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USE OF ACCELERATION
AND
DECELERATION LANES

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Highway
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Project

by
NEDDY JOUZY

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

USE OF ACCELERATION AND DECELERATION LANES

TO: K. B. Woods, Director
Joint Highway Research Project
February 14, 1962

FROM: H. L. Michael, Associate Director
Joint Highway Research Project
File No: 8-4-22
Project No: C-36-17V

The attached report entitled "Use of Acceleration and Deceleration Lanes" is the final report on Project C-36-17V. The report has been authored by Neddy C. Joux and was also used by Mr. Joux as his thesis in partial fulfillment of the requirements for the Ph.D. degree. Mr. Joux is a graduate assistant on the Project staff and performed the study under the direction of Professor H. L. Michael.

The report includes a large amount of speed and lateral placement data of passenger cars when entering and leaving interchanges on existing rural freeway roads in Indiana. Characteristics of use on various designs of acceleration and deceleration lanes are given and proposed acceleration and deceleration lane designs which would provide for improved operating characteristics are included.

The report is submitted for the record.

Respectfully submitted,

Harold L. Michael
Harold L. Michael, Secretary

HLM:kmc

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by

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Graduate Assistant

Joint Highway Research Project

File No: 8-4-22

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Purdue University
Lafayette, Indiana

February 14, 1962

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The author wishes to express his thanks and gratitude to his good friends for their great inspiration during the entire study.

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF ILLUSTRATIONS	v
ABSTRACT	x
INTRODUCTION	1
PREVIOUS INVESTIGATION	6
PURPOSE	9
SCOPE	10
EQUIPMENT	14
PROCEDURE	20
Field	20
Office	24
STATISTICAL ANALYSIS PROCEDURES	26
LOCATIONS AND RESULTS	33
Acceleration Lanes	33
Deceleration Lanes	97
FINDINGS AND RECOMMENDATIONS	153
General	153
Acceleration Lanes	155
Deceleration Lanes	156
PROPOSED STANDARD DESIGNS	160
Acceleration Lanes	161
Deceleration Lanes	166
BIBLIOGRAPHY	169
APPENDIX A	172
VITA	175

LIST OF TABLES

Table	Page
1. Summary of Statistical Analysis - Acceleration Lanes. 85th Percentile Speed of Through Lane Traffic, "Within Area of Conflict" vs "Beyond Area of Conflict."	31
2. Summary of Statistical Analysis - Acceleration Lanes. 85th Percentile Speed of Through Lane Traffic vs Average 85th Percentile Speed of Acceleration Lane Traffic as it Merged	31
3. Summary of Statistical Analysis - Deceleration Lanes. 85th Percentile Speed of Through Lane Traffic, "Within Area of Conflict" vs "Beyond Area of Conflict."	32
4. Summary of Statistical Analysis - Deceleration Lanes. 85th Percentile Speed of Through Lane Traffic, "Within Area of Conflict" vs "Beyond Area of Conflict."	32
5. Pertinent Data for Study Locations - Acceleration Lanes	35
6. Pertinent Data for Study Locations - Deceleration Lanes	98
7. Summary of Results - Acceleration Lanes	151
8. Summary of Results - Deceleration Lanes	152
9. Distances Required for Various Model Cars to Accelerate from 25 MPH to 70 MPH	161

LIST OF ILLUSTRATIONS

Figure	Page
1. 16mm Motion Picture Camera	15
2. Time Motion Study Projector in Operation	15
3. Electro-Matic Radar Speed Meter	17
4. 2 x 12 Foot Board for Establishing Grid Lines	21
5. Study Locations of Acceleration and Deceleration Lanes . . .	34
6. Typical Acceleration Lane - Indiana Toll Road - Type 1 . . .	37
7. View of Acceleration Lane - Type 1	38
8. Indiana Toll Road - Middlebury Interchange	40
9. Indiana Toll Road - Middlebury Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars . . .	42
10. Indiana Toll Road - Gary West Interchange	44
11. Indiana Toll Road - Gary West Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars . . .	46
12. Indiana Toll Road - Michigan City Interchange	48
13. Indiana Toll Road - Michigan City Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars . . .	50
14. Indiana Toll Road - Chesterton-Valparaiso Interchange	52
15. Indiana Toll Road - Chesterton-Valparaiso Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars	53
16. Indiana Toll Road - LaPorte Interchange	56
17. Indiana Toll Road - LaPorte Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars . . .	57

LIST OF ILLUSTRATIONS (continued)

Figure		Page
18.	Indiana Toll Road - Gary East Interchange	59
19.	Indiana Toll Road - Gary East Interchange - Acceleration Lane East Bound. Speeds and Lateral Placement of Cars . . .	61
20.	Typical Standard Acceleration Lane - Type 2	63
21.	View of Acceleration Lane - Type 2	64
22.	Interstate 65 and State Road 39 Interchange	65
23.	Interstate 65 and State Road 39 Interchange - Acceleration Lane North Bound. Speeds and Lateral Placement of Cars . . .	66
24.	Tri-State and Kennedy Avenue Interchange	68
25.	Tri-State Highway and Kennedy Avenue Interchange - Acceleration Lane East Bound. Speeds and Lateral Placement of Cars	70
26.	Interstate 74 and Post Road Interchange	72
27.	Interstate 74 and Post Road Interchange - Acceleration Lane East Bound. Speeds and Lateral Placement of Cars . . .	73
28.	Interstate 65 and State Road 60 Interchange	75
29.	Interstate 65 and State Road 60 Interchange - Acceleration Lane South Bound. Speeds and Lateral Placement of Cars . . .	76
30.	Interstate 65 and State Route 39 Interchange - Acceleration Lane South Bound. Speeds and Lateral Placement of Cars . . .	79
31.	Typical Standard Acceleration Lane - Type 3	81
32.	View of Acceleration Lane - Type 3	82
33.	Interstate 65 and State Road 56 Interchange	83
34.	Interstate 65 and State Road 56 Interchange - Acceleration Lane North Bound. Speeds and Lateral Placement of Cars . . .	85
35.	Interstate 65 and State Road 334 Interchange	87
36.	Interstate 65 and State Road 334 Interchange - Acceleration Lane North Bound. Speeds and Lateral Placement of Cars . . .	88

LIST OF ILLUSTRATIONS (continued)

Figure	Page
37. Typical Standard Acceleration Lane - Type 4	90
38. View of Acceleration Lane - Type 4	91
39. Tri-State Highway and Calumet Avenue Interchange	92
40. Tri-State Highway and Calumet Avenue Interchange - Acceleration Lane East Bound. Speeds and Lateral Placement of Cars	94
41. Tri-State Highway and Calumet Avenue Interchange - Acceleration Lane West Bound. Speeds and Lateral Placement of Cars	96
42. Typical Deceleration Lane - Indiana Toll Road - Type 1	100
43. View of Deceleration Lane - Type 1	101
44. Indiana Toll Road - Gary West Interchange - Deceleration Lane East Bound. Speeds and Lateral Placement of Cars	104
45. Indiana Toll Road - Michigan City Interchange - Deceleration Lane West Bound. Speeds and Lateral Placement of Cars	106
46. Indiana Toll Road - Chesterton-Valparaiso Interchange Deceleration Lane East Bound. Speeds and Lateral Placement of Cars	109
47. Indiana Toll Road - Chesterton-Valparaiso Interchange - Determination of Point where Deceleration Lane Traffic Begins to Decelerate on Through Lane	110
48. Determination of Point where Deceleration Lane Traffic Begins to Decelerate on Through Lane - Location Dlc	111
49. Typical Standard Deceleration Lane - Type 2	113
50. View of Deceleration Lane - Type 2	114
51. Interstate 65 and State Route 39 Interchange - Deceleration Lane South Bound. Speeds and Lateral Placement of Cars	116
52. Tri-State Highway and Kennedy Avenue Interchange - Deceleration Lane West Bound. Speeds and Lateral Placement of Cars	118
53. Interstate 65 and State Road 39 Interchange - Deceleration Lane North Bound. Speeds and Lateral Placement of Cars	120

LIST OF ILLUSTRATIONS (continued)

Figure	Page
54. Typical Standard Deceleration Lane - Type 3	122
55. View of Deceleration Lane - Type 3	123
56. Interstate 74 and State Road 9 Interchange	124
57. Interstate 74 and State Road 9 Interchange - Deceleration Lane East Bound. Speeds and Lateral Placement of Cars . . .	126
58. Interstate 74 and State Road 9 Interchange - Deceleration Lane East Bound. Determination of Point where Deceleration Lane Traffic Begins to Decelerate on Through Lane	127
59. Determination of Point where Deceleration Lane Traffic Begins to Decelerate on the Through Lane - Location D3a . . .	128
60. Interstate 65 and State Road 334 Interchange - Deceleration Lane South Bound. Speeds and Lateral Placement of Cars . . .	130
61. Interstate 65 and State Road 334 Interchange - Deceleration Lane South Bound. Determination of Position where Decelera- tion Lane Traffic Begins to Decelerate on Through Lane . . .	132
62. Determination of Point where Deceleration Lane Traffic Begins to Decelerate on the Through Lane - Location D3b	133
63. Interstate 65 and State Road 60 Interchange - Deceleration Lane North Bound. Speeds and Lateral Placement of Cars . . .	135
64. Typical Standard Deceleration Lane - Type 4	137
64A. View of Deceleration Lane - Type 4	138
65. Interstate 74 and Pleasant View Interchange	139
66. Interstate 74 and Pleasant View Interchange - Deceleration Lane East Bound. Speeds and Lateral Placement of Cars . . .	141
67. Typical Standard Deceleration Lane - Type 5	142
68. View of Deceleration Lane - Type 5	143
69. Tri-State Highway and Calumet Avenue Interchange - Deceleration Lane West Bound. Speeds and Lateral Placement of Cars	145

LIST OF ILLUSTRATIONS (continued)

Figure		Page
70.	Interstate 65 and State Road 56 Interchange - Deceleration Lane North Bound. Speeds and Lateral Placement of Cars . . .	147
71.	Tri-State Highway and Calumet Avenue Interchange - Deceleration Lane East Bound. Speeds and Lateral Placement of Cars .	150
72.	Car Misses the Deceleration Lane and Stops, then Backs on the Deceleration Lane and Enters the Exit Ramp	157
73.	Proposed Standard Acceleration Lane	162
74.	Time - Distance and Time - Speed Comparison of the Best Performing Cars for Three Model Years	163
75.	Time - Distance and Time - Speed Comparison of the Poorest Performing Cars for Three Model Years	164
76.	Proposed Standard Deceleration Lane	167

ABSTRACT

Jouzy, Neddy C. Ph. D., Purdue University, January 1962. Use of Acceleration and Deceleration Lanes. Major Professor: Harold L. Michael.

The speed and lateral placement of vehicles on the various designs of the acceleration and deceleration lanes of the Indiana Toll Road and the Interstate System of the State of Indiana were studied in order to correlate the acceleration and deceleration lane design with traffic behavior and driver requirements and determine the acceleration and deceleration lane designs which provide the most efficient and safest operation.

The data on speeds and lateral placement of traffic using the acceleration and deceleration lanes were obtained by use of a motion picture technique using a 16mm motion picture camera and analyzed by projecting through a time-motion study projector. The spot speeds of through lane traffic were measured using an electro-matic radar speed meter. The locations chosen included, whenever possible, different conditions of geometric design for each type of acceleration and deceleration lane design, i.e. whether they met or left the through lanes on a tangent or horizontal curve.

The speeds of through vehicles were studied in the vicinity of where the acceleration or deceleration lanes met or left the through lanes and also about one mile before or after the interchange in order to evaluate if the interchange traffic had any effect upon through traffic. The location where deceleration lane traffic begins to decelerate on the through lane before the beginning of the deceleration lane was also studied at a few locations.

The study revealed that a large number of the driving public do not know how to use properly acceleration and deceleration lanes. It was also found that it is desirable to have the through lanes, at the location of acceleration and deceleration lanes, on a tangent and as near a level grade as possible. Acceleration or deceleration lane traffic was found to have little effect upon the speed of the through traffic at the interchange and most drivers started to decelerate on the through lanes before diverging into the deceleration lanes. The long direct taper type of design was found to be superior for both acceleration and deceleration lanes.

Proposed designs for standard acceleration and deceleration lane are recommended and each design incorporated the relevant characteristics of the findings of the study.

INTRODUCTION

The recent rapid development of freeways has been termed by the late Thomas H. MacDonald, former Commissioner of the Bureau of Public Roads, as the beginning of the "Second era of modern highway transportation, the express-traffic era." (17)* Mr. MacDonald also stated that we now have substantial knowledge of the manner in which highways are used by the mass of traffic and are now able to coordinate driver behavior under prevailing traffic conditions with the geometric detail of highway design. The degree to which criteria so determined are accepted and intelligently applied in practice will determine the degree of safe efficiency of our future highways (27).

Freeway-type facilities are no longer just designers'dreams. They are rapidly becoming vital parts of the vast highway system of the United States, mainly as a result of the 1956 Federal-Aid Highway Act. The network of freeways to be built by 1973 will span the nation and ultimately serve one-fifth of all motor vehicle travel in the United States (11), (17).

On the basis of various and recent research studies, it is apparent that highway designers must become more concerned with the relationship between highway design and traffic behavior. An excellent example of current interest is the design of acceleration and deceleration lanes. In order to be able to obtain maximum efficiency and safety in the operation of acceleration and deceleration lanes, and to maintain efficiency on

* Numbers in parenthesis refer to listings in the bibliography.

the main facility, it is necessary to relate the design of such lanes to traffic behavior as indicated by the requirements and desires of drivers.

Very little research has been done on interchanges in general, and particularly on acceleration and deceleration lanes on high type facilities such as those on the Interstate Highway System.

Much needs to be learned before entrance and exit ramps can be designed on a more scientific basis with the assurance that traffic will use them - including the acceleration and deceleration lanes - as intended by the designer (25).

Drivers leaving a highway at an intersection usually are required to reduce speed before turning. On the other hand, drivers entering a highway at an intersection have to accelerate in order to reach the desired speed of the traffic on the facility. Whenever this deceleration or acceleration by exiting or entering traffic takes place directly on the main traveled way of the highway, it disrupts the flow of through traffic and is hazardous (1). Thus, in order to minimize these undesirable aspects, use should be made of acceleration and deceleration lanes.

Acceleration and deceleration lanes should be used, preferably, for the entire acceleration and deceleration phase by vehicles entering or leaving the through traffic lane. Each such acceleration and deceleration lane should be of sufficient width and length to enable a driver to maneuver his vehicle onto it without a major change in speed and, once on it, to make the necessary change between the speed of operation on the main facility and the lower speed required for turning. The optimum condition of operation for an acceleration lane is to have acceleration lane traffic accelerate on the acceleration lane and merge at approximately

the same direction of travel and at the same speed into through lane traffic. That for a deceleration lane is to have deceleration lane traffic leave the through lane at about the same direction of travel as through lane traffic and at the same speed, with all deceleration taking place in the deceleration lane.

There are no specific warrants for the use of acceleration and deceleration lanes as there are many factors to be considered such as speeds, traffic volumes, capacity, type of highway, accident experience, etc...(1), but acceleration and deceleration lanes are definitely warranted at intersections on all highway facilities which carry high traffic volumes at high speeds.

Acceleration and deceleration lane design varies very significantly from state to state. Some states follow the standards set forth in the manual, "A Policy on Geometric Design of Rural Highways" by the American Association of State Highway Officials (AASHO) (1). Other states have developed their own standards using the AASHO manual as a guide. The State of New York has established (1960) a fixed length of 400 feet for deceleration lanes and 1000 feet for acceleration lanes on all of their high type facilities. They report that they feel this gives some assurance to the driver that he will have the same length available to make his move at all critical interchange points.

The State of California believes that acceleration and deceleration lane design should be standardized. Their standard shape of deceleration lane is now (1960) being designed to fit the direct path which was found to be preferred by most drivers. This direct type deceleration lane was developed due to the unsatisfactory experience which had been encountered

with a design which provided for an added full lane preceded by a taper. The State of California has also developed an acceleration lane design standard having 50:1 direct taper. Studies revealed that the natural path of nearly all vehicles is contained within a 50:1 taper and this design provides sufficient acceleration distance for all turning speeds.

The State Highway Commission of Indiana has used several designs for acceleration and deceleration lanes. The parallel lane type of acceleration lane was initially adopted as a standard. This design consisted of a full width lane 350 feet long plus 400 feet of taper; this design was constructed at several locations. Later the length of the parallel acceleration lane was changed to 250 feet of full width with 250 feet of taper. Later yet, the direct taper type of acceleration lane design was adopted in order to correct a tendency for entering traffic to move into the through lane too quickly. This latter acceleration lane has a 750 foot long taper. More recently a standard acceleration lane having 50:1 taper was adopted. This design is similar to one described in "Traffic Behavior on Freeways," Highway Research Board Bulletin 235. To date (1961), however, this last design has not been incorporated in any completed construction.

Adopted standards for the State of Indiana for deceleration lanes have also included the parallel lane type and the direct taper type. One design used a taper from zero (0) to twelve (12) foot lane width in 250 feet, followed by 50 feet of tangent and then a curve. A second design utilizes a continuous radius curve. A third design has a taper followed by a curve, and a fourth design uses a straight short taper. Just recently (1961) they adopted a standard having about 900 foot straight taper.

The geometry of acceleration and deceleration lane design has gone through an evolutionary process through the years. In general, this process has been in the direction of more liberal lengths to provide greater smoothness and safety in acceleration and deceleration operations. There are questions, however, as to how liberal the design should be. On one hand is the requirement of liberal lengths as determined through experience to date, and on the other are the limitations of cost and space (12).

PREVIOUS INVESTIGATION

In general, very little research has been done on interchanges of high type facilities and particularly on acceleration and deceleration lanes. To this date experience and personal preference have largely influenced the design (9). A few states, however, have conducted studies to evaluate the relationship between the design of acceleration and deceleration lanes and traffic behavior.

The New Jersey State Highway Department made a study on "The Types And Lengths Of Acceleration And Deceleration Lanes As They Affect Traffic Accidents" (9). An effort was made to evaluate these lanes in regard to type and length by means of 1) accident record, 2) operation and 3) capacity. The first two phases of the study have been reported in the literature. The interchanges selected for study included many of the older ones that today would be considered substandard. This was done to get a range of values so as to be able to determine what standards are desirable for safe and efficient operation. Accident records were, in general, obtained for a four year period, a length of time which tended to minimize any unusual seasonal or temporary conditions. One of the findings of the study was that adequate length of acceleration and deceleration lanes together with careful treatment of the interchange area and control of access can practically eliminate accidents at interchanges.

The Oregon State Highway Department conducted a study "A Comparison Of The Vehicle Operating Characteristics Between Parallel Lane And Direct

Taper Types Of Freeway Off-Ramps" (5). The study was conducted at two locations. One had parallel type off-ramps while the other had direct taper type off-ramps. Both locations were on a freeway which is part of the Interstate Highway System. The procedure consisted of taking speed and lateral placement measurements of vehicles using the off-ramps. The study indicated that vehicle operating characteristics were superior on the direct taper type of off-ramp to those on the parallel lane type off-ramp.

The California State Highway Department made a study on "Traffic Behavior And On-Ramp Design" (12). The location studied was the entrance ramp at the Ashby Avenue Interchange on the East Shore Freeway (US 40). The procedure consisted of recording speed and lateral placement of vehicles on three ramp terminal designs. The on-ramp shapes studied were (1) one-lane 50:1 taper on-ramp, (2) one lane parallel on-ramp, (3) one lane 30:1 taper on-ramp. The first sequence of observations was made with a temporary ramp curb encroaching on the shoulder (two feet from edge of freeway pavement) and the second sequence was with the ramp curb offset by the shoulder width from the freeway pavement (in this case eight feet). The main findings of the study were that ramp terminal design should be standardized, that the natural path of nearly all vehicles is contained within a 50:1 taper, and that this design provides sufficient acceleration distance for all turning speeds.

The Texas Transportation Institute in cooperation with the Texas State Highway Department made a study on "Freeway Ramps" (27). Eleven separate ramp studies were conducted on freeways in four cities.- Dallas, Fort Worth, San Antonio, and Houston. The study locations were specifically selected to provide data on the operational and traffic behavior

aspects of freeway ramp operation on various types of ramps operating under different volume conditions. The data were obtained mostly by motion picture studies and analyzed by use of a time-motion study projector. The study indicated that it is necessary to relate the design of freeway ramps to traffic behavior as indicated by the requirements and desires of drivers if maximum efficiency and safety in ramp and freeway operation are to be obtained. It was also found that entrance and exit ramp design should provide the driver an easy and natural path, good sight distance and good delineation.

The Institute of Traffic Engineers recently conducted twelve (12) regional seminars on freeway operation. As an outgrowth of these seminars the booklet "Freeway Operation" was published (11). The main findings relative to acceleration and deceleration lanes included the following: In the case of deceleration lanes, an element of surprise should not be introduced; the alignment and appearance should clearly differentiate between the deceleration lane and through-roadway; and there should be a clear "orientation point" as to where the deceleration lane begins and a sufficient length beyond this point for adequate deceleration before a sharp curve is introduced. In the case of acceleration lanes, they should have a small angle of convergence; the entrance path should be natural and there should be pavement contrast or markings on both sides; and the existence of a safe acceleration-merging area beyond the beginning of the acceleration lane should be easily recognizable by entering drivers.

PURPOSE

The purpose of this investigation was to determine the speed and lateral placement of vehicles on various designs of acceleration and deceleration lanes. It was also hoped that acceleration and deceleration lane design could be correlated with traffic behavior and driver requirements and that the acceleration lane and deceleration lane design or designs which would provide the most efficient and safest operation could be determined.

SCOPE

The study was limited to high type facilities in the State of Indiana. Locations were chosen on the Indiana Toll Road and those sections of the Interstate System that were completed and had been opened to traffic. These sections included the Tri-State highway from the Calumet Avenue interchange to the Broadway Avenue interchange; Interstate 65 south of Lebanon from the State Road 32 interchange to the State Road 334 interchange; Interstate 65 south of Seymour from the U. S. 50 interchange to the U. S. 31W interchange and Interstate 74 southeast of Indianapolis from the Post Road interchange to the State Road 9 interchange.

The study locations were specifically selected to provide data on speeds and lateral placement for the various types of acceleration and deceleration lanes and for operations under different conditions.

Not all of the different typical standard designs of acceleration and deceleration lanes adopted by the Indiana State Highway Commission could be studied as some of these designs had not as yet been incorporated in any completed construction. Thus the latest adopted standard design for acceleration lanes, a 50:1 straight taper was not studied. The Indiana Toll Road typical acceleration lane design is somewhat similar to this type of straight taper design, however, and it is felt that the findings of the studies on the acceleration lanes on the Indiana Toll Road are indicative of what can be expected on the 50:1 straight taper design. Similar circumstances apply to the latest Indiana deceleration lane

standard, which is a straight taper about 900 feet long and which was adopted only very recently. This type of design is somewhat similar to that of the typical deceleration lanes on the Indiana Toll Road which were studied.

Locations were chosen, if possible, to include three conditions of geometric design, i.e. where the acceleration or deceleration lanes met or left the through lanes on 1) a tangent, 2) a right curve, and 3) a left curve. One location was also studied where an acceleration lane joined the through lane on the upgrade portion of a crest vertical curve, and another was included when the junction occurred on the downgrade portion of a sag vertical curve. All these conditions were studied in order to evaluate the effects, if any, that each of these conditions have on traffic behavior and to determine which condition provides for the most efficient and safe use of acceleration and deceleration lanes.

In four cases, more than one location having the same acceleration or deceleration lane design and similar conditions of geometric design were studied. These studies were made at different locations having different traffic, in order to evaluate if the results would be repetitive or if other factors such as traffic volumes and types of drivers using the facility have a significant bearing upon the results.

The speeds of through vehicles were also studied at each interchange in the vicinity of where the acceleration or deceleration lanes joined the through lanes. This was done in order to compare speeds of acceleration or deceleration lane traffic with through lane traffic at each location. The speeds of through traffic were also obtained before or after the interchanges as pertinent, in order to evaluate if the interchange traffic had any effect upon the speed of through traffic at the interchange.

The types of vehicles studied were passenger cars and light trucks, which were considered as passenger cars. Heavy trucks were not included as the percentage of such trucks using acceleration and deceleration lanes in Indiana is small. During the course of the study it was found to be of interest to determine the location where deceleration lane traffic begins to decelerate while on the through lanes and before the beginning of the deceleration lane. This information was obtained for a few of the study locations for deceleration lanes.

Only information for free-moving vehicles were recorded in this study. For a vehicle to be considered free flowing, it must be able to overtake and pass without any reduction in speed (22). Consequently only those vehicles were used which were not affected by other vehicles in their path of movement. This restriction applied to all vehicles for which data were recorded. Vehicles following or in an adjacent lane were not considered as affecting a subject vehicle and data for the subject vehicle were obtained. This restriction did result in only the lead vehicle in a platoon being recorded.

The vehicles that stopped on the acceleration or deceleration lanes were not considered in the speed and lateral placement evaluations but were recorded to determine the percentage of vehicles that stopped.

Data collection took place when the pavement was dry and under optimum atmospheric conditions, i.e. absence of fog or haze. This was particularly essential as much of the data was obtained photographically and a clear and sharp picture from a considerable distance was often necessary. Data were collected during the day on week days for most of the locations, but some studies were made on the weekend. It is felt that the day of observation

has no significant effect upon the vehicular characteristics for the type of traffic that used these high type facilities.

Reconnaissance studies and preliminary surveys for determining sample sizes were conducted in September and October 1960. The actual collection of speed and lateral placement data took place from November 1960 until July 1961 on days of good weather conditions. Approximately 1700 passenger cars using acceleration lanes were studied and about 1500 passenger cars using deceleration lanes were included in the study.

Volume counts for each of the locations studied were obtained from the Indiana Toll Road Commission or from the Planning Division of the Indiana State Highway Commission. The annual average daily traffic for each of the acceleration and deceleration lanes studied as well as for the through lanes at each location are included under the discussion of each study location.

Accident reports were obtained from the files of the Indiana State Police. The accidents studied were only those directly involving acceleration or deceleration lane traffic at each of the locations. For the Indiana Toll Road and Tri-State Highway locations, such accidents were analyzed for the years 1959 and 1960. As Interstate 74 was opened to traffic in October 1960, Interstate 65 south of Lebanon - the northern half in July 1960 and the rest in October 1960, and Interstate 65 south of Seymour in October 1960, no accident analysis was available on a yearly basis. The accidents studied for each of the locations on these Interstate Highways were from the month in 1960 when they were opened to traffic until July 1961.

EQUIPMENT

Motion Picture Camera

The camera used to photographically record vehicular use of the acceleration or deceleration lanes was a standard 16mm Bell and Howell Auto Master Camera (26) which has a built-in turret head (see Figure 1). The built-in turret head allows the use of different focal length lenses and equivalent view finder objectives depending upon the distance between the camera and the object. For this study both the 6 inch and 3 inch telescopic lenses and the 6 inch and 3 inch view finder objectives were used.

The camera uses a 50 foot magazine of 16mm film. Kodak plus X black and white film was used with filming done at a speed of 16 frames per second. The camera was mounted on a tripod by means of a standard socket found at the bottom of the camera.

Projector

The projector used to analyze the film for speed and lateral placement was a model SFDR-Time-Motion L-W Industrialist Projector (24)(see Figure 2). This projector is a complete modification of the Eastman Kodak Kodoscope 16mm Silent Analyst Projector by the L-W Photo Products Company of Northridge, California. It combines special purpose data-analysis adaptations with the precision and adaptability of the Kodak projector. The projector can be operated at movie speed forward and reverse with

FIGURE 1. 16mm MOTION PICTURE CAMERA

FIGURE 2. TIME MOTION STUDY PROJECTOR IN OPERATION

instant change of direction; it can be pulsed for single frame projection at a rate dependent upon the operators wish by manual push-button control; it has a special shutter to minimize flicker at low rates; it will project a single frame as a still picture for an indefinite period without loss of illumination or damage to the film; it has a frame counter which adds when the projector is operating forward and subtracts when it is operating in reverse and can be reset to zero. This last feature allows the operator to know the time that has elapsed between any two exposures.

This projector operates as a motion picture projector with a speed from approximately 5 to 24 frames per second which can be controlled by a variable speed control knob. It can be pulse operated by the operator at speeds of one frame per second and can be pulsed more rapidly to cover the range from one to five frames per second.

This projector projects an image onto a mirror that reflects the image onto a ground glass screen. This screen is seven inches high and nine inches wide. Since the screen is small, the image is very clear and easy to see. A grid line can be drawn on the screen and then erased. The projector can also be operated in a partially lighted room thereby reducing eyestrain.

Electro-Matic Radar Speed Meter

The radar meter (21) used to measure the instantaneous speed of some moving vehicles in this study is shown in Figure 3. As with all such meters, a transmitter-receiver unit beams a micro-wave radio frequency at an advancing or receding vehicle in the operating zone and receives this same frequency back plus or minus a doppler shift. The doppler shift is measured and converted to the speed of the vehicle and is read directly

FIGURE 3. ELECTRO-MATIC RADAR SPEED METER

in miles per hour on the linear scale of the indicator. The meter operates on 12 volts DC drawing 3.75 amperes. When in operation the batteries were regularly checked by means of a voltmeter to insure against speed readings being affected due to fluctuation of change in voltage. The instrument operates within a range from zero (0) to 100 miles per hour with an accuracy of plus or minus two (2) miles per hour throughout the range. The radar meter is linearly calibrated in scale divisions of two (2) miles per hour. When using the meter, vehicle detection is effective within a cone of approximately twenty (20) degrees throughout a range of 175 feet. The above range holds true when the unit is placed approximately three (3) feet off the ground. Increasing the height of the unit increases the range slightly, and conversely decreasing the height decreases the range slightly. Thus the unit was placed approximately three (3) feet off the ground throughout the study (Figure 3). The radar meter was also placed so that its beam was at an angle of ten (10) degrees or less with respect to the direction of traffic. By making this angle small, any error in the speed readings due to directional factors was negligible.

The radar meter provides an indicated speed by the needle swinging sharply to a definite reading when a vehicle comes into its operating beam, which is shaped somewhat like a spot light beam and has very much the same characteristics, remaining there for an instant, and then returning to zero when the car passes out of the beam. It is essential that the reading be maintained for an instant to insure a true reading. At the beginning and throughout the speed study, a tuning fork was used for calibration and for checking of the meter. This tuning fork vibrated at a frequency equivalent to that which would register 60 miles per hour on the indicator.

Trafficcounters

The volumes of traffic used in this study were obtained by using standard Model RC Trafficcounters made by Streeter-Amet Company of Chicago.

PROCEDURE

Field

The data on speeds and lateral placement of traffic using acceleration and deceleration lanes were obtained by use of motion picture techniques using the 16mm motion picture camera. The motion picture type of study was selected, after consideration of various other methods, as being the best approach to study and analyze.

Photography has been used in time and motion studies by industrial engineers for many years. Their experience had indicated that time-motion photography could be used for traffic analysis with great success (6).

The motion picture type of survey provides an accurate method of obtaining all necessary data for studying traffic operational characteristics. A permanent record of all collected data is also recorded on film which then may be rerun many times so that a given traffic situation can be studied over and over again (6), (17), (16).

Grid lines were established at each location on the pavement by placing transverse paint lines on the pavement, or by using a 2 ft. by 12 ft. board covered with white adhesive tape (Figure 4). In the latter case, a movie was taken with the board placed at each grid line location. These grid lines were placed perpendicular to the centerline of the acceleration and deceleration lanes at specific locations.

The filming was done from a vantage point, usually from the overpass over the main facility at the interchange. The camera used was a 16mm

FIGURE 4. 2 x 12 FOOT BOARD FOR
ESTABLISHING GRID LINES

Bell and Howell movie camera with a built-in turret head. Both the 6 inch and the 3 inch telescopic lenses were used in the study but due to the distance of the objects to be filmed the 6 inch lense was used in most locations. The camera was operated at 16 frames per second, which is the lowest number of frames possible on this type of camera. This was found to be adequate for this type of study from an economical and accuracy point of view.

This relatively slow camera speed did result in some loss of accuracy for high vehicular speeds. For example, a vehicle travelling a distance of 50 feet between two grid lines, during 18 frames would be travelling at a speed of 30 mph while during 19 frames it would be travelling 29 miles per hour. The variation per frame is one (1) mile per hour. On the other hand if only 9 frames were required the speed would be 61 miles per hour while for 10 frames it would be 55 miles per hour. The variation per frame at this speed is six (6) miles per hour. The minimum sample size for both acceleration and deceleration lanes was computed as 108 cars on the basis of an average possible speed error of four (4) miles per hour per frame. This possible error corresponds to a speed of about 50 miles per hour, which was the average anticipated speed.

One person recorded on film the traffic operation characteristics of each car using an acceleration or deceleration lane during the study. In the case of acceleration lanes, movies were taken of each car as it passed a designated point, usually the nose, beyond which it was able to maneuver and merge onto the through lanes, and until the left rear wheel of the car crossed from the acceleration lane onto the through lane. The left rear wheel of the car was chosen as the criterion because acceleration

lane traffic travelled away from the camera and therefore was visible, and for all practical purposes the instant the left rear wheel crosses from the acceleration lane onto the through lane is the practical initiation of conflict with the through traffic operation.

As for the deceleration lane, movies were taken of each car just as its left front wheel crossed from the through lane onto the deceleration lane and until it passed a designated point on the deceleration lane, usually the nose, beyond which the car is unable to maneuver back onto the through lane. Here the left front wheel of the car was chosen because for deceleration lanes, traffic travelled towards the camera and most of the car by that point had left the through lane and was no longer a conflict on the through lanes. A field record of each car was kept on a special sheet and all special operational characteristics were noted, as for example if the car stopped on the acceleration lane.

Spot speeds of through lane traffic were measured using the radar meter. The meter was placed on a stool in front of a study car which was parked either on the shoulder or in the median strip and its hood raised as if it were disabled (see Figure 3). This concealed the meter and avoided suspicion and curiosity from drivers who otherwise might have reduced their travel speed. The speed was measured after the vehicle had passed the transmitter which consequently was directed to transmit the beam in the direction of traffic flow. The spot speeds of through traffic were measured at two locations at each study site. The first of these was "within the area of conflict", the area where acceleration or deceleration lanes adjoined the through lane, and thus being an area of conflict between through traffic and acceleration or deceleration lane traffic. The second spot speed location

was "beyond the area of conflict", a point which was approximately a mile before or after the interchange. The minimum sample size taken for both locations was determined to be 150 cars.

Spot speeds of deceleration lane traffic were measured at three deceleration lane sites using the radar meter as an attempt to determine where traffic destined for a deceleration lane begins to decelerate on the through lane and prior to the beginning of the deceleration lane. The radar meter was placed so that the cars approaching the deceleration lane intersected the beam at the specified location, but only cars that proceeded to use the deceleration lane were recorded. Here sample size was taken as 50 cars.

Office

The film was analyzed by projecting it through the time-motion study projector (Figure 1). A grid was traced on the screen from the movies to the same relative scale as that which was placed on the pavement. The vehicle speeds at various locations on the acceleration and deceleration lanes were computed using the grid system by determining the distance traveled during a time period which was obtained from the number of frames each vehicle traveled between two grid lines. The lateral placement of the vehicles on the acceleration or deceleration lanes were also traced by using the grid system. The stations at which the left rear wheel of acceleration lane traffic and left front wheel of deceleration lane traffic crossed the line between the acceleration or deceleration lane and through lanes were noted.

The average speed, the 85th percentile speed and the standard deviation (definition of statistical terms is given in Appendix A) of acceleration or deceleration lane traffic were computed at station 0+00, or as

near to station 0+00 as was practical. Station 0+00 was located near the nose of each acceleration or deceleration lane and is shown for each study site in the sketch of each site in a following section of this report.

The speed data were grouped by 100 foot stations according to the location on the acceleration or deceleration lane where traffic merged or diverged. For example the speed data for all vehicles at a study site which merged or diverged between station 0+00 and station 1+00 were grouped for analysis. The average speed, 85th percentile speed, standard deviation and percent of total leaving or entering between stations was computed for each group. This 85th percentile speed and percent leaving or entering between 100 foot stations is indicated on the sketches of each study site which are included in a following section of this report. These values are indicated at the midpoint of each station group. A single value for the 85th percentile speed for all vehicles entering or leaving the deceleration or acceleration lane is shown on these same sketches in parenthesis.

A cumulative frequency graph of lateral placements was plotted for each study site. This graph was developed by plotting the cumulative percent of vehicles which merged or diverged into or from the through lane against the distance from the nose at which the merges or divergences occurred. It was found that the cumulative curves thus prepared tended to level off at approximately the 90 percent point. Thus the 90th percentile was taken as an important criteria for determining the length of an acceleration or deceleration lane which was effectively used.

STATISTICAL ANALYSIS PROCEDURES

Statistical procedures were used in the analysis of the speed data for the following two cases:

1. To determine whether the difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was significant; and
2. To determine whether the difference between the 85th percentile speed of the through lane traffic within the area of conflict and the average 85th percentile speed of the acceleration or deceleration lane traffic as it merged or diverged into or from the through lanes was significant.

The first situation was a case of testing the difference between two Pth percentile speeds whose basic unit was in mph. The speeds were assumed to be normally distributed, random and independent.

The hypothesis to be tested was that the parameters corresponding to the two samples were equal.

Hypothesis: $X_1' P = X_2' P$

Alternate Hypothesis: $X_1' P \neq X_2' P$

$\alpha = 0.005$ (two tail test).

Thus the statistic is:

$$Z = \frac{X_{1P} - X_{2P}}{\sqrt{\sigma_{X_{1P} - X_{2P}}^2}} = \frac{X_{1P} - X_{2P}}{\sqrt{\sigma_{1P}^2 + \sigma_{2P}^2}} \quad (1)$$

Where:

X_{1P} = Pth percentile speed

$\sigma_{X_{1P} - X_{2P}}^2$ = Variance of the difference

σ_{1P}^2 = Variance of individual sample

The following relationship exists between the standard deviation of the distribution of the sample percentiles and the standard deviation of the population:

$$\sigma_P = \frac{K_p \sigma}{\sqrt{n}}$$

Where

$$K_p = \frac{\sqrt{p(1-p)}}{f(\xi)} = \frac{\sqrt{pq}}{f(\xi)}$$

where

σ = standard deviation of the population

n = sample size

σ_P = standard deviation of the sample percentile

p = fraction or percentile i.e.: $P = 100_p$

$q = 1 - p$

$f(\xi)$ = ordinate to a standard normal curve at a point with (ξ) area below, here 0.85

Thus

$$\sigma_P = \sigma \sqrt{\frac{pq}{n}} \times \frac{1}{f(\xi)}$$

namely

$$\sigma = \sqrt{\frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n_1 + n_2 - 2}}$$

where

$$S_1^2 = \frac{\sum_{i=1}^{n_1} (X_i - \bar{X})^2}{n_1 - 1}$$

As in this case $n_1 = n_2 = n$

thus
$$\sigma = \sqrt{\frac{s_1^2 + s_2^2}{2}}$$

therefore
$$\frac{X_{1P} - X_{2P}}{\sqrt{\sigma_1^2 + \sigma_2^2}} = \frac{X_{1P} - X_{2P}}{\sqrt{\left(\frac{s_1^2 + s_2^2}{2}\right) \times \left(\frac{pq}{n}\right) \times \left(\frac{1}{f(\xi)^2}\right) \times 2}} \quad (2)$$

but $p = 0.85 \quad q = 1-p = 0.15$
 $n = 150 \quad f(\xi) = 0.2331 \text{ and } P_{th} = 85\text{th}$

Thus
$$Z = \frac{X_{1 \text{ 85th}} - X_{2 \text{ 85th}}}{\sqrt{\left(\frac{s_1^2 + s_2^2}{2}\right) \times \frac{.85 \times .15}{150} \times \frac{1}{(.2331)^2}}} = \quad (3)$$

$$\frac{(X_{1 \text{ 85th}} - X_{2 \text{ 85th}}) \times 8.01}{\sqrt{s_1^2 + s_2^2}}$$

The value of α was chosen small for each test, equal to 0.005, because in a test repeated m times, the probability of at least one error is $1 - (1-\alpha)^m$, rather than α .

An α value of 0.005 implies a probability of error on the repeated series of tests of $<.10$ for $m = 15$ for acceleration lanes and $m = 13$ for deceleration lanes.

The value of $\alpha = .005$ (two tail test) corresponds to a Z value of 2.81.

The same assumptions and hypothesis applied for the second determination as in the first case.

In this case the number of sample sizes were not equal.

$$\text{i.e. } n_1 \neq n_2$$

$$n_1 = 150 \text{ and } n_2 = 108$$

Let $\bar{n}$ = harmonic mean which is defined as:

$$\bar{n} = \frac{1}{\frac{1}{K} \sum_{i=1}^K \frac{1}{n_i}}$$

$$\bar{n} = \frac{1}{\frac{1}{2} \left(\frac{1}{150} + \frac{1}{108} \right)} = 125.8$$

Using in this case a weighted average of σ where

$$\sigma = \sqrt{\frac{(n_1 - 1)(S_1^2) + (n_2 - 1) S_2^2}{n_1 + n_2 - 2}}$$

Substituting values of σ and $\bar{n}$ in equation (2) of previous case.

$$\text{Thus } Z = \frac{X_{1P} - X_{2P}}{\sqrt{\frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n_1 + n_2 - 2} \times \frac{pq}{\bar{n}} \times \frac{1}{f(\xi)^2} \times 2}} \quad (4)$$

$$= \frac{X_{1P} - X_{2P}}{\sqrt{\frac{(149 S_1^2 + 107 S_2^2)}{256} \times \frac{.85 \times .15}{125.8} \times \frac{1}{(.2331)^2} \times 2}}$$

$$= \frac{(X_{1P} - X_{2P})}{\sqrt{\frac{149 S_1^2 + 107 S_2^2}{128}}} \times 7.33 \quad (5)$$

A tabulated summary of the results of the statistical analysis in terms of significant or not significant differences is given in Tables 1 and 2 for the acceleration lanes and Tables 3 and 4 for the deceleration lanes. The location symbols are described and explained in the next section of this report.

An illustrative example for both Case 1 and Case 2 is given in Appendix A.

ACCELERATION LANES

SUMMARY OF STATISTICAL ANALYSIS

TABLE 1

85th Percentile Speed of Through Lane Traffic,
"Within Area of Conflict" vs "Beyond Area of Conflict"

Location	Ala	Alb	Alc	Ald	Ale	Alf	A2a	A2b	A2c	A2d	A2e	A3a	A3b	A4a	A4b
Results	NS*	NS	NS	NS	NS	S ^o	NS	NS	NS	S	NS	S	NS	S	NS

TABLE 2

85th Percentile Speed of Through Lane Traffic vs Average
85th Percentile Speed of Acceleration Lane Traffic as it Merged.

Location	Ala	Alb	Alc	Ald	Ale	Alf	A2a	A2b	A2c	A2d	A2e	A3a	A3b	A4a	A4b
Results	S	NS	S	NS	S	NS	S	S	S	S	S	S	S	S	S

* NS = Not Significant

^o S = Significant

SUMMARY OF STATISTICAL ANALYSIS

TABLE 3

85th Percentile Speed of Through Lane Traffic,
"Within Area of Conflict" vs "Beyond Area of Conflict"

Location	D1a	D1b	D1c	D2a	D2b	D2c	D3a	D3b	D3c	D4a	D5a	D5b	D5c
Results	S*	S	NS	NS ^o	S	NS	S	NS	NS	NS	NS	NS	NS

TABLE 4

85th Percentile Speed of Through Lane Traffic vs
Average 85th Percentile Speed of Deceleration Lane Traffic as it Diverged

Location	D1a	D1b	D1c	D2a	D2b	D2c	D3a	D3b	D3c	D4a	D5a	D5b	D5c
Results	S	S	S	S	S	S	S	S	S	S	S	S	S

* S = Significant

^o NS = Not Significant

LOCATIONS AND RESULTS

Acceleration Lanes

Figure 5 shows on a map of the State of Indiana the location of the acceleration lanes studied. Pertinent data for each location are given in Table 5. These locations are referenced as follows: A1a, A2b, etc. where the "A" stands for Acceleration lane; the 1, 2, etc for the type of acceleration lane design; and a, b, etc. for the location.

Acceleration Lanes, Type 1

One type of acceleration lane studied was on the Indiana Toll Road and is of the design shown in Figures 6 and 7. The length of the acceleration lane is 1200 ft. from the end of the ramp curve to the intersection with the right edge of the through lane. A shoulder, which is paved but of different color, separates the acceleration lane from the through lane for a distance of 577.82 ft. For some of this distance, a curb also adjoins the acceleration lane. Beyond the point of separation, the acceleration lane is an extra lane with a 52:1 straight taper from a width of twelve (12) ft. to zero (0) ft. in a distance of 622.03 ft.

Six locations of this type of acceleration lane were studied. At two of these locations the acceleration lane meets the through lane on a tangent, at a third on a tangent and also on the downgrade portion of a sag vertical curve, at a fourth location on a right curve, at a fifth on a right curve and also on the upgrade portion of a crest vertical curve and at a sixth on a left curve.

FIGURE 5. STUDY LOCATIONS OF ACCELERATION AND DECELERATION LANES

TABLE 5

PERTINENT DATA FOR STUDY LOCATIONS - ACCELERATION LANES

Accel. Lane Identification	Location	Direction of Accel. Lane Traffic	Geometric Condition	Type of Accel. Lane
Ala	Indiana Toll Road - Middlebury	West Bound	Tangent	(1) Direct Taper 1200' - 1
Alb	Gary West	West Bound	Tangent	(1) Direct Taper 1200' - 1
Alc	Michigan City	West Bound	Tangent and Downgrade Portion of Sag Vertical Curve	(4) Direct Taper 1200' - 1
Ald	Chesterton-Valparaiso	West Bound	Right Curve	(2) Direct Taper 1200' - 1
Ale	LaPorte	West Bound	Right Curve and Upgrade Portion of Crest Vertical Curve	(5) Direct Taper 1200' - 1
Alf	Gary East	East Bound	Left Curve	(3) Direct Taper 1200' - 1
A2a	Interstate 65 - State Road 39	North Bound	Tangent	(1) Parallel-350' Str & 400' taper - 2
A2b	Tri-State - Kennedy Ave.	East Bound	Tangent	(1) Parallel-350' Str & 400' Taper - 2

x Numbers in parenthesis (1) identify the geometric conditions used in this report.

+ Numbers 1, 2, etc. refer to the type of acceleration lane used in this report.

TABLE 5 (continued)

Accel. Lane Identification	Location	Direction of Accel. Lane Traffic	Geometric Condition	Type of Accel. Lane
A2c	Interstate 74 - Post Road	East Bound	Tangent	(1) Parallel-350' Str & 400' Taper - 2
A2d	Interstate 65 - State Road 60	South Bound	Right Curve	(2) Parallel-350' Str & 400' Taper - 2
A2e	State Road 39	South Bound	Left Curve	(3) Parallel-350' Str & 400' Taper - 2
A3a	State Road 56	North Bound	Tangent	(1) Parallel-250' Str & 250' Taper - 3
A3b	State Road 334	North Bound	Left Curve	(3) Parallel-250' Str & 250' Taper - 3
A4a	Tri-State - Calumet Ave.	East Bound	Tangent	(1) Direct Taper 300' - 4
A4b	Calumet Ave.	West Bound	Right Curve	(2) Direct Taper 300' - 4

TYPICAL ACCELERATION LANE INDIANA TOLL ROAD

TYPE I

FIGURE 6

FIGURE 7. VIEW OF ACCELERATION LANE-TYPE I

Station 0+00 was taken as the end of the ramp curb, and beyond this point acceleration lane traffic could merge into the through lanes. Each location also exhibited certain special characteristics which will be described separately.

Location Ala: Indiana Toll Road - Middlebury Interchange -
Acceleration Lane West Bound

The acceleration lane meets the through lane on a tangent at this interchange (see Figure 8).

The annual average daily traffic (1960) on the acceleration lane was 620 vehicles per day and on the west bound through lanes was 3720 vehicles per day. This interchange is located in a rural area of the state and in the summer serves the vacation traffic to the lakes in the vicinity.

No accidents occurred on the acceleration lane during 1959 and 1960.

Figure 9 shows the results of the speed and lateral placement study made at this location. On this figure, as on similar figures for the other locations of acceleration and deceleration lanes studied, 85th percentile speeds are shown for acceleration lane traffic and for through lane traffic. For acceleration lane traffic, the 85th percentile speed is given for Station 0+00 and for all vehicles which left the acceleration lane in each 100 feet thereafter and at the time of merging. The percentage of the total non-stopping vehicles using the acceleration lane which left the lane in each 100 feet and the cumulative percentage leaving at the end of each 100 feet are also given. The average 85th percentile speed of all vehicles using the acceleration lane and at the time of merging, except those which stopped, is shown by a number in parenthesis, (55) in Figure 9. The 85th percentile speed for through lane traffic is given for a point within the area of merging and at a point approximately one (1) mile from this area.

FIGURE 8

All percentages of acceleration lane traffic used in this report refer to the total vehicles using the lane who did not stop before entering the through lane.

The 85th percentile speed of acceleration lane traffic for location Ala at Station 0+00 was 48 mph (see Figure 9). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lane was 14 mph (69-55). This difference is significant and indicates that most of this acceleration lane traffic did not accelerate to about the same speed before merging with through lane traffic.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0)(69-69).

Ninety percent of the traffic using the acceleration lane merged into the through lane prior to Station 4+50. This shows that the majority of drivers merged within a distance of about 185 feet (4+50-2+65) beyond the point of separation of the acceleration lane from the through lane by means of the paved shoulder.

For this 52:1 taper design and at this location the natural straight path of the left wheels of acceleration lane vehicles intersects the edge of the through lanes between Stations 4+00 and 5+00. Only 18.5 percent of acceleration lane traffic, however, merged in this area. The majority, 79.6 percent, merged between Stations 3+00 and 4+00. It thus merged earlier than the natural straight path and at significantly lower speeds than through lane traffic.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE - WEST BOUND
INDIANA TOLL ROAD
MIDDLEBURY INTERCHANGE

FIGURE 9

A small percentage, 1.9 percent, merged into the through lanes between Stations 5+00 and 6+00 at an 85th percentile speed of 51 mph. This small percentage of vehicles made use of a longer distance of the acceleration lane and yet they merged at lower speeds than those at the previous indicated locations. The reasons for this are either that these cars had to slow down due to conflicts with through traffic or that the drivers hesitated before merging due to inexperience of driving on high type facilities or not understanding the proper usage of acceleration lanes.

Of all vehicles using this acceleration lane, one (1) percent stopped on the acceleration lane.

These results indicate that at this location, this type of acceleration lane design is not being properly used by the majority of drivers.

Location Alb: Indiana Toll Road - Gary West Interchange -

Acceleration Lane West Bound

At this location the acceleration lane meets the through lane on a tangent (see Figure 10). The median is 20 ft. wide with a raised barrier in the center instead of the standard 50 ft. wide median. The curb adjoining the acceleration lane is longer than in the typical design (Figure 6) and extends to within about 100 ft. of the end of the shoulder separating the acceleration lane and the through lane.

The annual average daily traffic, on the acceleration lane was 1310 vehicles per day and on the through lanes west bound was 7860 vehicles per day. This interchange is located in an urban area of the state and serves mostly local traffic between the city of Chicago and the industrial area in the city of Gary.

FIGURE 10

Two accidents were reported on this acceleration lane for the year of 1959. Both accidents were caused by drivers travelling too fast on the entrance ramp curve. No accidents occurred in 1960.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 54 mph (see Figure 11). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lane was three (3) mph (65-62). This speed differential is not significant.

The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict was zero (0)(65-65).

About 90 percent of the acceleration lane vehicles merged into the through lane prior to Station 3+00. The majority of drivers merged within the first 200 feet (3+00 - 1+00) beyond the point of separation of the acceleration lane from the through lanes.

The natural straight path of the left wheels of acceleration lane vehicles at this location intersects the through lane between Stations 2+00 and 3+00. In this area, 80.6 percent of the acceleration lane traffic merged into the through lane at an 85th percentile speed of 62 mph.

A very small percentage of the acceleration lane traffic, 2.8 percent, merged between Stations 4+00 and 5+00 at an 85th percentile speed of 53 mph. This speed is considerably less (9 mph) than the speed at which all the acceleration lane traffic merged. The reasons for this condition could be the same as those previously stated for the preceding acceleration lane.

Of all vehicles using the acceleration lane, 10.7 percent stopped on the acceleration lane. This is a relatively high percentage and may be

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-WEST BOUND
INDIANA TOLL ROAD
GARY-WEST INTERCHANGE

FIGURE 11

due to the fact that some of general public using the facility at this location are not properly informed as to the proper use of acceleration lanes.

The results at this location, except for the stopping vehicles, approach the optimum conditions of operations for acceleration lanes, as the majority of acceleration lane traffic merged in approximately the same direction of travel and at about the same speed as the through lane traffic. A comparison of these results with those of the previous case, Ala, shows that these are not similar even though both locations have the same acceleration lane design and the same geometric condition, i.e. tangent. This indicates that other factors, such as type of drivers using the lane and traffic volume, may have a significant bearing upon the results.

Location Alc: Indiana Toll Road - Michigan City Interchange -
Acceleration Lane West Bound

The acceleration lane at this location meets the through lane on a tangent and on the downgrade portion of a sag vertical curve (see Figure 12).

The annual average daily traffic on the acceleration lane was 870 vehicles per day and on the west bound through lanes was 5950 vehicles per day. This interchange is located in a rural area. It intersects U. S. 421 which runs north to Michigan City and south to Indianapolis.

One accident was reported for the year 1960 and was caused by a driver stopping on the acceleration lane. No accidents were reported in 1959.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 54 mph (see Figure 13). The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lanes was ten (10) mph (67-57). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0)(67-67).

About 90 percent of the acceleration lane vehicles merged into the through lane prior to Station 5+00. Here again the majority of drivers merged within the first 200 feet (5+00 - 3+00) beyond the point of separation of the acceleration lane from the through lane by means of the paved shoulder.

The natural straight path of the left wheels of the acceleration lane traffic intersects the through lane at this location between Stations 4+00 and 5+00, where 86.1 percent of the acceleration lane traffic merged into the through lane at an 85th percentile speed of 55 mph. A small percentage, 4.6 percent, of acceleration lane traffic merged between Stations 5+00 and 6+00 at an 85th percentile speed of 70 mph. This small percentage of vehicles thus made use of a longer distance of the acceleration lane and accelerated to about same speed as through lane traffic before merging. These drivers approached the optimum conditions of operation for acceleration lanes as they merged at approximately the same speed and in the same direction of travel as the through lane traffic.

Of all vehicles using the acceleration lane, 1.8 percent stopped on the acceleration lane.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE - WEST BOUND
INDIANA TOLL ROAD
MICHIGAN CITY INTERCHANGE

FIGURE 13

These results show that at this location and for this geometric condition the majority of drivers are not properly using this acceleration lane from the speed point of view.

By comparing these results with the previous two cases, Ala and Alb, it is evident that the majority of drivers in this case merge at about same speed as in the first case (Ala) but at lower speeds than in the second case (Alb). This indicates that the acceleration lane being on the downgrade portion of a sag vertical curve may affect the speed of merging traffic.

Location Ald: Indiana Toll Road - Chesterton-Valparaiso Interchange -
Acceleration Lane West Bound

The acceleration lane at this location meets the through lane on a slight right horizontal curve (see Figure 14).

The annual average daily traffic, on this acceleration lane was 650 vehicles per day and on the through lanes west bound was 6420 vehicles per day. This interchange is located in a rural area. It intersects State Road 39 which serves Chesterton to the north and Valparaiso to the south.

No accidents were reported on this acceleration lane for the years 1959 and 1960.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 57 mph (see Figure 15). The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lane was three (3) mph (67-64). This difference is not significant.

FIGURE 14

INDIANA TOLL ROAD AND
VALPARAISO-CHESTERTON INTERCHANGE

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE - WEST BOUND
INDIANA TOLL ROAD
CHESTERTON-VALPARAISO INTERCHANGE

FIGURE 15

The difference between the 85th percentile speeds of through lane traffic within the area of conflict and that beyond the area of conflict was two (2) mph (69-67). This difference also is not significant.

About 90 percent of acceleration lane vehicles merged into the through lane prior to Station 4+60. This indicates that the majority of drivers merged within the first 260 feet (4+60-2+00) beyond the point of separation of the acceleration lane from the through lane.

The natural straight path of the left wheels of acceleration lane traffic intersects the through lane between Stations 3+00 and 4+00 where only 36.1 percent of acceleration lane traffic merged into the through lane and at an 85th percentile speed of 66 mph. The highest portion, 51.9 percent, of acceleration lane traffic merged between Stations 4+00 and 5+00 at an 85th percentile speed of 61 mph. Thus about half of the drivers utilized correctly most of the length of the acceleration lane. This could be due to the effect of the right curve which tended to cause drivers to follow the curve on the acceleration lane and then merge with through traffic. On the other hand, these drivers merged at lower speeds than those of several previously discussed locations. A small percentage, 2.8 percent, of acceleration lane traffic crossed over the paved shoulders and merged between Stations 0+00 and 2+00.

Of all vehicles using the acceleration lane, 3.6 percent stopped on this acceleration lane.

These results indicate that at this location and for this geometric condition, many of the drivers tended to approach the optimum conditions of operations for acceleration lanes as they merged in approximately the

same direction of travel and at the same speed as through lane traffic.

Location Ale: Indiana Toll Road - LaPorte Interchange -

Acceleration Lane West Bound

The acceleration lane at this location meets the through lane on a slight right horizontal curve and on the upgrade portion of a crest vertical curve (see Figure 16).

The annual average daily traffic on the acceleration lane was 1230 vehicles per day and on the through lanes west bound was 5030 vehicles per day. This interchange is located in a rural area. It intersects State Road 39 which serves the city of LaPorte to the south.

No accidents were reported on this acceleration lane for the years 1959 and 1960.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 48 mph (see Figure 17). The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lane was 12 mph (66-54). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0) mph (66-66).

Approximately 90 percent of acceleration lane vehicles merged into the through lane prior to Station 4+00. This shows that the majority of drivers merged within a distance of about 200 feet (4+00 - 2+00) beyond the point of separation of the acceleration lane from the through lane.

INDIANA TOLL ROAD AND
LAPORTE INTERCHANGE

FIGURE 16

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE - WEST BOUND
INDIANA TOLL ROAD
LA PORTE INTERCHANGE

FIGURE 17

The natural straight path of the left wheels of the acceleration lane traffic intersects the through lane between Stations 3+00 and 4+00 where 75 percent of the acceleration lane traffic merged into the through lane at an 85th percentile speed of 54 mph. At this location, as at a previously discussed site, a small percentage, 1.8 percent, of acceleration lane traffic crossed over the paved shoulders and merged between Stations 1+00 and 2+00.

Of all vehicles using the acceleration lane, 3.7 percent stopped on the acceleration lane.

These results indicate clearly that at this location and for this geometric condition, this type of acceleration lane design is not being properly used by many of the drivers. By comparing these results with those of the previous case, Ald, it is evident that some of the drivers at this site merged at lower speeds and after using a shorter distance of the acceleration lane. This may indicate that the different geometric condition of this acceleration lane, i.e. being on the upgrade portion of a crest vertical curve, has a significant adverse bearing upon the results.

Location Alf: Indiana Toll Road - Gary East Interchange -
Acceleration Lane East Bound

The acceleration lane at this site meets the through lane on a slight left horizontal curve (see Figure 18).

The annual average daily traffic on the acceleration lane was 590 vehicles per day and on the through lanes eastward 6520 vehicles per day. This interchange is located in an urban area. It intersects U. S. 12 and U. S. 20, and the studied acceleration lane serves mostly through traffic travelling eastward on the Toll Road from these state highways and the surrounding area and traffic from the nearby Tri-State highway.

INDIANA TOLL ROAD AND
GARY EAST INTERCHANGE

FIGURE 18

No accidents were reported on this acceleration lane for the years 1959 and 1960.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 58 mph (see Figure 19). The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of acceleration lane traffic as it merged into the through lane was one (1) mph (64-63). This difference is not significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was five (5) mph (69-64). This difference is significant and indicates that at this location some of the drivers of through traffic vehicles slowed at the interchange.

Ninety (90) percent of acceleration lane vehicles merged into the through lane prior to Station 3+90. The majority of drivers, therefore, merged within a distance of about 190 feet (3+90 - 2+00) beyond the point of separation of the acceleration lane from the through lane.

The natural straight path of entry of the left wheels of acceleration lane traffic intersects the through lane between Stations 3+00 and 4+00 where 91.7 percent of acceleration lane traffic merged into the through lane at an 85th percentile speed of 63 mph.

Of all vehicles using the acceleration lane, none stopped on the acceleration lane.

The results at this location approach the optimum condition of operation for acceleration lanes, as the acceleration lane traffic here merges in approximately the same direction of travel and at the same speed as the through lane traffic.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

FIGURE 19

Acceleration Lanes, Type 2

The second type of acceleration lane studied is shown in Figure 20 and a photograph of a highway with a typical lane of this type is shown in Figure 21. The acceleration lane is of the parallel type having a full width lane for 350 feet and 400 feet of taper.

Five locations were studied of this type of acceleration lane. At three of the locations the acceleration lane meets the through lane on a tangent, at the fourth location on a right curve, and at the fifth location on a left curve.

Station 0+00 for this type of lane was taken to be at the nose. Beyond this point acceleration lane traffic could merge into the through lane. Each of the locations exhibited certain special characteristics and each will be described separately.

Location A2a: Interstate 65 and State Road 39 Interchange -

Acceleration Lane North Bound

The acceleration lane at this site meets the through lane on a tangent (see Figure 22). The annual average daily traffic on the acceleration lane was 260 vehicles per day and on the through lanes north bound was 4550 vehicles per day.

This interchange is located in a semi-urban area. Most of the traffic using this acceleration lane comes from the surrounding region west of the interchange, and very little traffic from the city of Lebanon. No accidents were reported on this acceleration lane since the facility was opened to traffic in July 1960 until July 1961.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 42 mph (see Figure 23). The difference between the 85th percentile

TYPICAL STANDARD ACCELERATION LANE

TYPE 2

FIGURE 20

FIGURE 21. VIEW OF ACCELERATION LANE—TYPE 2

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-NORTH BOUND
INTERSTATE 65
STATE ROUTE 39 INTERCHANGE

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-NORTH BOUND
INTERSTATE 65
STATE ROUTE 39 INTERCHANGE

speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 19 mph (66-47). This difference is significant and indicates that most of the acceleration lane traffic did not accelerate to about the same speed as through traffic before merging.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was two (2) mph (68-66). This difference is not significant and shows that at this location most of the through traffic drivers did not slow for this interchange.

The acceleration lane traffic merged into the through lane for the entire length of the acceleration lane at low speeds and with no definite pattern. About 90 percent of the acceleration lane vehicles merged into the through lane prior to Station 4+50. This indicates that the majority of drivers merged while on the straight portion of the acceleration lane and not on the tapered portion as this type of design suggests.

Of all vehicles using the acceleration lane, 9.3 percent stopped on the acceleration lane. This is a relatively high percentage and may be due to the fact that the general public using these facilities is not properly informed as to the proper use of acceleration lanes.

These results indicate clearly that this type of acceleration lane design is not being properly used by drivers at this location.

Location A2b: Tri-State and Kennedy Avenue Interchange -

Acceleration Lane East Bound

The acceleration lane here meets with the through lane on a tangent (see Figure 24).

FIGURE 24

The annual average daily traffic on the acceleration lane was 680 vehicles per day and on the through lanes west bound was 17200 vehicles per day. This interchange is located in an urban area and serves mostly traffic from south of the interchange which wishes to travel eastward on the Tri-State Highway. No accidents were reported on this acceleration lane for the years 1959 and 1960.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 47 mph (see Figure 25). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 11 mph (62-51). This difference is significant. The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0) mph (62-62).

At this location the acceleration lane traffic merged into the through lane for the entire length of the acceleration lane at low speeds and with no definite pattern, similarly to that for the previous location discussed. Approximately 90 percent of the vehicles using the acceleration lane merged into the through lane prior to Station 5+00 with the majority of drivers merging while on the straight portion of the acceleration lane.

A relatively high percentage, 16 percent, of the cars using the acceleration lane stopped on the acceleration lane before entering the through lane. This percentage is higher than the previous case (A2a) and may be due to the heavier volume of traffic on the through lane at this location.

These results indicate clearly that this type of acceleration lane design is not being properly used by drivers at this location.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL ACCELERATION LANE - EAST BOUND TRI-STATE HIGHWAY AND KENNEDY AVENUE INTERCHANGE

FIGURE 25

Location A2c: Interstate 74 and Post Road Interchange -

Acceleration Lane East Bound

The acceleration lane at this site meets the through lane on a tangent (see Figure 26).

The annual average daily traffic on the acceleration lane was 1130 vehicles per day and on the through lane east bound was 3030 vehicles per day. This interchange is located in an urban area. Most of the traffic using this acceleration lane is through traffic by-passing the city of Indianapolis via State Road 100 and Post Road and going east bound toward Cincinnati. No accidents were reported on this acceleration lane since the facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 55 mph (see Figure 27). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was six (6) mph (61-55). This difference is significant. The difference between the 85th percentile speed of through traffic within the area of conflict and that beyond the area of conflict was two (2) mph (63-61). The difference is not significant.

Approximately 90 percent of the vehicles using the acceleration lane merged into the through lane prior to Station 3+85. Thus the majority of drivers merged while still on the straight portion of the acceleration lane, with about half of them, 49.1 percent, merging between Station 1+00 and 2+00. Most drivers did not use this acceleration lane properly as they merged at the same speed as traffic was travelling at Station 0+00. Of all vehicles using the acceleration lane, 4.4 percent stopped on the acceleration lane.

FIGURE 26

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

FIGURE 27

These results indicate clearly that this type of acceleration lane design is not being properly used by many of the drivers at this location.

By comparing these results with those of the previous two locations, A2a and A2b, it is evident that although the three locations have the same type of acceleration lane design operating under similar geometric conditions, i.e. tangent, the results are not similar. This also indicates that other factors such as type of driver and traffic volume may have a significant bearing upon the results.

Location A2d: Interstate 65 and State Road 60 Interchange -

Acceleration Lane South Bound

At this site the acceleration lane meets the through lane on a slight right horizontal curve (see Figure 28).

The annual average daily traffic on the acceleration lane was 880 vehicles per day and on the through lane south bound was 4530 vehicles per day. This interchange is located in a rural area. Most of the traffic using this acceleration lane is local traffic from city of Salem and the area west of the interchange and is travelling to Jeffersonville to the south. No accidents were reported on this acceleration lane since the facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed of acceleration lane traffic at Station 0+00 was 42 mph (see Figure 29). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 14 mph (64-50). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict

FIGURE 28

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-SOUTH BOUND
INTERSTATE 65 AND S.R. 60 INTERCHANGE

FIGURE 29

was six (6) mph (64-58). This difference is also significant and indicates that at this location some of the through traffic drivers were travelling faster at the interchange site than at a point one (1) mile past the interchange location.

The acceleration lane traffic merged into the through lane for the entire length of the acceleration lane and with no definite pattern and at speeds much lower than that of the through lane traffic. About 90 percent of the acceleration lane vehicles merged into the through lane prior to Station 6+00, which lies on the taper portion of the acceleration lane. At this location the majority of drivers merged while on the straight portion of the acceleration lane, but a higher percentage of drivers merged from the tapered portion and utilized more length of the acceleration lane than drivers did at the previous locations studied. This may be due to the effect of the right curve in encouraging drivers to follow the curve on the acceleration lane.

Of all the vehicles using the acceleration lane, 14.3 percent stopped on the lane. This is a relatively high percentage.

These results indicate clearly that for this geometric condition and type of design of the acceleration lane, the drivers were not properly using the acceleration lane at this location.

Location A2e: Interstate 65 and State Road 39 Interchange -

Acceleration Lane South Bound

The acceleration lane at this location meets the through lane on a slight left horizontal curve (see Figure 22).

The annual average daily traffic on the acceleration lane was 1380 vehicles per day and on the through lanes south bound was 4170 vehicles

per day. This interchange is located in a semi-urban area. Most of the traffic using this acceleration lane is local traffic from the city of Lebanon travelling south to Indianapolis. No accidents were reported on this acceleration lane since the facility was opened to traffic in July 1960 until July 1961.

The 85th percentile speed of the acceleration lane traffic at Station 0+00 was 44 mph (see Figure 30). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 20 mph (66-46). This difference is significant.

The difference between the 85th percentile speed of through traffic within the area of conflict and that beyond the area of conflict was one (1) mph (67-66). This difference is not significant. Approximately 90 percent of the vehicles using this acceleration lane merged into the through lane prior to Station 4+15. Thus the majority of drivers merged while still on the straight portion of the acceleration lane. More than half, 55.6 percent, of the acceleration lane traffic merged between Stations 0+00 and 1+00 at an 85th percentile speed of 44 mph. This indicates that more than half of the acceleration lane traffic merged into the through lane as soon as possible after they passed the nose and as a result at too low a speed. One of the causes of this result is most probably the effect the left curve has on drivers. The remainder of acceleration lane traffic merged all along the remaining length of the acceleration lane with no definite pattern and at speeds much lower than that of the through lane traffic.

A relatively high percentage - 10.7 percent - of the cars using the lane stopped on this acceleration lane before entering the through lane.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-SOUTH BOUND
INTERSTATE 65
STATE ROUTE 39 INTERCHANGE

FIGURE 30

These results indicate clearly that for the conditions and the type of design of the acceleration lane, drivers were not properly using this acceleration lane.

Acceleration Lanes, Type 3

The third type of acceleration lane studied is illustrated in Figure 31 and a photograph of a typical highway with such a lane is shown in Figure 32. The acceleration lane is of the parallel type having a full width lane of 250 feet plus 250 feet of taper.

Two locations of this type of acceleration lane were studied. At the first location the acceleration lane meets the through lane on a tangent and at the second on a left curve. No suitable location could be found where the acceleration lane met the through lane on a right curve.

Station 0+00 was taken for this type of design to be at the nose. Beyond this point the acceleration lane traffic could merge into the through lane. Each of the two locations studied exhibited certain special characteristics and each will be discussed separately.

Location A3a: Interstate 65 and State Road 56 Interchange -

Acceleration Lane North Bound

The acceleration lane at this site meets the through lane on a tangent (see Figure 33). The annual average daily traffic on the acceleration lane was 670 vehicles per day and on the through lanes north bound was 2800 vehicles per day.

This interchange is located in a semi-urban area. Most of the traffic using this acceleration lane is local traffic from the city of Scottsburg and the area in the vicinity of the interchange and is bound north

TYPICAL STANDARD
ACCELERATION LANE

TYPE 3

FIGURE 31

FIGURE 32. VIEW OF ACCELERATION LANE—TYPE 3

FIGURE 33

to Seymour. No accidents were reported on this acceleration lane since the facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed at Station 0+00 was 51 mph (see Figure 34). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was seven (7) mph. (61-54). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was four (4) mph (65-61). This difference is also significant and shows that at this location, some of the through traffic drivers slowed at the interchange.

The acceleration lane traffic merged into the through lane for the entire length of the acceleration lane, with the highest percentage, 40.7 percent, merging between Stations 1+00 and 2+00 at an 85th percentile speed of 52 mph.

Ninety (90) percent of the vehicles using this acceleration lane merged into the through lane prior to Station 3+75. Thus a majority of drivers at this location merged while on the straight portion of the acceleration lane.

A relatively high percentage, 14.3 percent, of the vehicles using the lane stopped on the acceleration lane before entering the through lane. These results indicate that this type of acceleration lane design is not being properly used by drivers at this location.

Location A3b: Interstate 65 and State Road 334 Interchange -

Acceleration Lane North Bound

The acceleration lane here meets the through lane on a slight left

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-NORTH BOUND
INTERSTATE 65 AND S.R. 56 INTERCHANGE

FIGURE 34

horizontal curve (see Figure 35). The annual average daily traffic on the acceleration lane was 1450 vehicles per day and on the through lanes north bound was 2650 vehicles per day. This interchange is located in a rural area. Most of the traffic using the acceleration lane is through traffic which by-passes the city of Indianapolis via route State Road 100 and is north bound toward Chicago. No accidents were reported on this acceleration lane since the facility was opened to traffic in October 1960 until 1961.

The 85th percentile speed at Station 0+00 was 50 mph (see Figure 36). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 11 mph (64-53). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was one (1) mph (64-63). This difference is not significant.

Ninety (90) percent of the vehicles using the acceleration lane merged into the through lane prior to Station 3+65. Thus the majority of drivers merged while on the straight portion of the acceleration lane. The majority, 63 percent, of acceleration lane traffic merged between Stations 1+00 and 2+00 at an 85th percentile speed of 53 mph. This indicates that more than half of the acceleration lane traffic merged into the through lane as soon as possible after they passed the nose and at too low a speed. This is a higher percentage than the previous case (A3a) and is most probably due to the effect that the left curve has on drivers. The rest of the acceleration lane traffic merged all along the remaining

FIGURE 35

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE - NORTH BOUND
INTERSTATE 65 AND S.R. 334 INTERCHANGE

FIGURE 36

length of the acceleration lane. A very small percentage, 0.9 percent, of acceleration lane traffic merged between Stations 5+00 and 6+00 at an 85th percentile speed of 62 mph. This small percentage of vehicles thus used the acceleration lane correctly by making use of a longer distance of the lane to accelerate to about the same speed as through lane traffic before merging.

Of all the vehicles using the lane, 3.6 percent stopped on it. These results indicate that for the condition and type of design of acceleration lane at this location, many of the drivers did not properly use it.

Acceleration Lanes, Type 4

The fourth type of acceleration lane studied is shown in Figure 37 and such a lane is shown in the background of Figure 38. This acceleration lane is of the taper design, but has only 300 feet of taper.

Two locations were studied of this type of acceleration lane and both locations were at the Tri-State and Calumet Avenue interchange. At the first location the acceleration lane meets the through lane on a tangent and at the second on a right curve. No suitable location could be found where the acceleration lane meets the through lane on a left curve.

Station 0+00 for this type of acceleration lane was taken to be at the nose. Beyond this point the acceleration lane traffic could merge into the through lane.

Location A4a: Tri-State and Calumet Avenue Interchange -

Acceleration Lane East Bound

At this site the acceleration lane meets the through lane on a tangent (see Figure 39). The annual average daily traffic on the acceleration

TYPICAL STANDARD ACCELERATION LANE

TYPE 4

FIGURE 37

FIGURE 38. VIEW OF ACCELERATION LANE-TYPE 4

FIGURE 39

lane was 1960 vehicles per day and on the through lanes east bound was 23,730 vehicles per day. This interchange is located in an urban area. Most of the traffic using this acceleration lane is through traffic traveling east bound. One accident on this acceleration lane was reported in the year 1959 and was caused by a faulty merging maneuver. No accidents were reported on this acceleration lane for 1960.

The 85th percentile speed at Station 0+00 of this site was 44 mph (see Figure 40). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 12 mph (60-48). This difference is significant.

The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict was six (6) mph (66-60). This difference is also significant and indicates that many of the through traffic drivers slowed at the interchange.

Ninety (90) percent of the vehicles using this acceleration lane merged into the through lane prior to Station 1+35. This shows that the majority of drivers merged into the through lane as soon as possible after they passed the nose and at too low a speed. More than a third, 34.6 percent, of cars stopped on the acceleration lane. This is a very high percentage and may be due to the fact that the length of taper is too short, together with the heavy traffic volume on the through lanes at this location. Under these conditions, drivers are not able to accelerate adequately on the acceleration lane before they must merge.

These results indicate clearly that this type of design is very inadequate and hazardous for the type and volume of traffic using this acceleration lane at this location.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL ACCELERATION LANE - EAST BOUND TRI-STATE HIGHWAY AND CALUMET AVENUE INTERCHANGE

FIGURE 40

Location A4b: Tri-State and Calumet Avenue Interchange -

Acceleration Lane West Bound

The acceleration lane studied here meets the through lane on a slight right horizontal curve (see Figure 39). The annual average daily traffic on the acceleration lane was 3880 vehicles per day and on the through lanes west bound was 21,620 vehicles per day. This interchange is located in an urban area. Most of the traffic using this acceleration lane is through traffic west bound to the Illinois Toll Road.

Two accidents were reported on this acceleration lane in 1959. The first was caused by drivers stopping on the acceleration lane and the second by loss of control of a vehicle while merging. No accidents were reported on the lane in 1960.

The 85th percentile speed at Station 0+00 was 41 mph (see Figure 41). The difference between the 85th percentile speed of through traffic within the area of conflict and the average 85th percentile speed of the acceleration lane traffic as it merged into the through lane was 15 mph (60-45). This difference is significant and indicates that most of the acceleration lane traffic did not accelerate to about the same speed as through traffic before merging.

The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict was zero (0) mph (60-60).

About 90 percent of the vehicles using the acceleration lane merged into the through lane prior to Station 1+30. This indicates that here also the majority of drivers merged into the through lane as soon as possible after they passed the nose and at too low a speed.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT REAR WHEEL

ACCELERATION LANE-WEST BOUND
TRI-STATE HIGHWAY AND CALUMET AVENUE
INTERCHANGE

FIGURE 41

A very high percentage, 28 percent of vehicles stopped on the acceleration lane before entering the through lane. The reasons are the same as those indicated in the previous case (A4a). These results show clearly that here also this type of design is very inadequate and hazardous for the type and volume of traffic using this acceleration lane.

Deceleration Lanes

The locations of the deceleration lanes studied are shown in Figure 5 on a map of the State of Indiana and pertinent data for each location is given in Table 6. These locations are referenced as follows: D1a, D2b, etc. where the "D" stands for deceleration lane; the 1, 2, etc for the type of deceleration lane design; and the a, b, etc. for the location.

Deceleration Lanes, Type 1

The first type of deceleration lane studied was on the Indiana Toll Road and is as shown in Figure 42. A photograph of a highway with such a lane is shown in Figure 43. The deceleration lane is 1200 feet long from the right edge of the through lane to the beginning of the ramp curve. It consists of 845.34 ft. of direct taper, having an angle of divergence of one (1) degree and thirty (30) minutes with the through lanes. Along this distance the deceleration lane is not separated from the through lane. It is then connected to a 355.82 ft. direct taper, having an angle of divergence of four (4) degrees with the through lane. For this 355.82 feet the deceleration lane is separated from the through lanes by a shoulder which is paved but of a different color than the travelled area. The exit nose is offset six (6) feet from the edge of the through lanes and there are 173.13 feet of recovery.

TABLE 6

PERTINENT DATA FOR STUDY LOCATIONS - DECELERATION LANES

Reference	Location	Direction of Deceleration Lane Traffic	Geometric Condition	Type of Decel. Lane
D1a	Indiana Toll Road - Gary West	East Bound	Tangent	Direct Taper 1200' - 1
D1b	Michigan City	West Bound	Tangent	Direct Taper 1200' - 1
D1c	Chesterton-Valparaiso	East Bound	Left Curve	Direct Taper 1200' - 1
D2a	Interstate 65 and State Road 39	South Bound	Tangent	250 ft Taper & 50 ft Straight + curve - 2
D2b	Tri-State and Kennedy Avenue	West Bound	Tangent	250 ft Taper & 50 ft Straight + curve - 2
D2c	Interstate 65 and State Road 39	North Bound	Right Curve	250 ft Taper & 50 ft Straight + curve - 2
D3a	Interstate 74 and State Road 9	East Bound	Tangent	Curve - 3
D3b	Interstate 65 and State Road 334	South Bound	Right Curve	Curve - 3

x Numbers in parenthesis (1) identify the geometric conditions used in this report.
 + Numbers 1, 2, etc. refer to the type of deceleration lane used in this report.

TABLE 6 (continued)

Reference	Location	Direction of Deceleration Lane Traffic	Geometric Condition	Type of Decel. Lane
D3c	Interstate 65 and State Road 60	North Bound	Left Curve - (3)	Curve - 3
D4a	Interstate 74 and Pleasant View	East Bound	Tangent - (1)	Direct Taper - 400 ft - 4
D5a	Tri-State and Calumet Avenue	West Bound	Tangent - (1)	Taper - 200 ft + curve- 5
D5b	Interstate 65 and State Road 56	North Bound	Tangent - (1)	Taper - 250 ft + curve- 5
D5c	Tri-State and Calumet Avenue	East Bound	Left Curve - (3)	Taper - 200 ft + curve- 5

FIGURE 43. VIEW OF DECELERATION LANE-TYPE 1

Three locations were studied of this type of deceleration lane. At two of the locations the deceleration lane leaves the through lane on a tangent and at the third on a left curve. No suitable location could be found where the deceleration lane leaves the through lane on a right curve.

Station 0+00 was taken at the nose which is the point where the paved shoulder which separates the deceleration lane and the through lane begins. At the end of the deceleration lane and the beginning of the exit ramp there is an advisory speed sign "Ramp Speed 25".

Each of the locations studied exhibited certain special characteristics and each will be discussed separately.

Location D1a: Indiana Toll Road - Gary West Interchange -

Deceleration Lane East Bound

The deceleration lane at this site leaves the through lane on a tangent (see Figure 40). At this location the median is 20 feet wide with a raised median barrier instead of the standard 50 foot wide median.

The annual average daily traffic on the deceleration lane was 1460 vehicles per day and on the through lanes west bound was 7680 vehicles per day. This interchange is located in an urban area and serves mostly local traffic between the city of Chicago and the industrial area in the city of Gary.

One accident on the deceleration lane was reported in 1959 and was caused by bad weather conditions. Two accidents were reported in 1960 and both were reportedly caused by the drivers travelling at too high a speed on the exit ramp curves.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed

of deceleration lane traffic as it diverged into the deceleration lane was minus seven (7) mph (63-70)(see Figure 44). In other words, those diverging were travelling faster, on the average, when they entered the deceleration lane than those vehicles which remained in the through lanes. This indicates that many of the vehicles using the deceleration lane did not start to decelerate until after they diverged into the deceleration lane.

The data given on Figure 44, as well as that on similar figures for other deceleration lanes, are similar to that given for acceleration lanes and explained in an earlier section of this report.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was six (6) mph (69-63). This difference is significant and indicates that at this location many of the through traffic drivers slowed at the interchange. Approximately 90 percent of the vehicles using the deceleration lane diverged within a distance of 300 feet.

The natural straight path of exit of the left wheels of the vehicles, which was taken as a line parallel to but offset by a distance of three (3) feet from that path joining the point of beginning of the deceleration lane with the midpoint of the deceleration lane at the nose (Station 0+00), intersects the through lane between Stations 5+00 and 6+00. In this area the largest percentage, 43.5 percent, of deceleration lane traffic diverged at an 85th percentile speed of 69 mph.

A very small percentage, 0.9 percent, of deceleration lane traffic diverged at an 85th percentile speed of 55 mph between Stations 6+00 and 7+00. This speed is slower than that of other deceleration lane traffic and could be because the drivers involved started to decelerate on the through lane before diverging into the deceleration lane.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE - EAST BOUND
INDIANA TOLL ROAD
GARY - WEST INTERCHANGE

FIGURE 44

These results approach the optimum condition of operation of deceleration lanes as the deceleration lane traffic diverged at about the same speed and direction of travel as the through lane traffic.

Location D1b: Indiana Toll Road - Michigan City Interchange -
Deceleration Lane West Bound

The deceleration lane leaves the through lane at this location on a tangent (see Figure 12). The annual average daily traffic on the deceleration lane was 310 vehicles per day and on the through lanes west bound was 5910 vehicles per day. This interchange is located in a rural area and intersects U. S. 421 which runs north to Michigan City and south to Indianapolis.

One accident was reported on this deceleration lane in 1959 and was caused by the driver reportedly travelling too fast on the exit ramp curve. Two accidents were reported in 1960 and both were caused by drivers travelling too fast on the exit ramp curve.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of deceleration lane traffic as it diverged into the deceleration lane was four (4) mph (64-60)(see Figure 45). This difference is significant and indicates that some of the deceleration lane traffic started to decelerate on the through lane before diverging into the deceleration lane.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was also four (4) mph (68-64). This difference is significant and indicates that, at this location, some of the through traffic drivers slowed at the interchange.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE - WEST BOUND
INDIANA TOLL ROAD
MICHIGAN CITY INTERCHANGE

FIGURE 45

Ninety (90) percent of the drivers using this deceleration lane diverged within a distance of approximately 300 feet. The natural straight path of exit of the left wheels of the exiting vehicles intersects the through lane between Stations 5+00 and 6+00. In this area the majority of drivers, 56.5 percent, diverged at an 85th percentile speed of 60 mph.

The results at this location indicate that some of the drivers are slowing slightly before entering the deceleration lane.

By comparing these results with those of the previous case, D1a, it is evident that although both locations have the same type of design of deceleration lane and similar geometric conditions, i.e. tangent, the results are not similar. This indicates that other factors, such as type of drivers using the deceleration lane and traffic volume, may have a significant bearing upon the results.

Location D1c: Indiana Toll Road - Chesterton-Valparaiso Interchange -
Deceleration Lane East Bound

The deceleration lane leaves the through lane at this location on a left curve (see Figure 14). The annual average daily traffic on the deceleration lane was 730 vehicles per day and on the through lanes east bound was 6630 vehicles per day. This interchange is located in a rural area and intersects State Road 39 which serves Chesterton to the north and Valparaiso to the south.

Two accidents on this deceleration lane were reported in 1960. The first was caused by a driver becoming confused and turning his vehicle off the road at a point past the deceleration lane, and the second by a driver travelling too fast on the exit ramp curve. No accidents were reported in 1959.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of deceleration lane traffic as it diverged into the deceleration lane was 14 mph (69-55)(see Figure 46). This difference is significant and indicates that most of this deceleration lane traffic started to decelerate on the through lane before diverging into the deceleration lane.

Because of the significant deceleration on the through lanes at this location, a study was made as to where it occurred with respect to the beginning of the deceleration lane. Figure 47 shows for 200 foot intervals prior to the beginning of the deceleration lane the averages and 85th percentile speeds for the traffic which later entered the deceleration lane. Through traffic in this area was travelling at 69 mph. These data are also plotted on Figure 48. There is a clear indication that some of the traffic planning to use the deceleration lane at this location begins to decelerate well in advance (over 1000 feet) of the deceleration lane.

Approximately ninety percent of the drivers using the deceleration lane diverged within a distance of approximately 400 feet.

The natural straight path of exit of the left wheels of exiting vehicles intersects the through lane between Stations 4+00 and 5+00, where only a small percentage, 8.3 percent, of deceleration lane traffic diverged at an 85th percentile speed of 68 mph. Most of the remaining drivers diverged later and at lower speeds thus indicating deceleration on the through lane instead of on the deceleration lane. This could have been aggravated by the effect of the left curve on drivers.

A small percentage, 3.7 percent, of deceleration lane traffic crossed the paved shoulders and diverged between Stations 0+00 and 1+00 at an

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE - EAST BOUND
INDIANA TOLL ROAD
CHESTERTON-VALPARAISO INTERCHANGE

FIGURE 46

INDIANA TOLL ROAD AND CHESTERTON-VALPARAISO INTERCHANGE

DETERMINATION OF POINT WHERE DECELERATION LANE TRAFFIC
BEGINS TO DECELERATE ON THROUGH LANE

FIGURE 47

FIGURE 48. DETERMINATION OF POINT WHERE DECELERATION LANE TRAFFIC BEGINS TO DECELERATE ON THROUGH LANE-LOCATION DIS

85th percentile speed of 46 mph. This speed is lower than that of other observed deceleration lane traffic, and this might have been caused by these drivers hesitating on the through lane and making the decision at the last minute to leave at this interchange.

These results indicate for this geometric condition and this type of deceleration lane design, that drivers are not properly using the deceleration lane at this location.

Deceleration Lanes, Type 2

The second type of deceleration lane studied is shown in Figure 49. Figure 50 is a photograph of a highway with such a lane. The deceleration lane has a taper from zero (0) feet to 12 feet in a distance of 250 feet, followed by 50 feet of tangent and 195 feet of curve. The exit nose is offset 12 feet and there are 360 feet of recovery. Near the exit nose there is a regulatory speed sign "Exit Speed 40".

Three locations of this type of deceleration lane were studied. At two of the locations the deceleration lane leaves the through lane on a tangent and at the third on a right horizontal curve. No suitable location could be found where the deceleration lane leaves the through lane on a left curve. Station 0+00 was taken at the nose of the deceleration lane. Each of the locations exhibited certain special characteristics and each are discussed separately.

Location D2a: Interstate 65 and State Road 39 Interchange -

Deceleration Lane South Bound

The deceleration lane at this site leaves the through lane on a tangent (see Figure 22). The annual average daily traffic on the deceleration

TYPICAL STANDARD DECELERATION LANE

TYPE 2

FIGURE 49

FIGURE 50 VIEW OF DECELERATION LANE-TYPE 2

lane was 240 vehicles per day and on the through lanes south bound was 4170 vehicles per day. This location is located in a semi-urban area and most of the traffic using this deceleration lane travels west from the interchange with very little traffic entering the city of Lebanon. No accidents were reported on the deceleration lane since this facility was opened to traffic in July 1960 until July 1961.

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 49 mph (see Figure 51). This shows that many of the drivers did not obey the signed speed of 40 mph. The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of deceleration lane traffic as it diverged into the deceleration lane was 18 mph (67-49). This difference is significant and indicates clearly that most of the drivers started to decelerate on the main facility before they diverged into the deceleration lane.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was one (1) mph (68-67). This difference is not significant.

Ninety percent of deceleration lane traffic diverged within a distance of 200 feet, with most of it not using any portion of the taper. The largest percentage, 76.9 percent, of the deceleration lane traffic diverged between Stations 1+00 and 2+00 at an 85th percentile speed of 50 mph.

These results indicate clearly that this type of deceleration lane design is not being properly used by many of the drivers at this location.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE-SOUTH BOUND
INTERSTATE 65
STATE ROUTE 39 INTERCHANGE

FIGURE 51

Location D2b: Tri-State and Kennedy Avenue Interchange -

Deceleration Lane West Bound

The deceleration lane leaves the through lane at this location on a tangent (see Figure 24). The annual average daily traffic on the deceleration lane was 1430 vehicles per day and on the through lanes west bound was 16,790 vehicles per day. This interchange is located in an urban area and serves traffic from the Tri-State going north and using Kennedy Avenue.

One accident was reported on this deceleration lane in 1959 and was caused by drivers failing to stop for the stop sign at the end of the exit ramp. No accidents were reported in 1960.

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 41 mph (see Figure 52). Most drivers, therefore, did obey the signed speed of 40 mph. The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 14 mph (60-46). This difference is significant.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was three (3) mph (63-60). This difference is also significant and indicates that, at this location, some through traffic drivers slowed at the interchange. Ninety percent of deceleration lane traffic diverged within a distance of slightly less than 200 feet, with almost none of them using the tapered portion of the lane.

These results clearly indicate that this type of deceleration lane design is not being properly used by many of the drivers at this location.

By comparing these results with those of the previous case, D2a, it is evident although both locations have the same type of design of deceleration lane and the same geometric condition, i.e. tangent, that the results

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

FIGURE 52

are not similar. This indicates again that other factors such as type of drivers using the deceleration lane and traffic volume may have a significant bearing upon the results.

Location D2c: Interstate 65 and State Road 39 Interchange -

Deceleration Lane North Bound

The deceleration lane here leaves the through lane on a slight right horizontal curve (see Figure 22).

The annual average daily traffic on the acceleration lane was 1060 vehicles per day and on the through lanes north bound was 4550 vehicles per day. This interchange is located in a semi-urban area. Most of the traffic using the deceleration lane is local traffic from the city of Lebanon returning from Indianapolis. No accidents were reported on the deceleration lane since this facility was opened to traffic in July 1960 until July 1961.

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 46 mph (see Figure 53). Thus many drivers obviously did not obey the signed speed of 40 mph.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 18 mph (68-50). This difference is significant. The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was two (2) mph (70-68). This difference is not significant.

Ninety percent of the vehicles using this deceleration lane diverged within slightly less than 200 feet with very few of them using any part of the taper.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE-NORTH BOUND
INTERSTATE 65
STATE ROUTE 39 INTERCHANGE

FIGURE 53

These results indicate, as for previous lanes, that this type of deceleration lane design is not being properly used by the majority of drivers at this location.

Deceleration Lanes, Type 3

The third type of deceleration lane studied is shown in Figure 54, while a photograph of a highway with such a lane is Figure 55. The deceleration lane in this design is a curve of varying degrees of curvature. The exit nose is offset six (6) feet and there are 180 feet of recovery. Near the nose there is a regulatory speed sign "Exit Speed 40".

Three locations were studied of this type of deceleration lane. At the first location, the deceleration lane leaves the through lane on a tangent, at the second on a right curve and at the third on a left curve. Station 0+00 was taken at the nose of the deceleration lane. Each of the locations exhibited certain special characteristics and each are discussed separately.

Location D3a: Interstate 74 and State Road 9 Interchange -

Deceleration Lane East Bound

The deceleration lane meets with the through lane at this site on a tangent (see Figure 56). The deceleration lane has a four (4) degree curve and is 260 feet long.

The annual average daily traffic on the deceleration lane and on the through lanes east bound was not determined at this location as this was the last completed interchange on Interstate 74 which was then open to traffic. Interstate 74 was open for only a few miles beyond this interchange and then connected with U. S. 421. It was felt that this condition

TYPICAL STANDARD DECELERATION LANE

TYPE 3

FIGURE 54

FIGURE 55. VIEW OF DECELERATION LANE-TYPE 3

INTERSTATE 74 AND
STATE ROAD 9 INTERCHANGE

FIGURE 56

caused more traffic to use the deceleration lane at the time of the study than that for which it was designed. This condition will be alleviated when additional mileage of Interstate 74 east of this interchange is opened to traffic.

This interchange is located in a semi-urban area and most of the traffic using the deceleration lane was local traffic between the city of Shelbyville and Indianapolis. No accidents were reported on this deceleration lane since this facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 46 mph (see Figure 57). This shows that many drivers did not obey the signed speed of 40 mph. The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 11 mph (62-51). This difference is significant and indicates that many of the drivers started to decelerate on the main facility before they diverged into the deceleration lane.

This location was also studied to determine the distance prior to the beginning of the deceleration lane in which the deceleration occurred. Figures 58 and 59 show the results of this study. Deceleration lane traffic began to decelerate noticeably on the through lane well in advance, over 1000 feet, of the beginning of the deceleration lane. The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was three (3) mph (65-62). This difference is significant and indicates that, at this location, some through traffic drivers slowed at the interchange.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE - EAST BOUND
INTERSTATE 74 AND STATE ROUTE 9
INTERCHANGE

FIGURE 57

INTERSTATE 74 AND STATE ROAD 9 INTERCHANGE

DECELERATION LANE EASTBOUND

DETERMINATION OF POINT WHERE DECELERATION LANE

TRAFFIC BEGINS TO DECELERATE ON THROUGH LANE

FIGURE 58

FIGURE 59. DETERMINATION OF POINT WHERE DECELERATION LANE TRAFFIC BEGINS TO DECELERATE ON THE THROUGH LANE - LOCATION D3a

Almost all, 95.4 percent, of drivers diverged as soon as possible after the beginning of the deceleration lane and within the first 100 feet at an 85th percentile speed of 51 mph.

These results indicate that many of the drivers at this location are not using properly, with reference to speed, this type of deceleration lane. This may be due to the very short distance over which they can decelerate on this type of design.

Location D3b: Interstate 65 and State Road 334 Interchange -

Deceleration Lane South Bound

The deceleration lane leaves the through lane at this location on a very slight right curve. The deceleration lane has a 14 degree curve and is 284 feet long (see Figure 35).

The annual average daily traffic on this deceleration lane was 1010 vehicles per day and on the through lanes south bound was 3230 vehicles per day. This interchange is located in a rural area. Most of the traffic using this deceleration lane was through traffic using State Road 100 to by-pass the city of Indianapolis.

Three accidents were reported on this deceleration lane from October 1960 to July 1961. The first was caused by a driver failing to stop for the stop sign at the end of the exit ramp, the second by a driver traveling the wrong way on this ramp and the third by a driver entering the deceleration lane at too high a speed.

The 85th percentile speed of the deceleration lane traffic at the nose, Station 0+00, was 50 mph (see Figure 60). This shows that many drivers did not obey the signed speed of 40 mph. The difference between the 85th percentile speed of the through lane traffic and the average 85th

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE-SOUTH BOUND
INTERSTATE 65 AND S.R. 334 INTERCHANGE

FIGURE 60

percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 11 mph (65-54). This difference is significant and shows that many drivers started to decelerate on the main facility before they diverged into the deceleration lane.

A study of the traffic using the deceleration lane relative to their deceleration prior to the beginning of the lane was also made at this site. Figures 61 and 62 show the results at this location. Deceleration lane traffic started to decelerate on the through lane about 1500 feet before the beginning of the deceleration lane. The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict was two (2) mph (67-65). This difference is not significant.

Almost all, 97.2 percent, of the drivers using this lane diverged as soon as possible after the beginning of the deceleration lane and within the first 100 feet of the lane at an 85th percentile speed of 54 mph.

These results indicate that here also many drivers are not using properly, with reference to speed, this type of deceleration lane.

Location D3c: Interstate 65 and State Road 60 Interchange -

Deceleration Lane North Bound

The deceleration lane at this location leaves the through lane on a slight left curve (see Figure 28). The deceleration lane has a one (1) degree curve and is 535 feet long. The annual average daily traffic on this deceleration lane was 930 vehicles per day and on the through lanes north bound was 4740 vehicles per day.

This interchange is located in a rural area. Most of the traffic using this deceleration lane is local traffic from Jeffersonville travelling

INTERSTATE 65 AND S.R. 334 INTERCHANGE DECELERATION LANE SOUTHBOUND

DETERMINATION OF POSITION WHERE DECELERATION
LANE TRAFFIC BEGINS TO DECELERATE ON THROUGH LANE

0+00 DECELERATION LANE
BEGINS

STATION

2+00

4+00

6+00

8+00

10+00

12+00

14+00

16+00

18+00

20+00

AVERAGE SPEED OF
DECELERATION LANE TRAFFIC

49

85th % SPEED OF
DECELERATION LANE TRAFFIC

55

85th % SPEED OF
THROUGH LANE TRAFFIC

69

60

64

58

66

59

65

59

65

59

64

56

62

54

61

55

60

51

57

69

1 MILE

FIGURE 61

FIGURE 62. DETERMINATION OF POINT WHERE DECELERATION LANE TRAFFIC BEGINS TO DECELERATE ON THE THROUGH LANE - LOCATION D3b

to Salem and the region west of this interchange. No accidents were reported on this deceleration lane since this facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed of the deceleration lane traffic at the nose, Station 0+00, was 54 mph (see Figure 63). Many drivers at this site obviously did not obey the signed speed of 40 mph. The difference between the 85th percentile speed of the through lane traffic and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was five (5) mph (60-55). This difference is significant but it also is less than at the other two locations where this deceleration lane design was studied.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0) mph (60-60).

Slightly over forty percent (41.7%) of the drivers diverged as soon as possible after the beginning of the deceleration lane and within the first 100 feet of useable lane and at an 85th percentile speed of 59 mph. These drivers approached the optimum condition of operation for deceleration lanes as they diverged in approximately the same direction of travel and at the same speed as through lane traffic.

The remaining drivers, 59.3 percent, diverged within the second 100 feet and at lower speeds, thus decelerating on the through lane instead of on the deceleration lane. Some of this number might have been affected by the left curve at this site.

These results indicate that about over half of the drivers at this location are using properly this type of deceleration lane. By comparing

SPEEDS AND
LATERAL PLACEMENT OF CARS
PATH OF LEFT FRONT WHEEL
DECELERATION LANE-NORTH BOUND
INTERSTATE 65 AND S.R. 60 INTERCHANGE

FIGURE 63

these results with the previous two cases, D3a and D3b, it is indicated that for this type of deceleration lane design, the smaller the degree of curve used, which results in this type of design approaching the straight taper type of design, the closer the results approach the optimum conditions of operation for deceleration lanes.

Deceleration Lanes, Type 4

The fourth type of deceleration lane studied is shown in Figure 64 and a highway using this type of lane is shown in Figure 64A. The deceleration lane in this design is a direct taper 400 feet long. The exit nose is offset six (6) feet and there are 180 feet of recovery. Near the exit nose there is a regulatory speed sign, "Exit Speed 40".

Only one location was studied of this type of deceleration lane as it was the only one completed as of the date of this study. Station 0+00 was taken to be at the nose of the deceleration lane.

Location D4a: Interstate 74 and Pleasant View Interchange -

Deceleration Lane East Bound

The deceleration lane leaves the through lane at this location on a tangent (see Figure 65). The annual average daily traffic on the deceleration lane was 250 vehicles per day and on the through east bound lanes was 3780 vehicles per day.

This interchange is located in a rural area and almost all of the traffic using this deceleration lane is local traffic travelling between Pleasant View, a local community, and Indianapolis. No accidents were reported on this deceleration lane since this facility was opened to traffic in October 1960 until July 1961.

FIGURE 64a. VIEW OF DECELERATION LANE-TYPE 4

FIGURE 65

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 50 mph (see Figure 66). This shows that many drivers did not obey the signed speed of 40 mph (see Figure 66).

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of deceleration lane traffic as it diverged into the deceleration lane was six (6) mph (63-57). This difference is significant. The difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was zero (0) mph (63-63).

The natural straight path of exit of the left wheels of exiting vehicles intersects the through lane between Stations 2+00 and 3+00 where the majority, 81.5 percent, of drivers diverged at an 85th percentile speed of 58 mph. These results indicate although most drivers use the full length of the deceleration lane that some of these drivers decelerate prior to diverging. This may be due to the deceleration lane being too short.

Deceleration Lanes, Type 5

The fifth type of deceleration lane studied is shown in Figure 67 and a photograph of a highway with such a lane is Figure 68. The deceleration lane in this design is a variable distance direct taper followed by a curve. The nose is offset 12 feet and there are 150 feet of recovery. Near the exit nose there is a regulatory speed sign "Exit Speed 40".

Three locations were studied of this type of deceleration lane. At the first two locations the deceleration lane leaves the through lane on a tangent and at the third on a left curve. Station 0+00 was taken to be at the nose of the deceleration lane.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE - EAST BOUND
PLEASANT VIEW AND INTERSTATE 74 INTERCHANGE

FIGURE 66

TYPICAL STANDARD DECELERATION LANE

TYPE 5

FIGURE 67

FIGURE 68. VIEW OF DECELERATION LANE—TYPE 5

Location D5a: Tri-State and Calumet Avenue Interchange -

Deceleration Lane West Bound

The deceleration lane at this location leaves the through lane on a tangent (see Figure 39). In this case the length of the tangent section is 200 feet and the length of the curve portion to the nose is 139 feet.

The annual average daily traffic on the deceleration lane was 4100 vehicles per day and on the through lanes west bound was 21,820 vehicles per day. This interchange is located in an urban area. Most of the traffic using this deceleration lane is through traffic using U. S. 41 north to Chicago.

Three accidents were reported on this deceleration lane in 1959. The first was caused by bad weather conditions, the second by drivers traveling too fast on the exit ramp curve and the third by a driver missing the deceleration lane and then backing on the through lane. This last accident resulted in one person being killed. No accidents were reported in 1960.

The 85th percentile speed of the deceleration lane traffic at the nose, Station 0+00, was 32 mph (see Figure 69). Most drivers at this location obeyed the signed speed of 40 mph. The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 17 mph (63-46). This difference is significant and indicates clearly that many of the drivers started to decelerate on the main facility before they diverged into the deceleration lane.

The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

FIGURE 69

was one (1) mph (63-62). This difference is not significant. Nearly all drivers, 94.4 percent, diverged between Stations 1+00 and 2+00 at an 85th percentile speed of 48 mph. This was about as quickly as the design permitted.

These results indicate that this type of design is very inadequate, with reference to speed, and probably very hazardous for the volume of traffic using this deceleration lane at this location.

Location D5b: Interstate 65 and State Road 56 Interchange -

Deceleration Lane North Bound

The deceleration lane at this site leaves the through lane on a tangent (see Figure 33). In this case the length of the taper is 250 feet and the curved portion to the nose is 217 feet. The annual average daily traffic on this deceleration lane was 770 vehicles per day and on the through lanes north bound was 2800 vehicles per day.

This interchange is located in a semi-urban area. Most of the traffic using this deceleration lane is local traffic travelling from Jeffersonville to the city of Scottsburg. No accidents were reported on the deceleration lane since the facility was opened to traffic in October 1960 until July 1961.

The 85th percentile speed of the deceleration lane traffic at the nose, Station 0+00, was 51 mph (see Figure 70). This shows that many drivers did not obey the signed speed of 40 mph.

The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of deceleration lane traffic as it diverged into the deceleration lane was eight (8) mph (64-56). This difference is significant. The difference between the 85th percentile speed of the through lane traffic within the

SPEEDS AND
LATERAL PLACEMENT OF CARS
PATH OF LEFT FRONT WHEEL
DECELERATION LANE-NORTH BOUND
INTERSTATE 65 AND S.R. 56 INTERCHANGE

area of conflict and that beyond the area of conflict was three (3) mph (67-64). This difference is not significant.

The majority of drivers, 89.8 percent, diverged between Stations 2+00 and 3+00 at an 85th percentile speed of 56 mph. They could have diverged a little earlier and thereby would have used more of the deceleration lane.

These results indicate that this type of deceleration lane design was not being properly used with reference to speed by drivers at this location.

In comparing these results with those of the previous case, D5a, it is evident although both locations have the same type of design of deceleration lane and the same geometric condition, i.e. tangent, that the results are not the same. The results in case D5b which has the longer deceleration lane, tend to be much nearer the optimum conditions of operation for deceleration lanes. This may be due to the increase in the length of the deceleration lane.

Location D5c: Tri-State-Calumet Avenue Interchange -

Deceleration Lane East Bound

The deceleration lane here leaves the through lane on a slight left curve (see Figure 39). In this case the length of the taper section is 200 feet, and the curve portion to the nose is 139 feet.

The annual average daily traffic on the deceleration lane was 1830 vehicles per day and on the through lane east bound was 23,530 vehicles per day. This interchange is located in an urban area. Most of the traffic using this deceleration lane is through traffic using the Illinois Toll Road and Calumet Avenue.

Two accidents were reported on this deceleration lane in 1959. The first was caused by a driver missing the deceleration lane and then slowing on the through lane, and the second by a driver missing the deceleration lane and then turning from the outside lane to get on a crossover. One accident was reported in 1960, and was caused by a driver turning from the inside lane onto the deceleration lane.

The 85th percentile speed of deceleration lane traffic at the nose, Station 0+00, was 35 mph (see Figure 71). This shows that most drivers obeyed the signed speed of 40 mph. The difference between the 85th percentile speed of through lane traffic within the area of conflict and the average 85th percentile speed of the deceleration lane traffic as it diverged into the deceleration lane was 19 mph (61-42). This difference is significant.

The difference between the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict was one (1) mph (61-60). This difference is not significant.

Nearly all drivers, 97.2 percent, diverged as soon as they could between Stations 1+00 and 2+00 at an 85th percentile speed of 43 mph.

These results indicate clearly that this type of design is inadequate and hazardous for traffic using this deceleration lane at this location.

Summary of Field Results

A summary of the important acceleration lane characteristics and a summary of the results obtained at each location studied are given in Table 7. A similar table for the deceleration lanes studied is Table 8. These two tables are included to provide a comparison of the various designs and to permit a quicker evaluation by the reader of the findings which are given in the next section of the report.

SPEEDS AND LATERAL PLACEMENT OF CARS PATH OF LEFT FRONT WHEEL

DECELERATION LANE-EAST BOUND
TRI-STATE HIGHWAY AND CALUMET AVENUE
INTERCHANGE

FIGURE 71

TABLE 7
SUMMARY OF RESULTS - ACCELERATION LANE

Location	Figure No.	Geometric Condition No.	Type of Accel. Lane - No.	AADT ³		85th Percentile Speed						Distance Beyond Point of Separation Within Which 90% of Accel. Lane Traffic Merged	Usable ⁷ Length of Accel. Lane	Length of Accel. Lane Used by 90% of Through Lane Traffic	% of Accel. Lane Traffic That Stopped	Was This Accel. Lane Used Satisfactorily As To	
				Accel. Lane	Through Lane	Station O O	Average Accel. Lane	Through Lane MAOC ⁴	Speed Mfr. and (S) or (NS) ⁵	Through Lane MAOC ⁴	Speed Mfr. and (S) or (NS)					Speed	Placement
A1a	8, 9	(1)	1	620	3720	48	55	59	14 (S)	69	0 (NS)	185	890	125	1.0	No	No
A1b	10, 11	(1)	1	1320	7860	54	62	65	3 (NS)	65	0 (NS)	200	890	110	10.7	Yes	Yes
A1c	12, 13	(4)	1	870	5950	54	57	67	10 (S)	67	0 (NS)	200	890	110	1.8	No	Yes
A1d	14, 15	(2)	1	650	6420	57	64	67	3 (NS)	69	2 (NS)	280	890	60	3.6	Yes	Yes
A1e	16, 17	(5)	1	1230	5030	48	54	66	12 (S)	66	0 (NS)	200	890	110	3.7	No	Yes
A1f	18, 19	(3)	1	590	6520	58	63	64	1 (NS)	69	5 (S)	190	890	120	0	Yes	Yes
A2a	22, 23	(1)	2	260	4350	42	47	66	19 (S)	68	2 (NS)	450	650	200	9.3	No	No
A2b	24, 25	(1)	2	680	12200	47	51	62	11 (S)	62	0 (NS)	900	650	150	16.0	No	No
A2c	26, 27	(1)	2	1130	3030	55	55	61	6 (S)	63	2 (NS)	385	650	265	4.4	No	No
A2d	28, 29	(2)	2	880	4530	42	50	64	14 (S)	58	-6 (S)	600	650	50	14.3	No	No
A2e	32, 30	(3)	2	1380	4170	44	46	66	20 (S)	67	1 (NS)	415	650	235	10.7	No	No
A3a	33, 34	(2)	3	870	2800	51	54	61	7 (S)	65	4 (S)	375	475	100	14.3	No	No
A3b	35, 36	(3)	3	1450	2650	50	53	64	11 (S)	63	1 (NS)	365	475	110	3.6	No	No
A4a	39, 40	(2)	4	1960	23730	44	48	60	12 (S)	66	6 (S)	135	250	115	34.6	No	No
A4b	39, 41	(2)	4	3880	21620	41	45	60	15 (S)	60	0 (NS)	130	250	120	28.0	No	No

1. Numbers in parenthesis (1) refers to the condition referenced in Table 5.

2. Numbers refer to types referenced in Table 5.

3. AADT = Annual Average Daily Traffic.

4. MAOC = Within Area of Conflict

5. (S) = Significant (NS) = Not Significant

6. MAOC = Beyond Area of Conflict

7. Usable length of Accel. Lane is taken as that length from the end of the ramp curve to where the Accel. Lane width is 6 feet wide.

TABLE 6
SUMMARY OF RESULTS - DECELERATION LANES

Location	Figure No.	Geometric ¹ Condition No.	Type of ² Decel. Lane No.	AADT ³		85th Percentile Speed						Distance Within Which 90% of Decel. Lane Traffic Diverged In.	Vehicle ⁷ Length of Decel. Lane	Length of Decel. Lane Not Used by 90% of Traffic	Was This Decel. Lane Used Satisfactorily As To Speed Placement	
				Decel. Lane	Through Lane	Station 0 00	Average Decel. Lane	Through Lane SAC ⁴	Speed Diff. and (S) or (NS) ⁵	Through Lane SAC ⁶	Speed Diff. and (S) or (NS)					
21a	20, 44	(1)	1	1460	7680	70	70	63	-7 (S)	49	8 (S)	300 ft	990	50	Yes	Yes
21b	12, 43	(1)	1	310	3930	52	60	64	4 (S)	68	4 (S)	300	990	30	No	Yes
21c	14, 46	(3)	1	700	6630	48	55	69	14 (S)	69	0 (NS)	400	990	230	No	No
22a	22, 51	(1)	2	260	4370	49	49	67	18 (S)	66	1 (NS)	200	370	120	No	No
22b	24, 52	(1)	2	1430	14290	41	46	60	14 (S)	63	3 (S)	200	370	75	No	No
22c	22, 53	(2)	2	1060	4590	46	50	68	18 (S)	70	2 (NS)	200	370	90	No	No
23a	56, 57	(1)	3	—	—	46	51	60	11 (S)	65	3 (S)	100	130	0	No	Yes
23b	35, 60	(2)	3	1010	3230	50	54	65	11 (S)	67	2 (NS)	100	130	0	No	Yes
23c	28, 63	(3)	3	930	4740	54	55	60	5 (S)	60	0 (NS)	200	300	25	No	Yes
24a	63, 66	(1)	4	230	3780	50	57	63	6 (S)	63	0 (NS)	200	308	20	No	Yes
25a	29, 69	(1)	5	4100	12800	38	46	63	17 (S)	62	1 (NS)	100	240	40	No	Yes
25b	33, 70	(1)	5	770	2800	51	56	64	8 (S)	67	3 (NS)	100	340	30	No	Yes
25c	29, 71	(3)	5	1830	5580	29	42	60	19 (S)	60	1 (NS)	100	240	50	No	Yes

1. Numbers in parentheses (1) refer to the geometric condition referenced in Table 5.

2. Numbers refer to types referenced in Table 5.

3. AADT = Annual Average Daily Traffic

4. SAC = Within Area of Conflict

5. (S) = Significant and (NS) = Not Significant

6. SAC = Beyond Area of Conflict

7. Vehicle length of Deceleration Lane is taken as that length from the beginning of the ramp curve to where the Deceleration Lane width is 6 feet wide.

FINDINGS AND RECOMMENDATIONS

The behavior of vehicles on acceleration and deceleration lanes reported in this study shows that:

In General:

1. There are large differences in speed between acceleration or deceleration lane traffic at the time of merging or diverging, respectively, and that of the through lanes on the Interstate Sections studied. This indicates that better use of these and similar facilities which will be constructed is desirable.
2. A large number of the driving public do not know how to properly use acceleration and deceleration lanes. Thus, for the most efficient and safest operation of traffic, it is imperative that the driving public be better informed on the proper use of acceleration and deceleration lanes. It is recommended that all the interested agencies of the City, State and Federal Government recognize their responsibility in this area and formulate at an early date a program of education directed toward the proper use of acceleration and deceleration lanes.

To facilitate this education of the driving public in the use of such lanes one standard design for acceleration lanes and one for deceleration lanes should be adopted for the Interstate System. The Indiana State Highway Commission has already constructed three different types of design of acceleration lanes

and four different types of design of deceleration lanes on the Interstate Sections that have been opened to traffic. On some of these sections the type of design varies from one interchange to the next. These different designs tend to confuse the driving public.

3. The results are not similar at all locations of acceleration and deceleration lanes having the same type of design and operating under the same geometric conditions. This indicates that other factors, such as type of drivers using the lanes and traffic volume, may have a significant bearing upon the results.
4. Acceleration or deceleration lane traffic has little effect upon the speed of through traffic at interchanges where acceleration and deceleration lanes of the designs studied in this project are provided and where the acceleration or deceleration lanes and ramps have adequate capacity.

At only eight (8) of the 28 acceleration and deceleration lane locations studied was the difference in the 85th percentile speed of the through lane traffic within the area of conflict and that beyond the area of conflict statistically significant. Drivers slowed at seven (7) of these locations and travelled faster at the eighth. The change in speed was never greater than six (6) mph. At some of the locations where the speed effect was significant other factors, such as a narrow median or a horizontal curve, might have also contributed to the changes in speed.

5. For the best use for both acceleration and deceleration lanes at an interchange location, it is desirable to have the through

lanes, at the location of the acceleration or deceleration lanes, on a tangent and as near a level grade as possible.

For Acceleration Lanes:

1. A higher percentage of drivers utilize more length of the acceleration lane when the acceleration lane meets the through lane on a right curve, and less length of the acceleration lane when it meets the through lane on a left curve, than the condition when the acceleration lane meets the through lane on a tangent.
2. Most of the few accidents reported on the acceleration lanes studied were caused by drivers stopping on the acceleration lanes or faulty merging maneuvers. Both of these causes are most probably due to drivers not understanding the proper use of acceleration lanes.
3. Of the four types of acceleration lane design studied, the long direct taper type of design with separation from the through lanes for approximately 500 feet was found to be the only type where most drivers tended to approach the optimum condition of operation for acceleration lanes.
4. For the long direct taper type of design, a high percentage of drivers followed a natural straight path from the beginning of the acceleration lane at the end of the ramp curve until they merged into the through lanes. Some control, such as a curb, appeared to be desirable beyond the end of the ramp curve to properly align some motorists in the straight path that most of them used on this type of acceleration lane and thus prevent a too early merging into the through lane.

5. For the long direct taper type of design studied, most drivers merged (left rear wheel entered through lane) within a maximum distance of 260 feet beyond the nose.
6. Most drivers tended to merge soon after entering all parallel acceleration lanes studied and at too low a speed. Increasing the length of the parallel portion of the acceleration lane did not improve the usage.
7. Most drivers tended to merge as soon as possible and at too low a speed on the short taper design acceleration lanes which had no separation from the through lanes.

For Deceleration Lanes:

1. A higher percentage of drivers utilized less length of the deceleration lane and diverged later at lower speeds, thereby decelerating more on the through lane, when the deceleration lane left the through lane on a left curve than when the deceleration lane left the through lane on a right curve or tangent.
2. The largest proportion of deceleration lane accidents at the locations studied, 44.4 percent, were caused by drivers traveling too fast on the exit ramps. This was most probably due to the deceleration lanes being too short for drivers to decelerate to the exit ramp design speed; the ramp speed sign being improperly posted; and/or drivers having difficulty adjusting to lower speeds while still in the environment of the main facility.

On the other hand, 22.2 percent of the accidents were caused by drivers missing the deceleration lane. This is illustrated in Figure 72 where a vehicle is shown missing the deceleration lane

FIGURE 72. CAR MISSES DECELERATION LANE AND STOPS THEN BACKS ON THE DECELERATION LANE AND ENTERS THE EXIT RAMP.

and stopping, then backing onto the deceleration lane and entering the exit ramp. This may be due to drivers not being able to clearly differentiate between the deceleration lane and the through lane, because of short deceleration lanes and/or because of driver inattention.

3. Most drivers at most of the locations studied did not obey the regulatory speed sign "Exit Speed 40" placed near the nose of the deceleration lane on the Interstate sections.

It is recommended that this regulatory speed sign be changed to an advisory ramp speed sign with the numerical value the safe design speed of the exit ramp and placed so as to permit comfortable deceleration to this safe speed.

4. At all but one of the locations studied, much of the deceleration lane traffic started to decelerate on the through lane before diverging into the deceleration lane. The results further show that many drivers began to decelerate well in advance, more than 1000 feet, of the beginning of the deceleration lane.
5. Of the five types of design studied, the long direct taper type of deceleration lane with separation of the lane from the through lane for about 300 feet (as on the Indiana Toll Road) was found to be the best. On this design most drivers tended to approach the optimum condition of operation for deceleration lanes. On the lanes of this design studied, it appears that a shorter diverging distance and a longer separated deceleration lane would be desirable.
6. Most drivers on the deceleration lanes studied desired to follow a natural straight path of exit with a minimum of maneuvering.

Thus only a small percentage of drivers properly used the parallel type of design. This type of design requires drivers to make an additional maneuver and to follow the pattern of a reverse curve - a movement which apparently appears to be inconvenient to most drivers.

7. Ninety percent of the drivers diverging onto a deceleration lane did so within a maximum distance of 300 feet except for one case where the lane was on a left horizontal curve.
8. The curve type design for deceleration lanes tended to provide good usage throughout the length of the lane but most drivers decelerated before entering this type of lane. This latter tendency may be correctible through the use of a long and very slight curve.
9. Most drivers tended to decelerate appreciably on the through lane where a short direct taper design was used.

PROPOSED STANDARD DESIGNS
FOR ACCELERATION AND DECELERATION LANES

A good design for acceleration and deceleration lanes should provide:

1. Adequate length for acceleration lane traffic to accelerate comfortably from the safe ramp speed to the through lane traffic speed.
2. Adequate length for deceleration lane traffic to decelerate from the through lane traffic speed to the safe ramp speed.
3. Adequate merging or diverging distance to handle safely low volumes as well as high volumes (to practical capacity) of traffic on both the through lanes and the acceleration or deceleration lanes.
4. Adequate sight distance to allow drivers to maneuver safely through the interchange area.
5. Adequate signage and delineation at the interchange area to eliminate any confusion in differentiating between the acceleration or deceleration lanes and the through lanes and in properly maneuvering through the interchange.
6. A small angle, one to three degrees if possible, of convergence (acceleration lanes) and a small angle of divergence (deceleration lanes) so that the maneuver can be made in approximately the same direction of travel as that being performed by through traffic.
7. Separation of the acceleration lane or deceleration lane from the through lane for an adequate portion of the length of the acceleration or deceleration lane. At the beginning of an acceleration

lane a curb may be necessary to align properly drivers coming from the ramp curve.

The above characteristics and other findings of this study were used to prepare the Proposed Standard Acceleration Lane and Proposed Standard Deceleration Lane shown in Figures 73 and 76 respectively.

Proposed Acceleration Lane Design

This proposed design is to handle two fundamental maneuvers, acceleration followed by merging.

The accelerating distance is that length of the acceleration lane from the end of the ramp curve to the nose. This length permits acceleration lane traffic to accelerate from the safe ramp speed, assumed for Figure 73 to be 25 mph, to the design speed of the facility, assumed to be 70 mph for Figure 73.

From Figures 74 and 75 the distance required to accelerate from one speed to another is determined for the best and poorest performing cars for three model years. These distances for 25 mph to 70 mph are tabulated in Table 9, which shows that the maximum acceleration distance required is 612 feet.

TABLE 9

DISTANCES REQUIRED FOR VARIOUS MODEL CARS TO
ACCELERATE FROM 25 MPH TO 70 MPH

Year of Model	Poorest Performing Cars	Best Performing Cars
1951	612	312
1955	560	250
1959	475	257

Figure 74 - Time-Distance and Time-Speed Comparison of the Best Performing Cars for Three Model Years (29)

Figure 75 - Time-Distance and Time-Speed Comparison of the Poorest Performing Cars for Three Model Years (29)

A distance of 625 feet was assumed for the proposed example design.

The merging distance is that length of the acceleration lane from the nose to the end of the acceleration lane. This length enables acceleration lane traffic to merge from the acceleration lane to the through lane while travelling at the design speed of the facility, 70 mph in the example. This study reported that the majority of drivers merged on the long taper type acceleration lane within a maximum distance of about 260 feet. This distance was for the left rear wheel and means the total vehicle could be in the through lane within 500 feet. This distance was adequate for the volume of traffic using the main facility and the acceleration lane at the time of the study, but acceleration lanes should be designed so that the facility can accommodate practical capacity. However recent capacity studies (12) (25) (30) have shown that maximum flow can only be obtained where the "squeeze off" distance is about 500 feet, and that longer merging areas do not handle larger merging volumes. A distance of 500 feet, therefore, is assumed for this design and this should be adequate for the expected future volume of traffic on the facility.

The length of the acceleration lane, therefore, for an increase in speed from 25 to 70 mph is 1125 feet from the end of the ramp curve to the intersection with the right edge of the through lane. It has about 45:1 direct taper all along its merging distance. A curb adjoins the acceleration lane for the first 425 feet and for the next 200 feet a shoulder, which is paved but of different color, separates the acceleration lane from the through lane. The acceleration lane shown has a very small angle of convergence, about one (1) degree.

Proposed Deceleration Lane Design

This proposed deceleration lane is also designed to accommodate two fundamental maneuvers, diverging and then deceleration.

The diverging distance is that length of the deceleration lane from the beginning of the lane to the nose. This length enables deceleration lane traffic to diverge from the through lane onto the deceleration lane while still travelling at the design speed of the facility, assumed for Figure 76 to be 70 mph. This study indicated that most drivers diverged within a maximum distance of 300 feet. Allowing for a factor of safety the diverging length proposed is 500 feet.

The deceleration distance is that length of the deceleration lane from the nose to the beginning of the ramp curve. This length enables deceleration lane traffic to decelerate from the design speed of the facility to the safe speed of the exit ramp.

Various studies (2, 3, 31) have recommended comfortable deceleration rates ranging from 6.2 mph per second to 9.4 mph per second. A uniform deceleration rate of 6.2 mph per second was used in the design shown in Figure 76.

Thus time (t) required to decelerate from the 70 mph to 25 mph used for Figure 76 equals

$$t = \frac{(70 - 25)}{6.2} = 7.26 \text{ seconds}$$

$$\begin{aligned} \text{The deceleration distance (d)} &= 7.26 \times 1.47 \frac{(70 + 25)}{2} = \\ &= 7.26 \times 69.82 \\ &= 506 \text{ feet, say 500 feet} \end{aligned}$$

PROPOSED STANDARD DECELERATION LANE

FIGURE 76

The deceleration lane for Figure 76 is 1000 feet long, from the edge of the right lane to the beginning of the ramp curve. It has a small angle of divergence, about two (2) degrees, at the through lane.

The exit nose is offset six (6) feet and there are 175 feet of recovery. Two advisory speed signs are posted indicating to the drivers the design speed of the exit ramp. One is located at the nose to give the driver advance warning and to enable him to decelerate in the deceleration distance, and the other is located at the beginning of the exit ramp.

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APPENDIX

RELATIONSHIP OF VARIATION TO TIME

The amount of variation is

which is the same as the variation in the

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APPENDIX

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APPENDIX A

DEFINITION OF STATISTICAL TERMS

Average Speed

The average of individual speeds

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

where X_i is an individual speed measurement.

Pth Percentile Speed

That speed at and below which P percent of the drivers travel i.e. 85th percentile speed is that speed at and below which 85 percent of drivers travel.

Standard Deviation (σ) and (S)

A measure of general variability and the square root of the average of the squared deviations from the mean.

$$\sigma = \sqrt{\frac{\sum_{i=1}^n P_i (X_i - \bar{X})^2}{n}}$$

$$S = \sqrt{\frac{\sum_{i=1}^n P_i (X_i - \bar{X})^2}{n-1}}$$

Variance (σ^2) and (S^2)

The square of the standard deviation.

Cumulative Frequency

The frequencies of a frequency distribution are cumulated.

Statistical Hypothesis (H)	A statement which usually assigns one or more values to a population parameter. Other characteristics of the population are assumed.
Alternate Hypothesis (Alt H)	Refers to other possible values of the population parameter using the same assumptions as in (H).
Significance Level (α)	The probability of the test statistic lying in the rejection region when the hypothesis is, in fact, true.
Population	The collection or aggregate of elements about which an inference is to be made.
Population Parameter	A characteristic of the population.
Sample	A number of elements selected from the population.
Normal Distribution	A certain theoretical relation between the values of the measured variable and the relative frequency of the value.

Illustrative Example

The purpose of this calculation was to determine whether the difference between the 85th percentile speed of through lane traffic within the area of conflict and that beyond the area of conflict was significant or not.

The example chosen is at location Ald where

I_1 85th = 69	I_2 85th = 67
S_1 = 6.7	S_2 = 5.3
n = 150	n = 150

From equation (3) page 28

$$Z = \frac{(I_1 \text{ 85th} - I_2 \text{ 85th}) \times 8.01}{\sqrt{s_1^2 + s_2^2}}$$

$$= \frac{(69 - 67) \times 8.01}{\sqrt{(6.7)^2 + (5.3)^2}} = \frac{2 \times 8.01}{8.54}$$

$$Z = 1.88 \text{ (NS)}$$

This value of Z is less than 2.81 and this difference is not significant (NS).

The purpose of this calculation was to determine whether the difference between the 85th percentile speed of the through lane traffic within the area of conflict and the average 85th percentile speed of acceleration and/or deceleration lane traffic as it merged and/or diverged into and/or from the through lane was significant or not.

The example chosen is at location Alc where

$I_1 \text{ 85th} = 64$	$I_2 \text{ 85th} = 60$
$s_1 = 6.04$	$s_2 = 6.45$
$n_1 = 150$	$n_2 = 108$

From equation (5) page 29

$$Z = \frac{(I_{1P} - I_{2P}) \times 7.33}{\sqrt{\frac{149 s_1^2 + 107 s_2^2}{128}}}$$

$$= \frac{(64 - 60) \times 7.33}{\sqrt{\frac{149 \times (6.04)^2 + 107 \times (6.45)^2}{128}}} = \frac{29.32}{8.8}$$

$$Z = 3.33 \text{ (S)}$$

This value of Z is more than 2.81 and thus the difference in this case is significant (S).

VITA

VITA

Neddy C. Jouzy was born in Jerusalem, Jordan, on June 30, 1929. Mr. Jouzy received his primary and secondary education in Jerusalem and was graduated from Al Ummah School in June 1947. He attended Loughborough College, Loughborough, England from 1948-1951 and was graduated in July 1951 with Diploma Loughborough College (Honors) in Civil Engineering as well as B. Sc. Degree in Engineering from London University, London, England. After graduation he was employed by the Arabian American Oil Company, at Dhahran, Saudi Arabia, as a Civil Engineer from 1952-1954. He then joined the Ministry of Public Works, Roads Division, at Amman, Jordan and was employed as a Highway Engineer from 1954-1957.

In the fall of 1957, Mr. Jouzy enrolled at Purdue University, as an exchange student, to begin graduate work in Civil Engineering and was awarded the MSCE degree in Transportation in January 1959. He then was employed by the Indiana State Highway Commission, Indianapolis, Indiana as a Traffic Engineer from February 1959 until September 1959. Subsequently he returned to Purdue University to work on his Doctor's degree and complete the Ph. D. requirements in January 1962.

Mr. Jouzy is co-author of a paper entitled "Uses of Acceleration-Deceleration Lanes". He is a member of the following Societies: American Society of Civil Engineers, Tau Beta Pi and Sigma Xi.