8
4	S	6.1	11.6	16.8	21.9	26.9	31.9	37.0	42.0	47.0	52.0	57.0	62.0	67.0	72.0
	T	7.0	12.1	17.1	22.1	27.1	32.1	37.1	42.1	47.1	52.1	57.1	62.1	67.1	72.1
5	S	6.0	11.8	17.0	22.1	27.1	32.1	37.2	42.2	47.2	52.2	57.2	62.2	67.2	72.3
	T	7.3	12.3	17.3	22.3	27.3	32.3	37.3	42.3	47.3	52.3	57.3	62.3	67.3	72.3
6	S	5.9	11.9	17.1	22.2	27.3	32.3	37.4	42.4	47.4	52.4	57.4	62.4	67.5	72.5
	T	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5
7	S	5.8	11.9	17.2	22.4	27.4	32.5	37.5	42.6	47.6	52.6	57.6	62.6	67.6	72.6
	T	7.7	12.7	17.7	22.7	27.7	32.7	37.7	42.7	47.7	52.7	57.7	62.7	67.7	72.8
8	S	5.7	12.0	17.3	22.5	27.6	32.7	37.7	42.7	47.8	52.8	57.8	62.8	67.8	72.8
	T	7.8	12.9	17.9	22.9	27.9	32.9	37.9	42.9	47.9	52.9	57.9	62.9	67.9	72.9
9	S	5.5	12.0	17.4	22.6	27.7	32.8	37.8	42.9	47.9	52.9	57.9	63.0	68.0	73.0
	T	8.0	13.1	18.1	23.1	28.1	33.1	38.1	43.1	48.1	53.1	58.1	63.1	68.1	73.1
10	S	5.3	12.1	17.5	22.7	27.9	32.9	38.0	43.0	48.1	53.1	58.1	63.1	68.1	73.1
	T	8.1	13.2	18.3	23.3	28.3	33.3	38.3	43.3	48.3	53.3	58.3	63.3	68.3	73.3
11	S	5.1	12.1	17.6	22.8	28.0	33.1	38.1	43.2	48.2	53.2	58.2	63.3	68.3	73.3
	T	8.2	13.4	18.4	23.4	28.4	33.4	38.4	43.4	48.4	53.4	58.4	63.4	68.4	73.4
12	S	4.9	12.1	17.7	22.9	28.1	33.2	38.2	43.3	48.3	53.3	58.4	63.4	68.4	73.4
	T	8.4	13.6	18.6	23.6	28.6	33.6	38.6	43.6	48.6	53.6	58.6	63.6	68.6	73.6
13	S		12.1	17.7	23.0	28.2	33.3	38.4	43.4	48.4	53.5	58.5	63.5	68.5	73.6
	T		13.7	18.7	23.7	28.7	33.7	38.7	43.7	48.7	53.7	58.7	63.7	68.7	73.7
14	S		12.1	17.8	23.1	28.3	33.4	38.5	43.5	48.6	53.6	58.6	63.6	68.7	73.7
	T		13.8	18.9	23.9	28.9	33.9	38.9	43.9	48.9	53.9	58.9	63.9	68.9	73.9
15	S		12.1	17.9	23.2	28.4	33.5	38.6	43.6	48.7	53.7	58.7	63.8	68.8	73.8
	T		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49.0	[illegible]	[illegible]	[illegible]	[illegible]	74.0

85TH PERCENTILE SPACE DISTRIBUTED (S) AND TIME DISTRIBUTED (T) VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN		5	10	15	20	25	30	35	40	45	50	55	60	65	70
20	S		12.0	18.1	23.5	28.8	33.9	39.0	44.1	49.2	54.2	59.3	64.3	69.3	74.3
	T		14.5	19.6	24.6	29.6	34.6	39.6	44.6	49.6	54.6	59.6	64.6	69.6	74.6
25	S		11.8	18.2	23.7	29.1	34.3	39.4	44.5	49.6	54.7	59.7	64.8	69.8	74.8
	T		15.0	20.1	25.2	30.2	35.2	40.2	45.2	50.2	55.2	60.2	65.2	70.2	75.2
30	S		11.5	18.2	23.9	29.3	34.6	39.8	44.9	50.0	55.1	60.1	65.2	70.2	75.2
	T		15.5	20.6	25.6	30.7	35.7	40.7	45.7	50.7	55.7	60.7	65.7	70.7	75.7
35	S		11.1	18.2	24.1	29.5	34.8	40.0	45.2	50.3	55.4	60.5	65.5	70.6	75.6
	T		15.9	21.0	26.1	31.1	36.1	41.1	46.1	51.1	56.1	61.1	66.1	71.1	76.1
40	S		10.6	18.1	24.2	29.7	35.1	40.3	45.5	50.6	55.7	60.8	65.9	70.9	76.0
	T		16.2	21.4	26.5	31.5	36.5	41.6	46.6	51.6	56.6	61.6	66.6	71.6	76.6
45	S		10.1	18.0	24.2	29.9	35.3	40.5	45.7	50.9	56.0	61.1	66.2	71.2	76.3
	T		16.6	21.8	26.9	31.9	36.9	41.9	47.0	52.0	57.0	62.0	67.0	72.0	77.0
50	S		9.5	17.9	24.3	30.0	35.4	40.7	46.0	51.1	56.3	61.4	66.5	71.5	76.6
	T		16.9	22.1	27.2	32.3	37.3	42.3	47.3	52.3	57.3	62.3	67.3	72.3	77.3
55	S			17.8	24.3	30.1	35.6	40.9	46.2	51.4	56.5	61.6	66.7	71.8	76.9
	T			22.5	27.6	32.6	37.7	42.7	47.7	52.7	57.7	62.7	67.7	72.7	77.7
60	S			17.6	24.3	30.2	35.7	41.1	46.4	51.6	56.7	61.9	67.0	72.1	77.1
	T			22.8	27.9	33.0	38.0	43.0	48.0	53.0	58.0	63.0	68.0	73.0	78.0
65	S			17.4	24.2	30.2	35.8	41.2	46.5	51.8	56.9	62.1	67.2	72.3	77.4
	T			23.1	28.2	33.3	38.3	43.3	48.3	53.4	58.4	63.4	68.4	73.4	78.4
70	S			17.1	24.2	30.3	35.9	41.4	46.7	52.0	57.1	62.3	67.4	72.5	77.6
	T			23.4	28.5	33.6	38.6	43.6	48.7	53.7	58.7	63.7	68.7	73.7	78.7
75	S			16.9	24.1	30.3	36.0	41.5	46.9	52.1	57.3	62.5	67.6	72.7	77.8
	T			23.6	28.8	33.9	38.9	43.9	49.0	54.0	59.0	64.0	69.0	74.0	79.0
80	S			16.6	24.1	30.3	36.1	41.6	47.0	52.3	57.5	62.7	67.8	73.0	78.1
	T			23.9	29.1	34.2	39.2	44.2	49.2	54.3	59.3	64.3	69.3	74.3	79.3
85	S			16.3	24.0	30.3	36.2	41.7	47.1	52.4	57.7	62.9	68.0	73.2	78.3
	T			24.1	29.3	34.4	39.5	44.5	49.5	54.5	59.5	64.6	69.6	74.6	79.6
90	S			16.0	23.9	30.3	36.2	41.8	47.3	52.6	57.8	63.0	68.2	73.3	78.5
	T			24.3	29.6	34.7	39.7	44.8	49.8	54.8	59.8	64.8	69.8	74.8	79.8

TABLE 21

85TH PERCENTILE SPACE DISTRIBUTED (S) AND TIME DISTRIBUTED (T) VELOCITIES AS A FUNCTION OF MEAN AND VARIANCE OF TIME DISTRIBUTED VELOCITIES (ASSUMING TYPE III DISTRIBUTIONS)

VAR \ MEAN		5	10	15	20	25	30	35	40	45	50	55	60	65	70
100	S			15.2	23.6	30.3	36.3	42.0	47.5	52.9	58.1	63.4	68.6	73.7	78.8
	T			24.8	30.1	35.2	40.3	45.3	50.3	55.3	60.3	65.4	70.4	75.4	80.4
110	S			14.4	23.3	30.2	36.4	42.1	47.7	53.1	58.4	63.7	68.9	74.0	79.2
	T			25.2	30.5	35.7	40.7	45.8	50.8	55.8	60.9	65.9	70.9	75.9	80.9
120	S			13.6	23.0	30.1	36.4	42.3	47.9	53.3	58.6	63.9	69.2	74.3	79.5
	T			25.6	31.0	36.1	41.2	46.3	51.3	56.3	61.3	66.3	71.3	76.4	81.4
130	S				22.6	30.0	36.4	42.3	48.0	53.5	58.9	64.2	69.4	74.6	79.8
	T				31.4	36.5	41.6	46.7	51.7	56.8	61.8	66.8	71.8	76.8	81.8
140	S				22.2	29.8	36.4	42.4	48.1	53.7	59.1	64.4	69.7	74.9	80.1
	T				31.7	37.0	42.1	47.1	52.2	57.2	62.2	67.2	72.2	77.3	82.3
150	S				21.9	29.6	36.3	42.4	48.2	53.8	59.3	64.6	69.9	75.1	80.3
	T				32.1	37.3	42.5	47.5	52.6	57.6	62.6	67.7	72.7	77.7	82.7
160	S				21.3	29.4	36.3	47.5	48.3	53.9	59.4	64.8	70.1	75.4	80.6
	T				32.5	37.7	42.9	47.9	53.0	58.0	63.1	68.1	73.1	78.1	83.1
170	S				20.7	29.2	36.2	42.5	48.4	54.1	59.6	65.0	70.3	75.6	80.8
	T				32.8	38.1	43.2	48.3	53.4	58.4	63.5	68.5	73.5	78.5	83.5
180	S				20.2	28.9	36.1	42.5	48.4	54.2	59.7	65.2	70.5	75.8	81.1
	T				33.1	38.4	43.6	48.7	53.8	58.8	63.8	68.9	73.9	78.9	83.9
190	S				19.6	28.7	36.0	42.4	48.5	54.3	59.8	65.3	70.7	76.0	81.3
	T				33.4	38.8	44.0	49.1	54.1	59.2	64.2	69.2	74.2	79.3	84.3
200	S				19.0	28.4	35.8	42.4	48.5	54.3	60.0	65.5	70.9	76.2	81.5
	T				33.7	39.1	44.3	49.4	54.5	59.5	64.6	69.6	74.6	79.6	84.6
210	S					28.1	35.7	42.4	48.5	54.4	60.1	65.6	71.0	76.4	81.7
	T					39.4	44.6	49.8	54.8	59.9	64.9	69.9	75.0	80.0	85.0
220	S					27.7	35.5	42.3	48.5	54.5	60.2	65.7	71.2	76.5	81.8
	T					39.7	44.9	50.1	55.2	60.2	65.3	70.3	75.3	80.3	85.3
230	S					27.4	35.3	42.2	48.5	54.5	60.2	65.8	71.3	76.7	82.0
	T					40.0	45.3	50.4	55.5	60.6	65.6	70.6	75.7	80.7	85.7
240	S					27.0	35.1	42.1	48.5	54.5	60.3	65.9	71.4	76.8	82.2
	T					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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