State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

AN INTERIM REPORT ON AN INVESTIGATION FOR DETERMINATION OF 85 PERCENTILE OPERATING SPEED OF MOTOR VEHICLES ON ILLINOIS HIGHWAYS

A Study Conducted by the
Illinois Division of Highways in Cooperation with the
U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads

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INTRODUCTION

This study was undertaken in 1959 to obtain information on operating speeds that will assist in selecting speed criteria for use in geometric design and signing of traffic interchanges and at-grade intersections. The problem is being approached by determining speed habits of motorists at existing at-grade intersections and interchanges. These habits are being studied in connection with existing geometric designs and current design speeds.

Speed data were obtained during the summers of 1959, 1960, and 1961. The collected data have been summarized and some preliminary analyses have been run. Three administrative reports have been prepared to describe the progress made on the study through June 1962. In addition, some of the data also were used in a study to determine the suitability of left-hand on-and-off ramps for expressways and freeways.

This report describes the research procedures being following in conducting the study, defines and discusses the work that has been accomplished to date, and outlines the work remaining to be done to completely answer the objectives of the study.

RESEARCH PROCEDURE

General.

The research procedure being followed in conducting this study is concerned with determining the speed habits of motorists by measuring actual vehicle speeds at various selected locations within the limits of at-grade intersections and interchanges, and relating these speed habits to the geometric and signing features of the various types of intersections and interchanges.

Radar equipment is being used to measure vehicle speed. The study is intended to lead to the development of a new set of speed criteria founded on factual data that will more nearly meet the needs and desires of the traveling public.

Locations Selected for Study

In the initial planning it was decided to include a comprehensive program of speed surveys at representative samples of all of the seven basic types of intersections and interchanges used in Illinois. Each type has been designated as a series and identified by number. For example, the 100 series consists of exit ramps at grade-separated interchanges on four-lane divided highways; the 200 series is approach ramps at grade-separated interchanges on four-lane divided highways, etc. The seven basic series were further divided into 36 subseries, dependent upon posted speed limits and whether driving conditions are rural or urban in character. The different types of locations representing the seven series are shown in Figure 1. Also shown are the position and number of radars used, and the directional traffic movements studied.

Equipment

The primary equipment consisted of eight radar speed timers. Each of the timers has three major components: antenna, amplifier and meter. The equipment can be operated on either 12-Volt DC or 110-Volt AC. It is possible to use 75-foot extension cords on the antenna, which permits operation up to this distance from the amplifier. The meters can be operated at distances up to 1,500 feet from the amplifier. The power for the radars was furnished by six 12-Volt batteries, and one 110-Volt AC generator.

As a means of concealing the radar antenna they were often mounted behind highway signs or on temporary sign posts constructed specifically for this purpose. The temporary posts were 4 x 4-in. x 5-ft timber equipped with

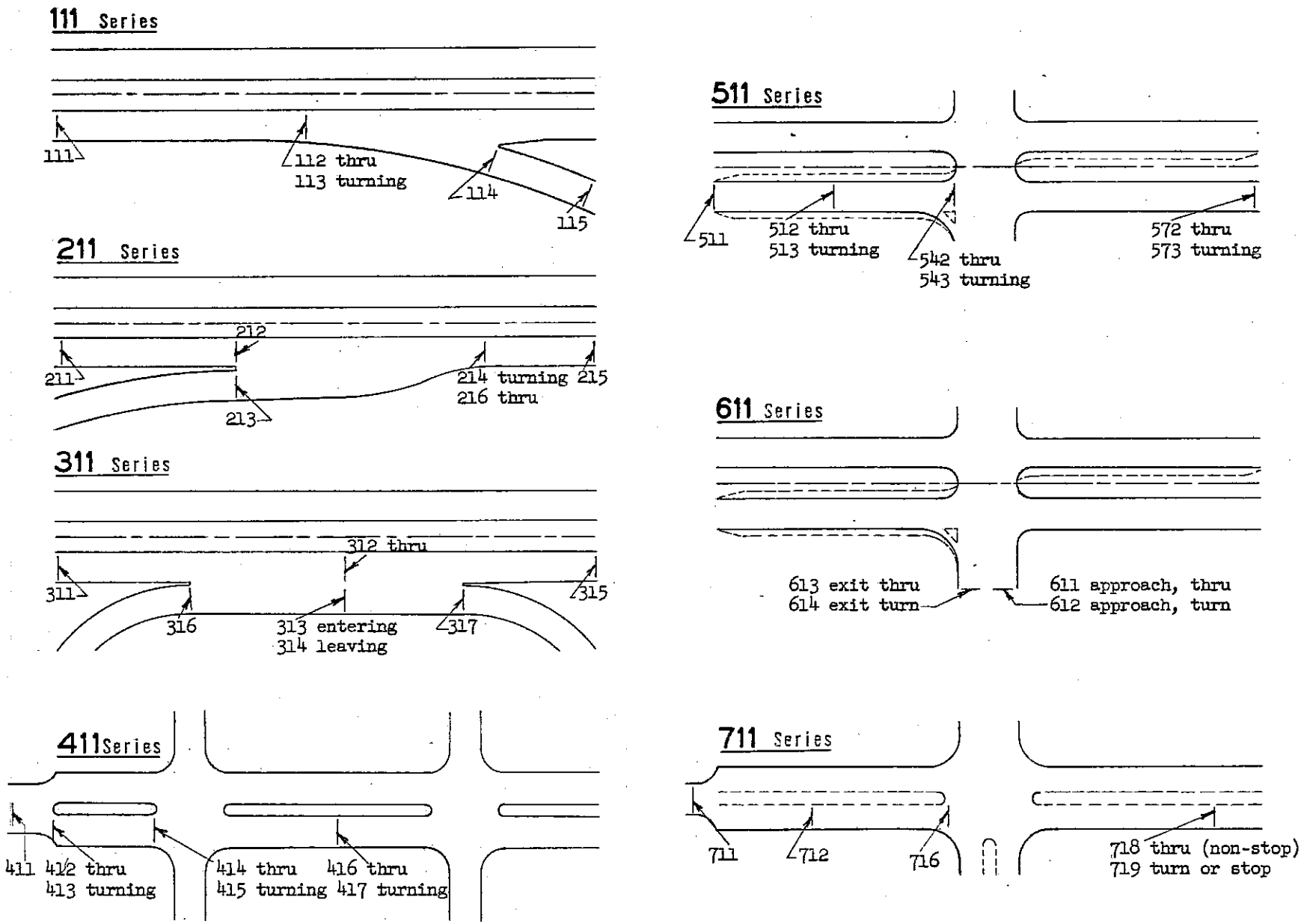

FIGURE 1. BASIC TYPES OF INTERSECTIONS INCLUDED IN 85 PERCENTILE SPEED STUDY.

a 1/2-inch steel rod at the base for easy mounting on the highway shoulder. Signs made of masonite and containing highway information of a general nature not likely to influence speed were mounted on the posts. The radar antennas were mounted behind the masonite signs, the masonite having no effect on the radar waves.

Field Operations

Field operations for the collection of speed data were carried out with a party of seven or eight men. Field operations began with a few pilot studies that were made to familiarize the operating crew with the equipment, and to determine the degree of concealment needed to avoid influencing normal speed habits.

The pilot studies showed that adequate concealment of personnel and equipment was very important in the measurement of normal speed habits. At one location a study was made first with the radars in vehicles parked on the shoulder of the road, then with the personnel and radars well concealed. The vehicles measured in the first portion of the study where the personnel and radars were plainly visible averaged 7.2 miles per hour slower than vehicles measured during the second portion of the study when the personnel and radars were well concealed.

All subsequent studies were made with particular attention being given to adequate concealment. The success of concealment was manifested when highway employees having knowledge of the general location of the speed-check crew were speed-checked as many as five times without being aware of it.

To accomplish concealment, radar antennas were placed below, over and alongside of highway signs, posts, trees, bushes, etc. They were also attached

to the dummy sign posts mentioned previously. Meter operations and vehicles used by the survey crew were always stationed well away from the pavements.

WORK ACCOMPLISHED TO DATE

Collection of Field Data

As previously mentioned, speed data were obtained during the summers of 1959, 1960, and 1961. The data were concerned primarily with exit and entrance ramps at interchanges of expressways and freeways (series 100 and 200 respectively). All field data for series 100 and 200 locations have been collected and some data have been collected for series 300, 400, and 600 locations.

The speed studies at all locations were made with several radars operating simultaneously at various points of the intersection or interchange. At least four or five radar timers were set up for each series and speeds were recorded for five to seven traffic movements. Measurements of geometry and sign placement also were made at all study locations.

Forty-eight speed surveys were made at 27 locations in 1959 on four-lane divided pavement of the 100,200, 300, 400, and 600 series. Most of the studies were made on Route US 66, Calumet Expressway and Kingery Expressway. Other locations studied were on Route US 45-54 at Kankakee and Route US 12 at Wauconda in Lake County.

The 1960 field work was confined entirely to exit-ramp and entrance-ramp locations at interchanges of rural four-lane divided highways (series 100 and 200 respectively). Speed surveys were made at a total of 59 such locations.

The 1961 speed studies included 35 surveys at 20 separate interchanges. These study locations included exit-ramps, (Series 111 and 121) entrance-ramps, (Series 211 and 221) and weaving lanes of four-lane divided highways (Series 311 and 321).

Summarization and Analysis of Speed Data

The data secured in the field were summarized on forms arranged so that the information could be taken directly from the summary sheets and punched on IBM cards. One card was established for each mile-per-hour speed recorded for each traffic movement. The speed, number of vehicles traveling at that speed, vehicle classification, and numerous other items of information were recorded on each card. An IBM 604 Calculator was used to make the following calculations for each movement.

1. Per cent of vehicles involved in movement traveling at each speed.
2. Cumulative number of vehicles measured.
3. Cumulative percentages.
4. Arithmetic mean speed.
5. Fx^2 (Vehicle frequency x square of speed for use in computing standard deviation).

IBM tabulation sheet listings were made for each check point. Individual listings at each check point were made for the following classifications.

1. Illinois passenger cars
2. Out of state passenger cars
3. Total passenger cars
4. Light trucks
5. Medium & heavy trucks
6. Total trucks
7. Total vehicles

The 5th, 15th, 50th, 85th and 95th percentile speeds for each traffic movement were obtained by visual inspection and interpolation of the tabulations. Summary data of a similar nature were obtained for the various location types.

Data on physical characteristics and the geometry of the study locations were also punched on IBM cards and a tabulation made. Separate cards were used to record this information, with each card representing one study location.

A summary IBM card was designed to include the essential items of information on speed and physical measurements for each vehicle classification at each check point of each study location. This greatly reduced the number of cards needed for analysis. With these summary cards, tabulations were made for all of the surveys, grouping all study locations in a given series by vehicle classification at each of the check points so that overall average speeds and percentages could be obtained.

The analysis work to date has been concerned primarily with the 100 and 200 series interchange exit and entrance ramps. Summaries of the results are given in Tables 1 through 5. Table 1 includes a comparison of design or posted speed to free running speeds on the main lanes. Tables 2 and 3 list mean and various percentile speeds at each check point for the 100 and 200 series, respectively. Tables 4 and 5 are concerned with speed differentials between various check points of the 100 and 200 series. Locations of the check points with respect to the interchanges are depicted in Figure 1.

Discussion

The phase of the study concerned with exit and entrance ramps of grade-separated interchanges, although not complete as yet, is indicating some definite trends of driver behavior.

The average measured running speeds on the through lanes of the main pavements correspond to the average running speeds suggested as being representative of low-volume conditions included in "A Policy on Geometric Design of Rural Highways", published in 1965 by the American Association of State Highway Officials. These suggested speeds are being used as a basis for design of exit and entrance ramps at interchanges.

TABLE 1. COMPARISON OF DESIGN TO RUNNING SPEEDS

Design of Posted Speed	AASHO Suggested Average Running Speed 1/		Survey Mean Running Speed		Survey 85 Percentile Speed	
	Speed	% of Design Speed	Speed	% of Design Speed	Speed	% of Design Speed
(mph)	(mph)	(%)	(mph)	(%)	(mph)	(%)
70	58	70	58.6	82	65.6	94
65	55	72.5	54.4	84	61.2	94
60	52	75	52.2	87	58.2	97

1/ For main highways - low volumes.

TABLE 2.
SUMMARY OF SPEED MEASUREMENTS - 100 SERIES

CHECK POINT	MEAN	PERCENTILES 5TH	15TH	50TH	85TH	95TH	RANGE
		SERIES 111 - 70 MPH POSTED SPEED LIMIT (MPH)					
111	58.2	44.9	50.1	58.3	65.3	68.8	15.2
112	57.0	42.8	48.6	57.0	64.3	68.1	15.7
113	46.2	33.4	38.6	45.7	52.7	56.9	14.1
114	38.8	28.7	32.2	38.2	43.6	48.5	11.4
115	35.9	25.9	29.7	35.2	41.2	44.9	11.2
		SERIES 121 - 65 MPH POSTED SPEED LIMIT (MPH)					
121	53.4	40.1	45.3	53.1	60.5	65.0	15.2
122	53.1	39.6	44.8	52.6	60.3	64.6	15.5
123	44.7	34.1	38.2	45.3	52.6	57.1	14.4
124	39.0	27.8	31.9	38.5	45.0	48.9	13.1
125	19.7	14.2	16.1	19.4	22.6	24.8	6.5
		SERIES 121 - 60 MPH POSTED SPEED LIMIT (MPH)					
121	51.3	40.6	44.2	50.8	57.0	60.6	13.2
122	51.6	41.7	45.0	50.9	57.2	60.5	12.2
123	43.0	32.3	36.5	42.3	48.2	51.9	11.7
124	37.4	27.8	31.4	36.8	42.4	45.6	11.0
125	31.6	23.6	26.4	30.8	35.9	38.7	9.5

TABLE 3.
SUMMARY OF SPEED MEASUREMENTS - 200 SERIES

CHECK POINT	MEAN	PERCENTILES 5TH	15TH	50TH	85TH	95TH	RANGE
		SERIES 211 - 70 MPH POSTED SPEED LIMIT (MPH)					
211	58.8	44.5	50.2	58.9	65.9	69.7	15.7
212	58.5	45.1	50.7	58.4	65.1	68.7	14.3
213	37.1	24.7	28.9	36.7	44.0	48.0	15.1
214	47.8	35.3	39.7	47.3	54.4	58.6	14.7
215	58.9	44.9	50.6	59.0	65.9	69.9	15.3
216	58.8	44.9	50.4	58.0	65.7	69.6	11.8
		SERIES 221 - 65 MPH POSTED SPEED LIMIT (MPH)					
221	55.1	40.8	47.0	55.2	62.1	66.3	15.1
222	54.9	42.4	47.2	54.8	61.1	65.0	13.9
223	36.0	25.2	29.7	35.3	42.2	46.1	12.5
224	45.4	33.3	38.0	45.0	51.8	56.5	13.8
225	54.2	41.5	46.0	54.3	61.2	65.3	15.2
226	54.6	41.8	46.9	54.5	61.0	64.9	14.1
		SERIES 221 - 60 MPH POSTED SPEED LIMIT (MPH)					
221	53.2	41.1	45.6	53.4	59.3	62.9	13.7
222	51.8	40.2	45.1	51.5	57.5	60.8	12.4
223	31.2	20.5	24.2	30.9	38.0	40.4	13.8
224	42.2	32.2	35.8	41.6	45.4	51.5	9.6
225	52.8	41.3	45.8	52.5	58.6	62.2	12.8
226	51.8	40.8	45.0	51.4	57.6	61.8	12.6

TABLE 4.
SUMMARY OF SPEED DIFFERENTIALS -- 100 SERIES

BETWEEN CHECK POINTS	MEAN	PERCENTILES 5TH	15TH	50TH	85TH	95TH	PERCENT OF DECELERATION
	(MPH)			(MPH)			(%)
		SERIES 111 - 70 MPH POSTED SPEED LIMIT					
111-112	-1.2	-2.1	-1.5	-1.3	-1.0	-0.7	
111-113	-12.0	-11.5	-11.5	-12.6	-12.6	-11.9	62.4
113-114	-7.4	-4.7	-6.4	-7.5	-9.1	-8.4	37.6
111-114	-19.4	-16.2	-17.9	-20.1	-21.7	-20.3	
114-115	-2.9	-2.8	-2.5	-3.0	-2.4	-3.6	
		SERIES 121 - 65 MPH POSTED SPEED LIMIT					
121-122	-0.3	-0.5	-0.5	-0.5	-0.2	-0.4	
121-123	-8.7	-5.1	-6.6	-7.8	-7.9	-7.9	57.8
123-124	-5.7	-6.3	-6.3	-6.8	-7.6	-8.2	48.2
121-124	-14.4	-11.4	-12.9	-14.6	-15.5	-16.1	
124-125	-19.3	-13.6	-15.8	-19.1	-22.4	-24.1	
		SERIES 121 - 60 MPH POSTED SPEED LIMIT					
121-122	+0.3	+1.1	+0.8	+0.1	+0.2	-0.1	
121-123	-8.3	-8.3	-7.7	-8.5	-8.8	-8.7	61.3
123-124	-5.6	-4.5	-5.1	-5.5	-5.8	-6.3	38.7
121-124	-13.9	-12.8	-12.8	-14.0	-14.6	-14.0	
124-125	5.8	-4.2	-5.0	-6.0	-6.5	-6.9	

TABLE 5.
SUMMARY OF SPEED DIFFERENTIALS - 200 SERIES

BETWEEN CHECK POINTS	MEAN (MPH)	PERCENTILES 5TH (MPH)	15TH	50TH	85TH	95TH
		SERIES 211 - 70 MPH POSTED SPEED LIMIT				
211-212	-0.3	0.6	0.5	-0.5	-0.8	-1.0
212-216	0	-0.2	-0.3	0.5	0.6	0.9
212-213	-21.4	-20.4	-21.8	-21.7	-21.1	-20.7
213-214	10.7	10.6	10.8	10.6	10.4	10.6
214-216	11.0	9.6	10.7	11.6	11.3	11.0
216-215	0.1	0	0.2	0.1	0.2	0.3
		SERIES 221 - 65 MPH POSTED SPEED LIMIT				
221-222	-0.2	1.6	0.2	-0.4	-1.0	-1.3
222-226	-0.3	-0.6	-0.3	-0.3	-0.1	-0.1
222-223	-18.9	-17.2	-17.5	-19.5	-18.9	-18.9
223-223	9.4	8.1	8.3	9.7	9.6	10.4
224-226	9.2	8.5	8.9	9.5	9.2	8.4
226-225	-0.4	-0.3	-0.9	-0.2	0.2	0.4
		SERIES 221 - 60 MPH POSTED SPEED LIMIT				
221-222	-1.4	-0.9	-0.5	-1.9	-1.8	-2.1
222-224	0	0.6	-0.1	-0.1	0.1	1.0
222-223	-20.6	-19.5	-20.9	-20.6	-19.5	-20.4
223-224	11.0	11.7	11.6	10.7	7.4	11.1
224-226	9.6	8.6	9.2	9.2	12.2	10.3
226-225	-1.0	-0.5	-0.8	-1.1	-1.0	-0.4

Some preliminary analysis has been accomplished on the speed data for the 100 and 200 series obtained in 1959 and 1960. Cumulative percentile speed curves of total passenger cars were plotted for each individual check point of the 111 and 211 series. These curves presented two major differences between design and actual speeds. The design criteria established by AASHO assumes all deceleration to be done on the deceleration lane. The average curve for ramp traffic at the start of widening shows that vehicles have decelerated about ten miles per hour on the main pavement. This indicates that vehicles using the exit ramp decelerate 60 per cent on the main road before they reach the deceleration lane.

The second major difference is relative to the speed of approach-ramp vehicles when entering the through lane. According to AASHO design criteria, vehicles on approach ramps should enter the through traffic lane at a speed within five miles per hour of the through traffic speeds. Data from this study indicate that the average speed of ramp vehicles entering the through traffic lanes at the end of widening is about 10 mph slower than the average through traffic speed. However, under the free-running conditions of the study, this does not seem to affect the speed of the through traffic to any great extent. Traffic volumes at all surveyed locations are well below the design capacities.

A study of the relationship between AASHO assumed average running speeds at the nose of the ramp and actual survey running speeds at the nose of ramp showed that actual running speeds were faster than the AASHO assumed design running speeds for short radius curves, but much slower for long radius curves. A comparison of AASHO design 95-percentile and free running speeds vs radius of curvature for fourteen survey locations showed

that the actual measured speeds were higher than those suggested by AASHO for curves having radii up to 600 to 700 feet and were much lower for larger radii curves.

A series of correlative analyses with respect to various physical characteristics and actual speeds showed the following degrees of correlation (see Figure 1 for identification):

(1) Series 111, 70 mph; Series 121, 65 mph, 60 mph.
(85 Percentile Speeds were used)

A. Distance from 1st slow sign to start of widening vs:

(a) Differential in speed from free running to start of widening for ramp vehicles for Series 111 - good correlation; and,

(b) Speed differential from free running to nose of ramp for Series 111 - little or no correlation.

B. Length of deceleration lane vs:

(a) Speed differential between check points 113 and 114, Series 111 - no correlation;

(b) Speed of vehicle at nose of ramp check point 114, Series 111 no correlation;

(c) Speed differential between check points 123 and 124, Series 121, 60 mph - no correlation;

(d) Speed at nose of ramp, check point 124, Series 121, 60 mph no correlation;

(e) Speed differential between check points 123 and 124, Series 121, 65 mph - little or no correlation; and

(f) Speed at nose of ramp, check point 124, Series 121, 65 mph little or no correlation.

C. Initial degree of curvature vs:

(a) Speed at nose of ramp, Series 111 - good correlation;

(b) Speed at nose of ramp, Series 121, 60 mph - good correlation; and

(c) Speed at nose of ramp, Series 121, 65 mph - good correlation.

(2) Series 211, 70 mph, Series 221, 65 mph, 60 mph
(85 Percentile Speeds were used)

A. Length of acceleration lane vs:

(a) Speed differential between check points 214 and 216, Series 211 - good correlation;

(b) Speed at end of widening, check point 214, Series 211 good correlation;

(c) Speed differential between check points 224 and 226, Series 221, 65 mph - good correlation;

(d) Speed differential between check points 224 and 226, Series 221, 60 mph - good correlation;

(e) Speed at end of widening, check point 224, Series 221, 65 mph - good correlation; and

(f) Speed at end of widening, check point 224, Series 221, 60 mph - good correlation.

B. Initial degree of curvature vs:

(a) Speed at nose of ramp, Series 211 - good correlation;

(b) Speed at nose of ramp, Series 221, 65 mph, good correlation; and

(c) Speed at nose of ramp, Series 221, 60 mph - good correlation.

Tables of the values of the standard deviation and error of mean for each classification at each check point of each interchange were prepared. These were all sufficiently low to indicate that the data are statistically sound.

WORK REMAINING TO BE PERFORMED

Exit and Entrance Ramps - Series 100 and 200

All field measurements at selected survey locations for the 100 and 200 series have been completed and some preliminary analysis work has been done. Final analyses of the data remain to be completed and an interim report covering the findings will need to be prepared.

The analyses are intended to develop relationships to show the effects of intersection design variables and of intersection signing on vehicle speeds. These relationships, in some instances, will probably suggest modifications of tables and graphs included in the AASHO Geometric Design Policy, corresponding to actual traffic usage of existing entrance and approach ramps at interchanges on Illinois primary highways. Also, an attempt will be made to develop new relationships that can be applied to intersection design.

For many of the individual analyses it appears that it will be necessary to select the intersections to be included, and to separate them into groups of similar geometric design characteristics. Wherever possible, mathematical models will be developed and regression analyses run to determine the best fit.

The relationships to be considered for the 100 and 200 series will include such as the following:

1. Design or posted speed limits versus average running speeds and selected percentile speeds on main highways at low-volume conditions.

2. Radius of initial curve at nose of ramp versus design, average running, and selected percentile speeds at nose of ramp on entrance and exit ramps.

3. Radius of initial curve at nose of exit ramps versus (1) speed at beginning of widening, (2) deceleration on through lane, (3) deceleration on deceleration lane, and (4) total deceleration.

4. Length of deceleration lane and tangent of angle between widening and pavement edge versus (1) speed at beginning of widening, (2) speed at nose of ramp, (3) deceleration on through lane, (4) deceleration on deceleration lane, and (5) total deceleration.

5. Radius of curve at nose of entrance ramps versus (1) speed on ramp at end of widening, (2) differential speed between through and ramp traffic at end of widening, and (3) acceleration on acceleration lane.

6. Length of acceleration lane versus (1) speed of ramp traffic at end of widening, (2) differential speed between through and merging traffic at end of widening, and (3) acceleration on acceleration lane.

Remaining Series of Intersections and Interchanges

The remaining intersections and interchanges to be studied include the 300, 400, 500, 600, and 700 series (see Figure 1). Except for a minor amount of speed data for Series 300, 400, and 600, no work has been performed on these series as yet. Field speed data will be collected at the various check points as indicated in Figure 1. The data will be summarized and analyzed following the general procedures described above for the 100 and 200 series. Interim reports will be prepared on the results obtained on the various intersection and interchange series, and the study will be completed with preparation of a final report summarizing the results of the entire study and outlining revisions in geometric design and signing suggested by the results.