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Optimal Design of Work Zone Median Crossovers

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16. Abstract

The use of temporary median crossovers in work zones allows for the closure of one side of a multi-lane roadway while maintaining two-way traffic on the opposite side. This process provides the ability for construction and maintenance crews to construct, rebuild, or perform maintenance on a portion of one direction of a roadway segment while allowing roadway users continued access through the facility. A number of behavior studies were conducted on single-lane and dual-lane crossovers at work zone locations in the State of Nebraska resulting in general guidelines for optimal geometric design features of such work zone elements.

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Disclaimer

Abstract

The use of temporary median crossovers in work zones allows for the closure of one side of a multi-lane roadway while maintaining two-way traffic on the opposite side. This process provides the ability for construction and maintenance crews to construct, rebuild, or perform maintenance on a portion of one direction of a roadway segment while allowing roadway users continued access through the facility. A number of behavior studies were conducted on single-lane and dual-lane crossovers at work zone locations in the State of Nebraska resulting in general guidelines for optimal geometric design features of such work zone elements.

Chapter 1 Introduction

1.1 Background

Safety is a primary concern in the design and operation of every work zone on the nation's highways. The potential for property damage, injury, and loss of life provides an impetus to investigate work zone design and operation. One component of many work zones that warrants investigation is the work zone crossover. For this project, a work zone crossover is defined as temporary segments of roadway that transfer one or more lanes of traffic across a median away from an adjacent construction zone segment.

The use of a crossover allows for the closure of one side of a multi-lane roadway while maintaining two-way traffic on the opposite side (1). This process provides the ability for construction and maintenance crews to construct, rebuild, or perform maintenance on a portion of one direction of a roadway segment while allowing roadway users continued access through the facility.

1.2 Single- and Dual-Lane Crossovers

Work zone crossovers exist on multilane roadways with varying numbers of lanes and consist of one or more driving lanes crossing the median. The geometry of the configuration in figure 1.1 allows only a single lane of traffic to be crossed over the median resulting in head-to-head traffic on the opposite side. Figure 1.1 shows a work zone on U.S. Highway 34 in Lincoln, NE utilizing a crossover to sustain traffic flow during the life of the maintenance project. Table 1.1 defines a general set of sections within a work zone that utilizes a single-lane crossover.

Figure 1.1 Work Zone Crossover along U.S. Highway 34 in Lincoln, NE

Table 1.1 Work Zone Section Definitions for a Single-Lane Crossover

Work Zone Section	Definition
Advance Warning Area	Warning signs inform drivers that a work zone is ahead. Any changes in speed limits are posted.
Lane Reduction	The number of available driving lanes may be reduced from two to one.
Single-Lane Operation	A single lane is available for traffic
Entrance Crossover	The entrance crossover shifts traffic entering the work zone across the median.
Two-Way Traffic	A four-lane roadway divided by a median is reduced to a two-lane roadway. Both directions of travel exist on one set of lanes.
Activity Area	Section of roadway where the work activity takes place.
Exit Crossover	The exit crossover moves traffic back across the median.
End of Work Zone	The work zone ends and traffic is separated once again by the median of the four-lane roadway.

The geometry of the work zone configuration in figure 1.2 allows two lanes of traffic to be crossed over the median resulting in head-to-head traffic on the opposite side.

Figure 1.2 Work Zone Crossover along Interstate 80 and 70th Street in Lincoln, NE

Table 1.2 defines a general set of sections within a work zone that utilizes a dual-lane crossover.

Table 1.2 Work Zone Section Definitions for a Dual-Lane Crossover

Work Zone Section	Definition
Advance Warning Area	Warning signs inform drivers that a work zone is ahead. Any changes in speed limits are posted.
Dual Lanes in Advance of Crossover “STAY IN YOUR LANE” Advisory Signs	The number of lanes of through traffic remains the same as in the non-work zone segment (2 lanes). Advisory signs are to encourage drivers to avoid weaving since the horizontal alignment of driving path will be changing a short distance ahead.
Entrance Crossover	The entrance crossover shifts traffic entering the work zone across the median. The width accommodates two full traffic lanes.
Two-Way Traffic, Two Lanes in Each Direction	A four-lane roadway divided by a median is maintained as a four-lane roadway but the lanes are separated by temporary concrete barriers instead of a median with substantial width.
Activity Area	Section of roadway where the work activity takes place.
Exit Crossover	The exit crossover moves two lanes of traffic back across the median.
End of Work Zone	The work zone ends and traffic is separated once again by the median of the four-lane roadway.

Currently, guidance for the three-dimensional elements of a median crossover design relies on limited research. Today’s design standards that are applied to crossovers are within the latest editions of resources such as state design manuals and the American Association of Safety and Highway Transportation Officials Policy on Geometric Design of Highways and Streets, also known as the AASHTO Green Book (2). A majority of these available standards are suitable for roadway design in typical construction conditions. However, work zone crossovers are not representative of typical conditions for roadway design due to constraining features within a median, surrounding work zones, and limitations of available sight distance caused by channelization traffic control devices. Available literature relating to vehicular shifts away from the permanent driving lane alignment (lateral displacements) shows that this may be a safety issue with respect to transitions into and out of crossovers.

Work zone crossovers are often constructed using a standard “one-design-fits-all” plan that may not be the optimal design with respect to safety, operations, maintenance and construction costs. Project design plans for such crossovers are also sometimes modified by field personnel during the construction process without regard to the negative impacts which may result.

1.3 Objectives

This research project examines the behaviors and expectations of drivers at single-lane crossovers (one traffic lane shifted across the median) and dual-lane crossovers (two traffic lanes shifted across the median). Single-lane crossovers will be reported in the first part of this report and dual-lane crossovers reported in the latter part of the report, since their character and operation are different enough to warrant two separate study methodologies.

Reviews were made of current traffic control plans, crossover accident reports, and interviews Nebraska district construction personnel to develop guidelines for use by engineers to create a work zone crossover design that best fits the given situation.

Chapter 2 Literature Review of Single-Lane Crossovers

This literature review covers previous research related to work zone crossovers and available standards that can be applicable to crossover design. Driver considerations were addressed to determine the demands that exist for drivers that may be different from the typical highway driving experience when traversing work zone crossovers. Many design considerations are covered including the use of superelevation, design type, and other factors that may be taken into account for the design of crossovers. Reviewing literature related to these topics aided in gaining a background on crossover design and identifying gaps in research on lateral displacements and other potential safety problem areas. Figure 2.1 shows a basic layout for a maintenance project on a four-lane roadway using 2 crossovers.

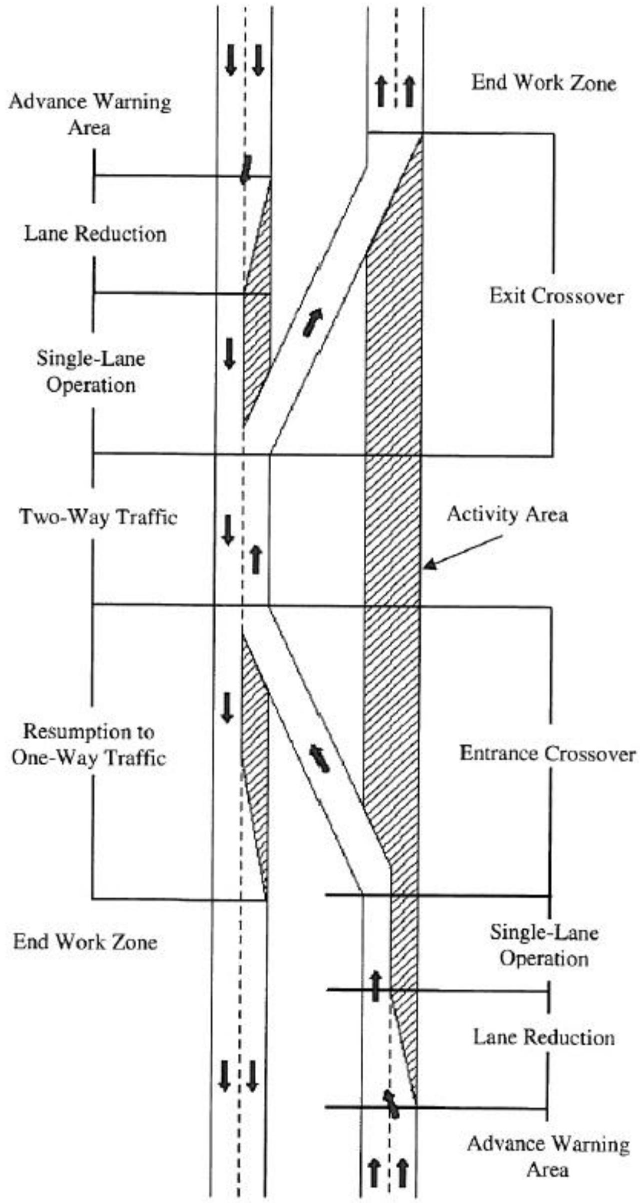

Figure 2.1 Plan View of Work Zone Utilizing Crossovers (not to scale)

2.1 Driver Considerations

In a study of 76 highway patrolmen, 84% of those surveyed considered driver inattention and improper behavior as the major cause of work zone crashes (3). Drivers' experience in work zone crossovers is significantly different than the typical highway. For example, as shown in figure 2.1, drivers must merge into a single lane and continue through the entrance crossover across the median to enter the two-way traffic portion of the work zone. Many crossovers guide drivers through uncommon driving paths using traffic cones, barrels, and other traffic control devices (3). With these site characteristics in place, inattentive or unfamiliar drivers are more likely to experience difficulty in crossover negotiation that could result in a crash.

2.2 Design Considerations

In studying available standards for crossovers, the Manual on Uniform Traffic Control Devices (MUTCD) provides a general crossover diagram (figure 2.2) as well as the following guidance for the layout and design of crossovers (4):

- Tapers for lane drops should be separated from the crossovers.
- Crossovers should be designed for speeds no lower than 10 mph below the posted speed, the off-peak 85^{th}-percentile speed prior to work starting, or the anticipated speed of the roadway, unless unusual site conditions require that a lower design speed be used.
- A good array of channelizing devices, delineators, and full-length, properly-placed pavement markings should be used to provide drivers with a clearly defined travel path.
- The design of the crossover should accommodate all vehicular traffic, including trucks and buses.
- When the crossover follows a curved alignment, the design criteria contained in the AASHTO “Policy on the Geometric Design of Highways and Streets” should be used.

Figure 2.3 includes notes from the MUTCD guide referring to the diagram in figure 2.2.

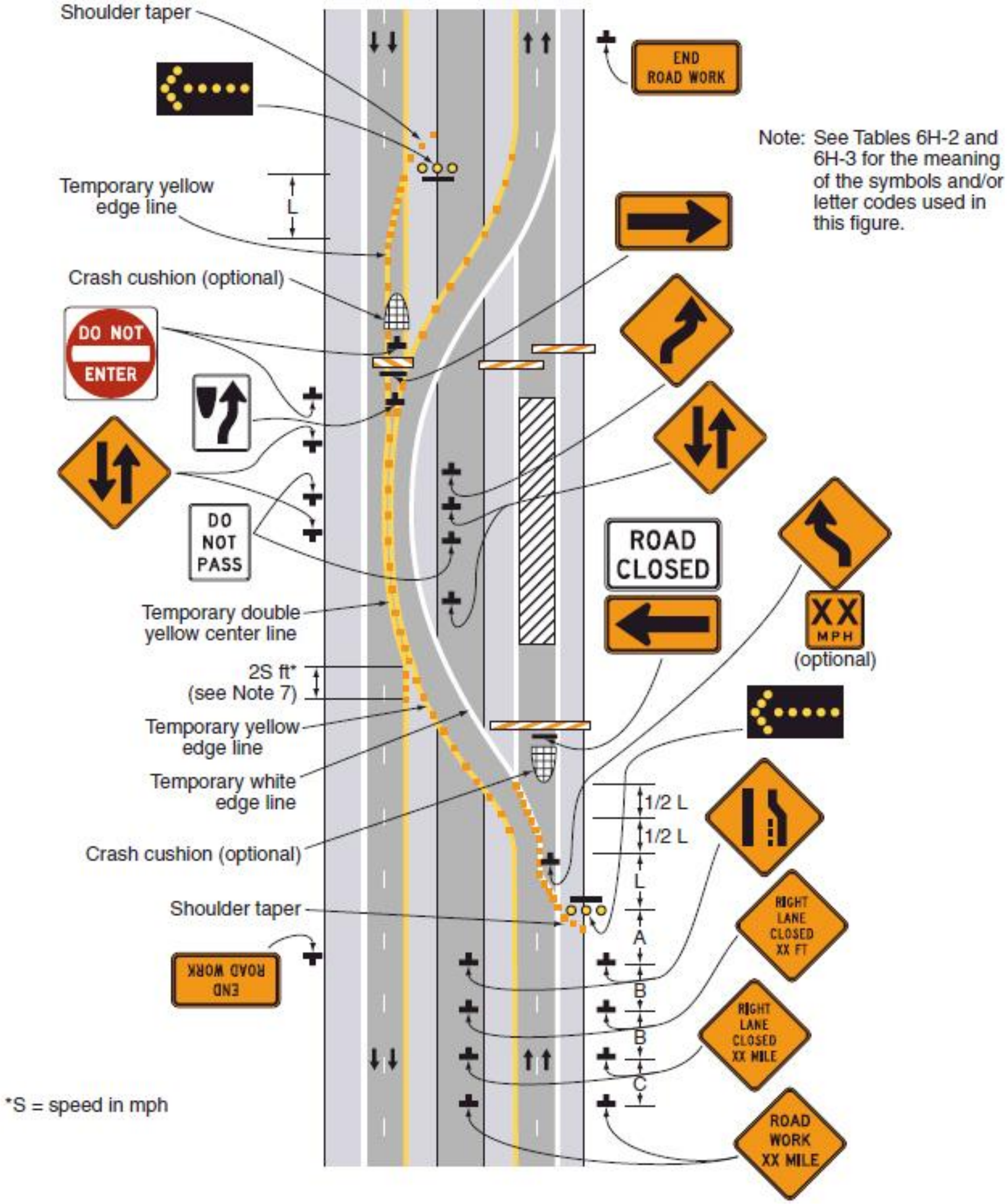

Figure 2.2 MUTCD Guidance for Temporary Traffic Control Devices at Median Crossovers Along Freeways, Exhibit 6H-39, page 711(4)

Notes for Figure 6H-39—Typical Application 39
Median Crossover on a Freeway

Standard:

1. **Channelizing devices or temporary traffic barriers shall be used to separate opposing vehicular traffic.**
2. **An arrow board shall be used when a freeway lane is closed. When more than one freeway lane is closed, a separate arrow board shall be used for each closed lane.**

Guidance:

3. *For long-term work on high-speed, high-volume highways, consideration should be given to using a temporary traffic barrier to separate opposing vehicular traffic.*

Option:

4. When a temporary traffic barrier is used to separate opposing vehicular traffic, the Two-Way Traffic, Do Not Pass, KEEP RIGHT, and DO NOT ENTER signs may be eliminated.
5. The alignment of the crossover may be designed as a reverse curve.

Guidance:

6. *When the crossover follows a curved alignment, the design criteria contained in the AASHTO "Policy on the Geometric Design of Highways and Streets" (see Section 1A.11) should be used.*
7. *When channelizing devices have the potential of leading vehicular traffic out of the intended traffic space, the channelizing devices should be extended a distance in feet of 2.0 times the speed limit in mph beyond the downstream end of the transition area as depicted.*
8. *Where channelizing devices are used, the Two-Way Traffic signs should be repeated every 1 mile.*

Option:

9. NEXT XX MILES Supplemental Distance plaques may be used with the Two-Way Traffic signs, where XX is the distance to the downstream end of the two-way section.

Support:

10. When the distance is sufficiently short that road users entering the section can see the downstream end of the section, they are less likely to forget that there is opposing vehicular traffic.
11. The sign legends for the four pairs of signs approaching the lane closure for the non-crossover direction of travel are not shown. They are similar to the series shown for the crossover direction, except that the left lane is closed.

Figure 2.3 Notes Referring to MUTCD Guidance for Temporary Traffic Control Devices at Median Crossovers Along Freeways, Exhibit 6H-39, page 710(4)

According to MUTCD guidance, the Green Book should be directly applied for the design of work zone crossovers. The Green Book does not mention or provide any direct guidance specific to the design of crossovers (2). Past editions of the Green Book were also checked for any mention of work zone crossovers, and no information was found (5, 6, 7, 8, 9). As there are no crossover-specific recommendations available, the basic roadway design guidelines in the Green Book are likely applied. To negotiate a crossover, drivers must change direction to depart from the existing driving lane to enter the crossover. Next, a second change in direction is needed to traverse the exit portion of the crossover to reach the roadway on the opposing side of the median. As most crossovers are located on high-speed roadways, a design that can accommodate high speeds and multiple changes in direction must be used.

2.3 Coefficient of Side Friction

A number of factors must be considered for a crossover design employing the two horizontal curves that are present in reverse curve crossovers. For vehicles following a curve, a component of centripetal acceleration will act on the vehicle in the direction of the driving path's center of curvature (2). This acceleration is sustained by either the component related to the vehicle's weight from roadway superelevation, side friction between the vehicle's tires and the pavement surface, or a combination of both (2).

As there tends to be a wide variation in vehicle speeds on curves, there is usually a force created pointing towards the origin of the curve due to centripetal acceleration whether the curve is superelevated or not (2). Equation 2.1 shows that varying speed values along a curve with the same radius and superelevation would result in different values for the coefficient of friction. As the centripetal force acts towards the center of the curve, a balancing force is created through the distortion of the contact area of each tire with the pavement surface (2).

$$f = \frac{V^2}{15R} - 0.01e \qquad (2.1)$$

where:
f = Coefficient of side friction
V = Vehicle speed, mph
R = Radius of curve measured to a vehicle's center of gravity, ft, and
e = Rate of roadway superelevation, percent.

The coefficient of side friction is an important measure of inferred safety as it is a physical indicator of excessive curve speed that is discernable to the driver as he/she traverses an arced portion of a roadway at high speeds. The most important factors related to the chosen coefficient of side friction are the speed of the vehicle, the type and condition of the roadway surface, and the type and condition of the vehicle tires (2). While these factors might be significant in design, the Green Book uses driver discomfort as a “key consideration” in the selection of a maximum side friction value (2). From the compiled research available, AASHTO developed the graph in figure 2.4 to determine maximum coefficient friction value from a selected design speed, and equation 2.2 uses the maximum coefficient friction value to determine a minimum curve radius.

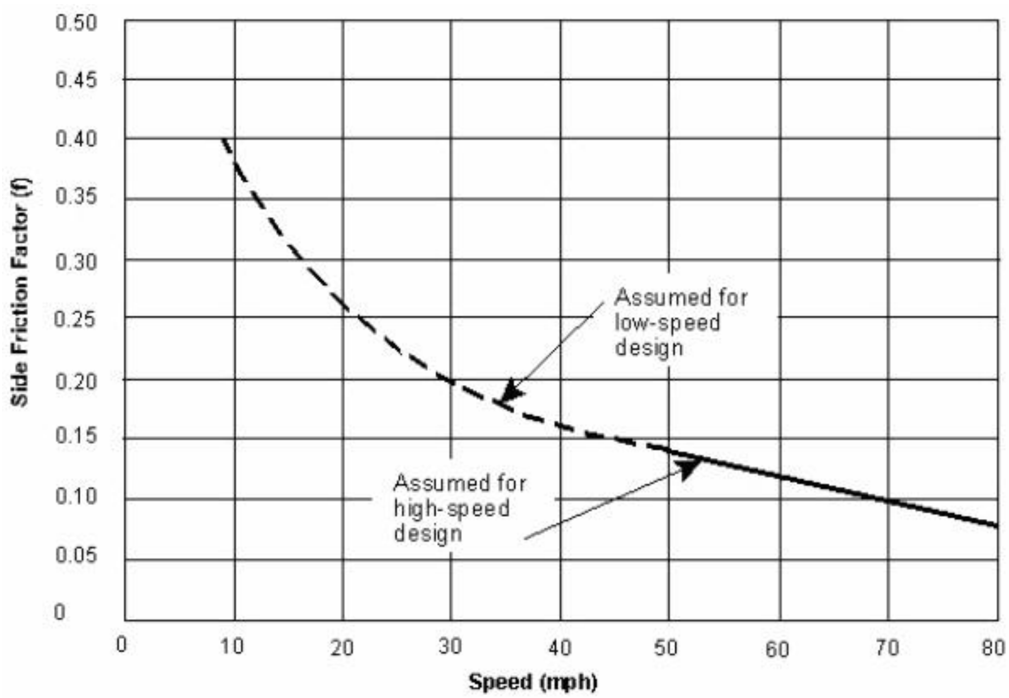

Figure 2.4 Side Friction Factors Assumed for Design (2, p. 139)

$$R_{min} = \frac{V^2}{15(0.01e_{max} + f_{max})} \qquad (2.2)$$

where: f_{max} = Maximum coefficient of friction,
V = Vehicle speed, mph,
R_{min} = Minimum curve radius measured to vehicle’s center of gravity, ft, and
e_{max} = Maximum rate of roadway superelevation, percent

Through the review of the coefficient of side friction, it can be seen that drivers following curved paths without appropriate superelevation may experience alarming discomfort if the curved roadway is not designed to mitigate the forces of centripetal acceleration. The Green Book provides a substantial amount of guidance for the design of horizontal curves with superelevation which may be applied to the design of work zone crossovers.

When considering the applicability of superelevation for a maneuver that would take a vehicle from an existing driving lane into the median, the cross slopes of the roadway must be considered. After entering the work zone, the single-lane operation section of the work zone on the approach to the crossover leaves a single driving lane with an adverse slope. This slope is considered to be "adverse" as drivers have to make a maneuver towards the median which is in the opposite direction of the curved path the vehicle is taking (2). Figure 2.5 shows how median crossover pavement cross slopes are controlled somewhat by existing pavement edge elevations.

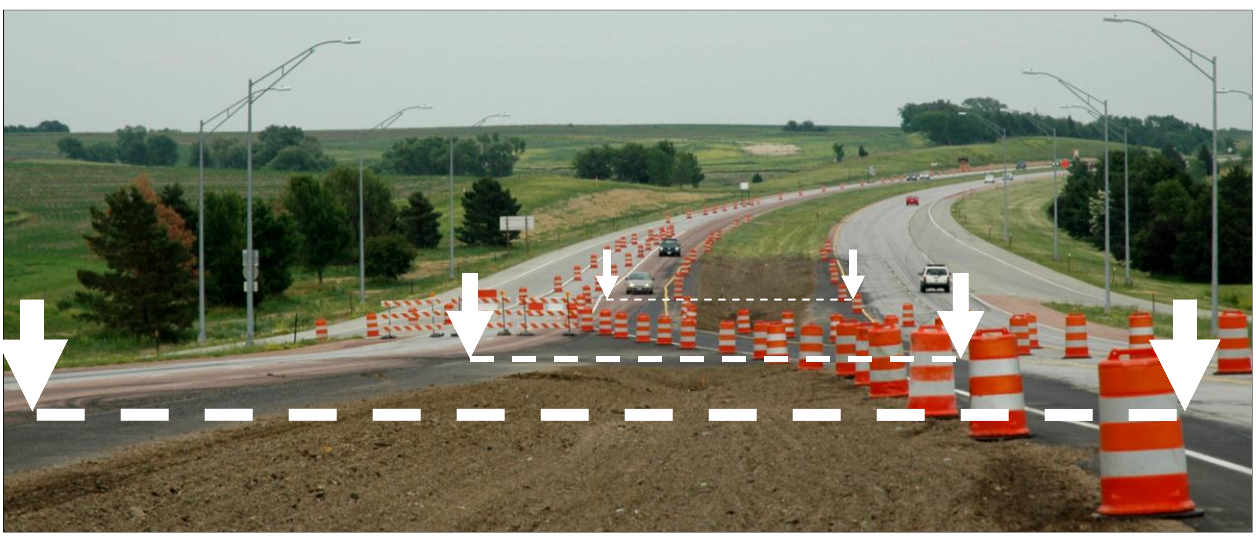

Figure 2.5 Controlling Edges of Existing Pavement Affects Geometry and Cross Section Slopes of Crossover Pavement

To best convey traffic along a curved path, a non-adverse slope is desirable to help sustain the forces present during lateral acceleration. Normally, the median-side surfaced shoulder is sloped in the appropriate direction, but the driving lane may not be, if the driving lanes are tangent rather than crowned, as shown in figure 2.6.

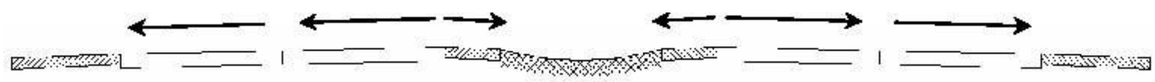

Figure 2.6 Typical Tangent Slope Roadway Cross-Section for a Four-Lane Divided Highway in Nebraska

Therefore a vehicle must negotiate a cross-slope “rollover” mathematically considered as the algebraic difference in grade between two adjacent lane cross slopes. The Green Book recommends that the maximum algebraic difference in the traveled way and shoulder cross slope grades should be from 6% to 7%, admitting that the maximum allowable change is not desirable.

In the example presented in figures 2.7 and 2.8, vehicles begin on the right side of the roadway and cross over to the left side of the roadway. On approach to the crossover, one lane will carry vehicular traffic. The outside lane is closed during the lane reduction section and traffic continues on in single-lane operation. As the closed lane will not carry traffic into the crossover, it will not need to be superelevated. Desirably, a superelevated lane would be partially constructed on the existing driving lane and would balance forces generated by centripetal acceleration due to the change in direction to enter the crossover.

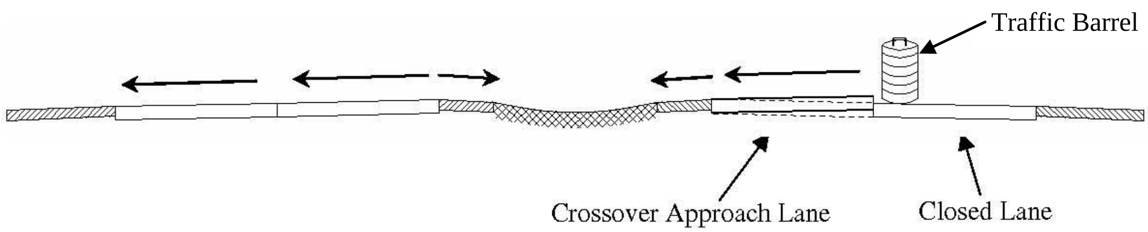

Figure 2.7 Desirably Superelevated Cross-Section for Crossover Entrance

To navigate a crossover, two changes in direction must occur. The first change in direction has already been noted with a transition from the existing driving lanes into the crossover. A second change in direction occurs when drivers exit the crossover. If the two-way traffic section of the work zone has a similar cross section to that shown in figure 2.6, there would be another adverse slope facing drivers on the exiting curve in opposition to balancing forces impacting their vehicles. Desirably this would warrant a non-adverse superelevated segment to assist drivers in negotiating the transition into the two-way traffic segment shown in figure 2.8.

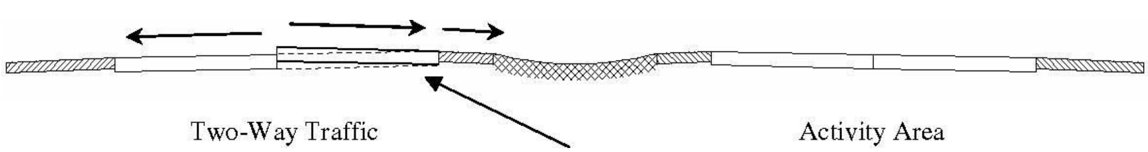

Figure 2.8 Desirably Superelevated Cross-Section for Crossover Exit

One concern for the design process previously described would be the practicality for existing lanes to be superelevated. Application of a new surface on existing lanes to provide a superelevation transition into or out of a crossover will create another source of "lost" costs (non-recoverable costs for temporary surfacing and disruption of traffic) for the construction project. This temporary surfacing may conflict with guidance in the Green Book which states that "geometric design should be based on acceptable surface conditions attainable at reasonable cost," and concerns are present with superelevating existing driving lanes as there would be costs for the labor to build, maintain, and remove this surfacing during the life of the maintenance project (2, p 134).

2.4 Crossover Design

In Nebraska, many single-lane crossover sites are designed to be reversible. This means that the same location in the median may be used at one time to act as an entrance to the work zone and as an exit crossover at another time during the construction project. A close examination of figure 2.9 provides an example of how the site could be used as an entrance crossover or an exit crossover. Figure 2.9 shows two arrows in the direction of travel for each crossover path to be used during the life of the project. The existing exit crossover conveys traffic along the path of the thin arrow while the path of the thicker arrow shows where drivers would pass along an entrance crossover.

Figure 2.9 Reversible Crossover Design in Nebraska on U.S.-34 in Lincoln, NE

As shown in figure 2.9, the crossover itself appears to be designed more as a flat diagonal or tangent design as there is a general 'X' shape to the asphalt that comprises the crossover within the median. In contrast, the pavement striping and traffic barrels provide a curved alignment for drivers to enter the crossover, a tangent path in the middle of the crossover, and then a curved path to exit the crossover. This would indicate a reverse curve crossover design with an intermediate tangent. In this research, the crossovers in Nebraska were considered to operate as reverse curve crossovers with intermediate tangents.

2.5 Crossover Design Types

A Federal Highway Administration (FHWA) sponsored study done by Graham and Migletz identified two separate types of crossovers from a geometric standpoint shown in figure 2.10. A reverse curve crossover was defined as employing two curves in the crossover while frequently using superelevation in the curves, and a flat diagonal design was identified that did not include curvature or superelevation (10).

After reviewing the Green Book's standards, a design that employs curvature may be the most appropriate for work zone crossovers. The use of superelevation provides for a more appropriate design when considering the force created by centripetal acceleration due to the changes in direction that crossovers require. From the two types of designs described by Graham et al., the reverse curve design will be considered first. Within the reverse curve design type, two categories can be considered. These include reverse curves with and without intermediate tangent segments between the first and second curves.

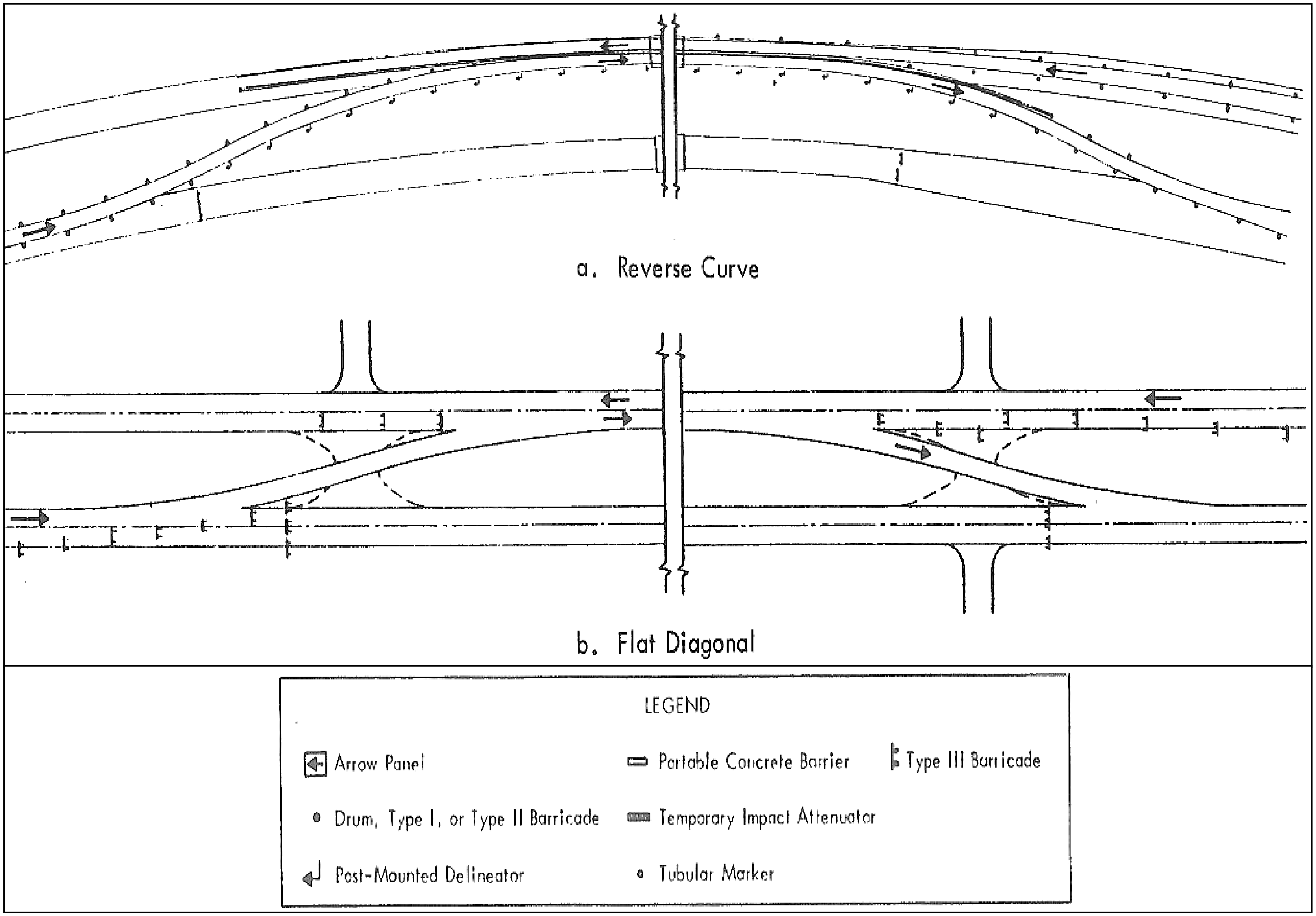

Figure 2.10 Crossover Design Types (10)

When designing reverse curves, AASHTO (4) does not offer any specific guidelines for the design of a reverse curve segment. Instead, the AASHTO guidelines would typically be applied for each curve individually (11). Easa et al. studied the design of reverse curves in a three-dimensional environment for trucks using data generated with Vehicle Dynamics Models Roadway Analysis and Design (VDM RoAD) simulation software. The conclusion from this project was that the "use of an intermediate tangent helps improve the driving dynamics of large vehicles such as heavy tractor-trailer combinations and increases the stability of vehicles operating on the alignment" (11). The existence of an intermediate tangent section between reverse curves improves safety and reduces the risk of rollover (11).

The second design category was the flat diagonal design. Another common name for this design is the tangent design type. The exclusion of curvature and superelevation makes for relatively easy field construction application, but may present some concerns in operation, especially on high-speed facilities. A possible technique to mitigate this problem would be to decrease the angle of departure at which vehicles transition from an existing lane into the crossover and then into an existing lane on the other side of the median. This decrease in the degree of directional change acts similar to an increase of the curve radius as vehicles would travel along a smoother and less abrupt driving path. This is supported by the Green Book which states that "very flat horizontal curves need no superelevation" (4, p. 144).

2.6 Crash Rates

Crash reports were analyzed by Graham et al. from multiple sites for tangent and reverse curve designs. At entrance crossovers, reverse curves had a crash rate of 1.66 crashes per million vehicles while for tangent designs the crash rate was lower at 0.88 crashes per million entering vehicles (10). In exit crossovers, the crash rate for the reverse curve design type was

1.66 crashes per million entering vehicles, and the tangent design type rate was 0.34 crashes per million entering vehicles (10). An important consideration for these rates is that they were not statistically different from each other. In further analysis, Graham et al. found that flat diagonal designs led to smoother speed transitions for drivers than reverse curve designs. In reverse curve designs, vehicles were observed to slow down along the beginning of the curve, speed up in the middle of the crossover, and then slow down at the ending curve (10).

In a study of work zone crashes along a 240-mile long turnpike in Ohio, Nemeth et al. (3) showed the need to improve safety for drivers at crossovers. A total of 185 crashes were observed over a period of 28 months summarized in table 2.1. The crash total was not able to be compared to other sites as no exposure data was available which would have compared the crash data during the work zone study to crash data over the same area during a period without the work zone in place. Also, the crash reports for crossovers do not include crossover design types. However, this data does provide the opportunity to compare crash frequency of work zone crossovers to other portions of a work zone.

Table 2.1 Work Zone Crash Statistics (2)

Zone		**Number of Crashes**		**Trucks at Fault**	**Injury Crashes**	**Multiple Vehicle Crashes**
		Total	Percentage of Total			
Advance		12	(6%)	2	3	5
Taper		17	(9%)	7	3	7
Single Lane		43	(23%)	23	16	19
Crossover:	First Curve	49	(26%)	36	9	9
	Total	63	(34%)	47	11	14
Bi-Directional		41	(22%)	16	19	22
Other Work		9	(5%)	1	0	2
Zone Total		185	(100%)	96	52	69

From the data compiled in table 2.1, Nemeth et al. determined that about 34% of the total crashes occurred within the limits of crossovers. The majority (78%) of these crashes occurred along the first curve, or entrance, of the crossover. Trucks were at fault for nearly 75% of the total crashes on the observed crossovers from the studied crash reports. As currently recommended by the MUTCD, a crossover should be designed to accommodate all types of vehicular traffic. The number of crashes seen in this study that were attributed to trucks implies that the studied crossovers may not have been designed to safely accommodate trucks. Nemeth et al. found that "in some cases drivers simply could not negotiate the first curve at the beginning of crossovers," and that the majority of these "tended to be drivers of heavy trucks" (2).

2.7 Horizontal Curve Transitions

NCHRP Report 439 was reviewed to provide background on possible study methodologies for work zone crossovers. Bonneson used the lateral placement of vehicles in a driving lane to develop evaluation criteria for tangent-to-curve and spiral transition designs. One goal of Bonneson's study stated that the lateral velocity and displacement for vehicles should be as small as possible when exiting a transition into a curve (12). Among the developed evaluation criteria, Bonneson specified that the lateral displacement should not exceed 1.0 m (3.28 ft) for vehicles passing through the horizontal curve transitions (12).

Additionally, Bonneson's research into lateral accelerations may have an application to the design of reverse curve crossovers. In Bonneson's analysis, the effects of accelerations for vehicles passing through tangent-to-curve designs were found to be independent of curve direction. This result indicates that the magnitude of acceleration created for drivers navigating curves to the left was equal for curves to the right (12). In reverse curve crossovers, this allows for the two individual curves to be studied independent of curve direction. Furthermore, the sum of superelevation and friction accelerations was not found to be great enough at the point of curvature (PC) along the curve to counterbalance the centripetal acceleration, which meant that a lateral displacement was considered inevitable (12).

2.8 State Standards

To further research crossover guidelines, roadway manuals and specifications were reviewed on all state department of transportation websites. Out of the 50 states reviewed, all 50 states had roadway design standards available. Upon further review of the available standards and specifications, a total of 11 states included specific guidance for the design of work zone crossovers. To provide a brief overview, the available guidance from each state was organized into separate categories and table 2.2 summarizes the compiled results.

Table 2.2 Summary of State Standards by Design Category

State DOT		Guidance Categories		
		Design Type (Tangent/Reverse Curve)	Minimum Lane Width	Design Speed
Connecticut	(13)		X	X
Iowa	(14)	X	X	X
Michigan	(15)	X		X
Mississippi	(16)			X
Montana	(17)		X	X
Nebraska	(18)		X	
New York	(19)		X	X
Oregon	(20)	X		
South Dakota	(21)	X	X	
Washington	(22)	X	X	X
Wisconsin	(23)			X

Note: (Reference Number), ‘X’ indicates that guidance is available.

Some inconsistencies exist amongst the crossover guidelines provided by different states. For example, in the design type category, five states provided conflicting guidance. The

Washington DOT directly stated that "flat diagonal crossovers are better than reverse curves with superelevation" (22). Michigan DOT (15) includes guidelines for the design of reverse curve crossovers without superelevation. The three remaining states, Iowa (14), Oregon (20) and South Dakota (21), include guidelines for the design of superelevated reverse curves. For the state of Nebraska, the only stated standard is a crossover lane width of 16 feet (18).

2.9 Summary

Direct guidance specific to crossover design was not available in the 2004 AASHTO Green Book. Research by Easa et al. into reverse curve design shows that current standards in the Green Book may not be sufficient for the design of reverse curves. The research of Graham et al. and Nemeth et al. showed that the safety of crossovers may be suspect. Bonneson's research with horizontal curve transitions provides evidence that lateral shifts are inevitable for vehicles going through transitions into and out of crossovers and that the measurement of lateral placement is a valid benchmark for safety. The guidance available from a few states is variable and not consistent.

Chapter 3 Single-Lane Crossover Site Selection

In the summer of 2006, a list of work zone crossovers in the State of Nebraska was compiled and is shown in table 3.1.

Table 3.1 List of Single-Lane Crossover Projects in Summer 2006

Project Name	Highway	Distance from University of Nebraska-Lincoln Campus
Doniphan North	US-34	96 miles
York N & S	US-81	54 miles
Lincoln West	US-34	7 miles
Fremont East Bypass	US-275	50 miles
Springfield North	N-50	47 miles
Jackson East	US-20	155 miles

From these projects, only single-lane crossovers were considered for this study. The decision to study single-lane crossovers over multi-lane crossovers or a selection of both groupings was due to the concept that single-lane crossovers would eliminate any influences on lateral displacement due to vehicles in adjacent crossover lanes. Any interactions or influences due to vehicles traveling in multiple crossover lanes would not be present in the collected data.

Of the six single-lane crossover projects that were in progress during the summer of 2006, several considerations were taken into account for study site selection. Funding limitations necessitated selection of study sites within a distance of less than 100 miles from the the University of Nebraska-Lincoln (UNL) campus. Figure 3.1 presents a map of Nebraska and the geographic locations of each of the 6 available project sites. Site visits and the proximity of the Lincoln West and Springfield North project sites to the UNL campus resulted in selection for data collection.

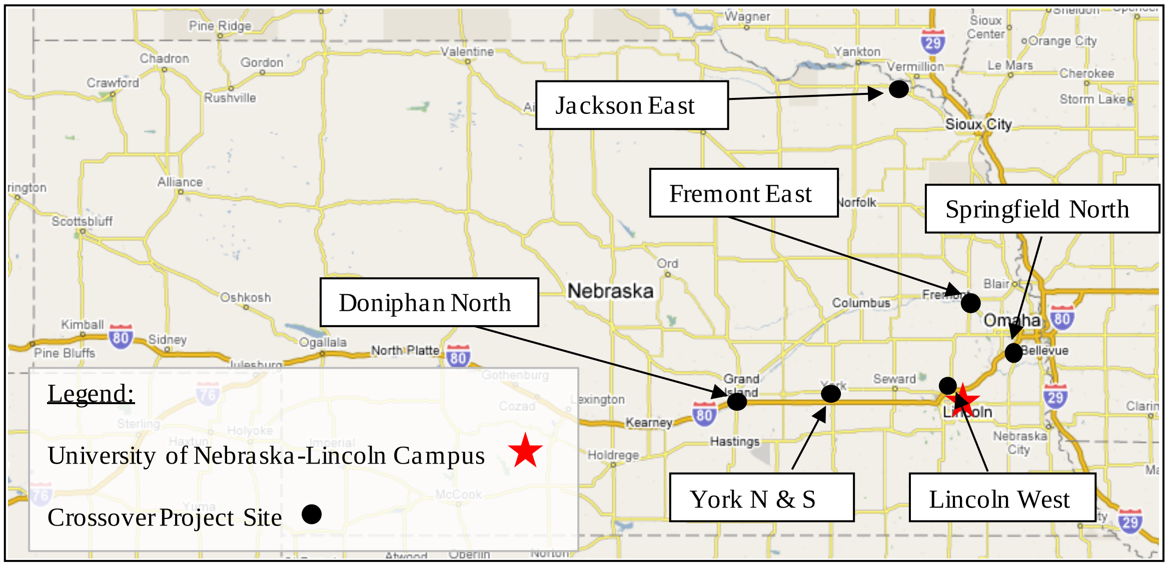

Figure 3.1 Map of Available Study Site Locations

The Lincoln West site only included one crossover shown in figure 3.2 but its proximity to the UNL campus allowed for testing the data collection method. One issue arose that arose during collection at Lincoln West was that some of the bolts securing the protecting rubber covers for the NC-97 detectors were bent during the time of data collection as vehicles drove over the protective covers. This issue was rectified by the acquisition of larger and stronger bolts for the Springfield North data collection.

Figure 3.2 Lincoln West Entrance Crossover

The Springfield North site offered two unique crossovers for data collection. The approach to the entrance crossover led drivers from a four-lane divided roadway into a lane reduction section, single-lane operation, through a stop-controlled intersection on the minor approach, and into the entrance crossover as shown in figure 3.3.

Figure 3.3 Springfield North Entrance Crossover

The exit crossover shown in figure 3.4 was located three miles away from the entrance crossover eliminating any effects that may have been observed due to the entrance crossover on the driver's speed choice and overall behavior. This crossover conveyed drivers from the two-way traffic portion of the work zone back across the median into a four-lane roadway section with a signal-controlled intersection. This situation occurs frequently as the majority of the six projects listed in table 3.1 had crossovers that began or terminated near major intersections that were signal-controlled.

Figure 3.4 Springfield North Exit Crossover

Chapter 4 Single-Lane Crossover Preliminary Behavior and Conflict Studies

4.1 Background

In order to fully understand the broad scope of features that are influential upon driver behavior and properly assess any variables that may impact safety in a work zone crossover, it was necessary to gather feedback from experienced construction personnel employed by NDOR that managed construction projects with crossovers. Appendix A shows an example of a Work Zone Crossover Questionnaire that was sent to the eight NDOR construction districts in the State of Nebraska.

The goal of determining the most favorable design of the work zone involves consideration of all possible features that affect its cost, planning, construction, operation, maintenance and removal and optimizing them into an effective, efficient and safe work zone feature. The questionnaire was separated into categories to cover the possible feature areas listed below:

Complicating Features

- Traffic control devices
- Intersections

Vehicular Accidents

- In approach section
- In lane reduction section
- In single-lane operation
- In entering portion of the crossover
- In the exiting portion of the crossover
- In the head-to-head section of construction zone

Advance Visibility

- Flat terrain, easy to see in advance
- Flat terrain, difficult to see in advance
- Rolling terrain, easy to see in advance
- Rolling terrain, difficult to see in advance

Edgeline Striping

- Smooth curve striping
- Angled segment striping
- Drivers able to stay within striping limits
- Drivers able to stay within barrel limits

Traffic Control Device (TCD) Location and Type

- Traffic plans easily understood
- Difficult to place TCDs according to plan
- Location and spacing of barrels adjusted for adequate sight distance
- Traffic barrels or channelizer cones used

Drainage

- Surface drainage a problem
- Ditch drainage a problem

Surface Construction

- Asphalt or concrete
- Detailed staking points established
- Surfacing elevations defined by existing traffic lane edge elevations
- Surfacing holds up to traffic loads

Other Problems Encountered

Other Comments

- About design
- About construction
- About maintenance
- About removal

4.2 Questionnaire Responses

Only two NDOR District construction project managers completed and returned the questionnaires. Both were concerning projects along Interstate 80. One project west of Big Springs, NE had a low enough traffic volume for the work zone crossover to be of the single lane type. The other project was in the higher-traffic-volume eastern part of the state, west of the Platte River Bridge and required a dual-lane crossover.

4.3 Single-Lane Crossover Comments

There weren't any complicating features or accidents along the single-lane crossover project. One crossover was in flat terrain and easily seen for several hundred feet before the lane reduction and the other was in rolling terrain but easily seen in advance. Edgeline striping was smooth along the crossover curves and drivers were easily able to stay within striping and construction barrel limits. Traffic plans were easily understood and followed. Barrels were used for channelizing and were adjusted for adequate sight distance once positioned according to plan. No surface or ditch drainage problems were experienced. Culverts were installed during crossover construction to ensure this. Surfacing was asphalt and was applied based on connection points with adjacent existing lanes. No detailed staking information was used. The surfacing held up well during use of the crossover. Overall, the crossover worked well.

Temporary lighting was installed which allowed good night vision and concrete barriers separated head-to-head traffic in the construction zone.

4.4 Review of Crashes within Single-Lane Work Zone Crossover Limits

Records of work zone crossover crashes were very difficult to find within the NDOR crash database. Of 15 crash reports collected from 3/18/1995 through 7/16/2006 on construction projects throughout the state, only one crash was reported within a crossover during icy surface conditions and no injuries were reported.

4.5 Preliminary Conflict Studies

Preliminary video recordings were taken of the three locations selected for single-lane crossover studies to better understand driver behavior and conflict types in entrance and exit crossver locations. This would allow refinement of more detailed studies to collect speed and vehicle lateral positioning data.

4.6 Lincoln West Single-Lane Crossover Observations

A feature that could be considered irregular at this location was the fact that it was in the vicinity of the NW 27th Street off ramp. The design of the crossover was such that drivers were channeled through a lane reduction from two through lanes to one through lane, then traffic barrels and multiple signs were used to alert drivers that the exit lane ramp diverged from the through lane to the right, which met drivers' expectations for an off ramp. The situation is depicted by figure 4.1.

Figure 4.1 Lincoln West Entrance Crossover and Well-Delineated Off Ramp for Access to NW 27th Street

Video recordings were taken of driver behaviors in daylight conditions. Video was reviewed for odd driver behaviors and vehicle conflicts. There were a very low number of conflicts and what few were observed were the result of a speed differential between a lead vehicle and a following vehicle. If the first driver in a platoon reduced speed, sequential drivers engaged their brakes and therefore their brake lights were observed which was considered a potential conflict. No unsafe driving behaviors were observed at this location during initial filming.

Due to the fact that the entrance crossover's physical location was along the approach to an overpass bridge and the preceeding vertical alignment was fairly flat, the configuration of the crossover could be viewed from a considerable distance in advance. This no doubt had an influence on a driver's ability to see the desired path ahead and allowed the time for adequate behaviors. The posted speed in the area in advance of the crossover was 50 mph for which decision sight distance for a speed/path/direction change on a rural facility is 750 ft which was exceeded at this location (2, p. 116).

In the guidelines of the MUTCD, in areas of crossovers, “pavement markings are used to effectively convey regulations, guidance, or warnings in ways not obtainable by the use of other devices” (4, p. 3A-1). The manner in which these markings are applied may have an impact on the positions drivers choose to locate their vehicles within the driving lane. Figure 4.2 shows a distant view of the edgelines that were applied on the Lincoln West entrance crossovers curves. Although somewhat distorted by the angle of the photograph, it is obvious that the lane lines were applied in straight lines between location marks provided for the striping crew. Resulting driver behavior, influenced at least somewhat by the edgelines, is shown in figure 4.3. The path defined by the edge lines can be critical to a driver approaching a curve transition if the view path is blocked by a slow-moving driver immediately ahead. It is desirable that lane edges in crossover zones be applied as accurately as possible. A significant number of initial location marks placed by a surveyor or member of the construction crew would aid the striping crew in this effort. The placement of smooth edgelines is also dependent upon the longitudinal smoothness of the crossover pavement. Special efforts should be made by the contractor to insure that the pavement (whether asphalt or concrete) when placed be up to the standards of permanent pavement installations. If this requirement isn’t already in a State’s standard specification, a special provision should be added to the contract to allow enforcement related to this issue. It is understandable that the position of the crossover between two active traffic roadway segments on either side of the construction of it and the fact that crossover construction is normally on a very fast track to avoid traffic conflicts makes the effort of quality control a challenge but specific alerts to attention in this critically important part of the work zone should reduce the chance that unsafe driver behaviors may occur.

Figure 4.2 Segmental Edgeline Striping at Lincoln West Entrance Crossover

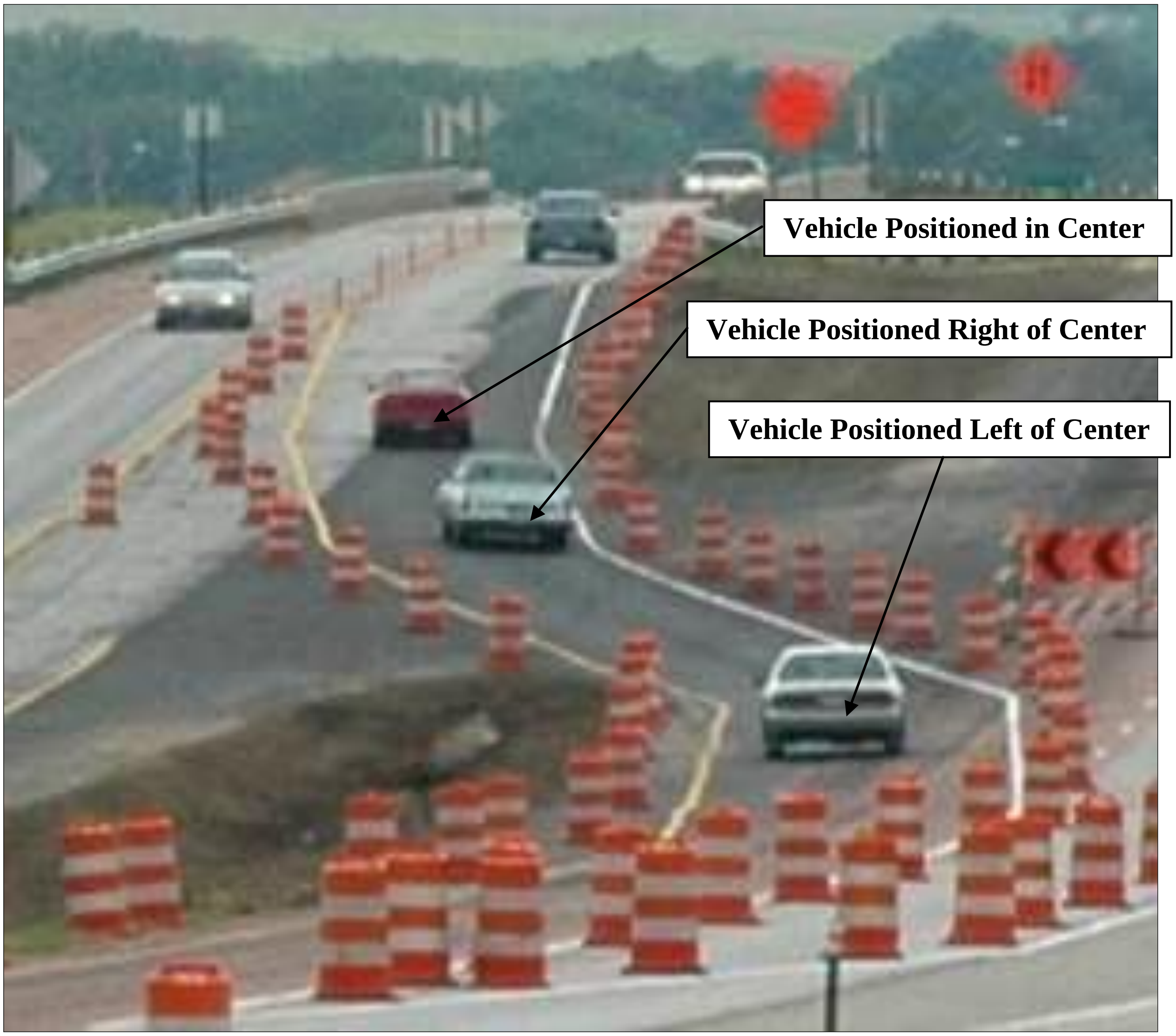

Figure 4.3 Driver Vehicle Positioning Relative to Edgeline Striping at Lincoln West Entrance Crossover

Another issue that was observed at the Lincoln West entrance crossover location was that the multitude of traffic barrels required according to the traffic control plans may actually block the view of a driver to see the advanced path required to successfully maneuver within the crossover. Figure 4.4 shows how sequential barrels placed in a line can significantly block a driver's vision with a relatively low line of sight, especially if the crossover is in flat terrain over an extended segment. This issue was investigated further by creating a realistic three-dimensional model of the Lincoln West crossover using MicroStation software. Creating the model allowed perspective views of the Lincoln West crossover when used as an entrance and as an exit. The simulated view position was set at 3.5 ft above the pavement surface and located relative to where a driver would be seated if the vehicle driven was centered within the traffic lane. Pairs of views from the simulation model are shown in figures 4.5 and 4.6 to exhibit the differences between using traditional traffic barrels and channelizer traffic cones.

Figure 4.4 Line of Sight Blockage Produced by Sequentially Located Traffic Barrels

Figure 4.5 Driver's View from Simulation Model of Lincoln West Crossover Entrance with Traditional Traffic Barrels (A) and Channelizer Traffic Cones (B)

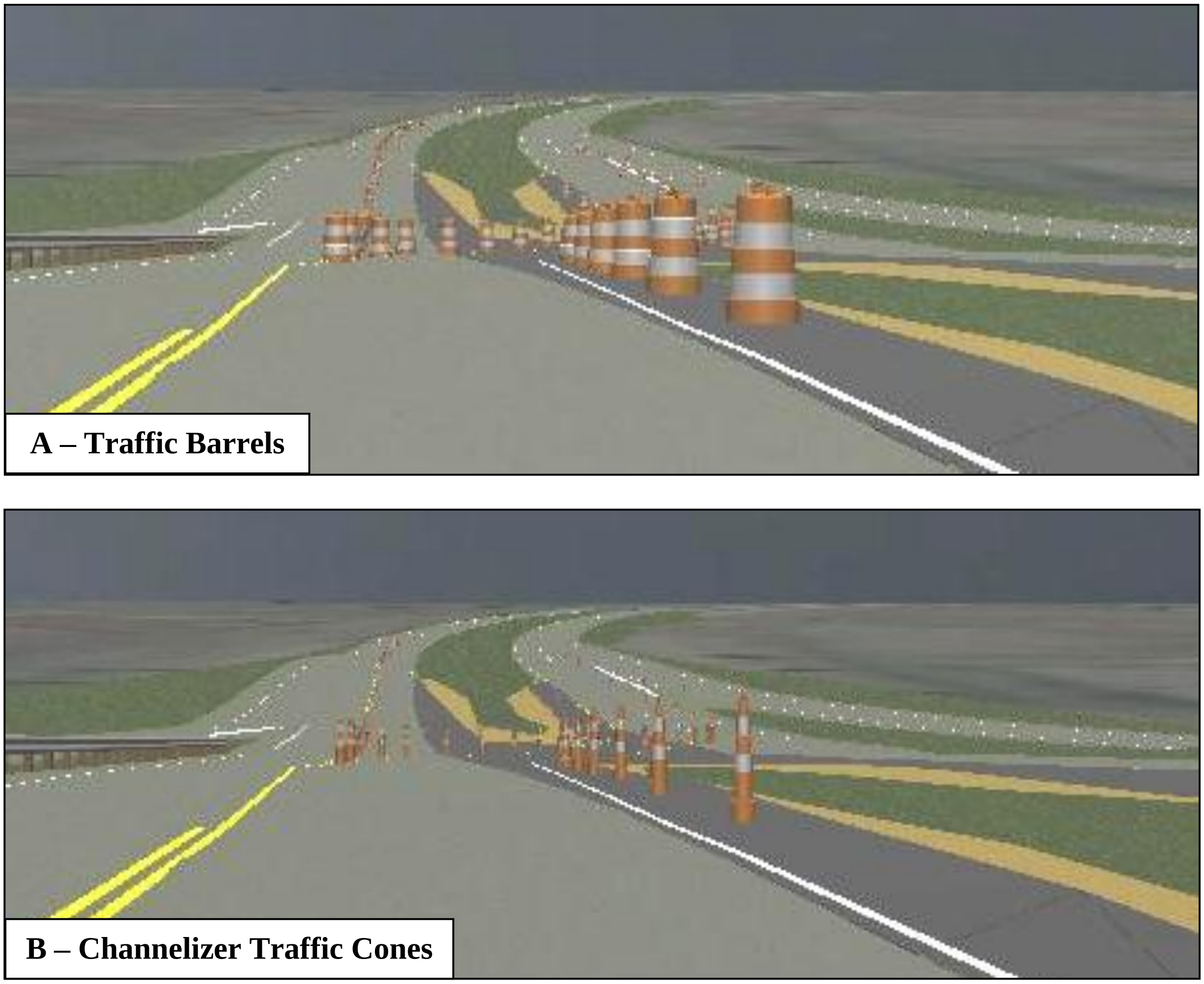

Figure 4.6 Driver's Eye View from Simulation Model of Lincoln West Crossover Exit with Traditional Traffic Barrels (A) and Channelizer Traffic Cones (B)

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Visual challenges for drivers are especially pronounced at night when retroreflective materials on the barrels bounce headlight illumination back at the drivers' eyes making the sequentially placed barrels appear like a glowing wall ahead. The use of channelizing cones appears to be the best choice of traffic control device, based on the simulation model and field observations. The MUTCD says "Applying…guidelines to actual situations and adjusting the field conditions requires judgment. Other devices may be added to supplement the devices and device spacing may be adjusted to provide additional reaction time or delineation" (4, p. 6H-1).

Drainage on the pavement of the crossover as well as drainage of the median ditch adjacent to the crossover is critical to account for in the optimal design of a crossover. If possible, the location selected for the crossover should be along a slope of ±0.5% if possible to encourage positive ditch and pipe flow. Figure 4.7 shows an example of the where the drainage concerns are located. Each crossover situation should be considered on a case-by-case basis to 1) determine the most appropriate initial location for the crossover, 2) acquire accurate elevation data on roadway cross slopes, edge line elevations of driving lanes and shoulders, and elevations of median flow lines to insure that design plans can be created that match the existing conditions. The designer must also recognize that areas on either end of the crossover location proper will be disturbed during its construction and should supply specific elevations that the contractor may use to reconstruct existing drainage conditions that complement the intended design.

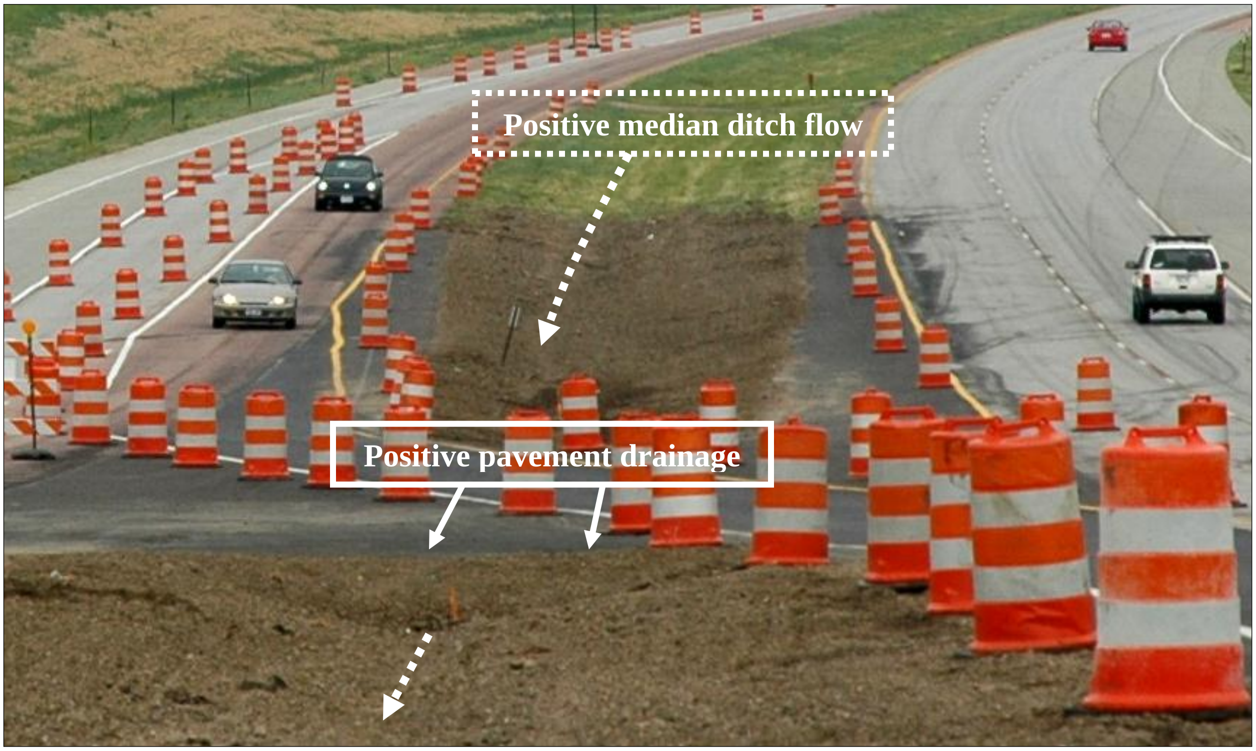


Figure 4.7 Locations of Concern for Positive Drainage

All of the recommendations above must be reasonable with respect to the ability of the project manager and the contractor to execute them under specific project field conditions.

4.7 Springfield North Behavior Observations

By far, the greatest conflict causes on the entrance and exit crossovers on the Springfield North project were the fact that there was a stop-controlled intersection with a minor road immediately preceeding the entrance crossover (as shown in figure 4.8) and there was a traffic signal immediately following the exit crossover depicted in figure 4.9. Of 468 total vehicles filmed in a one-hour preliminary behavior study video, 269 (over 57%) experienced conflicts that required braking. Entering traffic from the minor roadway directly impacted drivers on the major road approaching the entrance crossover and resulting in tailgating behaviors. Similar issues resulted from speed adjustments made due to cycle changes in the signal just beyond the exit crossover. It was clear that locating a crossover near either of these features had a negative safety outcome. If possible, the crossover location should be as far from intersecting roadways as possible or intersecting roadways should be temporary closed during construction if there is no other option for the crossover location.

Figure 4.8 Stop-Controlled Minor Road Intersection Immediately Preceeding Work Zone Crossover Entrance at Springfield North Project

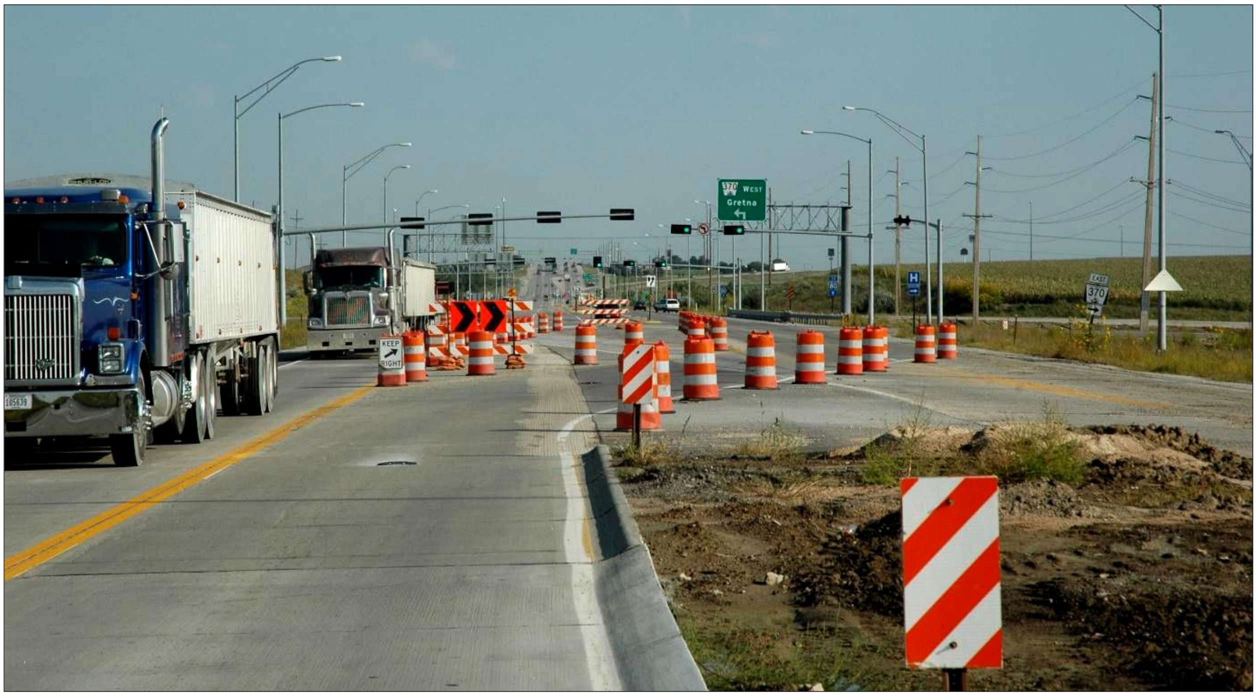


Figure 4.9 Traffic Signals at Intersection Immediately Following Work Zone Crossover Exit at Springfield North Project

Chapter 5 Single-Lane Crossover Data Collection

5.1 Data Considerations

For this research project, lateral displacement was selected as one type of safety benchmark for a work zone crossover study. Figure 5.1 shows several categories of factors possibly affecting or associated with lateral displacement of vehicles negotiating a work zone crossover. Ideally, the research effort should aim to collect data on all factors possibly affecting lateral displacement. However, funding resource constraints and practical considerations limit the data that can be collected in any research methodology.

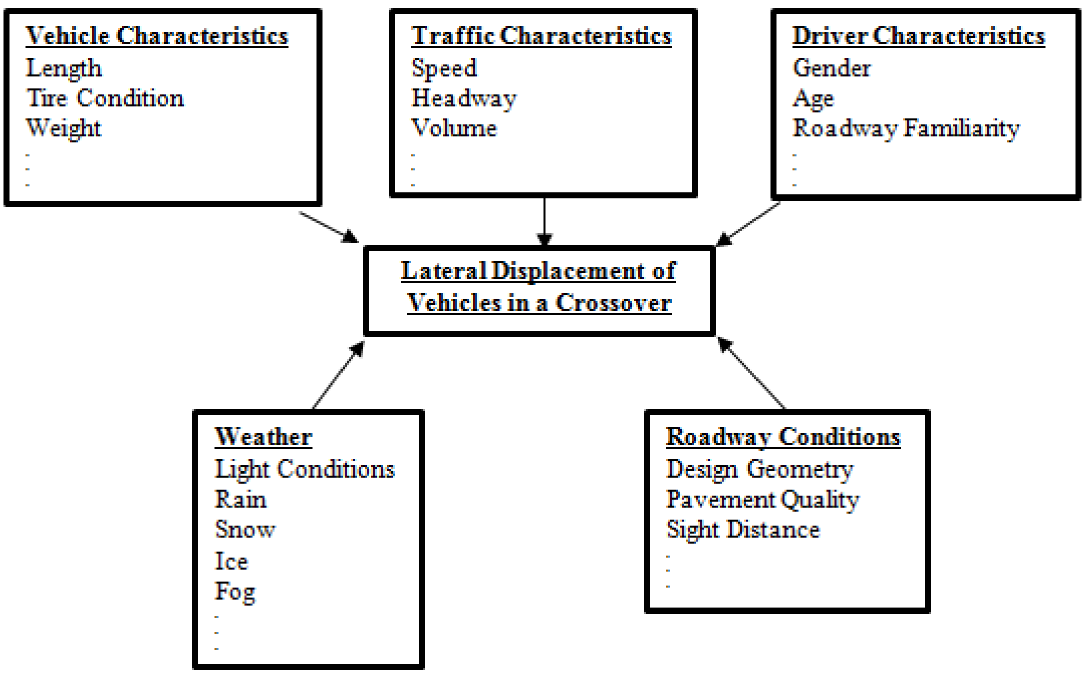


Figure 5.1 Possible Factors Influencing Lateral Displacement Reseach Data Collection Methodology

Of the considered categories, driver characteristics were difficult to collect as these required interviewing drivers in a work zone. Items listed in the roadway conditions category did not present enough variation due to the limited number of crossovers studied in this research.

Weather conditions were held constant by collecting data during clear weather conditions and during daylight hours. The collected item from the vehicle characteristics was vehicle type (passenger car or heavy vehicle) which was based on the measurement of vehicle length. Amongst traffic characteristics, speed, headway and volume were measured.

One focus of this research study concerns lateral displacements of vehicles within work zone crossovers. A set of hypotheses were developed to focus on lateral displacement and speed of vehicles within crossovers which was then followed by a model investigating the effects of multiple factors on lateral displacements of vehicles. HiSTAR NC-97 detectors manufactured by Nu-Metrics and video cameras manufactured by Canon were used to collect the data.

5.1.1 Single-Lane Crossover Studies

Studies were undertaken to investigate and analyze lateral displacements of vehicles along reverse curve crossovers in the state of Nebraska to determine the nature and possible influences of lateral displacements of vehicles within work zone crossovers. The research identified three hypotheses to investigate the lateral displacements of vehicles in single-lane work zone crossovers:

1. Mean lateral displacements are different for all three observation locations along each individual crossover. This allows any statistically significant changes between the lateral displacement means from one observation location to the next observation location along a crossover to be discerned. It will provide insights into whether or not vehicles follow a path of significantly differing displacements.
2. Mean vehicular speeds will be equal for all three observation locations along each individual crossover. This allows any statistically significant change in vehicular speed between one location to the next along the crossover to be discerned. Testing of

the hypothesis provided insights on whether or not changing speeds are a factor on observed lateral displacements along the studied crossovers.

3. Mean lateral displacements at all three observation locations along each crossover is less than 3 feet. This determined if conditions indicate that the majority of drivers vary less than 3 feet from the center of their lane.

While ANOVA (analysis of variance) tests and confidence intervals were used to verify the three hypotheses listed above, linear regression and panel models were utilized to obtain additional insights into lateral displacements of vehicles in a crossover. These models analyzed the effects of vehicle type, vehicle speed, headway, direction of displacement, and free-flow conditions on lateral displacements within work zone crossovers while comparing the model results to hypothesis expectations.

Perspective driver views of the construction zone were also developed and reviewed for recommendations to improve the visual attributes of the work zone crossover to improve driver expectancies.

5.1.2 HiSTAR NC-97 Detectors

The ability to collect three separate types of data (vehicle speed, vehicle length, and headway) and availability of in-house detection devices led to the selection of NC-97 detectors for data collection. These detectors use a technique known as Vehicle Magnetic Imaging (VMI) to detect vehicles. When a vehicle passes over the detector, the magnetic mass of the vehicle's metal parts interferes with the normally static magnetic field produced by the Earth. This interference produces an electrical charge in the detector's sensors directly proportional to the vehicle's magnetic mass (24). This technique allows the detector to detect the presence of a vehicle, measure the vehicle's speed, and length. The NC-97 model determines the speed by using Multiple Derivative Correlation (MDC). This process employs the hardware to convert the analog magnetic signals from the sensors into a random number of derivatives representing a digital binary format for each area of magnetic influence from the passing vehicle (24). This method is utilized in speed determination as it “greatly improves the accuracy of speed and length classification,” for each observation (24). Specifications for the NC-97 detectors show that measured vehicle speeds are accurate to +/- 4.2% at a 95% probability level and measured vehicle lengths are accurate to +/- 8.0% at a 95% probability level (24).

NC-97 detectors were installed on the pavement surface as shown in figure 5.2. First, the detectors were centered laterally within the driving lane. Next, protective rubber covers were placed over each detector and bolted to the pavement. Following installation, the detectors began collecting data at a specified program time.

Figure 5.2 Installation and Installed View of NC-97 Traffic Counter/Classifier

The two types of vehicles (passenger cars and large vehicles) were determined based upon measurements of vehicle length from the NC-97 detectors. Each vehicle passing through a crossover study site was classified based on the collective results of the NC-97 detectors at that site. The vehicle lengths used in determining these classifications were based on the NC-97 detector manual (24). In the NC-97 manual, passenger cars were considered to have lengths of 21 ft or less. The ranges for the two vehicle categories are shown in table 5.1.

Table 5.1 NC-97 Defined Vehicle Classifications by Length

Vehicle Classification	Numerical Value	Length (ft)
Passenger Car	0	0-21
Large Truck	1	Greater than 22

5.1.3 Video Cameras

Lateral displacement was determined through the use of video cameras. One concern from this method of data collection was an influence on driver behavior due to cameras being located around the study locations. To mitigate any influence of the video cameras on driver behavior, the cameras were placed on tripods and then concealed within traffic barrels as shown in figure 5.3.

Figure 5.3 Video Camera Concealed from Immediate View by Traffic Barrel

Passing vehicles were filmed by concealed video cameras at angles perpendicular to the roadway's direction of travel. To measure the lateral displacements on the recorded video, blue dots were painted along a 2-ft by 2-ft spacing in a diagonal manner shown in figure 5.4.

Figure 5.4 Painted Dots Used for Estimation of Lateral Positioning

Blue paint was used to make the dots less visually apparent to drivers. This process allowed specific points in the viewing area of the camera to be recorded for distance. The camera's field of view from left to right allows the use of painted dots act as distance benchmarks. The distance between any two points represents two feet of distance in the direction of traffic flow as well as two feet of lateral distance within the driving lane. For the video cameras, length of video collection was limited to the recording time of one video tape, or the length of the battery life of the video camera (about two hours).

To enable comparisons of lateral displacements of vehicles within crossovers with the position drivers normally place themselves within a driving lane, control data was needed. Two locations along Hwy N-50 south of the Springfield North project were selected to collect baseline data to compare with crossover positioning data to be collected on the single-lane crossovers of Lincoln West and Springfield North project and dual-lane crossovers to be studied later. One location was on a two-lane segment of N-50, shown in figure 5.5, and one was on a four-lane segment of Hwy N-50 which had recently been completed, depicted in figure 5.6. Both locations were in level terrain and were similar in overall traffic volumes to the projects under study.

Figure 5.5 Two-Lane Segment of Hwy N-50 Used for Baseline Lateral Vehicle Lane Positioning

Figure 5.6 Four-Lane Segment of Hwy N-50 Used for Baseline Lateral Vehicle Lane Positioning

5.2 Baseline Data Collection

Figure 5.7 shows a plan view of the method of measurement of vehicular lateral displacements. The centerline of the driving lane is defined as zero feet of lateral displacement. Measurement of lateral displacement is determined from the distance between the vehicle centerline and the driving lane centerline. Lateral displacements are observed along the studied crossovers at three data collection locations:

- Location 1 – Beginning of the crossover
- Location 2 – Middle of the crossover
- Location 3 – Exit of the crossover

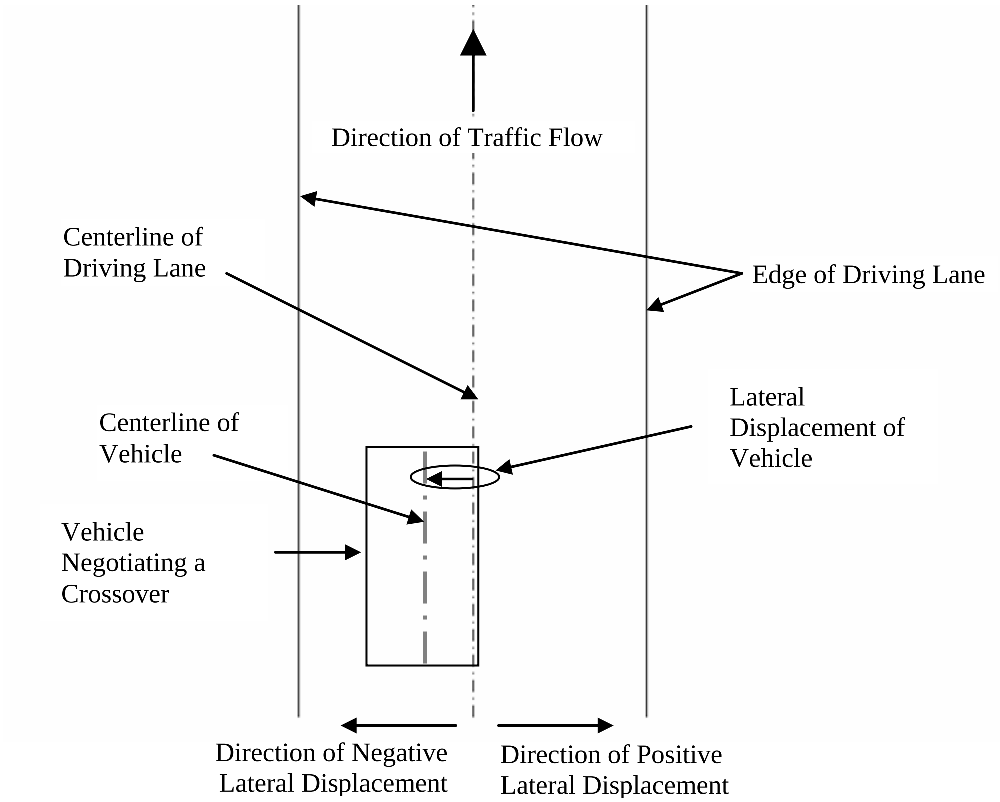


Figure 5.7 Example of Lateral Displacement Measurement on a Crossover Study Site

Baseline data was collected on the two-lane and four-lane locations by placing three NC-97 detectors 250 ft apart to collect speed and vehicle classification information. Barrel cameras were set adjacent to the speed detectors to capture lateral vehicle positioning. Figure 5.8 shows schematic drawings of the installations.

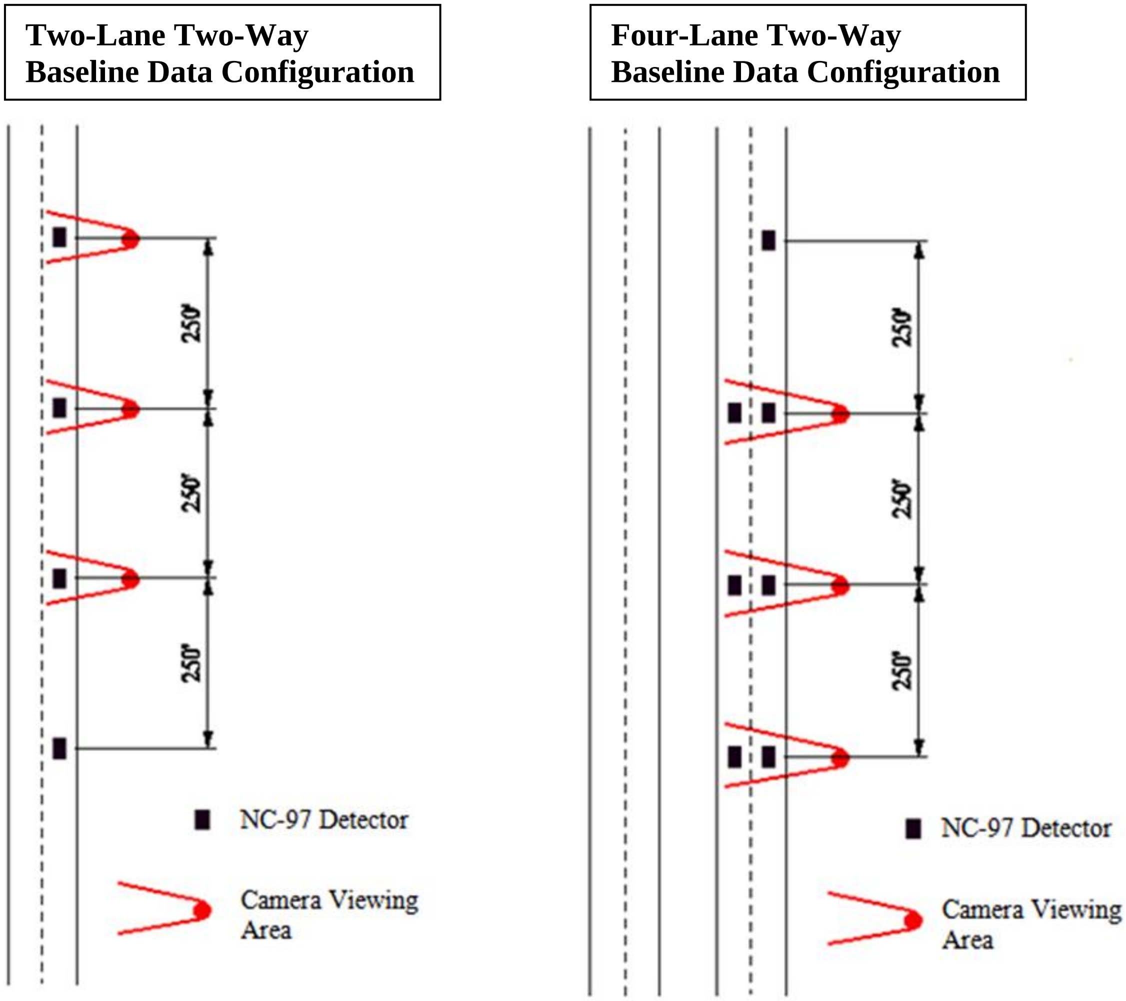


Figure 5.8 Data Collection Layout Schematics for Baseline Lateral Vehicle Positioning within Driving Lane

The average displacement on the two-lane roadway segment was +0.29 ft (to the right) of the center of the driving lane. The average displacement of drivers in the left lane of the dual-lane segment was +0.34 ft (to the right) and +0.11 ft (to the right) in the right lane of the dual-lane segment. This indicates that drivers tend to shift from 3 to 4 inches right from both approaching traffic and adjacent lane traffic in the same direction.

5.3 Data Collection

Data collection for the crossover sites focused on the critical locations where vehicles would be observed. Three critical locations were defined within the crossover at each study site. Video collection took place at each critical location along the crossovers to determine lateral displacements. These locations were variable depending on site conditions, but generally occurred in the entrance, middle, and exit areas of each crossover. These general areas are referred to as Location 1, Location 2, and Location 3, respectively. Figure 5.9 shows the crossover layout along U.S.-34 at the Lincoln West project site. Figures 5.10 and 5.11 present the layouts along Hwy N-50 at the Springfield North project site for the entrance and exit crossover, respectively.

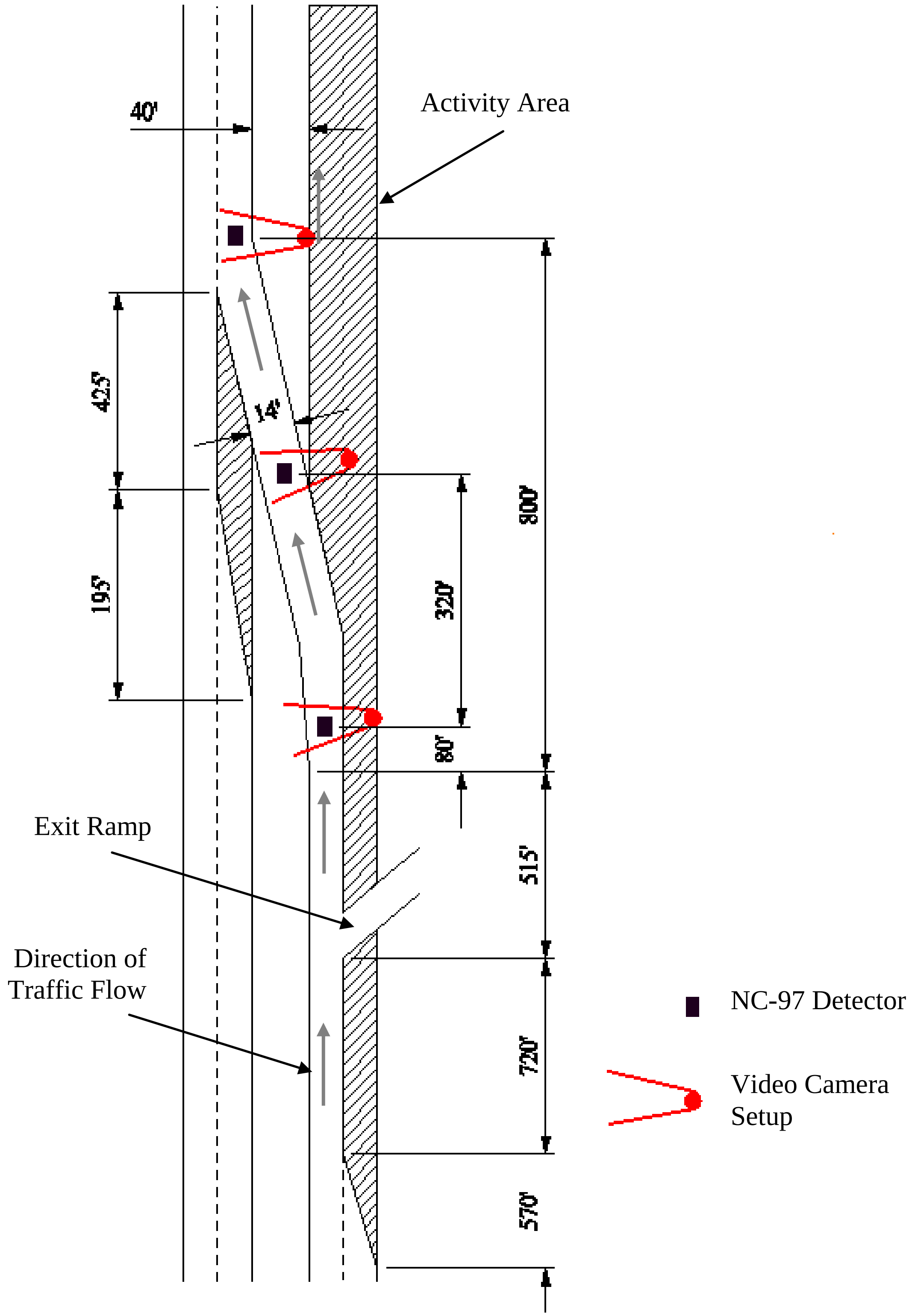


Figure 5.9 Data Collection Layout for Lincoln West Crossover (not to scale)

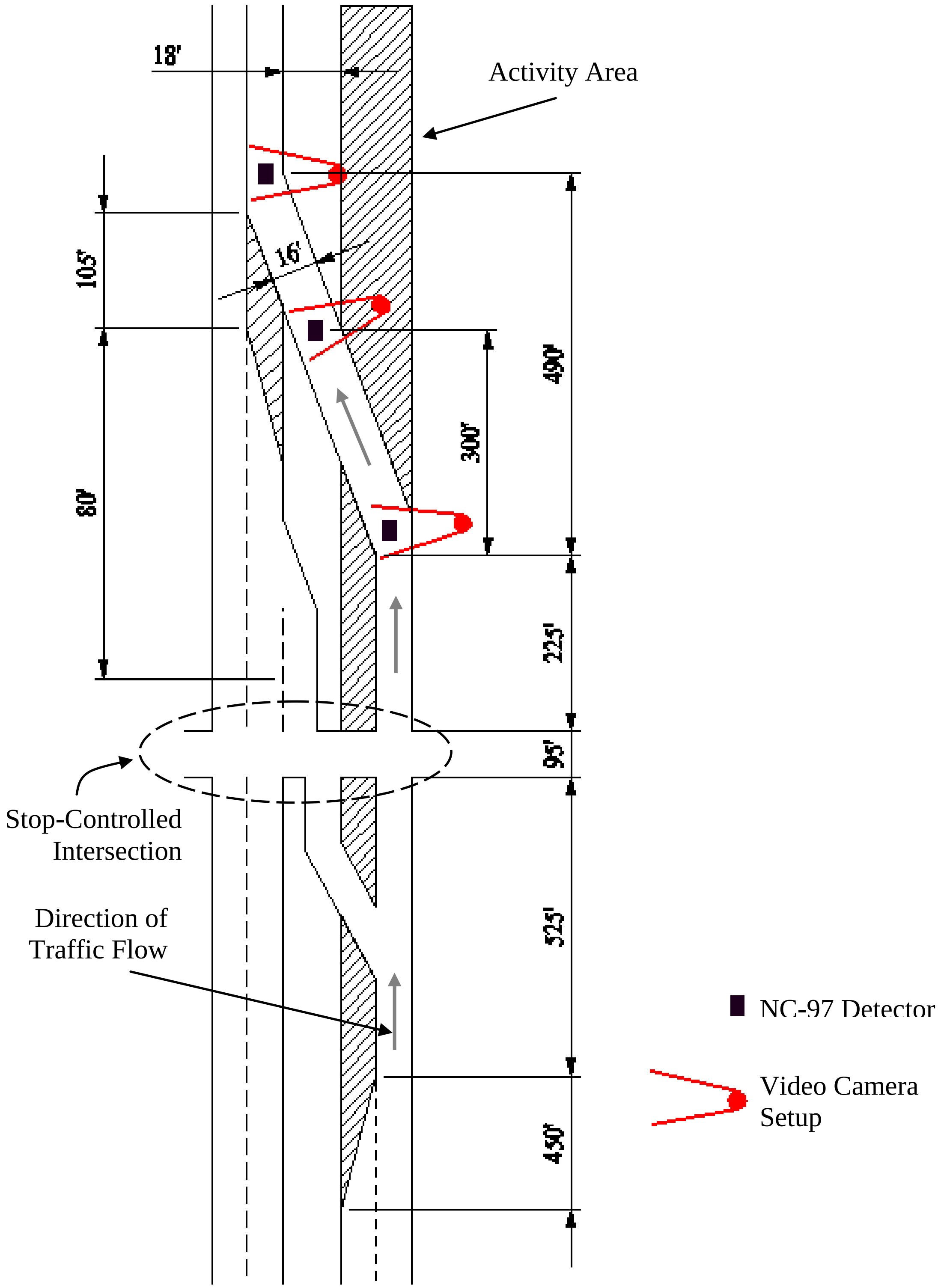


Figure 5.10 Data Collection Layout for Springfield North Entrance Crossover (not to scale)

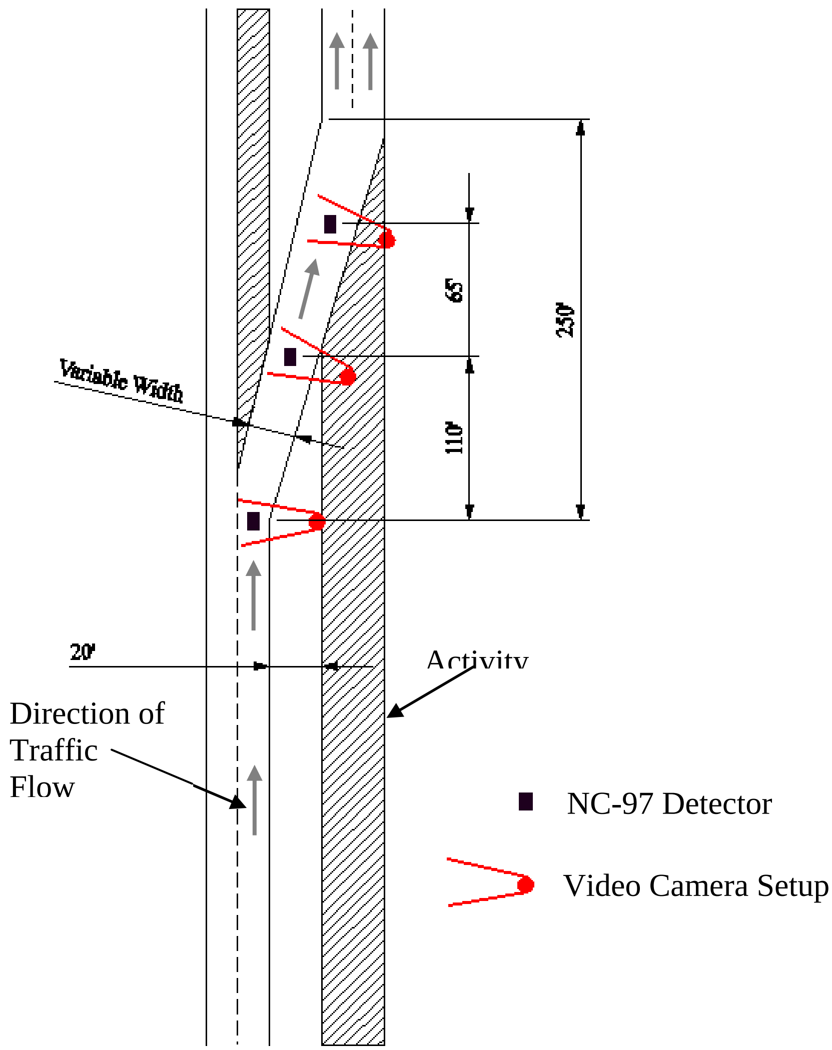


Figure 5.11 Data Collection Layout for Springfield North Exit Crossover (not to scale)

5.4 Collected Data

From the data collection process, the majority of the nine study locations provided complete data sets over the two-hour study periods. Three instances of equipment malfunction resulted in limited data collection. For the exit crossover on N-50 at Springfield North, the NC-97 detector located at Location 2 of the crossover failed to collect any data points. Therefore, no data was available for vehicle speed, type, and headway at this point. The second instance concerned short battery life for one of the video cameras. The video camera viewing Location 3 of the entrance crossover at Springfield North stopped recording after approximately one hour. The third instance was a minor problem at Location 1 of the Springfield North exit crossover when the video camera battery stopped recording near the end of data collection. This instance was considered minor as more than 454 observations had been collected out of the approximate total of 560 observations.

In some cases, there were differing numbers of vehicle observations between crossover observation locations due to camera start and end times or from vehicles already present in the study area when data collection began or ended. Appendix B displays the final data set from each crossover location.

Chapter 6 Single-Lane Crossover Lateral Displacement and Speed Data

A preliminary analysis of the collected lateral displacement and speed data at each observation location was conducted to assess normality and dependence. This process allowed an understanding of any influences on the results of the analysis that may be due to the nature of the data collected.

6.1 Lateral Displacement Data

6.1.1 Assessing Normality

Normality of the lateral displacement data at each of the nine observation locations was reviewed. This review was conducted to assist in the selection of a proper analysis technique. Appendix C shows distributions of the lateral displacement data for the nine observation locations and a brief discussion on how the Central Limit Theorem was applied to support the assumption of the data being normally distributed.

6.1.2 Data Dependence

With the observation locations located in series along a single lane roadway, the possibility of dependence within the data was investigated. First, dependence was investigated at each individual observation location. In Chapter 7, a panel analysis is discussed that determines the impact of dependence through the use of all collected data.

For the review of dependence at individual observation locations, the difference between free-flow and non-free-flow conditions was used to investigate dependence. As vehicles passed through the studied crossovers, there were two observation conditions. Some drivers were observed in free-flow conditions while other drivers were observed in non-free flow conditions. Observations collected during free-flow conditions were assumed unaffected by other vehicles in the area. Observations collected during non-free-flow conditions were considered influenced by nearby vehicles in the crossover lane. Therefore, any dependence within the lateral displacement data was attributed to the speed differential with nearby vehicles.

Determination of free-flow condition was based upon headway. The Highway Capacity Manual (HCM) provided guidance on assessing free-flow conditions. A lane density of 11 cars per lane per mile, representing a level of service A on multilane highways, was used to calculate a vehicle spacing of 507 ft (25). From this value, the time it would take drivers to travel 507 ft at 50 mi/h was calculated to be 6.9 seconds.

A speed of 50 mi/h was used because the posted speed limit around all three crossovers was 50 mi/h. As the crossovers had advisory speeds of between 35 mi/h and 40 mi/h, many drivers decreased their driving speeds on the crossover approach. Less than 50% of drivers were observed to exceed the 50 mi/h speed limit at the eight observation locations for which speed data was available. This meant that the majority were traveling slower than 50 mi/h through the crossover, and indicated that the selection of the 50 mi/h speed was a conservative estimate of free-flow speed for the majority of the vehicles observed.

Individual vehicle observations were recorded as existing in free-flow conditions if the collected headway value was 7 seconds or greater which was based on the previously calculated value of 6.9 seconds. With the assignment of free-flow and non-free-flow conditions to each observation, the sample populations for each location were compared in Appendix D to determine if there was a significant difference in lateral displacement observations. The results from the analysis in Appendix D determined that only one location had a significant difference between free-flow and non-free-flow populations. This was Location 1 at the Springfield North exit crossover. For analyses at the location using lateral displacement data, the free-flow portion of the data was used. In all other analyses for specific observation locations, all of the collected lateral displacement data were used by grouping the two categories of data together.

6.1.3 Review of Data

As expected, lateral displacements along the crossover study sites showed a large range in average values as summarized in table 6.1. The measurement system first shown in figure 5.7 is used with displacements measured to the left of the roadway centerline being recorded as negative values, and displacements measured to the right of the centerline being recorded as positive values. The centerline of the roadway was considered to be the point of 0.00 ft of displacement. In Appendix E, the computer program AutoTrack was used to validate the assumption that the roadway centerline was a suitable location for 0.00 ft of lateral displacement.

At the Lincoln West crossover, the observation locations had mean displacement values ranging from -0.89 ft at Location 2 to 0.00 ft at Location 3. At the Springfield North entrance crossover, the mean displacements were to the left of the centerline in a narrow range from -1.06 ft to -0.88 ft. The biggest range in displacements occurred at the Springfield North exit crossover with values between -1.00 ft and 0.03 ft.

Table 6.1 Summary of Lateral Displacement at Crossover Sites

Crossover Site	Average Displacement (ft)			Total Number of Vehicles		
	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Lincoln West (Entrance Crossover)	-0.30	-0.89	0.00	537	534	535
Springfield North (Entrance Crossover)	-1.06	-0.95	-0.88	435	447	196
Springfield North (Exit Crossover)	-0.03	0.03	-1.00	454	566	563

6.1.4 Masking

An aspect that had to be considered for analysis was the occurrence of masking in the data. Masking can occur when means are calculated from negative and positive values. While the calculated means will show the true average of the data, the average magnitude of displacement may be masked resulting in a mean value closer to zero. A method to eliminate masking is to apply an absolute value to each lateral displacement value making the entire data set greater than or equal to zero. Another method is to review squared values. However, the decision was made not to pursue these options because the true distribution of displacements would be skewed. A skewing of the distribution would create an undesirable effect on the analysis process, so it was concluded that both positive and negative values would be used for analysis.

6.2 Speed Data

6.2.1 Assessing Normality

Research into vehicular speed data provided a more direct review into the normality of the collected data. While the normality of lateral displacement data was reviewed by distribution shape, analysis, and then referenced to the Central Limit Theorem, the normality of the collected speed data distribution was assumed as “speed… data is commonly described using the normal distribution” (26).

6.2.2 Data Dependence

Similar to lateral displacement data, the speed data was checked for dependence between vehicles considered to be traveling in free-flow conditions and non-free-flow conditions in Appendix F. The check for dependence showed that the free-flow speeds differed significantly from the non-free flow speeds for Locations 1 and 2 at Lincoln West and for Locations 1 and 3 at the Springfield North exit crossover. Therefore, speed data for these locations was limited to observations collected in free-flow conditions.

6.2.3 Review of Data

A background of the speed data is given for each observation point in table 6.2. For the eight locations where speed data were available, none of the observed mean speeds exceeded the work zone speed limit (50 mi/h in all cases). Five locations had mean speeds that exceeded the posted advisory speed for the crossover. Another observation is that the highest mean speed occurred at the middle location for two of the crossovers. The third crossover could not be assessed as there was no available speed data due to malfunctioning equipment.

Table 6.2 Posted and Observed Speeds in Crossovers

Crossover Site	Location	Work Zone Speed Limit (mi/h)	Posted Advisory Speed (mi/h)	Observed Mean Speed (mi/h)	Standard Deviation of Speeds (mi/h)
Lincoln West (Entrance Crossover)	1	50	35	47.5	5.72
	2	50	35	49.3	6.32
	3	50	35	47.2	8.76
Springfield North (Entrance Crossover)	1	50	40	36.6	9.12
	2	50	40	47.0	9.42
	3	50	40	43.5	9.63
Springfield North (Exit Crossover)	1	50	40	35.9	5.89
	2	50	40	N/A	N/A
	3	50	40	46.0	11.04

Note: 'N/A' means that data was not available due to equipment malfunction

Table 6.3 presents the observed speeds by percentage of drivers exceeding the posted speed values. While none of the mean speeds were above the posted speed limit of the work zone, more than 28% of drivers were observed at speeds above 50 mi/h and more than 92% of drivers were observed at speeds above the advisory speed at the Lincoln West crossover. The two crossovers at Springfield showed similar trends of high speeds, but to a lesser degree with greater speeds occurring towards the last half of the crossover in comparison to the beginning of the crossover.

Table 6.3 Posted and Observed Speeds in Crossovers

Crossover Site	Location	Observed Mean Speed (mi/h)	Percentage Exceeding Speed Limit	Percentage Exceeding Advisory Speed
Lincoln West (Entrance Crossover)	1	47.5	28.6%	97.4%
	2	49.3	43.9%	97.6%
	3	47.2	33.3%	92.5%
Springfield North (Entrance Crossover)	1	36.6	3.9%	39.5%
	2	47.0	37.2%	80.4%
	3	43.5	38.0%	79.0%
Springfield North (Exit Crossover)	1	35.9	1.1%	17.8%
	2	N/A	N/A	N/A
	3	46.0	31.8%	70.6%

Note: 'N/A' means that data was not available due to equipment malfunction

6.3 Results

Figure 6.1 shows the three crossover study locations with each of their data collection positions represented by 1, 2 and 3. In the direction of travel, Location 1 represents a location where a driver is entering the crossover, Location 2 is at the midpoint of the crossover and Location 3 is at the end of the crossover. Figure 6.2 shows the baseline average lateral lateral displacement compared to that of the three study site crossovers.

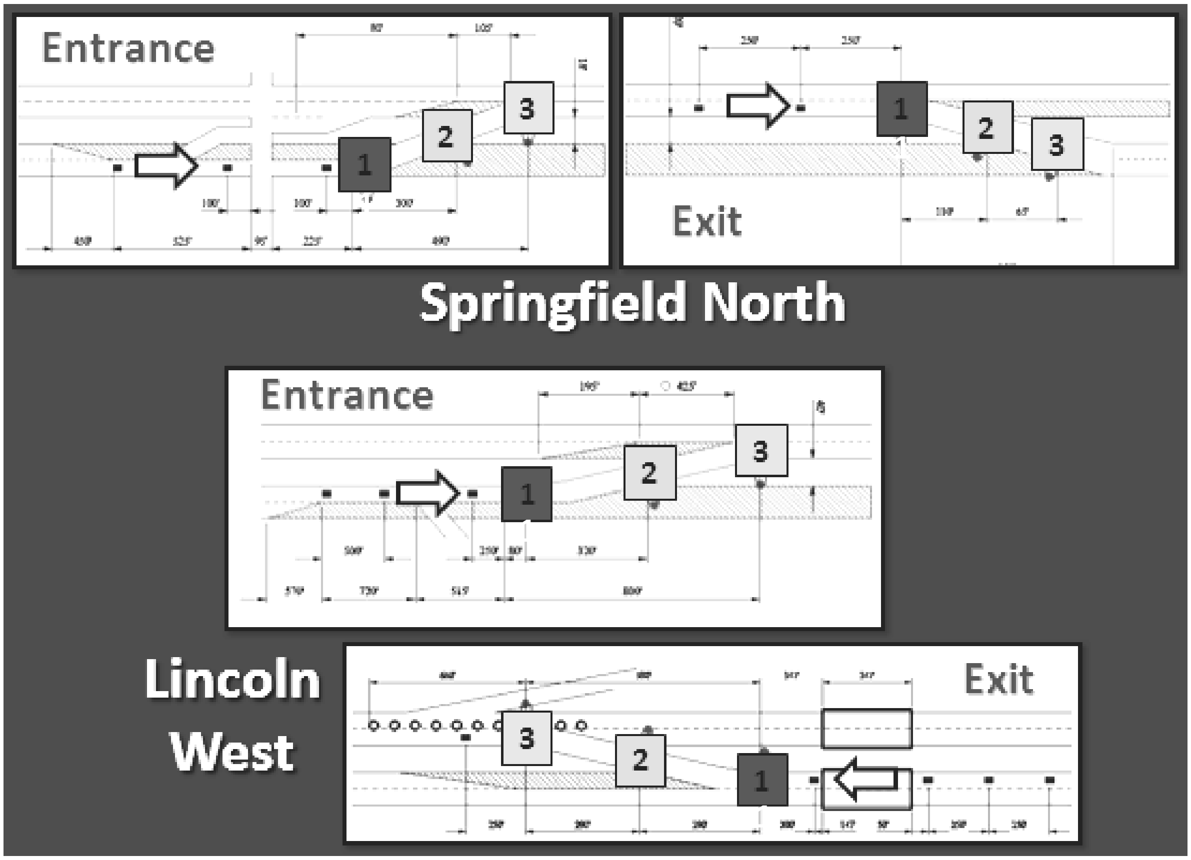


Figure 6.1 Schematics of Data Collection Positions at Crossover Study Site Locations

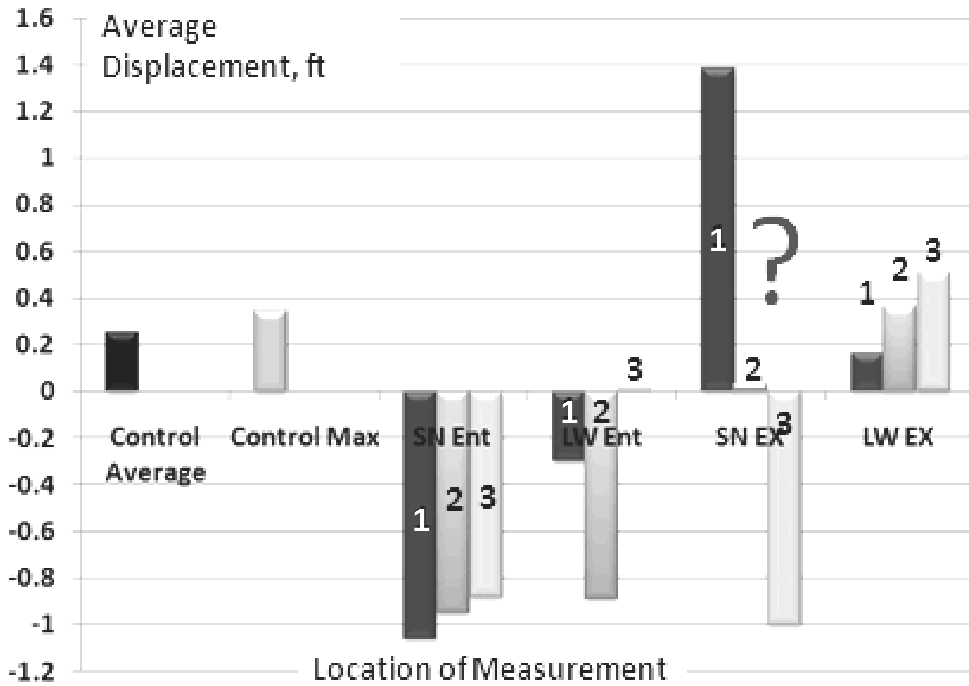


Figure 6.2 Comparisons of Average Lateral Displacement

The comparison of the results shows that in the control condition, drivers tend to shift from 3 to 4 inches to the right of the center of the driving lane, away from approaching traffic or adjacent lane traffic in the same direction. However, in the entry curve of a crossover, drivers tend to shift 4 to 12 inches to the left (the vehicle side closest to their vision center) in the entry curve to the crossover. The same was generally true in the exit curve. However, at exit curve of the Lincoln West site, drivers tended to shift 2 to 6 inches right in the curve, when nearing dual-lane roadway and non-work zone conditions. The large right displacement at Location 1 on the Springfield North exit was explained by the fact that the exit crossover expanded into two lane widths at its end. The fact that drivers are shifting to their left side which is closest to their vision center may indicate that they are concerned about providing excess space on the right of their vehicles to clear traffic control devices.

Shifting traffic control devices further away from drivers and edgelines may serve a better purpose for crossover drivers who are hugging the boundaries of the curves at the beginning and ending of crossovers.

Chapter 7 Single-Lane Crossover Data Analysis

7.1 Hypotheses

A set of hypotheses were developed to test expected outcomes for this part of the research study. These hypotheses are introduced in Chapter 1, and are shown collectively in table 7.1.

Table 7.1 List of Hypotheses

Hypothesis Number	Hypothesis	Test Type
1	For each crossover, the mean of absolute lateral displacement values will be the same at all three critical crossover locations	Two-Way ANOVA
2	For each crossover, the mean speed will be the same at all three critical crossover locations	Two-Way ANOVA
3	Mean lateral displacements observed at all locations along the crossovers will be less than 3 feet	Confidence Interval

7.1.1 Hypothesis 1

Hypothesis 1 was developed to determine if drivers maintained a path through the crossover that would follow a consistent displacement from the center of the driving lane. This hypothesis shown in equation 7.1 determines if vehicular position changed significantly between the observation locations within the studied work zone crossovers.

$$\begin{aligned} H_0 &: \mu_{Location1} = \mu_{Location2} = \mu_{Location3} \\ H_a &: \mu_{Location1} \neq \mu_{Location2} \neq \mu_{Location3} \end{aligned} \qquad (7.1)$$

Where: μ = Mean of absolute values of collected lateral displacements (ft)

Data used to analyze this hypothesis were selected after reviewing the results from Appendix D. In Appendix D, it was determined that eight of the nine observation locations did not exhibit signs of data dependence between observations. In the case of Location 1 at the Springfield North entrance crossover, the data did exhibit signs of dependence. For this site, the set of lateral displacement values was limited to the observations collected in free-flow conditions only. All other observation locations utilized all of the collected lateral displacement values.

The computer program Statistical Package for Social Sciences (SPSS) created by SPSS Inc. was utilized to conduct Two-Way Analysis of Variance (ANOVA) tests on the collected lateral displacement data. A two-way ANOVA was used to compare the differences between the three observation locations at each crossover as well as the two groups of vehicle types, passenger cars and large vehicles. The assumptions of Two-Way ANOVA are (26):

- Populations that the samples were taken from are normally distributed
- The samples must be independent
- Variances of the populations should be equal

ANOVA tests rely on the calculation of the F-statistic. This statistic can be calculated through the use of equation 7.2 (26):

$$F = \frac{SSR}{SSE} \tag{7.2}$$

Where: F = Calculated F-statistic
SSR = Treatment sum of squares
SSE = Error sum of squares

The results of the Two-Way ANOVA are shown in tables 7.2, 7.3 and 7.4 for the Lincoln West, Springfield North entrance, and Springfield North exit crossovers respectively. From the analyses, it was determined that the variable accounting for observation location was significant at all crossovers. This indicates that the mean lateral displacement changed significantly between the different crossover locations within each of the three crossovers studied, and that Hypothesis 1 should be rejected.

Table 7.2 Lincoln West Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	246.700	5	49.340	101.691	0.000
Intercept	136.254	1	136.254	280.824	0.000
Location	43.950	2	21.975	45.291	0.000
Vehicle Type	15.402	1	15.402	31.744	0.000
Location * Vehicle Type	12.682	2	6.341	13.069	0.000
Error	777.766	1603	0.485		
Total	1270.750	1609			
Corrected Total	1024.466	1608			
	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	538	535	536	1486	123

Table 7.3 Springfield North Entrance Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	739.768	5	147.954	160.798	0.000
Intercept	82.666	1	82.666	89.842	0.000
Location	462.832	2	231.416	251.505	0.000
Vehicle Type	16.536	1	16.536	17.972	0.000
Location * Vehicle Type	28.611	2	14.306	15.547	0.000
Error	986.372	1072	0.920		
Total	2088.500	1078			
Corrected Total	1726.139	1077			
	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	434	447	197	837	241

Table 7.4 Springfield North Exit Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	982.041	5	196.408	62.430	0.000
Intercept	5.151	1	5.151	1.637	0.201
Location	705.163	2	352.582	112.071	0.000
Vehicle Type	187.577	1	187.577	59.623	0.000
Location * Vehicle Type	1.640	2	0.820	0.261	0.771
Error	4152.795	1320	3.146		
Total	5193.750	1326			
Corrected Total	5134.836	1325			
	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	198	565	563	959	367

Additional resultsfor Hypothesis 1 showed that the vehicle type variable was significant at all three crossovers. This shows that the difference between passenger cars and large vehicles had an impact on observed lateral displacements. The interaction term of the location and vehicle type variables was significant at the Lincoln West and Springfield North entrance crossovers, but not at the Springfield North exit crossover. As an indicator that the type of vehicle at a specific location within a crossover affects lateral displacement, the interaction term of location and vehicle type implies that there was a statistically significant relationship at the Lincoln West and Springfield North entrance crossovers.

7.1.2 Hypothesis 2

In Hypothesis 1, the mean of observed lateral displacements at three locations within each crossover were analyzed. For Hypothesis 2, the same process was followed using the collected speed data to determine if driver speeds varied significantly between observation locations. Equation 7.3 expresses the hypothesis.

$$H_0 : \mu_{Location1} = \mu_{Location2} = \mu_{Location3}$$
$$H_a : \mu_{Location1} \neq \mu_{Location2} \neq \mu_{Location3} \quad (7.3)$$

Where: μ = Mean vehicular speed (mi/h)

SPSS was used to conduct Two-Way ANOVA with selected speed data. Tables 7.5, 7.6 and 7.7 display the results from the analyses. The review of these results indicates that the speeds were significantly different between the observation locations at all the studied crossovers, so Hypothesis 2 was rejected.

Table 7.5 Lincoln West Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	1806.648	5	361.330	6.372	0.000
Intercept	669607.9	1	669607.9	11809.2	0.000
Location	442.719	2	221.360	3.904	0.020
Vehicle Type	64.288	1	64.288	1.134	0.287
Location * Vehicle Type	7.794	2	3.897	0.069	0.934
Error	61635.32	1087	56.702		
Total	2613397.0	1093			
Corrected Total	63441.97	1092			

	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	281	281	531	1008	85

Table 7.6 Springfield North Entrance Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	31791.340	5	6358.268	72.142	0.000
Intercept	1729382.0	1	1729382	19621.8	0.000
Location	21957.071	2	10978.5	124.564	0.000
Vehicle Type	419.982	1	419.982	4.765	0.029
Location * Vehicle Type	14.610	2	7.305	0.083	0.920
Error	116427.1	1321	88.136		
Total	2662846.0	1327			
Corrected Total	148218.5	1326			
	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	441	444	442	1027	300

Table 7.7 Springfield North Exit Two-Way ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	15000.074	3	5000.025	60.284	0.000
Intercept	850809.5	1	850809.5	10258.0	0.000
Location	13024.458	1	13024.5	157.033	0.000
Vehicle Type	633.671	1	633.671	7.640	0.006
Location * Vehicle Type	265.797	1	265.797	3.205	0.074
Error	40060.439	483	82.941		
Total	939002.0	487			
Corrected Total	55060.513	486			
	Location			Vehicle Type	
Value	1	2	3	0	1
Number of Observations	251	N/A	236	289	198

For the vehicle type category, both of the Springfield North crossovers showed a significant difference in speeds between passenger cars and larger vehicles. The difference at the Lincoln West crossover for vehicle types was not significant. The interaction term of location and vehicle type was not significant at any of the three crossovers. This result indicates that there were no significant interactions, which implies that there was no measureable impact on speed due to the type of vehicle at the individual observation locations.

7.1.3 Hypothesis 3

In Bonneson's research, a distance of 1.0 m was used as a constraint which lateral displacements should not exceed. As approaches into highway curves typically have lane widths of 12 ft, a value of 1.0 m (3.28 ft) was still considered to be applicable for this research. To meet the intervals of collected displacement data, the value of 3.28 ft was conservatively rounded down to 3.0 ft for analysis as shown in equation 7.4.

$$H_0 : -3 \leq \mu \leq 3$$
$$H_a : \mu < -3 \quad \mu > 3 \qquad (7.4)$$

Where: μ = Mean of the absolute value of the observed lateral displacements at any crossover observation point (ft)

To analyze this hypothesis, a confidence interval was used to evaluate each study location. Equation 7.5 was used to calculate the range of the interval for each observation location (26). Table 7.8 shows the calculated ranges of the confidence intervals. At all nine locations, the confidence intervals did not include values that went below -3.0 ft or above 3.0 ft of lateral displacement. Therefore, the hypothesis was not rejected for any case.

$$\bar{x} - z_{\alpha/2}\frac{s}{\sqrt{n}} < \mu < \bar{x} + z_{\alpha/2}\frac{s}{\sqrt{n}} \qquad (7.5)$$

Where:
$\bar{x}$ = Sample mean
$z_{\alpha/2}$ = Calculated t-statistic
s = Sample standard deviation
n = Sample size

Table 7.8 Results for Hypothesis 3

Crossover Site	Location	Sample Mean	Standard Deviation	Sample Size	Interval Range Low	Interval Range High
Lincoln West (Entrance Crossover)	1	-0.30	0.469	537	-0.343	-0.264
	2	-0.89	0.616	534	-0.942	-0.837
	3	0.00	0.494	535	-0.044	0.040
Springfield North (Entrance Crossover)	1	-1.06	0.785	435	-1.134	-0.986
	2	-0.95	0.837	447	-1.028	-0.872
	3	-0.88	1.041	196	-1.023	-0.732
Springfield North (Exit Crossover)	1	1.38	0.631	454	1.326	1.442
	2	0.03	0.766	566	-0.033	0.093
	3	-1.00	1.663	563	-1.137	-0.863

While the results in table 7.8 provide evidence that the mean values of lateral displacements were significantly less than 3.0 ft, table 7.9 was included to provide additional background on the percentage of drivers that exceeded three feet of lateral displacement. Throughout the crossover sites, the percentage of drivers exceeding three feet of lateral displacement was typically below 5%.

The Lincoln West site did not have any displacements greater than three feet. This may be attributed to the 14 ft lane width which was smaller than the other study sites. The entrance crossover at Springfield North had a range of 1.4% to 5.1% of vehicles with observed displacements greater than 3.0 feet. For the exit crossover at Springfield North, a large number of displacements above three feet were observed at Location 3. These larger displacements were expected as the lane width expanded into the two driving lanes downstream of the crossover.

Table 7.9 Percentage of Vehicles Exceeding Three Feet of Displacement

Crossover Site	Location	Total Vehicles	Total Displacing Above 3 Feet	Percentage
Lincoln West (Entrance Crossover)	1	537	0	0.0%
	2	534	0	0.0%
	3	535	0	0.0%
Springfield North (Entrance Crossover)	1	435	6	1.4%
	2	447	13	2.9%
	3	196	10	5.1%
Springfield North (Exit Crossover)	1	454	0	0.0%
	2	566	7	1.2%
	3	563	142	25.2%

7.2 Model Estimation

7.2.1 Purpose

In addition to the AutoTrack analyses and the hypotheses tested, a linear regression model and a panel model were estimated. AutoTrack analysis provided background on the optimum vehicular paths that drivers could follow and showed that most drivers did not follow the optimum path. The three hypotheses investigated lateral displacement and speed observations at the crossover data collection locations. To further examine lateral displacements, the linear regression and panel analysis models were estimated.

7.2.2 Independent Variables

Before selecting the model types, a set of independent variables were compiled that could influence the dependent variable of lateral displacement. These variables were based on data collected from the studied crossovers. Several factors were considered in selecting the variables for the model. Among these factors were site characteristics such as crossover length, grade, and median width, but individual site characteristics were not considered to be suitable for testing with the model due to a low number of study sites. Table 7.10 displays the finalized set of independent variables and the expected effects of each variable on lateral displacement.

Table 7.10 List of Independent Variables and Expected Influences

Independent Variable	Definition	Expected Influence on Lateral Displacement
Vehicle Type	Categorical classification of an observed vehicle based upon vehicle length (0 = Passenger Car; 1 = Heavy Vehicle)	Decrease
Free-Flow Speed	Dummy variable indicating if the observed vehicle was traveling in free-flow conditions (0 = Non-Free-Flow Conditions; 1 = Free-Flow Conditions)	Increase
Vehicle Speed	Speed at which the vehicle is traveling at the observed point.	Increase
Headway	Time between two successive vehicles measured at a single point.	Increase
Direction of Displacement	Dummy variable accounting for the direction of lateral displacement. (0 = Negative, Left of Centerline; 1 = Positive, Right of Centerline)	No Effect
Vehicle Type * Direction of Displacement	Dummy variable for the interaction of the Vehicle Type and Direction of Displacement variables.	Decrease

In terms of the magnitude of lateral displacements, the vehicle type was predicted to have an influence where displacements would decrease as vehicle size increased. This expectation was attributed to the increased width of large trucks and the belief that passenger cars would be more likely to make tighter curved paths into and out of the crossovers which would create larger displacements.

In contrast, the variables for free-flow speed, vehicle speed, and headway were believed to cause increases in the magnitude of lateral displacements. While free-flow conditions were only significant through a t-test at one observation location, it was believed that free-flow conditions may create a situation where drivers would be more likely to drift in the lane without other vehicles to follow. Higher vehicle speeds were also seen as contributors to lateral displacements as drivers would need to create a narrower driving path to maintain higher speeds which would then result in larger displacements. Similar to the free-flow conditions prediction, larger headways were predicted to increase displacements.

The case of displacement direction to the left or right of the centerline was thought to have no effect on the magnitude of lateral displacement magnitude, but that it may be significant in cases where the distribution of displacement observations would be uneven between the left and right sides of the centerline.

An interaction term for the vehicle type and direction of displacement variables was included to observe if the interaction of these variables would account for a decrease in lateral displacement. This expectation was developed from the previous prediction for the vehicle type variable.

7.2.3 Model Selection

Several model types were considered to analyze the collected data. The lateral displacement data limited the available types of models to be considered. For example, models that would predict a value of 0 or 1 would not be applicable to the collected data. Lateral displacement observations included negative and positive values in intervals of 0.5 ft. The first model type that was considered was linear regression. This model was deemed to be applicable as the data at each observation location was determined to be normally distributed.

A second model type that was considered was an ordered logit model. This model type was considered since the collected data could be considered to be categorical with the 0.5 ft collection intervals. Following further review of the ordered logit model, it was discerned that the data would have to be grouped into whole number values (0, 1, 2, 3…n) and then reduced into about three or four total groupings. These two considerations made the ordered logit model an undesirable choice. Therefore, linear regression was determined to be the most applicable model choice. Following discussion on the linear regression model, the use of a panel analysis and its estimation will be covered. For the linear regression model type, the following assumptions are made (27):

- Random errors have an expected value of 0
- Random errors are uncorrelated
- Explanatory variables are independently distributed
- No correlation beween explanatory variables and random errors
- All random errors have the same variance

The dependent variable of lateral displacement can be predicted by equation 7.6 (27):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ..\beta_n x_n + \varepsilon \qquad (7.6)$$

Where:

y = Dependent variable
x = Parameters (Independent Variables)
β = Parameter coefficients
ε = Random error

7.2.4 Linear Regression Model

Analysis of the linear regression model using least squares was done using the computer program SPSS. For this model, nine new variables were created to account for the individual observation locations which can determine if the locations were significant within the entire data set. These variables were named according to their respective crossover and camera locations, and they were assigned a value of '1' if the data from the observed vehicle was collected at that location and a value of '0' if the data from the observed vehicle was not collected at that location. The SPSS result containing all of the variables is included in Appendix G. Table 7.11 shows the SPSS result with significant variables only.

Table 7.11 Model Result for Full Dataset

Independent Variable Name	Estimated Coefficient	t	Significance
Constant	-0.326	-2.919	0.004
Speed	-0.009	-4.338	0.000
Free Flow Conditions	0.002	2.247	0.025
Vehicle Type	-0.701	-12.535	0.000
Vehicle Type * Direction of Displacement	0.846	7.797	0.000
Lincoln West - Location 1	0.524	8.839	0.000
Lincoln West - Location 3	0.826	13.854	0.000
Springfield North Entrance - Location 1	-0.170	-2.471	0.014
Springfield North Entrance - Location 3	1.823	20.539	0.000
Springfield North Exit - Location 1	2.048	29.117	0.000
Springfield North Exit - Location 3	-0.271	-4.504	0.000

n	R^2	SSR	SSE	SSTotal	F	Significance
3642	0.390	2819.591	4403.013	7222.604	232.521	0.000

Table 7.11 shows that six observation locations were significant in the model. The variables for free-flow conditions, speed, vehicle type, and the interaction term of vehicle type

and direction of displacement were significant. Referring back to table 7.10, table 7.12 is shown to compare the expected influence for each of the four measurable variables. Each of the expectations was made to take into account that the overall mean of all lateral displacements was negative. This in turn led to expectations of increases in displacement to be decreases (-) and a similar case for expectations of decreases in displacement. In table 7.12, the variables for vehicle type and free-flow conditions did not meet the expectations while the variables for speed and the interaction term did meet expectations.

Table 7.12 Comparison of Expected and Estimated Model Results

Variables	Expected Influence	Model Estimated Influence
Vehicle Type	+	-
Free-Flow Conditions	-	+
Speed	-	-
Interaction Term	+	+

7.2.5 Panel Model

In the previously estimated linear regression model, any effects due to the observation locations being arranged in a series at each crossover were not accounted for. The collected set of data consisted of three groups observed at three points which is known as a panel data set. A panel data set is defined by Tarris et al. as "multiple observations on a specified group at several points in time" (28). In a manner similar to the crossover data, the research by Tarris et al. used a series of detectors to collect data on low speed urban streets which resulted in individual vehicles being measured at multiple points in time. To capture the unobserved variability of group and time effects, Tarris et al. used two-way fixed effects and random effects models (28).

Group effects were used to represent individual drivers, and time effects were used to account for the distance between detectors (28).

The fixed effects model examines whether or not the group and time effects are related to a deterministic pattern and is shown in equation 7.7 (28):

$$Y_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta' X_{it} + \varepsilon_{it} \qquad (7.7)$$

Where:

Y_{it}	=	Value of response variable for group I at time t
α_0	=	Overall constant from analysis
α_i	=	Constant for group effect
α_t	=	Constant for time effect
β'	=	Measure of the effect of changes in the independent variable
ε_{it}	=	Random error term

In equation 7.7, both the group and time effects are treated as constants. The fixed effects model uses the group, time, and independent variables to examine the variation in Y_{it} (28). Equation 7.8 shows the random effects model where the group and time effects are treated as random variables instead of constants (28):

$$Y_{it} = \alpha + \beta' X_{it} + \varepsilon_{it} + u_i + w_t \qquad (7.8)$$

Where:

ε_{it}	=	Random error term (Pure random noise)
u_i	=	Individual specific disturbance for each group
w_t	=	Individual specific disturbance for each time period

Using the computer program Limdep from Econometric Software Inc., a panel model was estimated. Following organization of the collected data, the analysis was estimated using all of the independent variables in table 7.10 except for headway and the interaction term of vehicle type and direction of displacement. These variables were excluded to eliminate conflicts during model estimation by Limdep. In addition, a reciprocal transformation was applied to the collected speed data to eliminate conflicts that prevented Limdep from conducting a complete analysis.

Table 7.13 shows the summary of the panel analysis model including significant variables. A summary showing the model results for all variables and the statistical tests used to select the final model is included in Appendix G. For the analyzed data, the panel analysis determined that the two-way fixed effects model was the most appropriate. The expected coefficients for the variables of direction of displacement and vehicle type were not met.

Table 7.13 Summary of Panel Analysis

Variable Name			Coefficient	t	Significance
(Constant)			-1.027	-47.899	0.000
Direction of Displacement			2.240	60.841	0.320
Vehicle Type			-0.189	-4.392	0.170
n	R^2	SSE	F		Significance
3638	0.551	3237.366	557.560		0.000

A total of five models were estimated in the panel analysis and review of the R^2 values in table 7.14 shows that the independent variables in the model (Vehicle Type, Direction of Displacement) accounted for 52.9% of the lateral displacement variation

Table 7.14 Panel Analysis R^2 Values

Model	R^2 (Percent)
(1) Constant term only	0.0
(2) Group effects only	2.5
(3) Independent Variables only	52.9
(4) Independent Variables & Group Effects	53.8
(5) Independent Variables, Group Effects, & Time Effects	55.1

As previously discussed, the purpose of the panel analysis model was to account for effects that were unable to be addressed in the least squares regression model. This is addressed with a review of the fourth and fifth models from the panel analysis.

In the fourth model, both the independent variables and group effects were used. This model showed a marginal increase of 0.9% in the R^2 value which can be directly attributed to the group effects. The fifth model builds on the fourth model by including time effects. The fifth model showed an increase of 1.3% in the R^2 value which was attributed directly to time effects.

7.3 Summary of Results

The three proposed hypotheses show that observed lateral displacements and speeds varied significantly throughout the observed crossovers and that the mean lateral displacement of observed vehicles at each location was less than 3.0 feet.

A least squares regression model estimated that speed, free-flow conditions, vehicle type, the interaction term, and dummy variables for six observation locations were significant factors influencing lateral displacement.

Further analysis shows that a panel model was more suitable than the least squares model. This model showed that the vehicle type and direction of displacement variables were significant factors for estimation of lateral displacement. The majority of variation in lateral displacements (52.9%) was attributed to the independent variables. A panel model accounting for independent variables, group effects, and time effects accounted for 55.1% of the variation in lateral displacements.

Chapter 8 Conclusions and Recommendations for Single-Lane Crossovers Based on Lateral Displacement Studies

8.1 Research Single-Lane Crossover Study Objective

The purpose of this part of the research project was to investigate the lateral displacement of vehicles at reverse curve work zone crossovers in the state of Nebraska. This objective was achieved through the collection of data of lateral displacements, vehicle speeds, vehicle types, and headways at three crossovers. The data was then analyzed using the computer program AutoTrack, a set of hypotheses, a least squares linear regression model, and a panel analysis model.

8.2 Data Collection and Methodology

Data were collected through the use of NC-97 detectors and video cameras. These instruments were utilized to compile information on vehicle speed, vehicle length, headway, and lateral displacement. A total of nine locations were observed along three individual crossovers. These locations were located along the general entrance, middle, and exit areas of the three crossovers.

8.3 Conclusions

8.3.1 Hypotheses

- Mean lateral displacements were not equal at the three observation locations for any of the crossovers. This showed that the lateral displacements changed significantly between each observation point.
- Mean speeds varied significantly between the three observation locations for all of the studied crossovers.

- The mean displacement at all nine observation locations did not exceed -3.0 ft or +3.0 ft. Further analysis showed that Location 3 at the Springfield North exit crossover had more than 25% of vehicles recording displacements that were greater than 3.0 ft. While this was an indicator that a degree of masking took place in the analysis, it could also be attributed to the widening of the crossover as it went from one lane to two lanes at the exit.

8.3.2 Linear Regression Model

- Individual observation locations were found to be significant in the overall model which supported the conclusion from Hypothesis 1 that lateral displacements were significantly different between the observation locations within each of the three crossovers.
- The variables for vehicle type and free-flow conditions were significant, but did not meet the expected influences. The collected speeds supported the expectation that greater speeds would result in greater magnitudes of displacement. For the interaction term of vehicle type and direction of displacement, the expectation was supported that the magnitude of displacement would decrease.

8.3.3 Panel Model

- Independent variables of vehicle type and direction of displacement were determined to be significant, but their coefficients did not meet expectations.
- Time effects due to the detectors being located in series were not determined to account for a large degree of variation within the lateral displacements.
- The majority of variation in the lateral displacement data (52.9%) was attributed to the variables of vehicle type and direction of displacement.

8.4 Recommendations for Future Research Based on Lateral Displacement Study Outcomes

As there has been limited research conducted concerning work zone crossovers, there are several options for continuing research. Four recommendations for future research are listed below.

- Among the three crossovers studied, there were lane widths of 14 feet, 16 feet, and 16 feet expanding into 24 feet. Research into the effects of lane widths should be done to determine if there are any safety impacts due to different sizes of lane widths in crossovers.
- Vehicle type was a predicted influence of lateral displacement, but decisive conclusions were not able to be reached. Larger sample sizes at additional sites may yield conclusive results on the influence of vehicle type on lateral displacement.
- Observation of the collected speed data showed high percentages of drivers exceeding the posted advisory speed. Research could be conducted to determine factors that influence driver speeds within crossovers. Analysis of these factors may yield potential methods to reduce driver speed choices which may create a safer environment for drivers.
- The literature review of this research identified three design types of work zone crossovers. The flat diagonal and reverse curve (tangent) crossover designs were not studied as a part of this research. The third type, a reverse curve with an intermediate tangent, was the type of crossover design that was present on the crossovers studied. Additional research could be conducted to compare the lateral displacements of each crossover design type.

Chapter 9 Dual-Lane Crossovers

9.1 Background

The geometry of a dual-lane work zone configuration (shown in figures 9.1 and 9.2) allows two lanes of traffic to be crossed over the median resulting in head-to-head traffic on the opposite side.

Figure 9.1 Dual-Lane Work Zone Crossover Carrying Interstate 80 Westbound Traffic West of N 70th Street Grade Separation Near Lincoln, NE

Figure 9.2 Dual-Lane Crossover Carrying Interstate 80 Eastbound Traffic Near West End of the Platte River Bridge Between Lincoln and Omaha, NE

Table 1.2, reprinted below for convenience, defines a general set of sections within a work zone that utilizes a dual-lane crossover.

Table 1.2 Work Zone Section Definitions for a Dual-Lane Crossover

Work Zone Section	Definition
Advance Warning Area	Warning signs inform drivers that a work zone is ahead. Any changes in speed limits are posted.
Dual Lanes in Advance of Crossover "STAY IN YOUR LANE" Advisory Signs	The number of lanes of through traffic remains the same as in the non-work zone segment (2 lanes). Advisory signs are to encourage drivers to avoid weaving to change lanes since the horizontal alignment of the driving path will be changing a short distance ahead.
Entrance Crossover	The entrance crossover shifts traffic entering the work zone across the median. The width accommodates two full traffic lanes.
Two-Way Traffic, Two Lanes in Each Direction	A four-lane roadway divided by a median is maintained as a four-lane roadway but the lanes are separated by temporary concrete barriers instead of a neutral median spacing with substantial width.
Activity Area	Section of roadway where the work activity takes place.
Exit Crossover	The exit crossover moves two lanes of traffic back across the median.
End of Work Zone	The work zone ends and traffic is separated once again by the median of the four-lane roadway.

9.2 Questionnaire Responses Relating to Dual-Lane Crossovers

Only two NDOR District construction project managers completed and returned the work zone crossover questionnaires. Both questionnaires described projects along Interstate 80 in Nebraska. One project west of Big Springs, NE had a low enough traffic volume for the work zone cross to be of the single-lane type. The other project was in the higher-traffic-volume eastern part of the state, west of the Platte River Bridge and required a dual-lane crossover to avoid extensive queuing of vehicles entering the construction zone. Responses from the dual-lane crossover construction project manager are summarized below.

9.3 Dual-Lane Crossover Questionnaire Comments

There were no complicating features near the concrete crossovers but there were accidents at the exit of the work zone crossover. The crossover was in flat terrain but difficult to see in advance. Edgeline striping was smooth but drivers had difficulty staying within the limits of the striping although they were able to stay within limits of the traffic barrels. The traffic plans were easily understood and followed to set the initial configuration of the traffic control devices. Barrels were adjusted for adequate sight distance after initial placement. A comment was made that the "traffic plans were easy to read but the design had very small room for error." Although there were no drainage problems per se, a slotted pipe was installed within the pavement of the crossover to collect drainage from the paved crossover area. Excessive traffic loads broke up concrete panels next to the pipe that required closing a traffic lane and repairing the pavement a number of times. Another crossover was built for the project and its surface was crowned to avoid another slotted pipe installation.

9.4 Review of Crashes within Dual-Lane Work Zone Crossover Limits

Records of work zone crossover crashes were very difficult to find within the NDOR crash database. Of 15 crash reports collected from 7/1/2005 through 12/19/2006 on construction projects throughout the State that had dual-lane crossovers, only one crash was reported within the limits of the crossover. The crash occurred during clear, daylight conditions. No reason was given for the crash but the road character was described as curved and level. No injuries were reported.

9.5 Dual-Lane Crossover Preliminary Behavior Study West of 27th and I-80 Near Lincoln, NE

Three dual-lane crossovers were studied to identify driver behavior and safety issues related to the characteristics of a given location. The first study on Interstate 80, west of the 27th Street interchange near Lincoln, NE was performed to get an idea of unsafe and inappropriate driver behavior at dual-lane installations, form a strategy for future feasible data collection and practice data collection with the use of the University of Nebraska-Lincoln's (UNL) Intelligent Transportation Systems (ITS) traffic data collection van. Figure 9.3 shows a view of the study site.

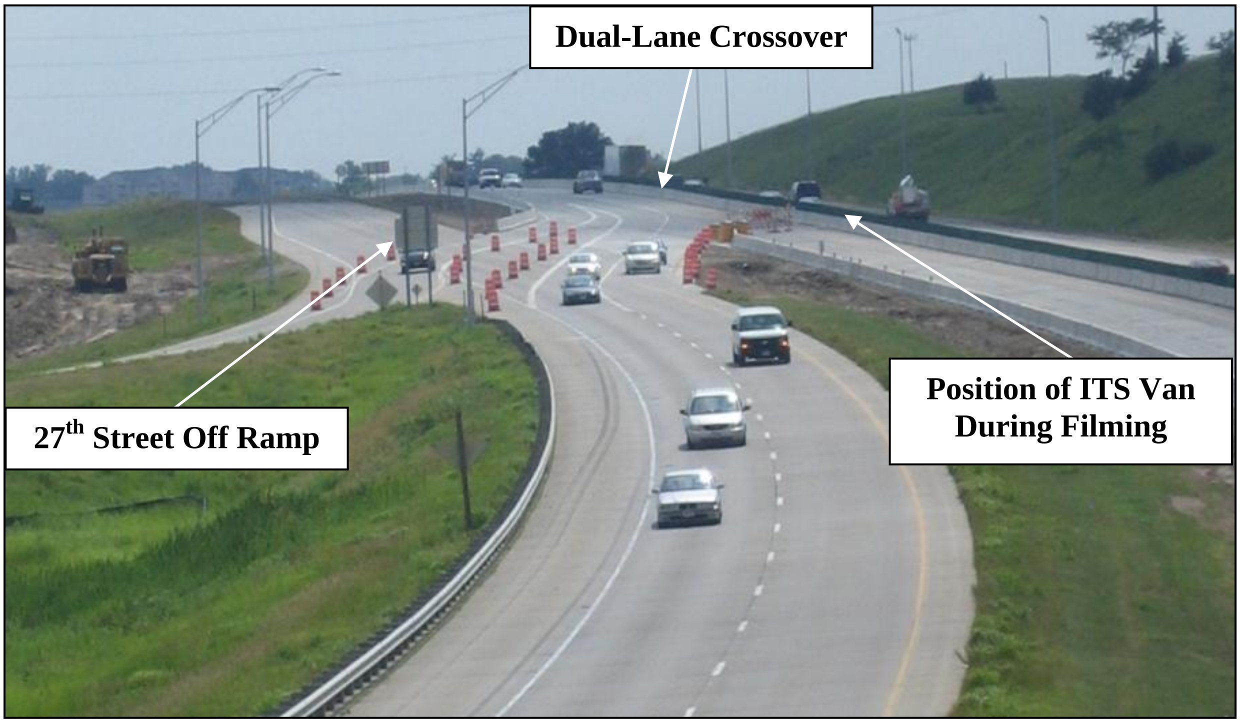


Figure 9.3 View of Preliminary Behavior and Speed Study West of 27th and I-80 near Lincoln, NE

Figure 9.4 shows the ITS van with its mast fully extended. With the aid of the ITS van, the speed and headways of the traffic at various points through the crossovers was examined, along with the lateral displacement of vehicles as they passed through the crossover.

Figure 9.4 ITS Traffic Data Collection Van with 42-ft Mast Fully Extended

9.6 Gathering Data

The ITS van contains two Autoscope cameras, a 42-foot mast, an on-board computer with DVRs, and an electric generator. One camera was focused on the entry curves to the crossover and one on the exit curves as depicted in figure 9.5. Pixel “speed traps” were configured on the screen view (shown as rectangles in figure 9.5) so when the pixels were “disturbed” by a screen version of a moving vehicle, the speed could be determined by dividing the distance traveled between the ends of the rectangles by the elapsed time between disturbance positions.

To ensure that the Autoscope would extract the data correctly, calibration was required for both camera view locations. This was done by setting up and measuring the distance between traffic channelizing cones used as reference points. These reference points were also captured on video, and the distance between them was entered into the Autoscope software to create a virtual grid and coordinate system. Using this data, the software calculated the speed and position of all the vehicles traveling through the crossover for the entire DVR recording. To confirm the accuracy of the speed data extracted, a UNL pickup truck was driven through the crossover at speeds of 55, 60, and 65 mph by a research assistant. The speed was shown by the odometer inside the truck as well as by a LIDAR speed-ranging instrument used by a research assistant manning the ITS van. After comparing the speeds calculated by the Autoscope software with actual driven speeds and LIDAR speeds, the use of the Speed Calibration Adjustment option in Autoscope was possible. This ensured that the other Autoscope speeds recorded were as accurate as possible given the limits of the data collection times.

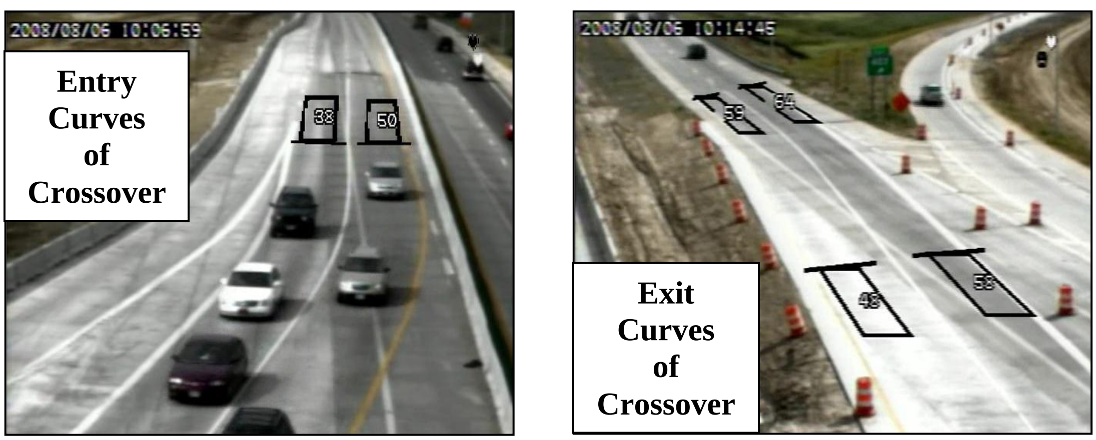


Figure 9.5 ITS Van Autoscope Camera Views from 27th and I-80 Study Site

The recorded video was later analyzed using the Autoscope software. The data was extracted and various speed frequency statistics were compiled and graphed. These statistics were grouped by the categories of vehicles, lane traveled, and the position locations along the crossover where the data was obtained.

Figure 9.6 shows an aerial photo of the three locations of dual-lane crossovers studied in the research project.

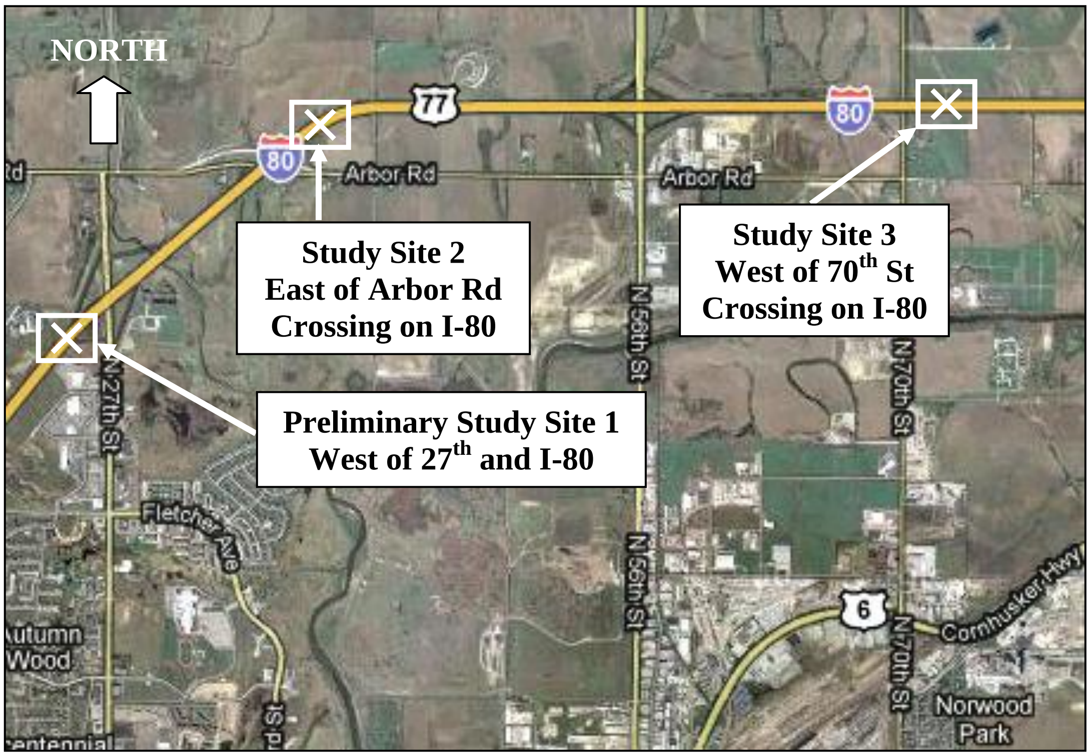


Figure 9.6 Location of Dual-Lane Study Sites on I-80 North of Lincoln, NE

9.7 Site 1, West of 27th Street Bridge and I-80

The first crossover was filmed from on Wednesday, August 6th, 2008. The data from the pixel speed traps were given specific identification numbers so vehicle speeds could be collected in categories for the different key locations of interest. Figure 9.7 shows the speeds trap locations along the middle through the end of the dual-lane crossover. The other Autoscope camera view of the initial curve experienced technical difficulties and data collected from it was not accurate and therefore is not presented.

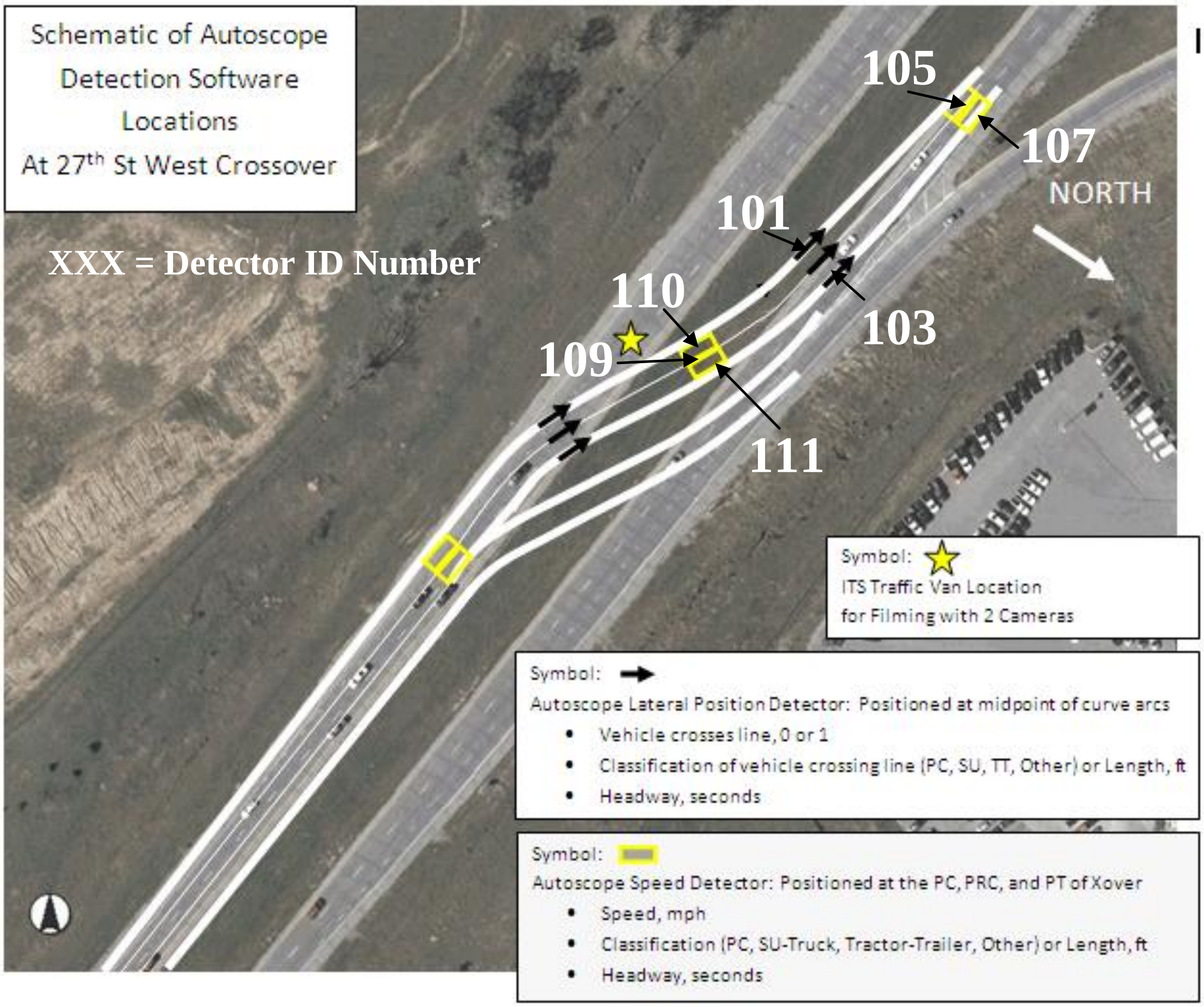


Figure 9.7 Configuration of Autoscope Speed Traps at Site 1

Figures 9.8 through 9.11 show speed statistics of all vehicles traversing the middle and exit curves of Site 1 during the study period.

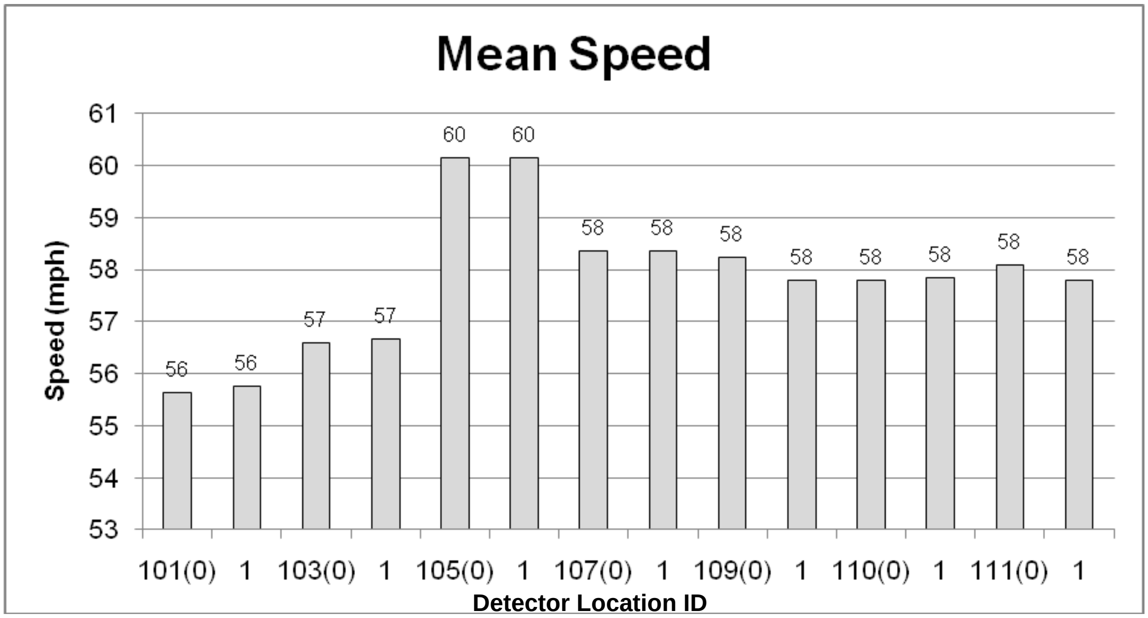


Figure 9.8 Mean Speed of Vehicles During Study Period at Site 1

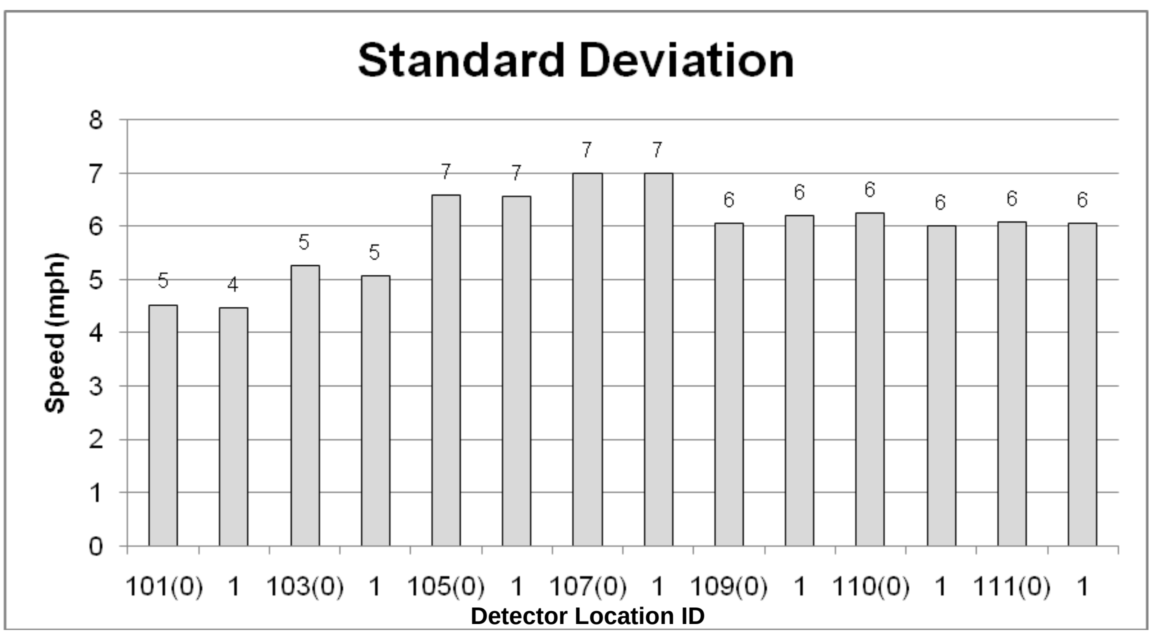


Figure 9.9 Standard Deviation of All Vehicles During Study Period at Site 1

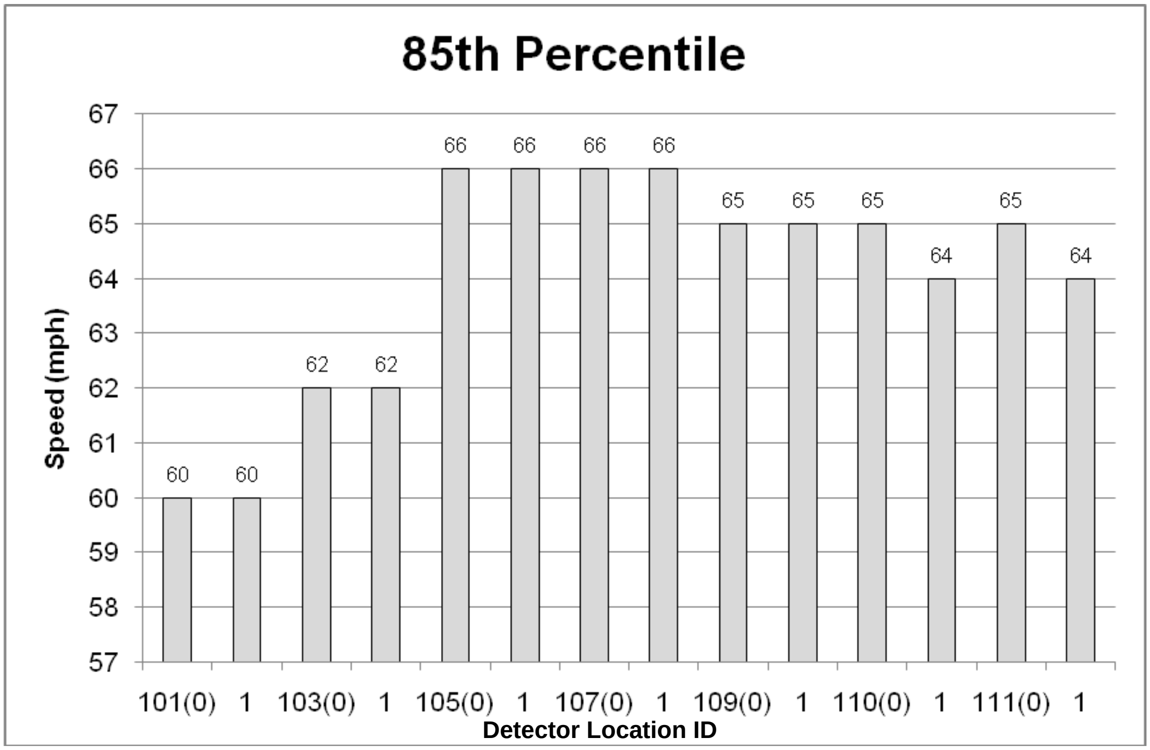


Figure 9.10 85th-Percentile Speed of All Vehicles During Study Period at Site 1

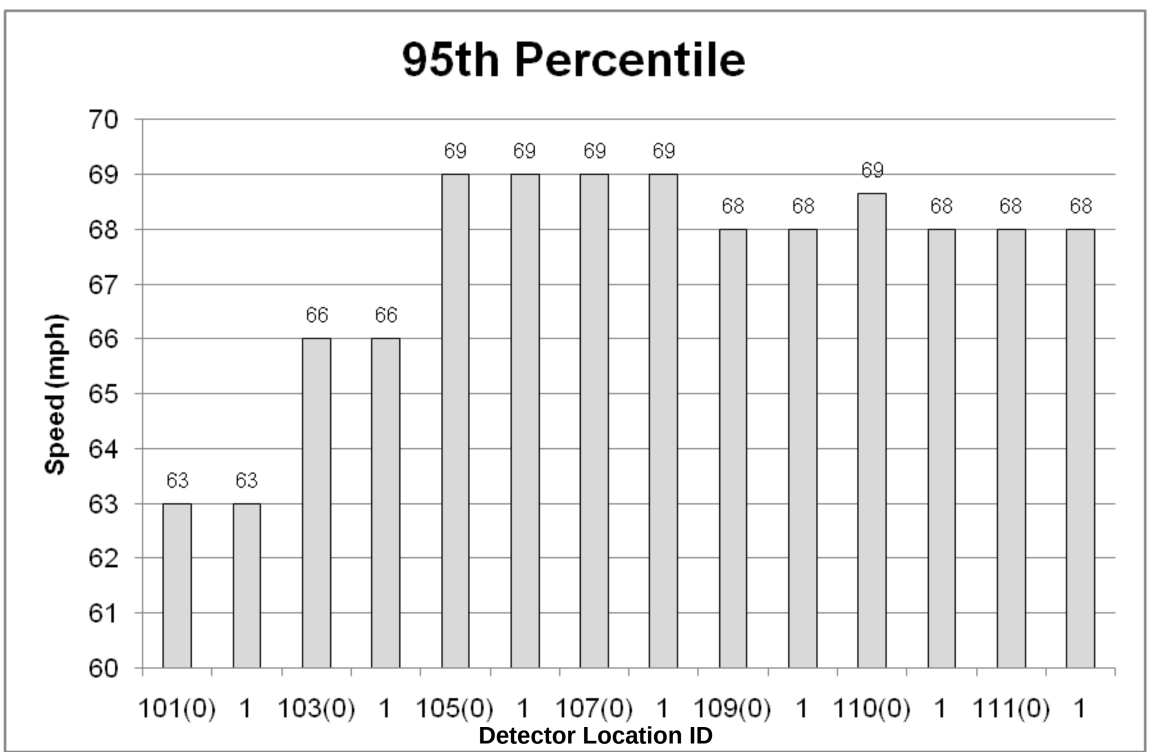


Figure 9.11 95th-Percentile Speed of All Vehicles During Study Period at Site 1

9.8 Summary of Speed Statistics and Inferences from Results

9.8.1 Mean Speeds (Running Speed Estimates)

The lowest mean speeds occurred midway in the exit curve (56-57 mph). The highest speeds were where the exit curve matched the existing lanes of Interstate 80 at the end limit of the crossover in the left lane (60 mph). Mean speeds in the middle of the entrance and exit curve and in the right lane of the exit curve were 58 mph. Overall, mean speed (which is a speed statistic that approximates running speed) through the crossover were fairly consistent and approximated the 55 mph posted speed limit (which should normally approximated by the 85^{th}-percentile speed).

9.8.2 Standard Deviations (Uniformity Estimates)

Standard deviations were least in the middle of the exit curve (4-5 mph), greatest at the end of the crossover (7 mph) and mid-range in the middle of the entrance and exit curves. This indicates that speeds between vehicles were most uniform through the exit curve.

9.8.3 85^{th}-Percentile Speeds (Operating Speed – Posted Speed Estimates)

The lowest operating speed was in the exit curve (60-62 mph) and the highest at the existing lanes match point (66 mph) with the middle of the entrance and exit curve location near that of the exit (64-65 mph).

9.8.4 95^{th}-Percentile Speeds (Conservative Design Speed Estimates)

The lowest "design speed" equivalent was at the midpoint of the exit curve (63-66 mph) and the highest values were at the midsection of the entrance and exit curves and at the existing lanes match point (68-69 mph). Desirably, the design speed chosen for a geometric feature like horizontal curvature should be around the 85^{th}- or 95^{th} percentile speed which in this case would be between 60 and 65 mph.

9.8.5 Inferences from Results

It appears that horizontal curvature within the crossover somewhat controls drivers' speed choice since the middle of the exit curve proved to be the point of lowest speed choice.

9.8.6 Recommendation from Results

When choosing curve radii for dual-lane median crossovers, recognize that drivers could be exceeding the design speed (55 mph) by about 10 mph. If possible, use a design speed of 65 mph for the choice of radii given the available superelevation. Since crossovers are locations where drivers likely expect some noticeable physical effects from centripetal acceleration, Method 2 of the five methods of sustaining centripetal acceleration on curves could be used to determine a reasonable superelevation rate for a given situation (2, p. 140-142).

9.9 Site 2, East of Arbor Road Crossing of I-80

The second study took place at Arbor Rd along I-80, a few miles east of the 27^{th} St exit. Arbor Road passes over I-80 at almost a 90 degree angle, which made it optimal to film from the overpass. The reconnaissance mission was completed and the filming took place on October 3^{rd}, 2008. Figure 9.12 shows the camera views of the crossover.

Figure 9.12 ITS Van Camera Views East of Arbor Rd Over I-80 Near Lincoln, NE

9.10 Headway Analysis

For the Site 2 headway analysis, a few items were considered to eliminate the inaccuracies and overly-sensitive nature of the Autoscope pixel detectors. First, all headways recorded as 2 seconds or less were considered an accidental trigger by shadow or Autoscope for both lanes. This decision was based on watching the video and seeing numerous double readings (by larger vehicles) and shadows (angle of camera and sunlight). As shown in table 9.1 below, deleting these invalid headways help improve the total numbers of vehicles recorded by each detector.

Table 9.1 Number of Vehicles Recorded, Deleted and Used for Headway Analysis

Before Bridge (Entrance)			Closest After Bridge (Midpoint)			Furthest After Bridge (Exit)		
Left	Headways	Right	Left	Headways	Right	Left	Headways	Right
815	Total Recorded	1525	927	Total Recorded	1550	818	Total Recorded	1512
269	2 sec or less	629	335	2 sec or less	653	256	2 sec or less	618
546	Used for analysis	896	592	Used for analysis	897	562	Used for analysis	894

The right lane values are justifiable because a relatively close number of vehicles were counted. The left lane data is mostly inaccurate due to shadows, considering the sunlight from the south shining on eastbound traffic. Two types of comparisons were made with this data set. The first analysis considers the headways at only the entrance and exit of the crossover for both lanes of traffic as shown in table 9.2.

Table 9.2 Headway Statistical Values at Site 2 Crossover Entrance and Exit, Both Lanes

	Entrance		**Exit**	
	Left Lane	***Right Lane***	***Left Lane***	***Right Lane***
Time Statistic	**Min:Sec**	**Min:Sec**	**Min:Sec**	**Min:Sec**
Min	00:03	00:03	00:03	00:03
Max	01:29	00:30	01:15	00:31
Mean	00:13	00:07	00:12	00:07
Median	00:08	00:06	00:08	00:05
Mode	00:03	00:03	00:03	00:03
Std Dev	00:12	00:04	00:11	00:05
Variance	00:00	00:00	00:00	00:00
85th Percentile	00:23	00:11	00:22	00:11
95th Percentile	00:35	00:16	00:34	00:17
1st Quartile	00:04	00:04	00:05	00:03
3rd Quartile	00:17	00:09	00:16	00:09

Figures 9.13 and 9.14 show the statistics in table 9.2 graphically.

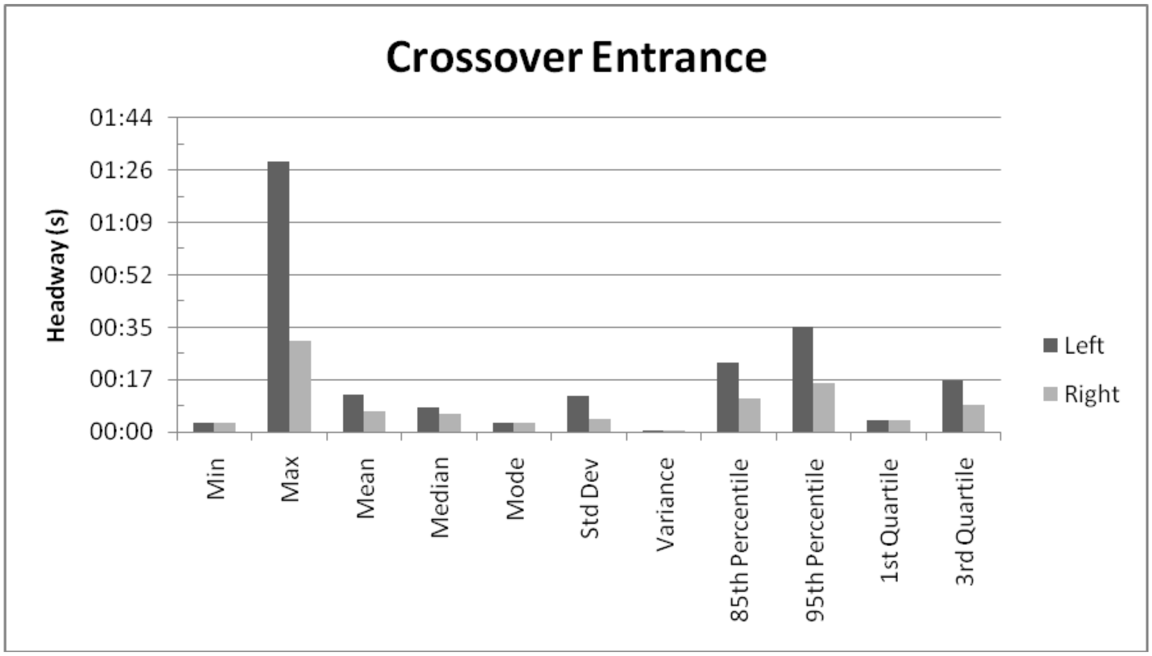


Figure 9.13 Statistical Values for Vehicle Headways at Site 2 Crossover Entrance

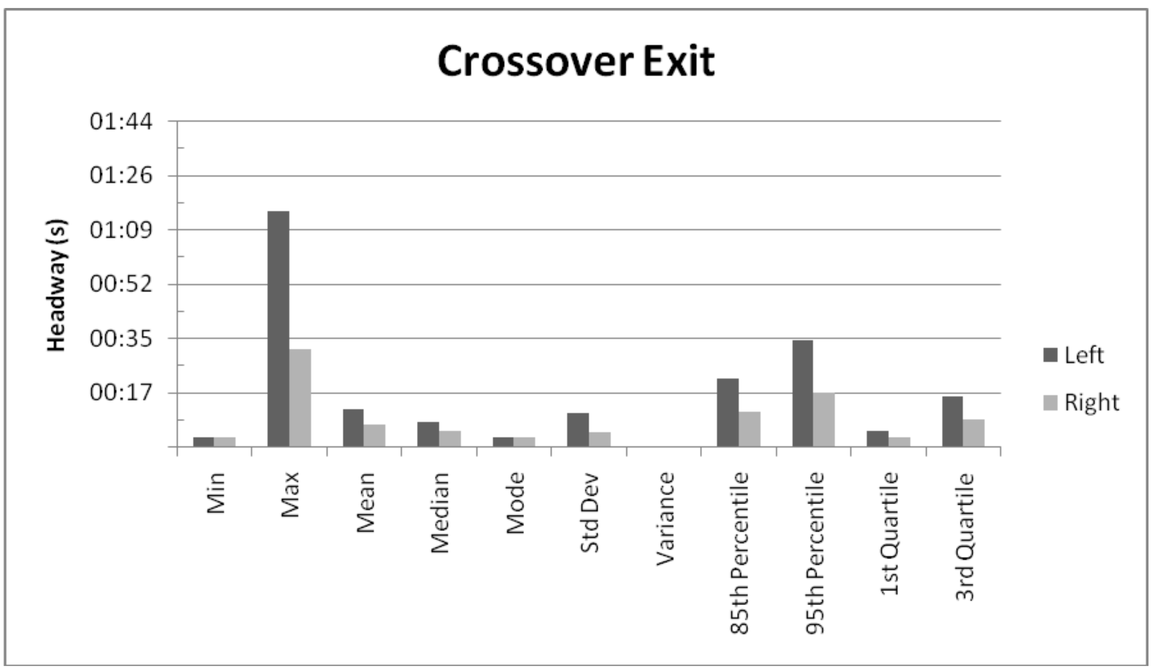


Figure 9.14 Statistical Values for Vehicle Headways at Site 2 Crossover Exit

Further analysis deals with the headways at the entrance, middle, and end of the crossover for the right lane only to emphasize accuracy.

Table 9.3 Headway Statistical Values at Site 2 Crossover Entrance and Exit, Right Lane Only

	Right Lane Only		
	Entrance	***Middle***	***Exit***
Time Statistic	**Min:Sec**	**Min:Sec**	**Min:Sec**
Min	00:03	00:03	00:03
Max	00:30	00:31	00:31
Mean	00:07	00:07	00:07
Median	00:06	00:05	00:05
Mode	00:03	00:03	00:03
Std Dev	00:04	00:05	00:05
Variance	00:00	00:00	00:00
85th Percentile	00:11	00:11	00:11
95th Percentile	00:16	00:17	00:17
1st Quartile	00:04	00:03	00:03
3rd Quartile	00:09	00:09	00:09

Figure 9.15 shows the statistics in table 26 graphically.

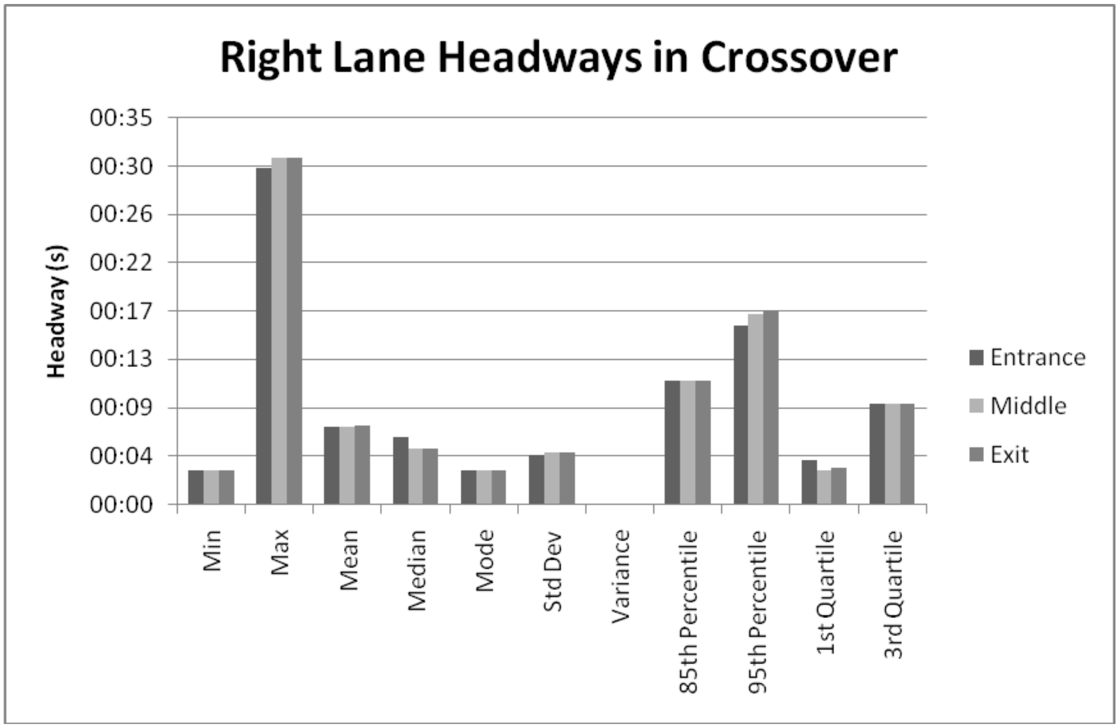


Figure 9.15 Statistical Values of Right Lane Vehicle Headways at Key Crossover Locations

9.10.1 Results, Inferences and Recommendations Related to Headway Spacing

Gaps remain fairly consistent throughout the geometric elements of the crossover (entrance, middle and exit). The mean and median headway (time between the passing of the front bumpers of two sequential vehicles in the same lane) values for the right lane are between 5 and 7 seconds apart, indicating a gap of about 440 ft to 620 ft if the average vehicle speed is 60 mph. The 3 second mode gap value would yield about a 265 ft gap. If there are a large number of trucks in the traffic stream, “STAY IN YOUR LANE” signs should be placed more frequently than specified by the MUTCD in order to remind drivers that they should stay in their original lane upon entering the crossover and remain there until they are out of the entire median crossover and head-to-head segment, if applicable. With gaps of less than an typical city block, drivers may not see “STAY IN YOUR LANE” signs due to blockage by large vehicles in front of them.

9.11 Site 3, N 70th Crossing of I-80

A third dual-lane construction crossover along I-80 was examined from the N 70th Street overpass bridge in Lincoln, NE. A video camera was set up on the overpass bridge and footage was recorded on July 6th, 2009 in sunny weather and dry pavement, as shown in figure 9.16. The speed limit of the crossover was 55 mph, a 10 mph drop from the pre-work zone segment speed of 65 mph.

Figure 9.16 Video Camera Installation for Filming Site 3, N 70th over I-80, Near Lincoln, NE

The free-flow speed of the crossover was determined. A LIDAR gun was used from a UNL pickup truck angled appropriately to collect speed data from vehicles before entering the crossover (under the N 70th Street overpass). Free-flow speeds and vehicle types of 200 vehicles in each lane were recorded on July 6th, 2009 in sunny weather on dry pavement. The vehicles were categorized into the three groups as shown in table 9.4 below.

Table 9.4 Vehicle Type Categories and Abbreviations

PC	Passenger Car	Motorcycles, Cars, Small Pickups
ST	Small Truck	Larger Pickups and Vans
LT	Large Truck	Construction Trucks, Pickups with Trailers
TB	Trucks & Buses	Semi-Trailer Trucks, Large Buses

Table 9.5 shows speed statistics for the data collected.

Table 9.5 Free-Flow Speed Statistics for Site 3

Left Lane	**All**	**PC**	**ST, LT**	**TB**
Min	47	51	48	47
Max	76	73	76	70
Mean	60	61	60	57
Median	59	60	59	56
Mode	59	59	57	56
Standard Deviation	5.1	5.0	5.1	4.1
Variance	26	25.2	25.7	16.8
85th Percentile	66	67	66	59
95th Percentile	69	69	69	63
1st Quartile	56	58	57	55
3rd Quartile	63	65	63	58

Right Lane	**All**	**PC**	**ST, LT**	**TB**
Min	47	49	48	47
Max	68	68	68	62
Mean	56	57	57	55
Median	56	56	57	56
Mode	56	56	57	56
Standard Deviation	3.9	4.1	3.7	3.5
Variance	15.2	16.9	13.8	12.1
85th Percentile	60	62	60	58
95th Percentile	63	64	62	61
1st Quartile	54	54	54	52.5
3rd Quartile	58	59	58	58

As expected, the crossover had solid white lines for lane separation and was also preceded with a “STAY IN YOUR LANE” sign. However, midway through the crossover, there was a variable message sign requesting that “TRUCKS USE LEFT LANE” and “NEXT 3 MILES”.   Figure 9.17 shows the results of driver behavior when obeying the sign instructions.

Figure 9.17 Vehicles Changing Lanes in the Middle of the Dual-Lane Crossover

This contradiction led to a substantial amount of semi-trucks switching to the left lane mid-crossover, rather than waiting until the crossover ended. Considering the size of the vehicles, the reduced lane-width, and the difference in free-flow speed between the two lanes, this could be identified as a hazardous situation with a high risk potential. In addition to switching lanes, the filming recorded many vehicles that “rode the line” and sometimes partially ended up in the other lane or shoulder. The lateral displacement was a common problem particularly in this crossover. In two hours of data recording, there were 100 drivers riding the lane line and 84 lane changes made by drivers.

9.12 Site 3, N 70th Crossing of I-80 After Changes in Location of Variable Message Sign

NDOR recognized the contradictory instructions to drivers before receiving notification from the research assistants recording the potentially hazardous situation. NDOR moved the "TRUCKS USE LEFT LANE NEXT THREE MILES" sign downstream so the traffic would only see it after the crossover was passed. After this change, the same speed data and video analysis were completed for comparison purposes. The video camera was set up on the overpass bridge and footage was recorded on July 27th, 2009 in sunny conditions on dry pavement and on July 28th, 2009 in partly cloudy weather on dry pavement. Free-flow speeds and vehicle types of 200 vehicles in each lane were recorded. The crossover specifications, vehicle types, and calculations methods were maintained for an 'after' analysis. Table 9.6 shows statistical data similar to that taken earlier during the contradictory sign phase. In two hours of data recording, there were 118 drivers riding the lane lines and 38 lane changes within the dual-lane crossover limits.

Table 9.6 Free-Flow Speed Statistics for Site 3 After Contradictory Signs Moved

Left Lane	All	PC	ST, LT	TB
Min	48	48	51	50
Max	71	71	70	65
Mean	59	59	60	57
Median	59	60	59	56
Mode	57	61	57	56
Standard Deviation	4.1	4.1	4.1	3.7
Variance	17	17	17	14
85th Percentile	63	63	65	62
95th Percentile	66	66	66	63
1st Quartile	57	57	57	55
3rd Quartile	62	62	62	60

Right Lane	All	PC	ST, LT	TB
Min	47	52	50	47
Max	70	70	66	64
Mean	57	58	58	55
Median	57	58	57	55
Mode	56	57	56	56
Standard Deviation	3.9	3.6	3.6	3.9
Variance	15	13	13	15
85th Percentile	61	61	61	59
95th Percentile	64	66	63	61
1st Quartile	55	56	55	53
3rd Quartile	59	60	60	58

9.13 Observations

Comparing the speed data between the two situations, there is not much difference. The mean is consistent but the variation and standard deviation dropped in the left lane after the sign was moved indicating more uniform flow. Figures 9.18 through 9.25 graphically show the speed statistics in table 9.6.

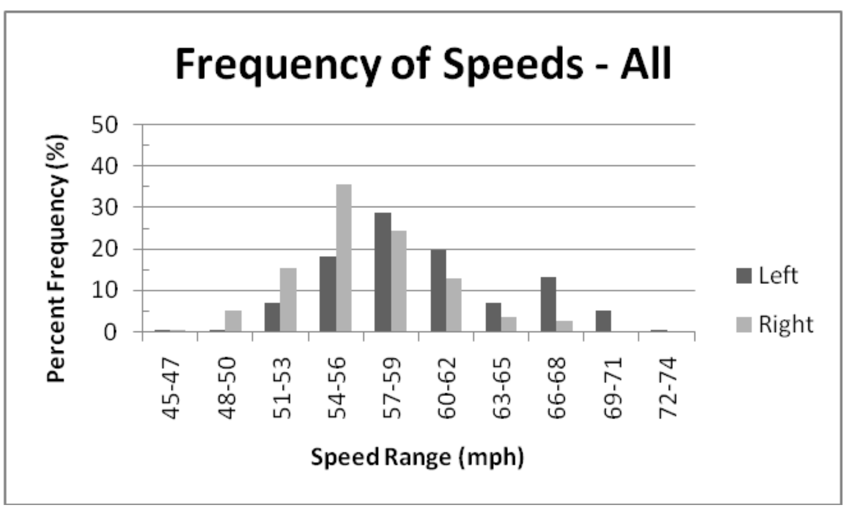


Figure 9.18 Frequency of All Vehicle Speeds in Left and Right Lanes During Contradictory Sign Period

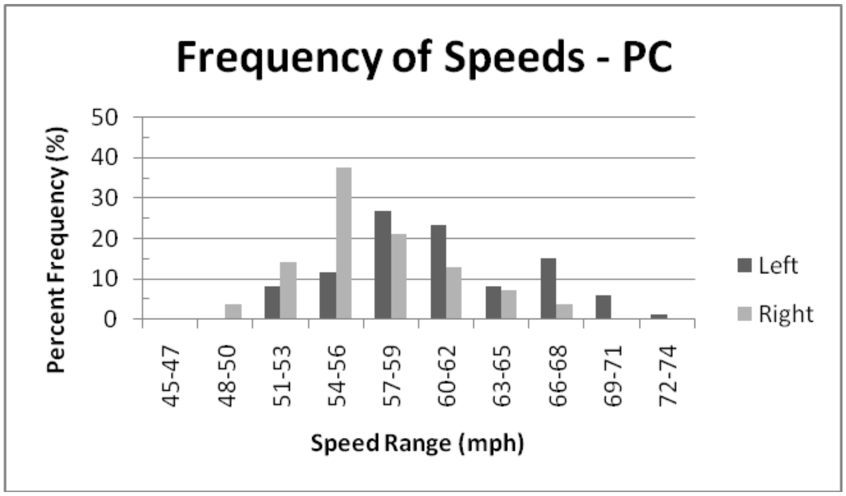


Figure 9.19 Frequency of Passenger Car Vehicle Speeds in Left and Right Lanes During Contradictory Sign Period

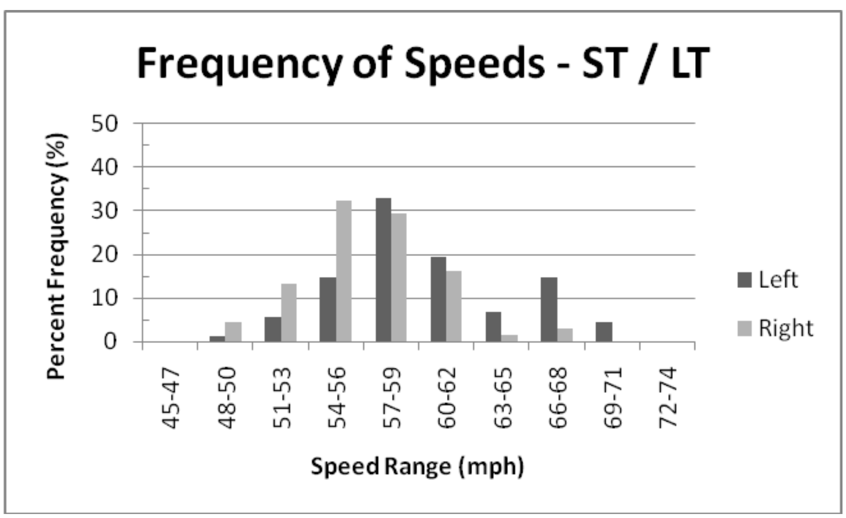


Figure 9.20 Frequency of Truck Speeds in Left and Right Lanes During Contradictory Sign Period

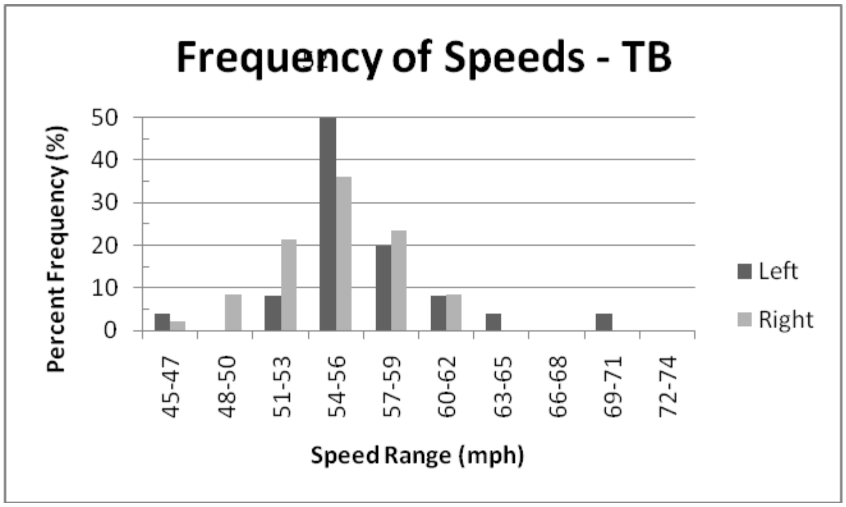


Figure 9.21 Frequency of Bus Speeds in Left and Right Lanes During Contradictory Sign Period

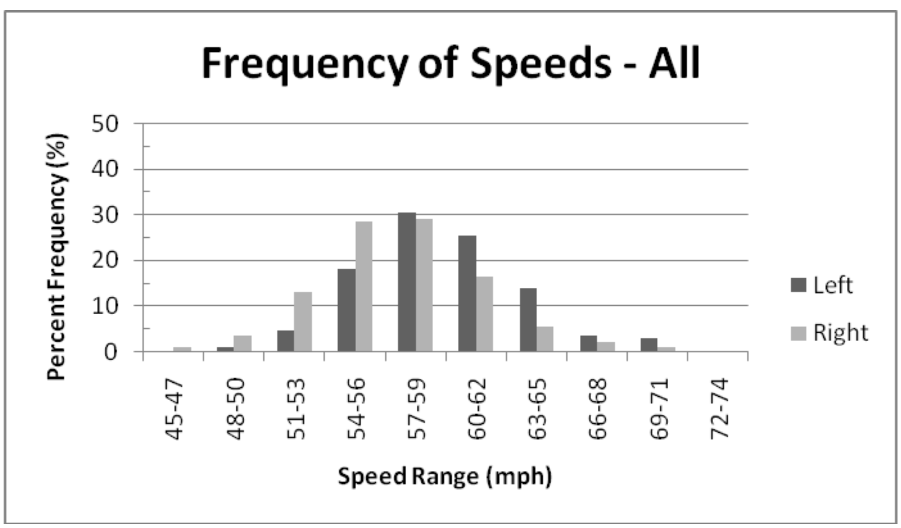


Figure 9.22 Frequency of All Vehicle Speeds in Left and Right Lanes After Contradictory Sign Period

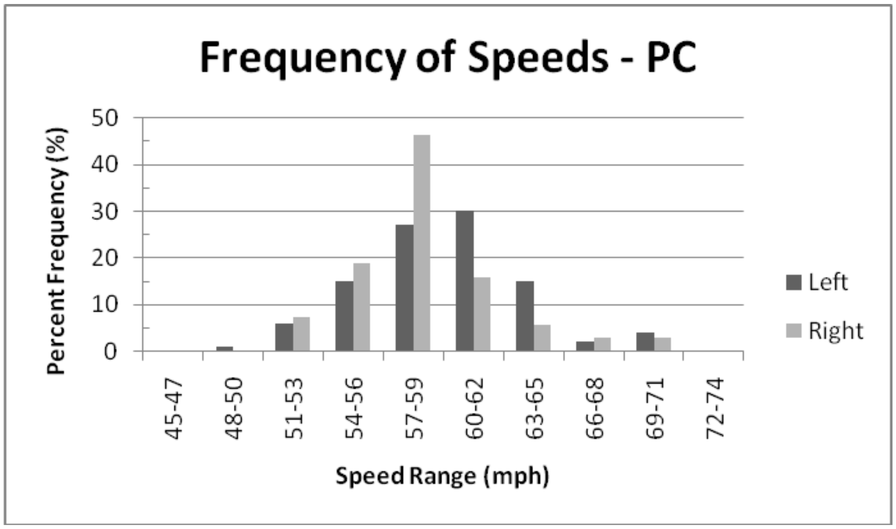


Figure 9.23 Frequency of Passenger Car Vehicle Speeds in Left and Right Lanes After Contradictory Sign Period

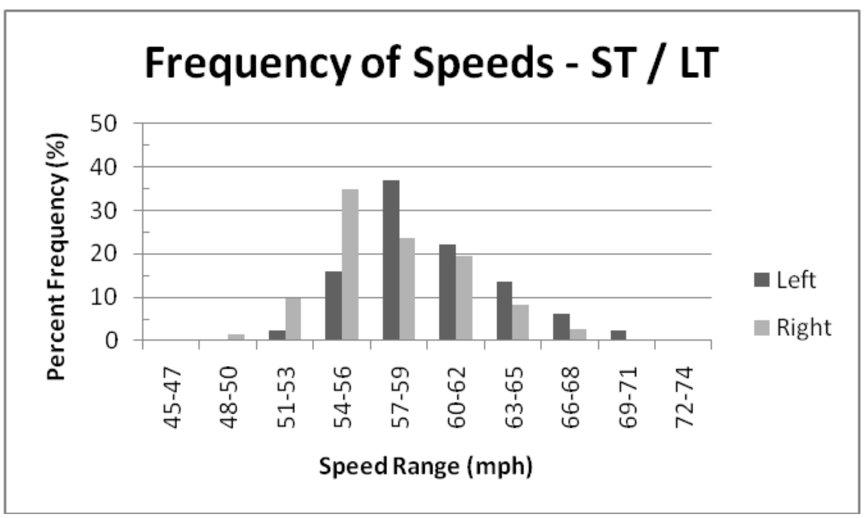


Figure 9.24 Frequency of Truck Speeds in Left and Right Lanes After Contradictory Sign Period

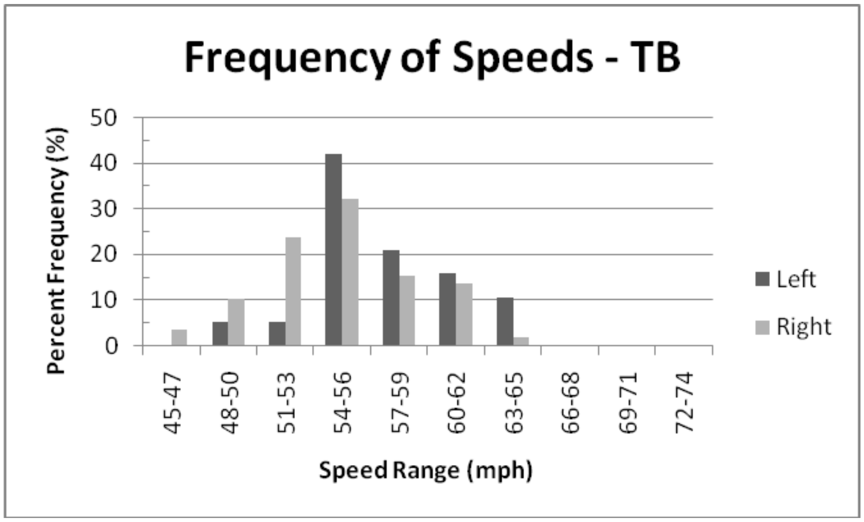


Figure 9.25 Frequency of Bus Speeds in Left and Right Lanes After Contradictory Sign Period

The number of 'riding the line' incidents increased from approximately 100 in the before period to 118 in the after situation. However, the number of lane changes dropped significantly, particularly for trucks and buses, as shown in table 9.7. The number of trucks and buses changing lanes dropped by over 88%.

Table 9.7 Before and After Contradictory Message Sign Condition Driver Behavior

	Riding the Lines	Lane Changes	Lane Changes (TB only)
Before	~100	84	51
After	~118	38	6

Chapter 10 Guidelines for Single-Lane Crossovers and Dual-Lane Crossovers

10.1 Crossover Guidelines

Table 10.1 contains guidelines recommended for single-lane crossovers from driver behavior data collected on this research project. Suggestions are listed in chronological categories of a typical surface transportation project.

Table 10.2 provides guidelines for dual-lane projects.

Table 10.1 Guidelines for Single-Lane Crossovers

PLANNING RECOMMENDATIONS
Consider political boundaries (city, county, state limits) that may impact union and non-union labor.
Profile median ditch grades of 0.5 percent or greater are preferable.
Avoid sags, crests and flat highway segments if possible.
Avoid stop-controlled or signalized intersections within 750 ft of the beginning of the first curve of the median crossover or the end of the last curve of the median crossover.
DESIGN RECOMMENDATIONS
Request field survey of driving lane cross slopes, shoulder cross slopes, lane edge elevations and median ditch elevations within 500 ft of the beginning of the beginning curve of the crossover and the end of the exit curve of the crossover.
Use a reverse curve design with an intermediate tangent segment (style currently used in Nebraska)
Use a posted advisory speed 10 mph below facility speed limit but design geometry for posted speed limit of the facility when not under construction.
Consider Method 2 of superelevation attainment given in Green Book, pp. 140-142
Provide a minimum 18-ft lane width, striped at 16-ft wide
Avoid use of slotted drain for internal crossover pavement drainage if possible.
Avoid concentrated drainage flow patterns within paved crossover area.
Subsoil of median should be analyzed for pavement foundation quality assurance.
Provide detailed contruction staking information at 50 ft increments within the limits of the crossover.
CONSTRUCTION RECOMMENDATIONS
Use construction staking information provided by design personnel. If the situation demands an alternate design, approval should be granted from roadway design engineer responsible for the original crossover design.
Special provisions should be added to the contract for permanent pavement quality control on crossover paving.
Survey in detailed edge line guide point on pavement for striping crew (50 ft increments)
Set channelizing traffic cones instead of traffic barrels in areas where viewing the crossover path ahead is essential.
Set traffic control devices at edge of paved surfacing of crossover.
Review traffic control device installation in the daylight and nighttime for best configuration BEFORE opening the crossover to traffic.
Review traffic control device locations in the daylight and nighttime for best configuration IMMEDIATELY AFTER opening the crossover to traffic.
OPERATIONS RECOMMENDATIONS
Provide a single-lane exit for 300 ft beyond the end of the crossover exit curve before providing existing dual traffic lanes.
Provide more advisory speed signs near the crossover entrance and exit.
MAINTENANCE RECOMMENDATIONS
Special provisions should be added to the contract for the daily review of traffic control devices, deteriorating surfacing conditions and driver behaviors to detect problem areas early.
REMOVAL
Special provisions should be added to the contract for the median ditch to be restored to its original condition for optimal drainage after crossover surfacing and embankment are removed.

Table 10.2 Guidelines for Dual-Lane Crossovers

PLANNING RECOMMENDATIONS
Consider political boundaries (city, county, state limits) that may impact union and non-union labor.
Profile median ditch grades of 0.5 percent or greater are preferable.
Avoid sags, crests and flat highway segments if possible.
Avoid stop-controlled or signalized intersections within 1000 ft of the beginning of the first curve of the median crossover or the end of the last curve of the median crossover.
DESIGN RECOMMENDATIONS
Request field survey of driving lane cross slopes, shoulder cross slopes, lane edge elevations and median ditch elevations within 500 ft of the beginning of the beginning curve of the crossover and the end of the exit curve of the crossover.
Use a reverse curve design with an intermediate tangent segment (style currently used in Nebraska)
Use a posted advisory speed 10 mph below facility speed limit but design geometry for posted speed limit of the facility when not under construction.
Consider Method 2 of superelevation attainment given in Green Book, pp. 140-142
Provide minimum 14-ft lane widths, each striped at 12-ft wide
Avoid use of slotted drain for internal crossover pavement drainage if possible.
Avoid concentrated drainage flow patterns within paved crossover area.
Subsoil of median should be analyzed for pavement foundation quality assurance.
Provide detailed contruction staking information at 50 ft increments within the limits of the crossover.
CONSTRUCTION RECOMMENDATIONS
Use construction staking information provided by design personnel. If the situation demands an alternate design, approval should be granted from roadway design engineer responsible for the original crossover design.
Special provisions should be added to the contract for permanent pavement quality control on crossover paving.
Survey in detailed edge line guide point on pavement for striping crew (50 ft increments)
Set channelizing traffic cones instead of traffic barrels in areas where viewing the crossover path ahead is essential.
Set traffic control devices at edge of paved surfacing of crossover.
Locate variable message signs in advance of desired driver behavior with care.
Review traffic control device installation in the daylight and nighttime for best configuration BEFORE opening the crossover to traffic.
Review traffic control device locations in the daylight and nighttime for best configuration IMMEDIATELY AFTER opening the crossover to traffic.
OPERATIONS RECOMMENDATIONS
Provide more “STAY IN YOUR LANE” signs within the crossover.
Provide more advisory speed signs near the crossover entrance and exit.
MAINTENANCE RECOMMENDATIONS
Special provisions should be added to the contract for the daily review of traffic control devices, deteriorating surfacing conditions and driver behaviors to detect problem areas early.
REMOVAL
Special provisions should be added to the contract for the median ditch to be restored to its original condition for optimal drainage after crossover surfacing and embankment are removed.

References

1. Jiang, Yi. 1999. “Traffic Capacity, Speed, and Queue-Discharge Rate of Indiana’s Four-Lane Freeway Work Zones.” In *Transportation Research Record 1657,* Transportation Research Board. Washington D.C., pp. 10-17.

2. American Association of State and Highway Transportation Officials. 2004. *A Policy on Geometric Design of Highways and Streets,* Washington D.C.

3. Nemeth, Z.A., and A. Rathi. January 1983. “Freeway Work Zone Accident Characteristics.” *Transportation Quarterly,* Vol. 37, No. 1, pp. 145-159.

4. *Manual on Uniform Traffic Control Devices 2003*. Federal Highway Administration. [PDF online]. Washington: Government Printing Office. 2003 [updated November 2004]. Available from http://mutcd.fhwa.dot.gov/HTM/2003r1/html-index.htm. Accessed 2 May 2007.

5. American Association of State and Highway Transportation Officials. 1973. *A Policy on Geometric Design of Highways and Streets,* Washington D.C.

6. American Association of State and Highway Transportation Officials. 1984. *A Policy on Geometric Design of Highways and Streets,* Washington D.C.

7. American Association of State and Highway Transportation Officials. 1990. *A Policy on Geometric Design of Highways and Streets,* Washington D.C.

8. American Association of State and Highway Transportation Officials. 1994. *A Policy on Geometric Design of Highways and Streets*, Washington D.C.

9. American Association of State and Highway Transportation Officials. 2001. *A Policy on Geometric Design of Highways and Streets,* Washington D.C.

10. Graham, J. L., and J. Migletz. 1983. *Design Considerations for Two-Lane, Two-Way Work Zone Operations*. Publication FHWA-RD-83-112. FHWA, U.S. Department of Transportation.

11. Easa, Said M., and Amir Abd El Halim. 2006. *Radius Requirements for Trucks on Three-Dimensional Reverse Horizontal Curves with Intermediate Tangents.* In *Transportation Research Record 1961*, Transportation Research Board. Washington D.C., pp. 83-93.

12. Bonneson, J.A. 2000. “Superelevation Distribution Methods and Transition Designs.” *National Cooperative Highway Research Program Report 439*, Transportation Reasearch Board, National Research Council, Washington, D.C.

13. *Connecticut Highway Design Manual.* Connecticut Department of Transportation. [PDF Online]. 2003 [updated December 2006]. Available from http://www.ct.gov/dot/lib/dot/documents/dpublications/highway/Cover.pdf. Accessed 20 March 2008.

14. *Iowa Design Manual*. Iowa Department of Transportation. [PDF online]. September 2005 [updated December 2006]. Available from http://www.dot.state.ia.us/design/desman.htm. Accessed 20 March 2008.

15. *Michigan Road Design Manual*. Michigan Department of Transportation. [PDF online]. November 1997 [updated July 2007]. Available from http://mdotwas1.mdot.state.mi.us/public/design/englishroadmanual/. Accessed 20 March 2008.

16. *Mississippi Roadway Design Manual*. Mississippi Department of Transportation. [PDF online]. July 2001. Available from http://www.gomdot.com/Divisions/Highways/Resources.aspx. Accessed 20 March 2008.

17. *Montana Road Design Manual*. Montana Department of Transportation. [PDF online]. June 2006. Available from http://www.mdt.mt.gov/publications/manuals.shtml. Accessed 20 March 2008.

18. *NDOR Roadway Design Manual.* Nebraska Department of Roads. [PDF online]. July 2005 [updated August 2006]. Available from http://www.nebraskatransportation.org/roadway-design/manual.htm. Accessed 20 March 2008.

19. *New York Highway Design Manual*. New York Department of Transportation. [PDF online]. 2006 [updated March 2007]. Available from https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm. Accessed 20 March 2008.

20. *Oregon Highway Design Manual*. Oregon Department of Transportation. [PDF online]. December 2003 [updated September 2007]. Available from http://www.oregon.gov/ODOT/HWY/ENGSERVICES/hwy_manuals.shtml#2003_English_Manual. Accessed 20 March 2008.

21. *South Dakota Road Design Manual*. South Dakota Department of Transportation. [PDF online]. Available from http://www.sddot.com/pe/roaddesign/plans_rdmanual.asp. Accessed 20 March 2008.

22. *Washington Design Manual*. Washington State Department of Transportation. [PDF online]. November 2007. Available from http://www.wsdot.wa.gov/publications/manuals/fulltext/m22-01/design.pdf. Accessed 20 March 2008.

23. *Wisconsin Facilities Development Manual*. Wisconsin Department of Transportation. [PDF online]. February 2007 [updated January 2008]. Available from http://roadwaystandards.dot.wi.gov/standards/fdm/index.htm. Accessed 20 March 2008.

24. NU-METRICS. 1999. *NU-METRICS HISTAR NC-97 Vehicle Magnetic Imaging Traffic Counter Operating Instructions*. Uniontown, PA.

25. Transportation Research Board. 2000. *Highway Capacity Manual*.

26. Roess, R. P., E. S. Prassas, and W. R. McShane. 2004. *Traffic Engineering*. Third Ed. Pearson Education Inc., Upper Saddle River, New Jersey.

27. Walpole, R., R. Myers, S. Myers, and K. Ye. 2002. *Probability & Statistics for Engineers & Scientists*. Seventh ed. Prentice Hall, Upper Saddle River, New Jersey.

28. Tarris, Joseph P., Christopher M. Poe, John M. Mason Jr., and Konstadinos G. Goulias. 1996. *Predicting Operating Speeds on Low-Speed Urban Streets: Regression and Panel Analysis Approaches*. In *Transportation Research Record 1523*. Washington D.C., pp. 46-54.

29. Savoy Computing Services Limited. 2004. *User Manual for AutoTrack: Advanced Vehicle Swept Path Analysis*., Kent, England.

30. Greene, William H. 1995. *Limdep Version 7.0 User's Manual*. Econometric Software, Inc., Bellport, NY.

Appendix A Work Zone Crossover Questionnaire

Work Zone Crossover Questionnaire

The Mid-America Transportation Center (MATC) at UNL is working on a NDOR research project for the Optimal Design of Work Zone Crossovers. To gain further insight into the construction, maintenance, and operations of temporary crossovers, we would like your assistance. If you have experience with projects in the past or present using temporary work zone crossovers, your help would be greatly appreciated to develop the most informed conclusions possible for our research. If you have any questions about the project please contact the project investigator, Karen Schurr, at kschurr1@unlnotes.unl.edu or (402) 472-2233.

University of Nebraska Lincoln

NDOR Nebraska Department of Roads

Respondent ID:

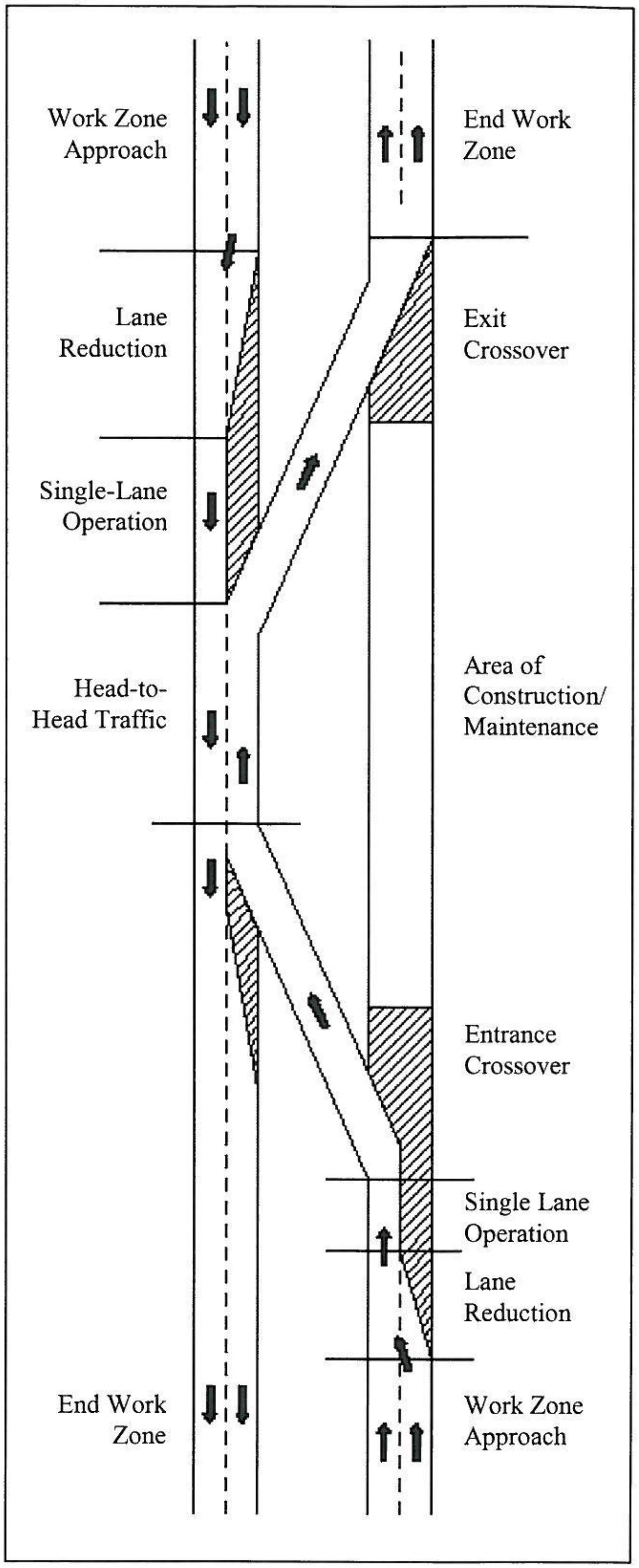
Name: ____________________________

E-Mail:____________________________

Number of Crossover Projects Participated In:_____

Crossover Diagram

The figure to the right is a general diagram of a work zone crossover. Each general area from start to finish for traffic in both directions is identified. For ease of communication, please refer to this diagram when answering questions or explaining your comments.



Questionnaire Details

The questionnaire is organized into three sections. Each section is to be used for one crossover project. If you have participated in multiple crossover projects, please use one section for each project. Answer as many of the questions as accurately as you can.

For e-mail responses, answers may be typed directly into the document on the lines provided. To answer Yes or No in the check boxes, click in the appropriate box and type in "x." When your questionnaire is complete, save the changes to the file and name the new file "Crossover Response" E-mail the final document to the graduate research assistant for the project, Brian Gardner, at bgardner@unlnotes.unl.edu

For hardcopy responses, print the questionnaire and write in your answers. Please send all hardcopy reponses by mail to:

Brian Gardner
Mid-America Transportation Center
W333.2 Nebraska Hall
University of Nebraska-Lincoln
68588-0530

Your reply to this questionnaire by **Friday, December 1st** would be greatly appreciated.

Crossover Project 1

Identification of project with crossover location (Fill in as many as possible)

Project Number ______________________________

Project Control Number ______________________________

Project Name ______________________________

Approximate Reference Post Location of Crossover ______________

Approximate Reference Post Location of Project ______________

Approximate dates when crossover was in operation

Month, Year at opening ______________________________

Month, Year at removal ______________________________

Complicating features near crossover:

	Yes	No
Was there a stoplight near the crossover?	☐	☐
Was there an intersection near the crossover?	☐	☐

Comments: ______________________________

____

____

Vehicle Accidents (See Crossover Diagram for Section Views):

	Yes	No
Accidents in work zone approach sections?	☐	☐
Accidents in lane reduction sections?	☐	☐
Accidents in single lane operation sections?	☐	☐
Accidents in the first half the crossovers (entrance and exit crossovers)?	☐	☐
Accidents in second half of crossovers (entrance and exit crossovers?	☐	☐
Accidents in head-to-head traffic sections near crossovers?	☐	☐

Comments: ______________________________

____

____

Advance Visibility:

	Yes	No
Was the crossover in flat terrain and easily seen from the approaching direction of traffic for several hundred feet before the lane reduction?	☐	☐
Was the crossover in flat terrain and difficult to see from the approaching direction of traffic for several hundred feet before the lane reduction?	☐	☐
Was the crossover in rolling terrain and easily seen from the approaching direction of traffic for several hundred feet before the lane reduction?	☐	☐
Was the crossover in rolling terrain and difficult to see from the approaching direction of traffic for several hundred feet before the lane reduction?	☐	☐

Comments: ______________________________

____

____

Edgeline Striping:

	Yes	No
Was the edgeline striping along the crossover laid in smooth curves?	☐	☐
Was the edgeline striping along the crossover laid in angled segments?	☐	☐
Were vehicles able to easily stay within the limits of the striping?	☐	☐
Were vehicles able to easily stay within the limits of the traffic barrels?	☐	☐


Example: Smooth Striping
Example:Segmented Striping

Comments: ____
____
____

Traffic Control Device Locations:

	Yes	No
Were the traffic plans for the crossover location easily understood?	☐	☐
Was it difficult to place traffic control devices according to the traffic plans?	☐	☐
Was the location and spacing of traffic barrels adjusted for adequate sight distance once positioned from the traffic plan recommendations?	☐	☐
Were traffic barrels or channelizer cones used for delineation?	☐	☐

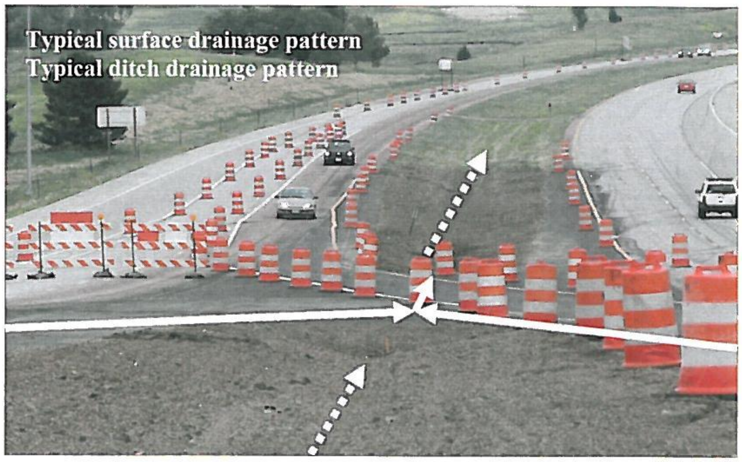

Barrel


ChannelizerCone

Comments: ____
____
____

Drainage:

	Yes	No
Was surface drainage on the crossover pavement a problem?	☐	☐
Was ditch drainage under the crossover a problem?	☐	☐



Comments: ____

____

____

Surface Construction:

	Yes	No
Was the surfacing type of the crossover asphalt?	☐	☐
OR		
Was the surfacing type of the crossover concrete?	☐	☐
Were detailed staking points located to establish elevations and cross slopes of the crossover pavement?	☐	☐
OR		
Was the surfacing applied based on connection points with existing traffic lanes?	☐	☐
Did the surfacing hold up under traffic or were repairs required during the project time frame?	☐	☐

Comments: ____

____

____

Other problems encountered that were not addressed?

Other comments about crossover design, construction, maintenance, or removal?

Appendix B Collected Data

In the following data sets, a value of -999 was input if there was a missing value for the observed vehicle.

Table B.1 Lincoln West Crossover Data

Vehicle Number	Vehicle Type	Speed by Location (mi/h)			Headway by Location (seconds)			Lateral Displacement by Location (feet)		
		1	2	3	1	2	3	1	2	3
5159	1	46	54	49	1	1	2	-999	-999	0.5
5160	1	44	46	47	4	5	4	0	-1.5	-0.5
5161	1	44	46	53	4	4	4	-0.5	0.5	-0.5
5162	1	41	43	46	3	2	3	0.5	0	0.5
5163	1	48	42	46	25	26	25	-0.5	-1	1
5165	1	39	39	36	17	18	20	-0.5	-0.5	-0.5
5166	1	37	36	41	2	1	1	0.5	-1	0.5
5167	2	35	41	44	3	3	3	0	-2	0
5168	1	43	43	45	24	23	22	-0.5	-1.5	0
5169	1	44	41	43	3	3	2	-0.5	-1.5	0
5170	1	52	56	53	14	14	13	0	-1	0.5
5171	1	48	49	54	13	13	14	-0.5	-1.5	-0.5
5172	1	49	47	42	1	2	2	-0.5	-0.5	0.5
5173	1	48	50	50	3	2	1	-1	-0.5	0.5
5174	1	56	55	50	39	39	40	0	-1	0.5
5175	1	53	55	33	7	8	8	-0.5	-0.5	0.5
5176	1	52	48	41	2	2	2	-2.5	0.5	-0.5
5177	2	52	52	49	3	3	4	0	-1	0
5178	2	39	39	40	29	29	30	0	-0.5	-1
5179	1	43	51	43	5	4	3	0	-0.5	-0.5
5180	1	42	49	45	36	37	37	-0.5	-1	-1.5
5181	2	45	46	41	4	4	4	-0.5	-1.5	0
5182	1	42	38	54	0	1	1	-0.5	0	-0.5
5183	1	40	43	41	2	2	2	-1.5	0	0.5
5185	1	45	43	41	7	6	5	-0.5	-0.5	1
5186	1	43	41	42	2	2	3	0	0.5	0.5
5187	1	49	54	41	3	3	1	-1.5	-0.5	1
5188	1	49	48	48	9	9	9	0	0.5	0
5189	2	40	55	49	4	4	5	0	-0.5	-1.5
5190	2	43	57	45	9	9	9	0	-1	-0.5
5191	1	43	47	45	3	3	2	0	0.5	0.5
5192	1	50	49	46	12	12	13	-0.5	-0.5	-0.5
5193	1	55	56	46	3	3	2	0	-1.5	0.5
5194	1	57	54	67	2	2	2	0.5	-1.5	0.5
5195	1	55	56	56	17	17	16	-1.5	-0.5	1.5
5196	1	47	47	45	16	16	18	-0.5	-0.5	1.5
5197	1	50	47	46	8	9	9	-1	0	0.5
5198	1	49	48	47	29	28	27	-0.5	-1.5	0.5
5199	1	55	55	41	3	3	4	-0.5	-1.5	1.5
5200	1	48	54	52	1	1	1	-0.5	-2.5	0.5
5201	1	53	52	48	8	8	7	-1	-1.5	1

5202	1	41	51	48	2	2	2	0.5	0.5	0.5
5203	2	45	46	63	2	2	3	0.5	-0.5	0
5204	2	48	54	55	10	10	10	-0.5	-0.5	-0.5
5205	1	48	51	45	42	42	42	-0.5	-0.5	0.5
5206	1	49	45	65	1	2	1	-0.5	-0.5	1
5207	1	50	55	-999	4	3	-999	-1	-1	2
5208	1	44	52	53	4	4	8	0	-1	0.5
5209	1	46	49	-999	2	2	-999	-0.5	-0.5	2
5210	1	50	50	36	2	2	5	0	-1.5	0.5
5211	1	45	52	51	34	34	33	-1.5	-0.5	0.5
5212	1	49	47	48	2	3	2	0.5	-0.5	0
5213	1	45	43	48	1	1	2	0.5	-1	1
5214	1	46	55	46	2	2	2	-0.5	-2.5	0.5
5215	1	41	41	42	1	1	2	0.5	0.5	-0.5
5216	2	47	47	54	8	8	6	0	-1.5	0
5217	1	45	48	38	2	1	2	-1.5	-2	1
5218	1	48	50	43	10	10	9	-0.5	-1	0
5219	1	48	50	43	2	3	3	-1.5	-0.5	1.5
5220	1	51	50	39	14	13	13	-0.5	-0.5	1
5221	1	51	53	42	10	10	9	-0.5	-0.5	0.5
5222	1	53	56	54	12	12	12	0.5	-0.5	1.5
5223	1	47	49	41	4	4	5	-1	0	1.5
5225	1	46	48	44	2	2	2	-0.5	-1	0.5
5226	1	48	51	64	2	2	2	0.5	-0.5	0.5
5227	1	47	72	54	7	7	7	0	0	0.5
5228	1	45	50	62	4	4	4	-1	-1	0
5229	1	37	52	77	15	15	16	-0.5	-2	-0.5
5230	1	44	44	-999	2	3	3	0	-0.5	0
5231	1	51	58	-999	22	21	19	0	-0.5	0
5232	1	46	44	40	61	62	64	0	-0.5	0
5233	1	45	43	40	2	1	2	0.5	0	0.5
5234	1	41	44	44	3	3	2	-0.5	-0.5	-0.5
5235	1	45	47	46	2	3	3	0	-0.5	-1
5236	1	47	52	52	4	3	2	-0.5	0	0.5
5237	1	47	54	49	2	2	2	-0.5	-2.5	-1
5238	1	51	51	46	4	5	5	-0.5	-1	0.5
5239	1	48	43	48	10	9	10	0	-2	-1.5
5241	1	46	49	54	52	53	52	0.5	1	0.5
5242	1	52	51	46	30	29	29	0	-0.5	-0.5
5244	1	45	47	38	41	41	41	0.5	-1	1
5245	1	62	56	57	24	24	24	0.5	-1.5	0.5
5246	1	55	56	58	1	1	1	0	-0.5	0.5
5247	1	47	47	54	9	10	10	0.5	-1.5	0.5
5248	1	45	40	40	12	12	14	0	-1	-0.5
5249	1	40	41	41	2	2	2	0	-0.5	0
5250	1	54	60	-999	15	15	-999	0.5	0	0.5
5251	1	54	58	44	2	2	40	0.5	0	0.5
5252	1	49	54	55	5	6	6	0.5	-0.5	1
5253	1	51	54	39	2	1	2	0.5	-2.5	0.5
5254	1	43	53	48	8	9	10	-0.5	-2.5	0.5
5256	1	49	52	41	43	42	41	-0.5	-2.5	0
5257	1	47	48	24	1	1	2	0.5	-0.5	-0.5
5259	1	50	49	52	15	15	14	0.5	-0.5	0
5260	1	50	53	42	1	1	1	0.5	0	0.5

5261	1	52	57	71	12	12	11	-0.5	-1	0.5
5263	1	61	63	56	3	3	3	-0.5	0	1
5264	1	54	48	56	16	16	17	0	0	1
5265	1	45	46	42	10	11	12	0.5	0.5	-0.5
5266	1	45	48	45	5	4	4	0.5	-0.5	0
5267	1	51	55	47	6	6	4	0.5	-0.5	0.5
5268	1	49	51	49	3	4	4	0.5	-0.5	0.5
5269	2	51	57	47	4	3	4	1	-2	1
5270	1	45	48	47	24	25	25	-0.5	-0.5	0.5
5271	1	61	56	47	8	6	6	0	-1	0.5
5272	1	52	61	47	9	11	11	0.5	-0.5	0
5273	1	50	57	47	45	45	44	0.5	-0.5	1.5
5274	1	39	36	32	28	29	32	-1	-1.5	0.5
5275	1	34	40	36	2	1	2	0	-1.5	0.5
5276	2	39	37	36	1	2	2	-1	-2	0
5277	1	46	46	44	39	37	35	-0.5	0	0.5
5278	1	45	50	40	36	37	36	-1.5	-1	1
5279	2	53	52	54	8	8	8	-0.5	-1	0
5280	1	50	55	39	11	10	9	0	-1	0
5281	1	49	51	38	14	14	15	1	0.5	1.5
5282	1	18	57	58	11	11	10	-0.5	-1	1
5283	1	50	53	44	2	2	3	0	-0.5	0.5
5284	1	49	48	15	22	22	23	-0.5	-0.5	0.5
5285	1	52	54	53	15	15	16	-0.5	-1	0.5
5286	1	48	-999	-999	2	-999	-999	-0.5	-2	-0.5
5287	1	53	19	45	0	3	1	-0.5	-0.5	0
5288	1	54	52	38	2	1	2	0	-1.5	1
5289	1	51	49	45	2	2	1	0	-0.5	0.5
5290	1	49	52	59	1	2	2	-0.5	-2	0
5291	1	45	58	50	3	2	2	-0.5	0	0
5292	1	46	46	57	2	2	2	-1	-1.5	-0.5
5293	1	55	53	51	22	22	22	-1.5	-0.5	0
5294	1	50	53	55	18	18	18	-0.5	-1	-0.5
5295	1	42	42	42	23	24	25	0	-1.5	-0.5
5296	1	42	45	63	1	1	1	-0.5	-1	1
5297	1	40	41	55	1	1	1	-0.5	-0.5	0.5
5298	1	42	39	41	3	3	3	-0.5	-1	0
5299	1	37	44	35	4	4	5	-0.5	-0.5	0.5
5300	1	41	32	35	1	2	4	0	1	0.5
5301	1	45	47	51	50	49	45	0.5	-0.5	1
5302	1	46	48	44	9	8	9	-1	-1	0.5
5303	1	44	49	44	5	5	4	-0.5	-1.5	0.5
5304	1	49	58	41	9	9	9	0	-1	1.5
5305	1	57	54	52	6	6	5	0	-1	0.5
5306	1	50	48	47	12	13	14	-0.5	-1.5	1
5307	1	52	57	47	29	28	28	-0.5	-2	0.5
5308	1	55	46	47	4	4	4	-0.5	-1.5	0.5
5309	2	53	55	53	6	6	6	0	-1	0
5310	1	50	48	49	9	10	10	-1	-1.5	0
5311	1	53	48	50	3	3	3	-1.5	-1.5	0.5
5314	1	45	48	46	10	10	11	-0.5	-2	0.5
5315	1	44	45	47	45	45	44	1	-1	1.5
5316	1	42	42	53	8	7	9	-1	-1	0.5
5317	1	41	44	43	1	2	1	-0.5	-1	1.5

5318	1	44	44	42	3	2	2	-0.5	-0.5	0.5
5319	1	50	55	44	41	41	40	-1.5	-0.5	0.5
5320	1	48	46	64	9	9	9	-1.5	-1.5	0.5
5321	1	51	51	54	5	5	6	0	-1.5	1.5
5322	1	56	62	56	29	28	27	0.5	0	1
5323	1	52	51	62	18	19	19	0	-1	0.5
5324	1	49	52	50	4	4	4	-1	-2.5	0.5
5325	1	49	53	47	2	2	3	-0.5	-2	0.5
5326	1	49	49	50	2	2	1	-1	-1.5	0.5
5327	1	47	47	49	2	2	3	-0.5	-1	1.5
5328	1	44	48	49	2	2	2	-1	-2	0
5330	1	48	50	49	7	7	6	-0.5	-1	1
5331	1	44	49	49	1	1	2	-0.5	-1.5	0.5
5332	1	51	53	49	29	29	28	0	0	1
5333	2	33	31	29	18	21	26	-1	-0.5	-1
5334	1	35	28	20	2	1	1	0	0	1
5335	1	36	37	29	11	11	8	-1	-1.5	0.5
5336	1	38	60	37	3	2	1	-1	-0.5	1
5337	1	34	39	40	1	1	2	-2.5	-1	0
5338	1	32	37	42	1	2	2	0	-0.5	1.5
5339	1	31	39	38	2	2	2	-0.5	-2.5	1
5340	1	46	39	34	3	1	3	0	0	1
5341	1	45	48	49	45	45	41	0	-2	1.5
5342	1	49	48	46	1	1	2	0.5	-1.5	1
5343	1	52	53	50	9	9	8	0.5	-2	1
5344	1	53	55	55	4	4	4	0	-0.5	0
5345	1	52	55	52	16	16	16	-0.5	-1	1
5346	1	51	54	46	23	23	23	0	-0.5	0.5
5347	1	51	64	48	8	7	7	-0.5	-1.5	0.5
5348	1	54	58	23	16	17	18	-0.5	-0.5	0.5
5349	1	39	40	35	14	15	16	-0.5	-0.5	0.5
5350	1	35	35	42	3	3	3	-0.5	-2	-0.5
5351	1	33	34	43	1	2	2	0.5	-0.5	0.5
5352	1	44	48	40	25	24	22	0.5	-1	0.5
5353	1	52	50	49	4	3	2	0	-1.5	1.5
5354	1	39	34	16	28	29	33	0	-0.5	1
5355	1	39	35	35	1	2	2	-2.5	-1	1
5356	1	42	39	33	3	2	1	-2.5	-0.5	0.5
5357	1	46	38	43	3	2	2	-1	-0.5	0
5358	1	38	42	47	1	2	2	-1.5	-0.5	0
5359	1	43	44	51	7	6	5	-0.5	-0.5	1
5360	1	48	48	14	30	31	30	-0.5	-2	1.5
5361	1	44	51	36	5	4	5	-1.5	-2	0.5
5362	1	38	44	42	2	3	3	-0.5	-1	1
5363	1	40	41	13	7	7	8	1	-0.5	1
5364	1	59	52	25	42	41	38	-0.5	-1.5	0.5
5365	1	66	57	55	10	10	10	-1.5	-2.5	0
5366	1	51	62	57	2	2	2	-1.5	-1.5	0.5
5368	2	45	44	40	30	31	33	0	-1.5	-1
5371	1	49	57	57	48	47	46	-0.5	-1	0
5372	1	37	36	25	26	28	31	-0.5	0	1
5373	1	47	47	22	9	8	5	-0.5	-1	0.5
5374	1	51	53	29	2	1	1	0	-0.5	1
5375	1	48	54	54	4	4	4	-0.5	-0.5	0.5

5376	1	53	55	49	2	2	2	-0.5	-1.5	-0.5
5377	1	50	53	52	1	2	2	-0.5	-1	1
5379	1	44	47	48	13	12	13	-1	-1	0.5
5380	1	47	39	48	1	2	2	-1.5	-2.5	0.5
5381	1	45	51	51	24	24	24	0	-0.5	0
5382	1	47	41	46	1	1	1	-1.5	-2	0.5
5383	1	48	61	56	46	44	43	0	-1	0
5384	1	44	53	68	11	12	12	-0.5	-0.5	0.5
5386	1	53	59	59	15	15	14	-0.5	-2	0
5387	1	55	52	47	8	9	9	-0.5	-2.5	-0.5
5388	1	43	46	53	5	5	6	0	-1	0.5
5389	2	49	52	58	15	14	14	-2	-2	-0.5
5390	1	48	44	42	40	40	41	0.5	-0.5	0
5392	1	55	47	55	53	53	52	-1	0.5	-0.5
5393	1	56	48	51	2	3	3	-0.5	-0.5	0.5
5394	1	49	48	47	2	1	2	-0.5	-1.5	0
5395	1	38	53	43	10	10	10	-1	-1.5	-0.5
5396	1	50	48	14	1	2	1	-0.5	-2.5	-0.5
5397	2	56	56	30	6	5	5	0	-0.5	-1
5398	1	46	57	30	4	5	5	-0.5	-2	0.5
5399	1	51	50	56	9	8	8	-0.5	-1	0
5400	1	54	52	71	38	38	38	0	-1.5	0.5
5401	1	51	56	51	1	1	1	0	-1	0.5
5402	1	51	51	54	2	2	3	-0.5	-2	0
5403	1	55	53	49	3	3	2	-0.5	-1.5	-2
5404	1	47	50	36	24	24	25	-0.5	-0.5	0.5
5405	1	53	56	58	4	4	2	0	-0.5	0
5406	2	42	41	37	12	13	16	0	-1	-1.5
5407	1	39	41	19	2	2	2	0.5	0.5	1
5408	1	51	54	43	19	18	15	0.5	-1.5	0.5
5409	1	56	58	57	5	5	5	0.5	-0.5	0.5
5410	1	47	48	47	22	23	25	-1	-0.5	0
5411	1	46	59	47	1	1	0	-0.5	-2	-0.5
5412	1	45	46	48	2	1	2	-0.5	-0.5	0
5413	1	44	50	47	1	1	1	-0.5	-1.5	0.5
5414	1	44	52	47	2	2	2	-0.5	-1.5	0.5
5415	1	44	51	47	13	13	12	-0.5	-1	0.5
5416	1	45	46	47	5	5	6	-0.5	-2.5	0.5
5417	1	55	45	46	17	17	17	-1	-1.5	-0.5
5418	1	50	52	53	29	30	28	-0.5	-0.5	-0.5
5419	1	61	49	58	50	49	50	-0.5	-0.5	0.5
5420	1	49	50	19	13	13	14	-0.5	-0.5	0.5
5421	1	65	49	58	5	4	2	-0.5	-1.5	0.5
5422	1	49	16	51	51	52	54	-1.5	-2	-0.5
5423	1	47	52	53	5	5	4	0.5	-0.5	-0.5
5424	2	49	51	44	2	3	3	-0.5	-1.5	-2
5425	1	47	46	49	1	2	2	-0.5	-0.5	0
5426	1	48	56	44	15	14	13	-0.5	-0.5	0
5427	1	50	55	26	23	23	24	-0.5	-0.5	0.5
5428	1	53	54	45	5	5	5	-0.5	-1	0.5
5429	1	57	53	40	7	7	7	-1	-0.5	0
5431	1	54	48	53	16	17	17	-1	-1	-0.5
5432	1	49	48	70	2	1	1	-1	-1	-0.5
5433	1	47	49	58	74	75	75	-0.5	-0.5	0

5434	1	49	50	29	3	3	4	-1	-1.5	0
5435	1	54	57	43	14	13	11	-1.5	-1.5	0.5
5436	1	45	42	32	20	20	22	-0.5	-0.5	0.5
5437	1	44	49	44	3	4	3	-0.5	-0.5	0
5438	1	40	47	48	1	1	2	-0.5	-0.5	-1
5439	1	43	37	69	20	20	22	-0.5	-1	-0.5
5440	1	51	59	56	26	25	22	-2.5	0.5	-0.5
5441	1	49	53	50	22	23	23	-0.5	0	-0.5
5442	1	47	49	49	2	2	2	-1	-0.5	-0.5
5444	1	51	49	45	79	78	78	0.5	-0.5	0.5
5445	1	44	50	31	1	1	1	-1.5	-1.5	0.5
5448	1	56	55	54	28	28	28	-1	-1.5	-0.5
5449	1	55	56	40	23	23	22	-0.5	-0.5	-0.5
5450	1	53	58	43	4	4	5	-1.5	-0.5	-0.5
5451	1	50	51	54	9	10	9	-0.5	-0.5	-0.5
5452	1	51	52	52	15	14	15	-1.5	-2	-1
5453	1	34	37	50	13	15	17	-0.5	-1	-1.5
5454	1	38	39	40	1	1	1	-0.5	-2.5	-1.5
5455	1	47	49	48	24	23	21	-0.5	-0.5	-1
5457	1	52	52	53	59	59	58	0.5	-1	-0.5
5458	1	50	50	53	2	1	1	0	-2	-0.5
5459	1	48	50	51	8	8	9	0	-2	-0.5
5460	1	47	48	52	1	2	2	-0.5	-1.5	-2.5
5461	1	38	59	48	1	1	1	-1.5	-2	-2.5
5462	1	44	47	45	3	3	3	-1	-1	-0.5
5463	1	48	49	42	40	40	41	-0.5	-0.5	-0.5
5464	1	44	42	35	70	70	71	-0.5	-0.5	0
5465	1	47	37	54	2	2	2	-0.5	0	1
5466	2	44	43	46	5	5	5	-1	-1	0
5467	1	44	44	39	2	1	1	-0.5	-0.5	0
5468	1	47	46	42	1	2	2	0	-1.5	0
5469	1	44	49	37	2	2	1	-1.5	-2	-0.5
5470	1	48	49	39	1	1	2	-0.5	-1.5	-0.5
5471	1	46	49	43	9	8	7	-0.5	-0.5	-0.5
5472	1	51	53	56	25	25	24	-0.5	-0.5	0.5
5473	1	48	51	49	61	61	62	-0.5	-1	0
5474	1	41	44	41	41	41	42	-0.5	-0.5	1
5475	1	43	47	44	2	3	2	0	-1	-0.5
5476	1	48	51	44	22	21	20	-0.5	-0.5	1.5
5477	1	43	45	-999	6	7	-999	0.5	0	0.5
5479	1	45	56	47	20	19	27	0	-0.5	-0.5
5480	1	55	61	57	23	23	21	-0.5	-0.5	0.5
5481	1	53	54	54	3	3	3	-0.5	-0.5	-0.5
5482	1	53	53	52	33	33	34	-0.5	-0.5	0.5
5483	1	47	48	46	15	16	16	-0.5	-0.5	0.5
5484	1	47	48	52	14	14	14	-0.5	-2	1
5485	1	11	51	49	19	17	18	-1	-1.5	0
5486	1	43	47	49	8	10	9	-0.5	-1	0
5487	1	36	53	58	30	29	28	-1	-1	1
5488	1	50	50	53	11	11	12	0.5	-1	0
5489	1	51	51	53	1	1	1	-0.5	-0.5	0.5
5490	1	49	54	48	7	8	8	-1	1	-0.5
5491	1	48	48	42	2	1	2	-0.5	-0.5	-0.5
5492	1	44	50	-999	12	12	-999	-0.5	0	0

5493	1	46	59	46	36	36	46	-1.5	-0.5	0
5494	1	39	38	39	6	7	10	-0.5	0	-0.5
5495	1	53	51	42	3	2	1	0	-0.5	0.5
5496	1	44	52	42	4	5	4	-0.5	-1.5	-1
5497	1	51	52	60	44	43	43	0	-0.5	1
5498	1	49	47	51	2	2	2	0.5	-0.5	-0.5
5499	2	52	48	51	10	10	11	-2	-3	-1
5500	1	35	31	32	57	58	60	-0.5	-2	-1.5
5501	1	50	54	39	12	11	8	0	-0.5	-1.5
5502	1	49	50	47	25	26	27	0.5	-1.5	-0.5
5503	1	46	44	54	31	31	31	1	-0.5	-0.5
5504	1	50	50	52	18	17	16	0	-0.5	-1.5
5505	2	48	50	52	4	4	4	-0.5	-2	-2
5506	1	48	47	49	2	2	2	0	-1	-0.5
5507	1	46	49	51	2	2	2	0	-1	0
5508	1	54	56	63	13	12	12	0.5	-1	-0.5
5509	1	52	58	52	7	8	8	-0.5	-0.5	-0.5
5510	1	56	56	54	39	38	38	-0.5	-1	0.5
5511	1	56	59	54	1	2	1	-1	-1	0
5513	1	49	52	51	44	44	45	-0.5	-1	-0.5
5514	1	44	45	43	4	4	5	-0.5	-0.5	-1
5515	1	45	47	47	1	2	1	-1	-0.5	-0.5
5516	1	48	43	44	14	13	15	-1	-0.5	0
5517	1	45	47	45	16	16	15	0	-2	0
5519	2	57	55	56	8	14	8	-2.5	-1.5	0
5520	1	44	45	45	20	21	23	-1	-1	-0.5
5521	1	56	59	48	18	17	16	-2.5	-0.5	-0.5
5522	1	50	53	65	27	27	27	-0.5	-0.5	0
5523	1	50	48	56	5	6	6	0	-0.5	0.5
5524	1	46	47	77	2	2	2	0.5	-0.5	0.5
5525	1	49	44	48	4	4	5	-0.5	-1.5	-1.5
5526	1	58	53	62	43	42	41	0.5	-0.5	-0.5
5527	1	43	44	41	26	27	28	0.5	-2	-0.5
5528	1	40	48	44	5	5	5	0.5	-1.5	-1.5
5529	2	52	56	47	22	21	20	1	-2	-1
5530	1	42	43	41	38	39	40	0	-0.5	-1.5
5531	1	-999	35	40	-999	0	1	-0.5	-2.5	-1.5
5532	1	51	52	35	24	23	21	-0.5	0.5	0
5533	1	52	53	55	31	31	32	1.5	1	0.5
5534	1	49	50	49	5	5	4	-0.5	0.5	-1
5535	1	46	49	53	1	1	1	0.5	-1	-1
5536	1	49	49	49	2	2	2	0	-1	-0.5
5537	1	48	49	46	1	1	1	-0.5	-1.5	1
5538	1	50	51	47	9	9	9	2	0	-0.5
5539	1	50	51	48	6	6	6	0	-0.5	-1.5
5540	1	53	54	54	7	7	6	0.5	-0.5	-0.5
5541	1	46	45	36	31	32	34	-0.5	-1	-0.5
5542	1	49	50	46	13	12	11	0	-2	0.5
5543	1	51	55	44	2	2	2	0.5	-1.5	0.5
5544	2	47	50	49	2	3	3	0	-1.5	0
5545	1	48	43	50	3	4	4	1	-0.5	0.5
5546	1	38	44	48	2	2	3	0.5	-1.5	0.5
5547	1	46	45	48	5	4	4	-1.5	-1	0.5
5548	1	40	43	40	61	62	63	-0.5	-0.5	1

5549	1	41	40	40	2	1	1	0.5	-0.5	0.5
5550	1	54	51	42	20	20	18	-0.5	-0.5	0.5
5551	1	58	58	45	1	2	2	-0.5	-0.5	1.5
5552	1	41	37	43	11	11	13	-1.5	-1	0
5553	1	38	38	40	1	1	2	-0.5	-1	0
5554	2	41	40	41	3	3	2	-0.5	-1	0
5555	1	47	50	39	6	5	4	0	-0.5	0.5
5556	1	47	63	49	2	2	1	-1	-2.5	0.5
5557	1	49	51	44	30	31	31	0.5	-1.5	0.5
5558	1	49	56	39	2	2	2	-0.5	-1.5	0.5
5559	1	46	49	41	5	5	4	0.5	-0.5	0.5
5560	1	53	52	43	9	9	11	-1.5	-2.5	-0.5
5561	1	44	47	46	2	1	1	0.5	0	0.5
5562	1	45	44	44	1	1	1	0.5	-0.5	0.5
5563	1	43	43	45	1	2	2	-0.5	-0.5	-0.5
5564	1	44	54	57	12	11	9	0	-0.5	-0.5
5565	1	59	49	50	27	27	27	0.5	-1.5	0
5566	2	50	49	53	16	17	18	0	-1	-0.5
5567	1	50	52	51	11	10	10	-0.5	-0.5	0.5
5568	1	51	53	38	3	3	3	-0.5	-0.5	0.5
5570	1	52	56	53	21	21	20	0	-1.5	0.5
5571	1	50	49	38	12	12	13	0.5	-0.5	1
5572	1	46	48	43	1	2	2	0.5	-0.5	0
5573	1	56	58	43	18	16	16	-0.5	-1	-0.5
5574	1	49	53	57	40	41	41	-0.5	-0.5	-1
5575	1	50	56	52	30	30	30	0.5	0	-1.5
5576	1	49	55	38	23	23	25	-0.5	-1	-2.5
5577	1	53	51	63	6	6	4	-1	-1	-0.5
5578	1	54	52	45	6	6	6	1	-1	-1
5579	2	54	52	33	7	7	7	0	-1	-1
5580	1	40	52	41	29	29	30	0.5	-0.5	0
5581	1	53	44	54	4	4	4	0.5	-1.5	-1
5582	1	53	56	49	3	3	2	0.5	-1	-0.5
5583	1	45	49	46	16	17	18	1	-1.5	-1.5
5584	1	43	53	47	25	24	23	0.5	-0.5	0
5585	1	46	51	47	25	25	26	0.5	-1.5	0.5
5586	1	48	54	55	12	12	11	-0.5	-0.5	-2.5
5587	1	46	52	47	2	2	2	-1.5	-0.5	-1
5588	1	44	40	39	57	58	59	0	-1.5	0.5
5589	2	43	44	50	2	2	2	0	-1.5	-1
5590	1	43	43	47	2	2	2	-0.5	-1.5	1
5591	2	46	46	43	17	16	16	0.5	-1	-0.5
5592	1	62	58	55	17	17	15	0.5	-0.5	0.5
5593	1	43	43	50	20	20	22	-0.5	-1.5	0.5
5594	1	36	33	37	26	28	30	0	-1	-0.5
5595	1	46	52	47	19	17	14	1.5	-0.5	-0.5
5596	1	51	53	46	3	3	3	-0.5	-2	0
5597	1	48	50	45	2	2	2	-0.5	-0.5	0
5598	1	50	48	58	40	40	40	0	-1.5	-0.5
5599	1	50	57	48	9	9	8	0.5	0	-1.5
5601	1	50	48	49	76	77	78	0.5	-0.5	0.5
5602	2	36	50	42	14	14	16	0	-1.5	-1
5603	1	37	39	35	2	2	2	0	-1	-0.5
5604	1	34	42	40	1	2	2	-1	-1.5	0

5605	1	51	48	50	15	13	11	-0.5	-0.5	-2
5606	1	47	48	51	12	12	12	0	-1.5	-1.5
5607	1	49	46	47	1	2	2	-0.5	-1.5	-1.5
5608	1	43	41	50	1	1	1	0.5	0	-1.5
5609	2	46	59	32	62	61	60	0	-1.5	-1
5611	1	55	56	63	50	49	48	-0.5	-1	0
5612	1	44	42	55	9	10	11	0	-1.5	-0.5
5613	1	50	47	46	2	1	2	-0.5	-0.5	0
5614	1	50	42	51	1	1	1	0.5	0	-1
5615	1	55	55	53	57	57	55	0	-0.5	0
5616	1	54	52	51	1	1	2	0.5	-0.5	-0.5
5617	1	42	41	47	18	19	21	-0.5	-0.5	0
5618	1	42	46	35	17	16	15	0.5	-0.5	1
5619	1	52	59	45	2	2	1	0	-1.5	0.5
5620	1	48	48	55	20	20	20	0	-0.5	0.5
5621	1	46	50	49	2	2	2	-1	-1	0
5622	1	43	48	55	1	1	2	-0.5	-0.5	-0.5
5623	1	44	44	48	5	6	6	0.5	-1	-1
5624	1	57	63	48	7	6	4	0.5	-1	-0.5
5626	2	51	53	49	17	18	19	-1	-1	-2
5627	1	50	54	74	46	45	45	0	-0.5	-0.5
5628	1	56	53	61	2	2	2	0.5	-0.5	0
5629	1	52	59	49	1	1	1	0.5	-1	-0.5
5630	1	50	51	51	16	16	17	-0.5	0.5	-1
5632	1	45	58	51	54	54	52	0.5	0	0
5633	1	51	50	52	2	3	3	-0.5	-0.5	-0.5
5634	2	53	59	54	17	16	17	0	-1.5	0
5635	1	55	49	47	15	15	15	-0.5	-0.5	0.5
5636	1	48	50	50	24	24	25	0.5	-0.5	0
5637	1	51	53	51	39	39	38	0.5	-0.5	-1
5638	1	46	50	50	6	6	6	0.5	-1	-1
5639	1	44	47	48	2	2	2	0.5	-1.5	-0.5
5640	1	49	52	52	12	12	11	-0.5	-1.5	0
5641	1	56	49	52	26	26	27	-0.5	-1.5	0
5642	1	47	55	55	1	1	1	0	-0.5	-0.5
5643	1	45	43	47	21	21	22	0	-0.5	0
5644	1	49	49	51	2	2	2	-0.5	-0.5	0.5
5645	1	48	53	55	31	31	30	0	-1.5	0.5
5646	1	46	50	51	2	2	2	0.5	-0.5	0.5
5647	1	49	48	57	13	13	13	0.5	-0.5	0
5648	1	50	50	45	2	2	2	-0.5	-0.5	-0.5
5649	1	48	50	53	13	13	13	0.5	-0.5	0
5650	1	51	54	51	5	5	5	0	-1.5	-0.5
5651	1	54	54	49	30	30	30	-0.5	-1	0
5652	1	51	56	48	7	7	7	-1.5	-1	0
5653	1	43	42	44	8	9	10	-0.5	-1.5	0.5
5654	1	41	47	50	3	2	2	0	-0.5	-0.5
5655	1	41	46	44	1	2	2	0	-1.5	0
5656	1	49	51	55	10	9	8	-1	-0.5	0
5657	1	56	57	49	16	16	16	-1	-1	0
5658	1	53	53	55	32	32	32	0.5	-1.5	0.5
5659	1	56	58	51	15	15	15	-2.5	0.5	0
5660	2	48	55	45	3	3	4	0	0	0
5661	1	49	51	61	40	39	39	0.5	-0.5	0

5662	1	44	55	25	3	3	3	-0.5	-0.5	0
5664	1	48	49	47	44	44	45	-0.5	-0.5	-0.5
5665	1	47	49	43	5	5	4	0	-1	0
5666	1	49	52	32	14	14	14	0	-0.5	-0.5
5667	1	52	51	58	5	5	4	1	-1	-0.5
5668	1	54	56	47	2	2	2	-0.5	-1.5	-0.5
5669	1	51	51	56	4	4	5	0	-1	-0.5
5670	1	43	53	50	10	11	12	0.5	-0.5	0
5671	1	40	52	42	1	1	1	-0.5	-0.5	0.5
5672	1	47	48	45	25	24	24	-0.5	-0.5	-1
5673	1	46	43	54	16	17	16	-0.5	-1.5	0
5674	1	45	53	57	7	6	6	-0.5	-1.5	-0.5
5675	1	44	44	56	1	2	2	0.5	-1	-0.5
5676	1	44	47	54	2	2	2	0.5	-1	0
5677	1	46	44	47	2	1	2	-0.5	-1	0.5
5678	1	46	44	47	1	1	1	0	-0.5	0.5
5679	1	41	45	48	1	1	2	0	-1	0.5
5680	1	47	48	39	3	3	3	-0.5	-1	0.5
5681	1	44	47	43	2	2	2	-0.5	-1.5	0
5682	1	42	50	43	2	2	1	-1.5	-2	0
5683	1	43	43	55	33	34	34	0	-0.5	0.5
5684	1	46	45	39	46	45	45	0	-0.5	0.5
5685	1	47	46	52	2	2	2	0	-1.5	-0.5
5686	1	42	41	48	3	4	4	-0.5	-1	-1
5687	1	42	41	50	2	2	2	0.5	-1	0.5
5689	1	46	47	48	12	11	11	-0.5	-0.5	0
5690	1	45	50	48	1	2	2	0.5	-1	0
5691	1	45	45	48	39	38	37	-0.5	-0.5	0
5692	2	47	44	46	10	11	12	0.5	-1	-1
5693	1	55	66	63	21	19	17	0	0	-0.5
5694	1	46	49	52	19	20	21	0	0.5	-0.5
5695	2	46	50	53	20	21	22	0	0	-0.5
5697	1	54	55	55	25	24	22	-1.5	-1	-1
5698	1	50	55	54	1	1	2	-0.5	-1.5	-0.5
5699	1	50	61	59	13	12	12	0.5	-0.5	-0.5
5700	1	46	51	52	63	64	65	0	-0.5	-0.5
5701	1	51	59	49	4	4	3	0	0.5	-0.5
5702	2	50	48	59	36	36	36	-1.5	-1	-1.5
5703	1	53	47	53	1	1	1	-0.5	-2	-1
5704	1	47	51	54	14	14	14	0	-2.5	-0.5
5705	1	55	52	54	34	34	34	-0.5	-0.5	-0.5
5706	1	51	54	54	8	8	8	0.5	-0.5	0
5707	1	44	49	48	2	2	2	-1	-1.5	-1
5708	1	45	49	48	6	7	7	0	-0.5	-0.5
5709	1	50	49	50	3	2	3	0	-0.5	-0.5
5710	1	42	44	49	9	10	10	-1	-0.5	0.5
5711	1	45	49	46	103	103	102	0.5	-0.5	0.5
5712	1	56	56	39	14	13	12	-0.5	0	0.5
5713	1	52	58	58	57	57	57	0.5	0	0.5
5714	1	48	52	32	7	7	9	-0.5	0	-0.5
5715	2	51	51	42	1	2	1	-0.5	1	-2
5716	2	40	52	54	2	1	2	-0.5	0	-3
5717	1	54	53	67	1	2	3	0.5	0	-1
5718	1	55	60	48	5	4	3	0	-0.5	-1.5

5720	1	49	48	52	34	34	34	0	0.5	0
5721	2	48	49	49	2	3	2	-1	-0.5	-2.5
5722	1	59	62	57	51	49	48	-0.5	-0.5	-1
5723	1	45	50	50	15	16	17	0	-0.5	-1
5724	1	47	48	46	8	9	9	-1	-0.5	0
5725	1	47	47	48	13	12	13	0	-1.5	-0.5
5726	1	50	49	49	10	10	9	-0.5	0	-0.5
5727	1	51	52	49	37	38	37	0.5	-0.5	0.5
5728	1	48	50	48	2	1	2	0.5	-0.5	-1
5729	1	61	34	41	52	53	55	-0.5	-999	-999
5730	1	51	52	36	15	14	12	-0.5	-999	-999
5731	1	50	56	40	5	5	6	-0.5	-999	-999

Table B.2 Springfield North Entrance Crossover Data

Vehicle Number	Vehicle Type	Speed by Location (mi/h)			Headway by Location (seconds)			Lateral Displacement by Location (feet)		
		1	2	3	1	2	3	1	2	3
1055	1	29	51	58	8	8	8	-999	4.5	4.5
1056	1	45	51	42	9	10	10	-999	-0.5	0.5
1057	2	35	47	55	6	5	5	-999	0	0
1058	1	52	58	59	6	6	6	-999	-3.5	2.5
1060	1	47	51	57	53	53	53	-1.5	-1.5	0.5
1061	1	29	43	56	6	8	8	0.5	0.5	3.5
1062	2	48	60	61	8	6	5	-0.5	-1.5	1.5
1063	2	44	58	62	3	3	3	0	-2.5	0
1064	1	43	56	77	12	12	13	-1	1	3
1065	2	23	55	29	16	20	23	-1.5	-1.5	0.5
1066	1	45	53	-999	22	18	-999	0.5	1	4
1067	1	34	48	47	7	8	24	-0.5	0.5	0.5
1068	1	34	50	11	12	12	12	-2.5	0	2.5
1069	1	34	44	46	7	7	7	1	-1	0.5
1070	2	45	46	54	5	5	5	-1	-3.5	1
1071	2	47	55	52	13	12	12	-1	-1	1
1074	2	43	58	48	85	85	85	0	0	2
1075	2	46	57	53	5	5	5	-1	-1	0.5
1076	1	38	46	44	12	13	13	-1.5	-1	2.5
1077	1	41	49	53	6	7	7	-0.5	-1.5	2
1078	2	48	46	54	22	20	20	-1.5	-3	0.5
1079	1	17	51	49	2	2	2	-1.5	-0.5	1
1080	1	35	43	39	26	27	28	-0.5	-1	0.5
1081	1	27	41	34	8	8	8	0.5	-1.5	1.5
1082	1	34	51	45	16	16	15	-0.5	-1.5	3
1083	1	44	49	47	16	16	16	0	0.5	0.5
1084	1	37	50	44	5	5	5	-1.5	-0.5	0
1085	2	26	39	41	8	9	10	-1.5	-1	0
1086	1	38	68	56	5	4	3	-2.5	-3.5	1.5
1087	1	43	43	56	30	31	31	-2.5	0.5	2.5
1088	1	45	54	56	6	6	6	-0.5	-0.5	1
1089	2	41	51	40	46	45	45	0	0	1.5
1090	1	43	52	48	1	2	2	-0.5	0	3
1091	1	51	52	49	53	52	52	-2.5	-0.5	0.5
1093	2	46	51	24	17	23	26	0	-0.5	1
1094	1	18	23	30	2	2	2	0.5	-1	2.5
1095	1	37	25	33	3	2	1	-0.5	0.5	2.5
1096	1	37	43	38	6	5	3	-0.5	-0.5	2.5
1097	1	45	47	51	8	6	6	-0.5	1	-0.5
1098	1	45	42	55	3	4	3	-1.5	0.5	1
1101	2	42	54	50	35	35	36	-1	0	1.5
1103	1	33	42	51	13	13	13	-0.5	0.5	2.5
1104	1	37	63	50	9	7	7	-2	-0.5	2.5
1105	1	40	54	60	8	9	9	1	-0.5	2
1106	1	38	54	55	33	33	33	-2.5	-1	0.5
1107	1	31	40	42	17	19	19	0	0	0.5
1108	1	34	64	48	51	49	49	-1	-1.5	2

1109	2	18	24	28	18	22	25	0	-0.5	0.5
1110	1	32	27	29	3	2	1	-1.5	-2.5	0
1111	1	29	46	47	8	6	4	-2.5	-0.5	1.5
1112	1	28	44	46	9	9	9	-1.5	-1	0.5
1113	1	42	49	50	13	13	13	0	-1	0.5
1114	1	35	56	47	4	4	4	-2	-0.5	0.5
1116	1	44	56	46	32	31	31	-1.5	-0.5	3
1117	1	33	40	44	23	25	25	-0.5	-0.5	-0.5
1121	1	36	31	-999	53	53	-999	-0.5	-0.5	4.5
1122	1	36	49	45	6	5	58	-1	-0.5	4
1126	2	17	31	30	38	42	45	0	-1.5	1.5
1127	1	18	24	28	2	4	3	-0.5	-0.5	0
1128	1	18	27	26	3	1	1	0.5	-2	1
1129	1	43	37	29	10	7	5	-1	-2.5	1.5
1130	1	30	42	43	9	9	10	-0.5	-0.5	0.5
1131	1	43	37	38	15	16	16	-1	-1	-0.5
1132	1	38	50	47	28	26	26	-1	-0.5	0
1133	2	48	50	61	5	5	4	-1	-4	1.5
1134	1	37	41	51	25	26	26	-0.5	-1	1
1135	1	37	54	51	5	5	5	-0.5	-0.5	3.5
1136	1	29	37	36	5	7	7	1	-2	0
1137	1	39	48	45	38	35	36	0.5	0.5	0
1138	1	51	47	31	0	1	1	-1.5	-1.5	0.5
1139	1	37	46	54	3	3	2	-1.5	-1	0.5
1140	2	18	24	26	14	18	20	-1	-1	1
1141	2	19	31	31	7	5	4	-1	-1	0.5
1142	1	25	44	51	3	13	14	0.5	0	0.5
1144	1	14	28	-999	15	14	-999	-1.5	-0.5	4.5
1145	1	29	40	48	47	34	48	-0.5	-0.5	-0.5
1146	1	34	39	40	14	13	14	-0.5	-0.5	1.5
1147	1	29	43	48	5	5	5	-1.5	-1	1.5
1148	1	-999	40	56	-999	16	15	-2.5	-3	-1
1149	1	38	23	-999	56	41	-999	-1.5	-2	4.5
1150	1	41	34	-999	1	1	-999	-1	-1	0.5
1155	1	46	50	50	102	101	95	-2	0	1.5
1156	2	26	44	45	23	24	24	-2	-2.5	2
1157	2	38	59	50	28	26	26	-2	-2	0.5
1158	2	35	28	33	28	32	34	0	-1	1.5
1159	1	45	50	44	14	11	8	-0.5	-0.5	1.5
1160	1	43	60	58	2	1	2	-0.5	-3	1.5
1161	1	35	38	39	17	19	19	0.5	-1	0.5
1162	1	39	45	48	4	3	3	-1	-0.5	1
1164	1	47	49	46	9	9	9	-1.5	-0.5	-0.5
1165	2	42	47	55	2	2	1	1	-1	2
1166	1	49	54	56	3	2	2	0.5	-1.5	0.5
1168	1	36	47	45	57	59	60	-0.5	-0.5	3
1169	1	40	44	43	7	6	6	-3	-0.5	2.5
1170	1	41	41	46	31	31	31	0	-2	2.5
1171	1	34	43	39	11	11	12	-2.5	-1.5	-1
1172	2	17	29	42	12	15	16	-1.5	-1.5	0.5
1173	1	27	42	37	6	5	4	-1.5	-1	0.5
1174	1	27	46	39	8	6	6	-2	-1.5	1.5
1180	1	37	45	49	128	129	129	-0.5	-1.5	-0.5
1181	1	29	39	43	7	7	8	0	-1	0.5

1183	2	16	41	43	35	39	40	0	-2	0
1184	1	19	30	24	4	3	2	0.5	-0.5	2.5
1185	1	21	45	45	38	35	34	-2	-0.5	2.5
1186	1	21	50	52	3	2	2	-1.5	-1.5	1
1187	1	43	51	43	2	2	2	0	-2.5	2
1188	1	32	60	54	8	8	8	-2	-1.5	0.5
1190	2	32	51	56	28	29	28	-0.5	-2	0
1191	2	39	52	51	29	28	29	-1	-1.5	0.5
1192	1	37	45	45	6	7	6	-0.5	-2.5	1
1193	2	36	48	47	6	6	7	0	-4	1
1194	1	30	44	45	4	4	4	-1.5	-0.5	0.5
1195	1	-999	44	51	-999	2	2	-2.5	-0.5	-0.5
1196	1	33	54	48	6	3	3	-1.5	-2	0.5
1198	1	53	74	56	58	58	57	-0.5	0	0.5
1199	1	43	52	51	19	19	20	-1.5	0.5	1
1202	1	41	55	55	53	53	52	-0.5	-0.5	0.5
1206	1	42	50	49	52	52	11	-3.5	-1	0
1208	1	48	55	51	16	17	17	-1	0	1.5
1209	1	41	47	52	42	41	41	0	-0.5	0.5
1210	1	52	56	56	14	14	14	0.5	-1	0.5
1211	1	47	58	50	8	8	7	-1.5	0	0.5
1212	2	47	41	22	31	37	40	-0.5	-3	-0.5
1213	1	47	27	25	4	2	2	-1.5	-0.5	0.5
1216	1	14	51	31	45	41	39	-1.5	-0.5	0
1217	2	45	58	31	6	6	6	-1.5	-1	0.5
1218	1	46	59	31	8	8	7	-1.5	-1.5	1.5
1219	1	53	57	51	14	14	14	-0.5	0	0.5
1220	2	38	51	50	33	34	35	-1	-2.5	0
1221	1	38	47	40	5	5	5	0.5	-1.5	0.5
1222	1	51	44	51	22	22	22	-1.5	-0.5	1
1224	1	41	50	52	16	15	15	-0.5	-2	-0.5
1225	1	42	57	52	7	7	7	-0.5	-1	1.5
1226	1	-999	55	50	-999	2	1	-3.5	-1	1.5
1227	1	39	49	50	13	11	12	0	-0.5	1
1228	2	49	60	60	23	23	22	-0.5	-2	1.5
1229	1	31	38	41	13	15	16	-0.5	-1.5	1
1230	1	48	63	54	4	2	2	-0.5	-1.5	0.5
1231	1	43	47	51	21	21	21	-1.5	-1	2.5
1232	1	42	49	52	20	20	20	-2.5	-1	1.5
1233	1	42	49	56	7	8	8	-2.5	-1.5	0.5
1234	1	42	57	53	14	14	13	-0.5	-0.5	3
1235	1	29	47	51	12	12	13	-2	-1.5	1
1236	1	45	64	54	39	38	37	-2	-1.5	1.5
1237	1	49	18	56	1	1	2	-2	-1.5	3.5
1239	2	49	58	52	72	73	72	-1	-1	1
1240	1	35	43	45	22	23	24	-1.5	-1	0
1241	2	42	45	51	8	7	7	-1	-2.5	-0.5
1244	1	41	-999	62	7	-999	6	-2.5	-1.5	1
1245	1	41	50	54	20	27	21	0.5	-0.5	0.5
1246	2	39	53	49	18	18	18	-1	-3	1
1247	2	22	32	37	8	10	11	-1	-2	0
1248	1	34	42	42	5	4	3	-1.5	-0.5	0.5
1249	1	41	48	42	6	4	4	-0.5	-0.5	0.5
1250	2	40	55	52	25	26	25	-2	0	1.5

1251	1	44	50	56	3	3	4	-1	-0.5	1
1253	1	55	52	50	38	38	38	-2	-1	0.5
1254	2	16	50	29	16	18	21	-1	-3.5	1.5
1255	1	19	28	31	4	4	3	0.5	0.5	3.5
1256	1	43	34	41	8	5	4	-1	0	2.5
1257	1	47	48	38	4	4	4	-2.5	-0.5	2
1258	1	40	45	65	4	4	4	-2	-0.5	3
1259	1	40	41	52	6	6	6	0	-0.5	0.5
1260	1	42	54	49	19	18	18	-1	-0.5	0.5
1261	1	-999	53	68	-999	12	11	-3.5	-2.5	-0.5
1262	1	46	58	58	18	6	7	-1.5	0	0.5
1263	2	43	55	61	3	3	3	-2	-1	1.5
1265	1	30	46	53	10	12	12	-1.5	-1.5	1
1266	1	36	57	60	12	10	10	-2	-1.5	1
1267	1	43	47	58	17	18	18	-0.5	-0.5	1.5
1268	1	47	60	48	5	5	4	-1	-0.5	1
1269	1	43	46	40	9	9	10	-1.5	-0.5	0.5
1270	1	43	55	46	12	11	11	-1	-0.5	0.5
1271	2	45	57	50	6	6	5	-1	-1	1
1272	1	36	55	60	14	14	15	0.5	-2	0.5
1273	1	49	53	65	8	8	8	-1	-0.5	0.5
1274	1	35	49	49	5	6	6	0	-1.5	3
1275	1	39	61	63	19	18	17	-1.5	-1	-0.5
1276	1	48	55	60	9	9	10	-2.5	-1.5	1
1277	1	48	54	57	59	59	58	0.5	-0.5	3
1279	1	45	53	56	4	4	5	0	-2.5	0.5
1280	1	45	56	54	24	25	24	-1	-0.5	-1
1281	1	45	46	42	17	17	19	-1.5	0.5	3
1282	1	34	46	50	11	11	9	-0.5	-0.5	0
1283	1	41	47	49	40	40	41	0	0.5	-0.5
1284	1	42	44	67	6	6	6	-1.5	0	2
1285	2	41	48	58	3	3	3	-1	0	0.5
1286	2	33	45	37	19	20	20	-1.5	-2	0
1288	2	48	50	49	12	11	11	-2	-1	0.5
1289	2	42	52	48	4	4	3	-2	-2.5	1.5
1290	1	32	51	36	6	5	6	-1.5	-0.5	1.5
1291	1	38	46	47	34	35	35	-0.5	-0.5	0
1292	1	34	50	51	35	34	34	-2.5	-0.5	0
1294	1	36	43	43	20	21	21	-0.5	-1	0.5
1295	1	35	45	45	2	2	2	-1	-1.5	1
1296	1	35	54	56	3	2	2	-2.5	-1	2
1297	1	35	45	47	91	92	92	-4	-0.5	0.5
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1300	2	35	51	53	31	31	32	-1	-3.5	-999
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1304	1	36	42	51	26	24	23	-1	-1	-999
1305	1	39	47	47	50	49	49	-1.5	-0.5	-999
1306	1	26	48	47	12	13	12	-2.5	-1.5	-999
1307	1	30	56	53	10	9	10	-2.5	-1	-999
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1310	2	50	60	65	24	23	22	-2	-1.5	-999
1311	1	40	40	44	8	9	11	-0.5	0	-999
1312	1	48	22	54	14	13	12	-0.5	-0.5	-999

1313	2	21	23	52	82	88	90	0	-4	-999
1314	1	27	30	34	7	5	5	0	-0.5	-999
1315	1	28	25	23	13	13	13	-1	0.5	-999
1316	1	28	25	28	3	3	4	0.5	1.5	-999
1317	1	37	42	28	12	10	7	-1.5	-0.5	-999
1319	2	37	54	47	7	7	6	-1.5	-2	-999
1320	1	34	43	49	36	36	36	-2.5	-1.5	-999
1321	1	34	48	55	2	2	2	-2	-2.5	-999
1323	2	37	44	49	8	7	8	-1	-2	-999
1324	1	36	49	47	3	3	3	-2.5	-1.5	-999
1325	1	28	42	40	15	16	16	-1.5	-1	-999
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1328	1	59	-999	56	22	-999	22	-2.5	-2.5	-999
1330	1	43	51	61	22	44	22	-0.5	-3.5	-999
1331	1	34	52	22	2	2	2	-0.5	-0.5	-999
1332	1	50	59	61	11	10	10	-1.5	-1.5	-999
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1334	1	39	50	44	7	8	9	-0.5	-1	-999
1338	1	43	40	47	51	51	51	-1.5	-2	-999
1339	1	42	40	43	32	32	33	-1.5	-1	-999
1340	2	42	50	52	6	5	4	-0.5	-2	-999
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1344	2	19	27	32	18	21	20	0	-1	-999
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1346	1	31	56	52	9	8	7	-1	-2.5	-999
1347	1	25	35	40	19	21	21	-1	-1	-999
1348	1	42	41	45	9	8	8	0	-0.5	-999
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1359	1	27	38	29	10	6	4	0	0.5	-999
1360	1	26	34	36	2	2	2	-1	-1.5	-999
1361	1	41	48	52	22	21	20	-0.5	0.5	-999
1362	2	48	41	51	34	33	33	-2	-1.5	-999
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1366	1	40	44	46	33	33	34	-0.5	-0.5	-999
1367	2	49	51	54	11	10	10	-1	-1	-999
1368	1	31	47	50	6	7	7	-1.5	-0.5	-999
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1370	1	26	41	44	11	7	5	-1.5	-1	-999
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1373	2	27	49	47	14	11	9	-0.5	-0.5	-999
1374	1	44	41	46	2	2	2	0.5	0.5	-999
1375	1	35	53	51	5	6	6	0	0	-999

1377	1	36	47	55	44	43	43	-1.5	0	-999
1378	2	18	31	51	30	34	36	-1.5	0	-999
1379	1	40	27	26	3	3	2	-0.5	-0.5	-999
1380	2	44	52	47	28	26	24	0	-2.5	-999
1381	1	38	58	48	3	2	2	-1.5	-1.5	-999
1382	1	26	42	44	6	8	8	-1.5	-0.5	-999
1383	2	27	27	30	43	46	47	-1.5	-2	-999
1384	1	24	28	28	3	2	2	-4.5	-1	-999
1385	1	52	48	49	13	11	9	-2	-0.5	-999
1386	1	38	64	17	40	39	39	-2.5	-1.5	-999
1387	1	43	54	47	16	16	17	-1	0.5	-999
1388	2	18	31	38	29	34	36	0	-1	-999
1389	1	35	52	42	9	6	4	-1.5	-0.5	-999
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1392	1	36	36	31	9	11	13	-1	-0.5	-999
1393	1	27	36	43	1	1	1	-1.5	0.5	-999
1395	1	33	52	46	78	76	75	-1	0	-999
1397	1	54	62	56	22	21	20	-0.5	-0.5	-999
1398	2	40	46	46	7	7	8	-0.5	0	-999
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1400	1	55	52	55	9	9	9	-1.5	-0.5	-999
1401	2	40	56	53	2	3	2	-1.5	-1	-999
1402	1	42	53	53	8	7	7	-2	-1.5	-999
1403	1	43	48	57	24	24	25	-1	-0.5	-999
1405	1	43	49	46	54	55	55	-1.5	0.5	-999
1406	2	31	39	50	4	5	5	-1	0	-999
1409	2	31	49	45	27	27	27	-2	-1	-999
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1412	1	39	49	43	5	5	5	-0.5	-1.5	-999
1413	2	39	60	57	22	21	20	-0.5	-0.5	-999
1414	1	43	47	51	14	15	15	-0.5	-1	-999
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1416	1	31	44	51	16	16	16	-2.5	0	-999
1417	1	37	53	51	58	58	58	-2	-0.5	-999
1418	1	48	54	55	31	30	31	-1.5	0.5	-999
1419	2	23	45	31	11	15	19	-0.5	-3	-999
1420	1	44	51	51	24	20	16	-1	-0.5	-999
1421	1	38	53	15	4	3	4	-1	-0.5	-999
1422	2	24	37	37	10	12	13	0	0	-999
1423	2	39	51	45	24	23	22	0	0	-999
1428	1	35	39	41	56	20	19	-0.5	-1	-999
1429	1	17	50	52	3	3	2	-1.5	-0.5	-999
1430	1	26	55	60	5	4	5	0	-1.5	-999
1431	2	44	57	52	20	20	19	-0.5	-2	-999
1432	1	22	28	50	12	15	15	-1.5	-0.5	-999
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1437	2	28	28	30	46	49	51	0	-2	-999
1438	1	27	37	45	20	19	17	-1	0.5	-999
1439	2	24	49	41	4	2	1	-2	-1.5	-999
1442	2	41	53	52	49	49	49	-1	-1.5	-999
1443	1	32	49	51	19	19	19	-3	-2	-999
1444	1	39	49	55	6	6	6	-2.5	0.5	-999
1445	1	35	52	51	6	6	7	-2	0	-999
1446	1	37	52	51	35	34	33	-0.5	0.5	-999

1447	1	36	72	52	7	8	8	-2.5	-0.5	-999
1448	1	30	43	46	44	44	45	0.5	-0.5	-999
1450	1	38	44	44	34	34	34	0	-0.5	-999
1451	1	37	45	42	19	19	19	-1.5	-1	-999
1452	1	30	38	34	16	17	17	-0.5	-1.5	-999
1455	1	38	47	51	28	27	27	-1	-1	-999
1456	1	20	46	44	2	2	2	-2	-0.5	-999
1457	1	27	56	44	1	1	1	-3	-2	-999
1459	2	27	50	23	33	36	33	-2	-3	-999
1460	1	21	49	47	21	18	15	-0.5	-0.5	-999
1462	1	32	45	46	8	8	9	-1.5	-1	-999
1463	1	22	75	56	26	26	25	-1.5	-0.5	-999
1465	1	34	45	69	11	11	12	-1	0.5	-999
1466	1	29	49	41	21	21	21	-1.5	0	-999
1467	2	46	53	43	19	18	18	-1	-1	-999
1469	1	30	51	49	44	45	44	-1.5	-2	-999
1470	1	38	42	49	48	48	49	-0.5	-1	-999
1472	2	46	52	53	31	30	30	0	0	-999
1473	1	42	48	54	1	2	2	-1	-0.5	-999
1474	1	42	43	47	3	3	2	-0.5	0.5	-999
1475	1	16	48	47	9	8	9	-1	0.5	-999
1476	1	32	42	43	16	17	17	-0.5	0	-999
1477	1	37	44	44	1	2	2	-0.5	-0.5	-999
1478	1	33	40	39	1	1	1	-2	-0.5	-999
1479	1	42	52	49	7	5	5	0.5	-0.5	-999
1480	1	37	60	72	6	6	6	-2	-1	-999
1481	2	34	49	48	49	50	50	-1.5	0	-999
1482	2	47	63	64	11	9	8	0	0	-999
1483	1	41	60	57	2	2	3	-1.5	-0.5	-999
1484	1	41	56	75	26	27	26	-1.5	-0.5	-999
1485	1	45	60	48	13	13	13	-0.5	-0.5	-999
1486	1	30	39	52	9	10	10	-1	-1.5	-999
1487	1	36	51	55	5	5	5	-2.5	-1	-999
1489	1	30	42	40	62	63	64	1	0	-999
1490	1	46	54	53	22	21	20	-0.5	-1	-999
1491	2	27	37	50	6	7	7	-1	-2	-999
1492	1	33	43	30	14	14	16	-2	-1.5	-999
1493	1	30	50	48	23	22	21	-1	-0.5	-999
1494	1	40	50	44	28	28	28	-1	-0.5	-999
1495	1	47	57	51	35	34	34	0.5	0.5	-999
1496	1	52	59	51	17	17	16	-1.5	-0.5	-999
1498	1	46	50	49	25	25	26	-0.5	-1	-999
1499	1	39	43	46	2	3	2	0	0.5	-999
1500	1	12	75	48	2	2	2	-2	-0.5	-999
1501	1	42	48	45	21	21	22	-1	-1	-999
1502	1	34	47	46	39	39	38	-1	-0.5	-999
1503	2	38	45	53	6	6	6	-1	-1.5	-999
1504	1	41	44	41	4	3	4	0.5	-1	-999
1505	2	50	62	45	7	7	6	-0.5	-0.5	-999
1506	1	31	50	52	4	5	5	-2	-1	-999
1507	2	43	40	42	8	8	9	-1	-2	-999
1508	1	30	40	46	11	12	12	0.5	-0.5	-999
1509	1	41	51	45	8	6	6	-1	-0.5	-999
1510	2	36	51	45	2	3	2	-1.5	-1	-999

1511	1	39	47	48	4	3	4	0	-1	-999
1513	1	25	54	63	11	12	11	-1.5	-0.5	-999
1515	1	37	40	52	12	12	13	-1	-0.5	-999
1516	1	15	46	39	9	9	9	-2	-0.5	-999
1517	1	24	47	35	2	2	1	-2.5	-1	-999
1518	1	-999	47	40	-999	2	3	-3.5	-1	-999
1519	1	33	45	45	7	6	5	0	-2.5	-999
1520	1	28	57	56	18	16	16	-1.5	-1	-999
1521	1	47	68	55	31	31	31	0.5	-1.5	-999
1522	1	35	47	47	4	5	5	-1	-0.5	-999
1523	1	43	56	55	4	4	4	0	-0.5	-999
1524	1	31	43	50	12	12	13	-0.5	-1.5	-999
1525	1	39	42	57	2	2	2	0.5	0.5	-999
1526	1	41	47	48	7	7	7	0.5	0	-999
1527	1	39	46	52	15	14	14	-2	-1	-999
1528	2	42	53	52	5	5	5	-1.5	-0.5	-999
1529	2	43	51	60	11	11	10	-1.5	-1	-999
1531	1	23	38	46	22	25	26	0	-1	-999
1532	1	29	36	42	5	5	5	-1	-0.5	-999
1538	1	33	40	46	61	59	59	-0.5	0.5	-999
1539	1	34	40	46	3	3	3	0.5	-0.5	-999
1540	2	29	33	28	5	6	6	-0.5	-3.5	-999
1541	1	30	45	39	2	2	2	-0.5	-0.5	-999
1542	1	29	31	35	1	2	2	-0.5	-0.5	-999
1543	1	34	49	36	3	2	2	-0.5	-0.5	-999
1544	1	31	42	39	2	1	2	-1.5	-0.5	-999
1545	1	31	51	37	4	4	3	-2	-1.5	-999
1546	1	31	39	48	6	7	6	0	-1	-999
1547	1	37	51	49	10	9	9	-1.5	-1	-999
1549	1	42	43	45	20	20	21	-2	-0.5	-999
1550	1	37	40	43	15	15	15	0	-0.5	-999
1551	1	31	40	40	2	2	2	-1	-2.5	-999
1552	1	38	45	48	5	5	5	-1	-2	-999
1553	1	14	47	45	10	10	10	0.5	-0.5	-999
1556	1	46	45	46	24	24	23	-1	-1.5	-999
1557	1	39	42	46	5	6	6	0	-1	-999
1558	1	37	43	48	40	39	40	0	-1.5	-999
1559	1	37	39	38	38	39	39	-1.5	-0.5	-999
1560	1	37	39	39	2	2	2	-1.5	0.5	-999
1561	1	37	58	50	31	29	28	-1	0	-999
1562	2	38	51	52	18	19	19	-2	0	-999
1563	1	37	57	53	4	3	3	-1.5	-0.5	-999
1565	1	42	47	50	18	19	19	0	1	-999
1566	1	43	48	50	21	21	21	-0.5	-1	-999
1567	1	43	49	50	18	17	18	-1.5	-0.5	-999
1568	2	41	51	49	5	6	6	-2	0	-999
1569	2	43	34	37	8	9	10	-1.5	-3.5	-999
1570	1	22	47	43	4	3	2	-0.5	-2	-999
1571	1	50	50	49	6	5	5	-1	-0.5	-999
1572	1	41	67	58	4	4	3	-1	-1	-999
1573	1	30	49	51	6	7	8	-1.5	-1	-999
1574	2	21	53	26	36	40	43	0	-1	-999
1575	1	17	20	31	2	2	2	-1.5	-0.5	-999
1576	1	19	43	46	9	4	2	-1	-0.5	-999

1577	1	40	43	36	16	17	17	-0.5	0	-999
1578	1	41	55	52	22	21	20	-1	0	-999
1579	1	42	58	49	56	56	56	-0.5	-0.5	-999
1580	2	44	51	47	7	8	8	0	0	-999
1581	1	41	56	42	7	6	6	-1.5	-0.5	-999
1582	1	44	52	59	32	33	33	-1	0	-999
1583	1	42	47	56	2	2	3	-0.5	-1	-999
1584	1	43	52	51	3	2	2	-1	0.5	-999
1586	1	42	54	43	53	54	54	-1	-0.5	-999
1587	2	42	47	45	3	2	2	-1	-1.5	-999
1588	1	41	45	40	1	2	2	-1.5	-1	-999
1589	1	44	52	51	7	6	5	0.5	-0.5	-999
1590	1	50	49	45	5	5	6	0	-0.5	-999
1591	1	30	55	58	2	3	2	-999	0	-999
1592	1	38	42	36	15	15	15	-999	-2.5	-999
1594	1	38	50	50	67	67	68	-999	-0.5	-999
1595	1	47	54	51	7	6	5	-999	0	-999
1596	1	42	43	55	6	7	7	-999	-1.5	-999
1597	2	20	28	28	14	18	20	-999	-1.5	-999
1598	1	24	53	52	12	9	7	-999	0	-999
1599	1	24	66	58	31	30	1	-999	-1.5	-999
1600	1	24	63	70	3	2	2	-999	-1.5	-999

Table B.3 Springfield North Exit Crossover Data

Vehicle Number	Vehicle Type	Speed by Location (mi/h)			Headway by Location (seconds)			Lateral Displacement by Location (feet)		
		1	2	3	1	2	3	1	2	3
82	1	38	-999	46	2	-999	2	-999	-999	-2
83	1	34	-999	38	55	-999	55	-999	3.5	-6
84	1	44	-999	44	5	-999	5	-999	-1	-1.5
85	1	41	-999	46	12	-999	12	-999	0	0
86	1	42	-999	11	2	-999	2	-999	0.5	-0.5
87	1	40	-999	27	1	-999	1	-999	2	2.5
88	2	37	-999	48	50	-999	50	-999	-2	-1.5
89	1	40	-999	-999	6	-999	-999	-999	-1	-6.5
90	2	36	-999	47	18	-999	24	-999	1	3
91	1	32	-999	42	1	-999	1	-999	1	2.5
92	1	36	-999	46	2	-999	2	-999	0	2
93	1	33	-999	-999	13	-999	-999	-999	2	5.5
94	2	26	-999	37	4	-999	17	-999	0	-1
95	1	30	-999	-999	22	-999	22	-999	-0.5	-1
96	1	34	-999	-999	2	-999	-999	-999	0	1.5
97	2	39	-999	-999	24	-999	24	-999	0	1.5
98	1	41	-999	41	2	-999	3	2	-1	-3.5
99	2	31	-999	35	44	-999	44	0.5	-2	0
100	2	30	-999	38	2	-999	3	1.5	-1.5	-6
101	1	30	-999	17	1	-999	1	2	0.5	1.5
102	1	25	-999	35	4	-999	4	1.5	0.5	0.5
103	1	26	-999	40	1	-999	1	2	0.5	3.5
104	1	27	-999	30	2	-999	2	1.5	0.5	0.5
105	1	27	-999	28	2	-999	3	1.5	0.5	2
106	1	27	-999	35	2	-999	1	1.5	1	-1
107	1	31	-999	32	2	-999	2	1	1	1.5
108	1	29	-999	-999	3	-999	-999	2	1.5	3.5
109	1	31	-999	-999	1	-999	-999	2.5	2.5	6
110	1	36	-999	46	33	-999	36	2.5	0.5	-3
111	1	34	-999	43	21	-999	22	2	-0.5	-1.5
112	1	34	-999	44	22	-999	21	2.5	-0.5	0.5
113	1	36	-999	33	4	-999	5	1.5	1.5	-2.5
114	2	39	-999	45	30	-999	28	1	-1	-5.5
115	1	39	-999	49	1	-999	2	2	1	-4.5
116	1	41	-999	48	2	-999	2	2.5	-1.5	-5
117	1	33	-999	11	37	-999	38	2.5	0.5	0.5
118	2	29	-999	31	23	-999	23	1.5	-1.5	-4.5
119	1	32	-999	30	2	-999	2	2	0	0.5
120	1	13	-999	32	1	-999	1	2	0.5	-0.5
121	2	33	-999	39	6	-999	6	1	-1.5	-0.5
122	1	32	-999	41	2	-999	2	2	-2	-3
123	1	14	-999	54	15	-999	14	2	0.5	-0.5
124	1	34	-999	46	12	-999	13	2	1.5	3
125	1	38	-999	40	10	-999	10	1.5	0.5	-1
126	1	29	-999	29	14	-999	15	2.5	0.5	3
127	1	28	-999	-999	7	-999	-999	2.5	2.5	3.5
128	1	33	-999	37	3	-999	9	2	1.5	2.5
129	1	37	-999	-999	19	-999	-999	2.5	3.5	5.5

130	1	33	-999	38	19	-999	39	2	1.5	2.5
131	1	34	-999	37	2	-999	1	2	0.5	-0.5
132	1	30	-999	37	3	-999	4	2.5	1	3.5
133	1	29	-999	34	2	-999	2	2	-0.5	-2.5
134	1	29	-999	42	1	-999	1	2	0.5	-0.5
135	1	29	-999	32	2	-999	2	1	0.5	-1
136	1	30	-999	34	2	-999	3	2	0.5	-2.5
137	1	29	-999	33	2	-999	1	2	0	-4.5
138	2	37	-999	49	28	-999	27	0	-2.5	-1
139	1	37	-999	49	1	-999	1	2	-0.5	-1
140	1	35	-999	50	2	-999	3	1.5	-0.5	0.5
141	1	29	-999	57	21	-999	20	2	1	2.5
142	2	37	-999	56	7	-999	7	0	-0.5	-3.5
143	1	38	-999	46	6	-999	6	2.5	0.5	-3
144	1	38	-999	44	22	-999	22	1.5	0.5	-1
145	1	40	-999	57	1	-999	1	1	-1.5	-4.5
146	1	33	-999	-999	41	-999	-999	2	2	6
147	1	35	-999	38	9	-999	50	2.5	1	3.5
148	2	29	-999	24	5	-999	6	1.5	-0.5	0
149	1	39	-999	57	27	-999	25	2.5	1	-5
150	1	37	-999	42	22	-999	23	1.5	-0.5	-0.5
151	1	34	-999	41	1	-999	1	2	0.5	-1.5
152	1	40	-999	-999	5	-999	-999	2	1.5	3
153	1	35	-999	39	8	-999	13	2	0.5	1.5
154	1	28	-999	40	8	-999	8	2.5	1.5	2.5
155	2	31	-999	37	61	-999	61	1	-3.5	-4
156	1	25	-999	16	1	-999	2	1.5	-0.5	0
157	1	31	-999	44	1	-999	1	2.5	-0.5	-4.5
158	1	29	-999	41	4	-999	4	2	-0.5	-0.5
159	2	40	-999	49	14	-999	13	0.5	-1	0
160	1	35	-999	43	16	-999	15	1.5	0.5	-1
161	2	53	-999	49	74	-999	76	1.5	-0.5	-3
162	1	28	-999	31	1	-999	1	2	0.5	-0.5
163	2	25	-999	34	3	-999	1	1.5	0.5	0
164	1	29	-999	-999	5	-999	-999	2	1.5	3.5
165	2	32	-999	29	3	-999	8	1.5	-0.5	0.5
166	1	30	-999	54	3	-999	1	2	0.5	5
167	1	31	-999	24	2	-999	4	2	0.5	1
168	1	22	-999	-999	4	-999	-999	1.5	1	3.5
169	2	37	-999	32	22	-999	26	1	-1	-3
170	1	33	-999	41	11	-999	11	1	-1	-2.5
171	1	39	-999	44	2	-999	1	2	0.5	-2.5
172	1	32	-999	52	12	-999	13	1	0.5	-0.5
173	1	34	-999	43	2	-999	1	1.5	0.5	-1
174	2	36	-999	42	17	-999	17	1.5	-1	-3
175	1	34	-999	46	1	-999	2	2	-1	-4.5
176	1	36	-999	49	2	-999	1	2	-0.5	-6
177	2	31	-999	33	10	-999	11	1.5	-1	-3
178	1	40	-999	34	4	-999	4	1.5	-1.5	-2
179	2	37	-999	46	13	-999	12	1	-1	1
180	1	32	-999	46	27	-999	27	1.5	1	0.5
181	1	32	-999	43	1	-999	2	2	1	0.5
182	1	34	-999	42	3	-999	2	1.5	1.5	0
183	2	31	-999	41	4	-999	3	1	0	-1

184	1	33	-999	47	3	-999	3	2	0.5	0
185	2	39	-999	59	9	-999	9	0.5	0	-1
186	1	39	-999	41	6	-999	6	2	-1	-2.5
187	1	43	-999	46	3	-999	2	2	-1.5	-7
188	2	38	-999	43	18	-999	19	1	-2	-5.5
189	1	34	-999	44	2	-999	2	2	-2	-4
190	1	36	-999	-999	2	-999	-999	2	1.5	3.5
191	1	37	-999	46	2	-999	4	1	0.5	0
192	1	33	-999	-999	2	-999	-999	1	2.5	2.5
193	1	50	-999	58	17	-999	18	2	-1	-5.5
194	1	42	-999	68	39	-999	40	1.5	1	-1.5
195	2	37	-999	50	75	-999	75	0.5	0	0
196	1	29	-999	54	6	-999	7	2	2	0.5
197	1	34	-999	29	2	-999	2	2	1.5	1.5
198	1	32	-999	34	2	-999	2	1.5	1.5	1
199	1	33	-999	-999	2	-999	-999	2	1.5	2.5
200	1	35	-999	48	6	-999	7	1.5	0.5	0.5
201	1	32	-999	46	1	-999	2	1.5	1.5	0
202	1	38	-999	46	2	-999	1	1	1	-0.5
203	1	35	-999	43	1	-999	2	2	0	-4.5
204	1	34	-999	42	2	-999	1	2.5	1.5	-1
205	1	36	-999	43	9	-999	10	1.5	-0.5	-1
206	1	37	-999	41	11	-999	10	1.5	0.5	-1.5
207	2	29	-999	39	6	-999	7	0	-1.5	-3.5
208	1	25	-999	31	2	-999	2	2	-1.5	-3.5
209	1	31	-999	30	25	-999	24	1.5	0.5	1.5
210	1	30	-999	34	2	-999	2	1.5	0.5	1.5
211	2	27	-999	30	16	-999	17	1	-1.5	1
212	2	29	-999	34	53	-999	52	1	0	-1.5
213	1	32	-999	32	5	-999	5	2	0	2
214	1	30	-999	32	2	-999	2	1.5	-1	1.5
215	1	28	-999	-999	2	-999	-999	2	0.5	2.5
216	1	48	-999	54	15	-999	15	2.5	-2.5	-4
217	1	35	-999	40	48	-999	49	2	-1.5	-0.5
218	2	34	-999	40	3	-999	4	0.5	-0.5	-1.5
219	1	32	-999	-999	28	-999	-999	0.5	0.5	3.5
220	2	41	-999	56	5	-999	32	1	0	-1.5
221	1	41	-999	45	3	-999	2	2	-0.5	-5.5
222	1	40	-999	65	1	-999	1	2	-1	-4.5
223	1	30	-999	30	1	-999	2	2	0	-0.5
224	1	43	-999	55	2	-999	2	2	-0.5	-0.5
225	1	38	-999	54	1	-999	1	2.5	0.5	-1
226	1	33	-999	54	2	-999	2	2	0	-3
227	1	36	-999	53	5	-999	4	1	0.5	-1
228	1	40	-999	51	2	-999	2	1.5	-0.5	-3
229	1	38	-999	38	54	-999	55	0.5	0.5	-3
230	1	32	-999	41	1	-999	2	2	0.5	-1
231	1	32	-999	40	2	-999	2	1.5	0.5	0
232	1	49	-999	49	6	-999	4	1.5	-1	-6
233	1	36	-999	43	4	-999	5	2.5	-0.5	-2.5
234	1	42	-999	53	1	-999	1	2.5	1.5	0.5
235	1	40	-999	48	23	-999	23	2	-1.5	-0.5
236	1	44	-999	48	8	-999	8	2	-1.5	-4
237	1	35	-999	31	32	-999	33	1.5	-0.5	-3.5

238	1	42	-999	52	16	-999	15	1.5	-0.5	-3.5
239	1	47	-999	57	2	-999	2	2	0.5	-0.5
240	2	37	-999	51	4	-999	3	1	0	-1
241	1	39	-999	54	4	-999	5	2	1.5	-3
242	1	35	-999	53	63	-999	63	2	0.5	-0.5
243	2	42	-999	42	24	-999	24	1	-0.5	-3.5
244	1	45	-999	48	2	-999	2	0	-1.5	-5
245	2	35	-999	44	30	-999	30	0	-1	-6
246	1	41	-999	53	17	-999	17	1.5	-1.5	-4.5
247	1	39	-999	54	1	-999	1	1.5	1	-3
248	1	46	-999	55	21	-999	21	2	-0.5	-0.5
249	1	42	-999	47	3	-999	3	2	0	-2.5
250	2	35	-999	41	53	-999	52	0.5	-1.5	-2
251	1	39	-999	42	22	-999	23	1.5	0.5	0.5
252	2	36	-999	48	53	-999	53	1	-1	-1.5
253	2	42	-999	53	8	-999	7	1	-1.5	-4.5
254	1	39	-999	55	2	-999	3	1	0.5	-1
255	1	39	-999	56	2	-999	1	2.5	0	-3.5
256	1	36	-999	54	14	-999	15	2.5	1	2
257	1	37	-999	37	1	-999	2	2.5	0.5	-0.5
258	2	37	-999	43	9	-999	8	1.5	0	-1.5
259	1	32	-999	40	16	-999	16	2.5	1	1.5
260	2	33	-999	46	25	-999	26	1.5	-1.5	-2
261	1	34	-999	45	2	-999	2	2	-0.5	-0.5
262	1	30	-999	-999	1	-999	-999	0.5	-3	-7.5
263	1	29	-999	37	1	-999	2	1.5	0	-1
264	1	29	-999	35	1	-999	1	2	1	-0.5
265	1	31	-999	29	3	-999	3	2	-1	0
266	1	33	-999	41	17	-999	16	2.5	0	-1
267	1	41	-999	68	6	-999	6	2	-0.5	-1
268	1	38	-999	41	15	-999	15	2.5	0	3
269	1	37	-999	46	4	-999	3	2	-1.5	0.5
270	1	38	-999	42	17	-999	18	1.5	-0.5	-1.5
271	1	38	-999	40	70	-999	70	2	1.5	2.5
272	1	34	-999	48	23	-999	24	2	1.5	0
273	1	31	-999	38	2	-999	1	2	1.5	0.5
274	1	34	-999	34	64	-999	64	2	2.5	2.5
275	1	36	-999	43	3	-999	3	2	1	-1
276	1	39	-999	48	4	-999	4	1.5	-0.5	-3.5
277	1	34	-999	49	2	-999	2	1.5	0.5	-0.5
278	1	35	-999	-999	2	-999	-999	1	2.5	1.5
279	2	33	-999	43	27	-999	29	1	0	-3.5
280	2	36	-999	40	7	-999	8	1	0.5	-2
281	1	41	-999	46	10	-999	9	2	0.5	-0.5
282	1	45	-999	54	30	-999	29	1.5	-1	-4
283	2	36	-999	49	58	-999	59	0.5	-1	-4
284	1	41	-999	73	30	-999	29	2	-1	-3.5
285	1	37	-999	39	3	-999	4	2	-0.5	-2.5
286	1	33	-999	-999	2	-999	-999	2	1	1
287	1	32	-999	44	1	-999	4	1.5	-1.5	-3.5
288	1	39	-999	54	28	-999	26	1.5	0.5	-1.5
289	1	39	-999	49	1	-999	2	1.5	0.5	-1.5
290	1	35	-999	50	2	-999	2	1.5	-0.5	-4.5
291	1	50	-999	49	1	-999	1	2	0.5	0

292	1	36	-999	51	2	-999	2	2	0	-0.5
293	1	39	-999	50	5	-999	5	1.5	1.5	0.5
294	2	38	-999	51	8	-999	9	1.5	-0.5	-0.5
295	2	38	-999	50	38	-999	37	-1	-1.5	-1
296	1	36	-999	51	2	-999	2	1	-1.5	-3
297	1	31	-999	19	26	-999	27	2	0.5	1
298	1	35	-999	45	2	-999	1	1.5	-0.5	0.5
299	1	37	-999	39	2	-999	2	1.5	0.5	0.5
300	1	42	-999	65	5	-999	5	1.5	-1	-3
301	2	38	-999	37	40	-999	41	1	-2.5	-2.5
302	1	33	-999	37	83	-999	83	1.5	0.5	0.5
303	1	32	-999	39	1	-999	1	2	0.5	-1.5
304	1	33	-999	23	1	-999	1	1	-2.5	-4.5
305	1	38	-999	53	2	-999	1	1.5	-2.5	-4
306	1	39	-999	42	5	-999	5	2	1.5	-2
307	1	43	-999	40	22	-999	22	1.5	-1	-5.5
308	1	42	-999	60	27	-999	26	2	-0.5	-3.5
309	2	40	-999	52	19	-999	19	0.5	0	-1
310	1	38	-999	54	2	-999	2	1.5	0.5	-0.5
311	2	35	-999	52	11	-999	12	0.5	-2.5	-5
312	1	38	-999	33	9	-999	8	1.5	0.5	2
313	1	32	-999	43	6	-999	7	1.5	-0.5	-1
314	2	35	-999	39	83	-999	83	0.5	0	1
315	1	38	-999	-999	6	-999	-999	1.5	0.5	4.5
316	1	33	-999	42	4	-999	10	2	0.5	2
317	1	34	-999	-999	1	-999	-999	2.5	3.5	5
318	1	31	-999	-999	1	-999	-999	1.5	-1.5	-1.5
319	1	33	-999	47	2	-999	3	1.5	1	3.5
320	1	34	-999	44	1	-999	3	1.5	1.5	0.5
321	1	33	-999	42	3	-999	2	0.5	-0.5	-1
322	1	28	-999	38	2	-999	3	2	-0.5	-1.5
323	1	32	-999	36	1	-999	1	2	-1.5	-3.5
324	1	38	-999	53	24	-999	23	1	-0.5	-1
325	2	35	-999	50	26	-999	26	1	-2	-3
326	1	34	-999	49	2	-999	2	1.5	-0.5	-0.5
327	1	36	-999	43	1	-999	1	1.5	0	-0.5
328	1	45	-999	56	4	-999	3	1.5	1.5	2.5
329	1	34	-999	49	1	-999	3	1	0.5	0.5
330	1	36	-999	49	2	-999	1	1.5	0	0
331	2	35	-999	44	2	-999	2	-1	-3	-7
332	1	37	-999	46	1	-999	2	1.5	1	-1.5
333	1	40	-999	-999	31	-999	31	2	0.5	2.5
334	2	40	-999	-999	24	-999	-999	1	-1	-4
335	1	35	-999	-999	4	-999	27	2	-0.5	-1
336	2	36	-999	45	2	-999	2	0.5	-2.5	0.5
337	1	40	-999	36	18	-999	18	1	0.5	3.5
338	1	36	-999	40	11	-999	11	1	-1	-0.5
339	1	42	-999	60	10	-999	10	1	0.5	-1
340	2	35	-999	60	12	-999	11	1.5	3	4
341	1	34	-999	37	2	-999	2	2	0.5	1
342	1	35	-999	49	1	-999	2	1.5	-1.5	-1.5
343	1	41	-999	53	3	-999	2	1.5	0.5	-1
344	1	31	-999	40	30	-999	31	1.5	-0.5	-1
345	1	38	-999	50	21	-999	21	2	1	4.5

346	1	37	-999	-999	1	-999	-999	1	-2	-3.5
347	2	26	-999	25	27	-999	30	0	-2.5	-1.5
348	1	40	-999	52	10	-999	8	1.5	-1.5	0.5
349	1	44	-999	42	13	-999	13	1	-2.5	-3.5
350	1	45	-999	42	6	-999	6	1.5	0.5	-1
351	1	41	-999	42	31	-999	30	-0.5	-1	-5
352	2	29	-999	51	10	-999	12	1	-0.5	0
353	2	32	-999	52	9	-999	8	1.5	-2	1
354	1	33	-999	50	3	-999	3	1.5	0.5	-1.5
355	2	39	-999	60	11	-999	10	0	0	-2.5
356	1	54	-999	54	5	-999	5	1.5	-1	-1.5
357	1	44	-999	58	47	-999	48	0.5	1	1.5
358	1	42	-999	56	28	-999	28	2	-2	-4
359	1	53	-999	68	22	-999	21	2	-1.5	-1
360	1	26	-999	-999	81	-999	-999	1.5	2.5	2.5
361	1	25	-999	-999	2	-999	-999	1.5	1.5	4
362	1	28	-999	-999	1	-999	-999	1.5	0	2.5
363	1	35	-999	62	47	-999	132	1	-0.5	1.5
364	1	35	-999	62	2	-999	2	1.5	0.5	0.5
365	1	34	-999	62	3	-999	3	1.5	-1	-3
366	1	37	-999	55	1	-999	1	1.5	-0.5	-1
367	1	38	-999	49	2	-999	2	1.5	0	0.5
368	1	31	-999	56	2	-999	2	2	0	-2.5
369	2	31	-999	50	29	-999	29	1	0	4.5
370	1	31	-999	33	4	-999	5	2	-1.5	0.5
371	1	39	-999	60	40	-999	39	2	0.5	-1
372	1	34	-999	40	37	-999	38	2	-1.5	-2.5
373	1	30	-999	48	1	-999	1	1.5	-1	-4.5
374	1	35	-999	50	2	-999	1	0.5	-1.5	-1
375	1	34	-999	44	51	-999	51	2	-0.5	-2
376	2	30	-999	46	5	-999	6	1	0	-1
377	1	31	-999	56	2	-999	2	2	0.5	1.5
378	1	27	-999	-999	1	-999	-999	2	-1.5	-3
379	2	39	-999	59	63	-999	62	0.5	0	-1.5
380	2	46	-999	65	16	-999	16	1	0	0
381	1	51	-999	60	8	-999	8	1.5	0.5	-1.5
382	1	46	-999	66	18	-999	19	1.5	0	-1
383	1	34	-999	48	22	-999	22	1.5	0.5	-0.5
384	1	38	-999	45	1	-999	1	2	-2	-1.5
385	2	38	-999	50	42	-999	42	1.5	-3	-6
386	2	39	-999	61	6	-999	6	1.5	0	-0.5
387	1	41	-999	18	1	-999	1	1.5	-1	-6.5
388	1	35	-999	60	34	-999	34	1.5	0	-3
389	2	30	-999	42	50	-999	51	-1	-2	0
390	1	33	-999	46	1	-999	2	1	-3.5	-2
391	1	39	-999	52	4	-999	2	1.5	-1.5	-3
392	1	39	-999	60	1	-999	2	1.5	0	-0.5
393	1	47	-999	72	9	-999	8	1	0.5	-0.5
394	2	45	-999	60	89	-999	90	0.5	-1	-1
395	1	42	-999	48	3	-999	2	1.5	-1.5	-4.5
396	1	42	-999	63	3	-999	3	1.5	-1	-2.5
397	2	43	-999	58	4	-999	3	0.5	-3	-3.5
398	1	33	-999	40	42	-999	44	1.5	0.5	2
399	1	44	-999	51	5	-999	3	1.5	0.5	-3.5

400	2	43	-999	64	33	-999	35	1.5	0.5	-2
401	1	38	-999	56	9	-999	9	2	0.5	3
402	1	40	-999	50	31	-999	30	1.5	-1	-4.5
403	1	36	-999	53	2	-999	3	2	-1.5	-0.5
404	2	32	-999	34	22	-999	22	1	-2	-2
405	1	47	-999	72	15	-999	15	2	0.5	-1
406	2	41	-999	53	14	-999	14	0.5	-2	-4.5
407	1	40	-999	73	16	-999	16	1.5	-1.5	-5.5
408	1	36	-999	53	2	-999	2	2	-1	-3
409	2	32	-999	58	4	-999	5	1	-2	-2
410	2	34	-999	43	4	-999	3	1	-1.5	-3.5
411	1	38	-999	30	1	-999	2	2	0.5	-2.5
412	1	32	-999	45	3	-999	2	0.5	0.5	0.5
413	2	28	-999	35	3	-999	4	0	-2.5	-1.5
414	2	36	-999	51	45	-999	43	0.5	0	0
415	1	36	-999	59	19	-999	19	1	-1.5	0.5
416	1	41	-999	62	1	-999	1	2	-0.5	-2
417	1	37	-999	46	3	-999	3	2	-1.5	-0.5
418	2	30	-999	36	25	-999	24	1	-1	0
419	1	34	-999	36	5	-999	6	1.5	-1	0
420	2	85	-999	43	89	-999	89	1	-1	-0.5
421	1	30	-999	37	1	-999	2	2	-1.5	-1
422	2	30	-999	38	4	-999	2	1	0.5	0.5
423	1	31	-999	31	1	-999	2	1.5	2.5	3.5
424	1	30	-999	50	2	-999	2	2	0.5	0.5
425	1	29	-999	41	3	-999	2	1.5	-0.5	0.5
426	1	36	-999	46	7	-999	7	2	1	-0.5
427	1	39	-999	64	7	-999	7	2	1.5	3.5
428	2	41	-999	67	3	-999	3	0.5	-1	-2
429	2	39	-999	55	40	-999	40	0.5	0	0
430	2	34	-999	30	16	-999	17	1	-0.5	0
431	1	36	-999	24	1	-999	2	2	-0.5	-2.5
432	1	32	-999	-999	35	-999	-999	2	3	5
433	1	40	-999	57	100	-999	133	2	1	0.5
434	1	25	-999	45	1	-999	1	2	0.5	-1
435	1	34	-999	45	7	-999	7	1	-1	-1
436	1	30	-999	31	49	-999	50	1.5	-1.5	-8
437	2	34	-999	51	35	-999	34	1	-1	-1
438	1	37	-999	51	2	-999	2	2	-0.5	-4.5
439	1	30	-999	51	2	-999	2	1.5	-1	-1.5
440	2	33	-999	53	1	-999	1	1	0.5	-1
441	2	34	-999	43	2	-999	2	0.5	0	-1
442	1	35	-999	67	17	-999	17	2	0	-5
443	2	34	-999	34	12	-999	13	0.5	-2.5	-1
444	1	31	-999	35	1	-999	1	2	0	0.5
445	2	40	-999	44	18	-999	17	0.5	-2	-2.5
446	1	36	-999	43	1	-999	2	1	0.5	0
447	1	38	-999	50	2	-999	1	1.5	0	-1
448	1	33	-999	36	73	-999	73	1.5	1	2.5
449	1	32	-999	41	1	-999	1	2	0.5	4
450	1	33	-999	40	2	-999	3	2	0.5	0.5
451	1	29	-999	43	3	-999	3	1	1	0.5
452	1	38	-999	41	4	-999	3	1.5	1	0.5
453	1	37	-999	53	45	-999	45	1	-1.5	-4

454	1	12	-999	43	1	-999	1	1.5	1	3
455	1	38	-999	36	2	-999	2	0.5	-0.5	2
456	1	35	-999	54	1	-999	1	0.5	0.5	0.5
457	2	40	-999	50	20	-999	20	-1	-0.5	0
458	1	40	-999	51	14	-999	14	1.5	0	-0.5
459	1	46	-999	73	31	-999	30	1.5	1.5	-2.5
460	2	42	-999	61	20	-999	20	0	-1	-4
461	1	40	-999	48	2	-999	3	0.5	-0.5	-4.5
462	1	36	-999	49	93	-999	93	1.5	0	-0.5
463	1	38	-999	37	53	-999	54	1.5	2	0.5
464	1	32	-999	41	2	-999	2	1.5	1.5	0
465	1	33	-999	40	1	-999	1	2	2.5	-0.5
466	1	34	-999	41	3	-999	3	-0.5	0.5	-2.5
467	2	35	-999	51	35	-999	33	-0.5	0	-1.5
468	1	38	-999	52	2	-999	2	1.5	0	-3
469	1	38	-999	48	2	-999	2	0.5	-1	-4.5
470	2	36	-999	50	3	-999	3	0	0	-2
471	1	34	-999	49	2	-999	3	1	-0.5	-3
472	1	49	-999	49	11	-999	10	1.5	2.5	2.5
473	1	42	-999	73	60	-999	62	1.5	3	4
474	2	42	-999	61	4	-999	1	0	-2	-4
475	2	43	-999	64	15	-999	16	-1	0	-3.5
476	2	39	-999	50	12	-999	11	0	0	-1
477	1	43	-999	59	7	-999	7	1	1	-1.5
478	2	37	-999	45	3	-999	3	1	0.5	-1.5
479	1	32	-999	39	49	-999	49	0.5	0.5	-3.5
480	2	38	-999	42	4	-999	5	1.5	0	-3
481	1	38	-999	45	3	-999	2	1.5	1	-2.5
482	1	37	-999	43	3	-999	3	1.5	1.5	0.5
483	2	43	-999	59	15	-999	15	0.5	0	-4
484	2	26	-999	30	10	-999	12	0	-1	-1
485	2	31	-999	24	21	-999	20	1.5	1	1
486	1	40	-999	52	17	-999	15	1.5	1	-0.5
487	1	33	-999	50	3	-999	4	1.5	0	-3.5
488	2	38	-999	46	9	-999	9	0.5	0	-4
489	1	36	-999	46	27	-999	28	1.5	1	2.5
490	2	31	-999	29	17	-999	17	0	0	-1
491	1	25	-999	37	1	-999	1	1.5	2.5	1
492	1	35	-999	50	4	-999	3	1	2.5	-0.5
493	2	47	-999	63	16	-999	16	0	-0.5	-1
494	1	33	-999	62	5	-999	23	2	4.5	-4
495	2	40	-999	43	19	-999	30	0	-1	-1.5
496	2	34	-999	53	28	-999	2	0	0	-2
497	1	36	-999	65	3	-999	25	0.5	-2	-2.5
498	2	41	-999	58	26	-999	0	0	-0.5	1
499	1	40	-999	29	4	-999	4	1	3	1.5
500	1	42	-999	-999	8	-999	-999	0.5	1	8.5
501	1	43	-999	76	30	-999	40	1.5	2	2.5
502	1	41	-999	48	2	-999	5	1	-0.5	-3
503	2	35	-999	39	3	-999	1	0	-1	-1
504	2	33	-999	48	3	-999	1	0	-1	-0.5
505	1	39	-999	58	19	-999	18	1.5	1	-3
506	1	40	-999	53	1	-999	2	1.5	0.5	-3.5
507	1	39	-999	52	1	-999	1	1.5	0.5	-3.5

508	1	28	-999	33	31	-999	32	1.5	1	-1.5
509	2	40	-999	62	8	-999	7	0	-1	-4.5
510	1	36	-999	52	2	-999	2	1.5	1	-2.5
511	1	35	-999	47	3	-999	3	1	0.5	-0.5
512	1	47	-999	70	10	-999	9	0.5	0.5	-3
513	1	43	-999	74	15	-999	16	1	1	-1
514	1	42	-999	66	14	-999	14	-0.5	0.5	-3.5
515	1	43	-999	55	22	-999	22	2	0.5	-1
516	1	38	-999	60	4	-999	4	2	1	0
517	1	34	-999	38	16	-999	16	1.5	1	1.5
518	1	31	-999	15	1	-999	2	2	2.5	0.5
519	1	30	-999	32	1	-999	1	1.5	1	0
520	2	33	-999	43	3	-999	1	0	0.5	0
521	2	32	-999	37	2	-999	3	1	-2	-1
522	1	36	-999	37	39	-999	38	1	-1	-6.5
523	2	31	-999	31	22	-999	24	0	0	-1
524	1	27	-999	35	2	-999	3	1.5	0.5	0.5
525	2	22	-999	37	4	-999	3	0	-2.5	-4.5
526	1	29	-999	38	2	-999	1	1.5	-1.5	-2.5
527	2	33	-999	35	5	-999	5	0	0	0
528	1	29	-999	25	3	-999	1	0.5	2	4.5
529	2	32	-999	30	53	-999	55	0	-0.5	-4
530	1	33	-999	50	15	-999	16	1.5	-0.5	-4.5
531	2	40	-999	51	3	-999	2	-0.5	0	-0.5
532	2	44	-999	67	12	-999	11	0.5	0.5	-0.5
533	2	42	-999	65	3	-999	4	-1.5	-1	-1
534	1	38	-999	58	3	-999	3	1	0.5	-0.5
535	1	43	-999	64	29	-999	29	1	0.5	-2.5
536	2	44	-999	40	3	-999	2	-1	-1	-2.5
537	1	42	-999	50	2	-999	3	0.5	-0.5	-1.5
538	1	40	-999	-999	37	-999	-999	1	1	2
539	1	40	-999	51	20	-999	57	2	1	0
540	1	42	-999	51	90	-999	89	1	0.5	-1
541	1	37	-999	52	1	-999	2	1	0	-4.5
542	1	53	-999	70	7	-999	6	1	0.5	-0.5
543	2	48	-999	60	6	-999	6	1	-1.5	-3
544	1	39	-999	56	31	-999	31	1.5	2	0.5
545	1	40	-999	64	5	-999	6	1.5	1	0.5
546	2	38	-999	68	12	-999	12	0.5	-0.5	0
547	1	35	-999	44	1	-999	1	1.5	1	1.5
548	1	39	-999	48	3	-999	3	1.5	0.5	-3
549	1	37	-999	51	2	-999	2	0.5	0	-0.5
550	1	41	-999	48	6	-999	6	1.5	0	-1
551	1	43	-999	59	2	-999	1	1.5	0	-1.5
552	1	44	-999	53	20	-999	21	-999	-1	-1
553	1	46	-999	66	3	-999	2	-999	1.5	0.5
554	1	45	-999	64	3	-999	3	-999	1	-0.5
555	2	38	-999	45	30	-999	31	-999	-1	-3
556	1	44	-999	59	9	-999	9	-999	-1	-2.5
557	1	39	-999	56	11	-999	11	-999	-0.5	-1.5
558	1	38	-999	46	26	-999	26	-999	0.5	0.5
559	1	39	-999	51	2	-999	2	-999	2.5	0
560	2	27	-999	39	52	-999	53	-999	0	0
561	1	43	-999	58	15	-999	14	-999	1	1

562	2	38	-999	46	41	-999	41	-999	0.5	-1
563	1	43	-999	61	4	-999	3	-999	0.5	-1.5
564	1	37	-999	54	6	-999	7	-999	1.5	0.5
565	2	35	-999	44	6	-999	6	-999	0	-4.5
566	1	36	-999	42	8	-999	8	-999	0	0
567	1	35	-999	52	4	-999	4	-999	0.5	-1
568	1	30	-999	31	15	-999	16	-999	1	-0.5
569	2	40	-999	44	20	-999	19	-999	0	-1
570	1	34	-999	34	18	-999	18	-999	-1.5	-5
571	1	35	-999	43	31	-999	31	-999	-0.5	-4.5
572	1	40	-999	40	2	-999	2	-999	-0.5	-3
573	1	41	-999	44	5	-999	5	-999	-1.5	-4.5
574	2	33	-999	39	13	-999	14	-999	2	5
575	2	29	-999	37	2	-999	2	-999	0	-0.5
576	2	27	-999	38	3	-999	3	-999	1	0
577	2	27	-999	20	15	-999	16	-999	0	-0.5
578	1	28	-999	29	1	-999	1	-999	1.5	0.5
579	1	28	-999	29	3	-999	2	-999	1	0
580	1	27	-999	-999	7	-999	-999	-999	1	2
581	2	27	-999	31	51	-999	57	-999	0	0
582	1	30	-999	42	1	-999	1	-999	1	-0.5
583	1	37	-999	40	26	-999	25	-999	0	-4.5
584	1	32	-999	48	1	-999	2	-999	0	-3.5
585	1	41	-999	-999	3	-999	-999	-999	2.5	2.5
586	2	37	-999	43	1	-999	4	-999	0	-5
587	1	28	-999	77	2	-999	1	-999	0	0.5
588	1	30	-999	45	2	-999	2	-999	-1	-2.5
589	1	29	-999	48	1	-999	2	-999	0.5	-3
590	1	42	-999	53	74	-999	73	-999	-0.5	-3.5
591	1	39	-999	48	11	-999	11	-999	0.5	-0.5
592	1	33	-999	37	2	-999	2	-999	1.5	0
593	2	38	-999	52	6	-999	5	-999	0	1
594	1	31	-999	55	18	-999	17	-999	1.5	-3.5
595	2	39	-999	50	46	-999	47	-999	0	0
596	1	36	-999	37	1	-999	1	-999	1	-5
597	1	32	-999	49	2	-999	2	-999	0.5	-0.5
598	1	32	-999	46	2	-999	3	-999	0	-3.5
599	2	32	-999	79	2	-999	2	-999	1	-1
600	1	40	-999	54	16	-999	15	-999	1.5	1
601	1	36	-999	51	12	-999	12	-999	-0.5	-2
602	2	37	-999	46	3	-999	3	-999	-0.5	-3
603	1	36	-999	50	2	-999	2	-999	0	-3.5
604	2	41	-999	50	23	-999	22	-999	0	-4
605	2	33	-999	42	13	-999	14	-999	0.5	1.5
606	1	39	-999	50	2	-999	2	-999	1.5	-0.5
607	2	36	-999	46	35	-999	35	-999	1	0
608	1	37	-999	50	1	-999	1	-999	-0.5	-3.5
609	1	32	-999	42	3	-999	3	-999	1	-0.5
610	1	32	-999	46	4	-999	4	-999	-1	-2.5
611	2	30	-999	39	2	-999	3	-999	-0.5	-1
612	1	28	-999	39	3	-999	3	-999	-1	-2.5
613	2	33	-999	44	26	-999	26	-999	0	0
614	1	30	-999	39	3	-999	3	-999	1.5	-1.5
615	1	34	-999	-999	9	-999	-999	-999	2.5	3.5

616	2	33	-999	42	4	-999	13	-999	-1	-3.5
617	2	33	-999	39	34	-999	34	-999	0	-0.5
618	1	42	-999	58	6	-999	4	-999	-0.5	0
619	1	40	-999	46	21	-999	21	-999	0	-3.5
620	1	36	-999	41	4	-999	5	-999	0	-4.5
621	1	37	-999	39	3	-999	3	-999	2	0.5
622	1	42	-999	55	4	-999	4	-999	-0.5	-1.5
623	1	40	-999	62	10	-999	9	-999	0.5	0
624	1	34	-999	42	13	-999	15	-999	1	1.5
625	2	34	-999	48	10	-999	9	-999	-2	-4
626	1	43	-999	54	11	-999	10	-999	1.5	-3.5
627	2	37	-999	62	27	-999	28	-999	0.5	1
628	1	37	-999	43	4	-999	4	-999	0.5	-1.5
629	1	37	-999	47	1	-999	1	-999	1.5	-0.5
630	1	36	-999	53	33	-999	33	-999	0.5	-2.5
631	1	41	-999	44	2	-999	2	-999	1.5	0.5
632	1	37	-999	39	2	-999	2	-999	1.5	2.5
633	1	34	-999	43	1	-999	2	-999	1	2.5
634	1	30	-999	43	2	-999	2	-999	0.5	-2
635	1	40	-999	70	23	-999	22	-999	3.5	2.5
636	2	46	-999	61	9	-999	9	-999	0	-4.5
637	2	36	-999	29	73	-999	74	-999	0	-4
638	1	29	-999	30	2	-999	2	-999	1	0
639	2	28	-999	32	2	-999	2	-999	0	2
640	1	36	-999	31	2	-999	1	-999	-0.5	-1.5
641	1	31	-999	22	1	-999	2	-999	1	2
642	1	28	-999	21	2	-999	3	-999	1.5	2.5
643	1	25	-999	18	2	-999	2	-999	0.5	-0.5
644	2	47	-999	22	5	-999	4	-999	-0.5	-4
645	1	37	-999	43	28	-999	26	-999	0	-999
646	2	36	-999	49	8	-999	8	-999	0	-999
647	2	38	-999	51	5	-999	4	-999	-1	-999

Appendix C Normality of Lateral Displacements

In the review of lateral displacement results, the distributions of values along each crossover were studied to provide insight into driver behaviors. The full data set for the crossover sites was separated into groups by each study site, and then the three observation locations were examined individually.

Distributions of Lateral Displacement Data

Lincoln West Study Site

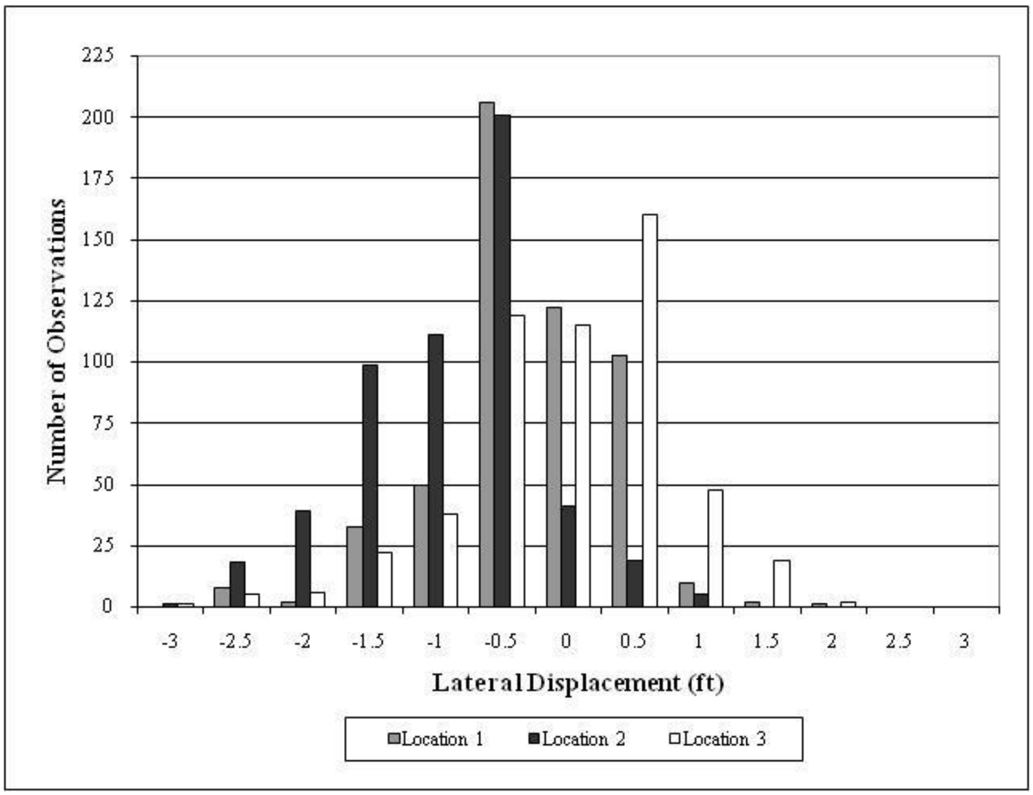

Figure C.1 Lincoln West Distribution for All Locations

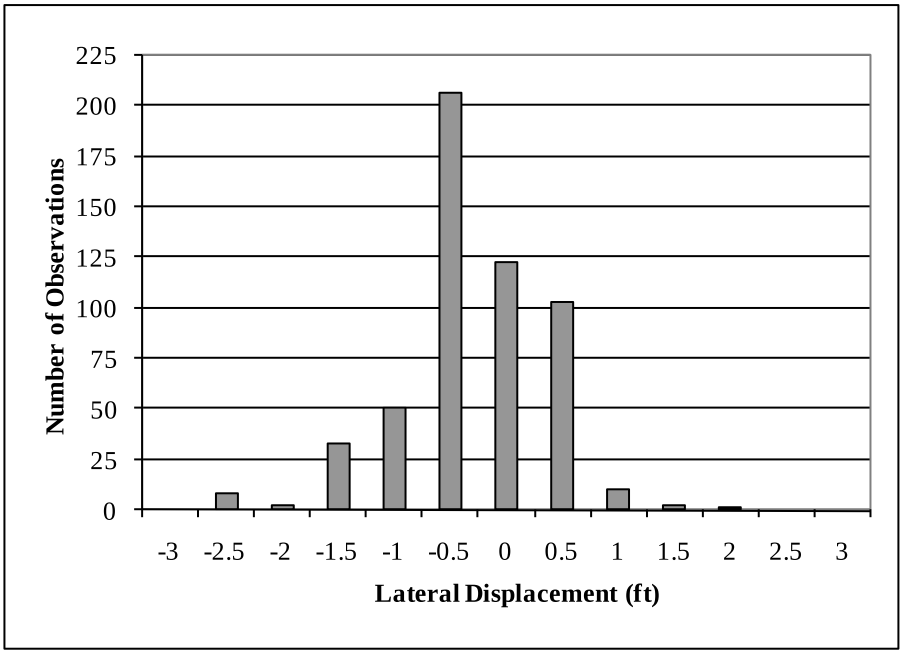

Figure C.2 Lincoln West Distribution at Location 1

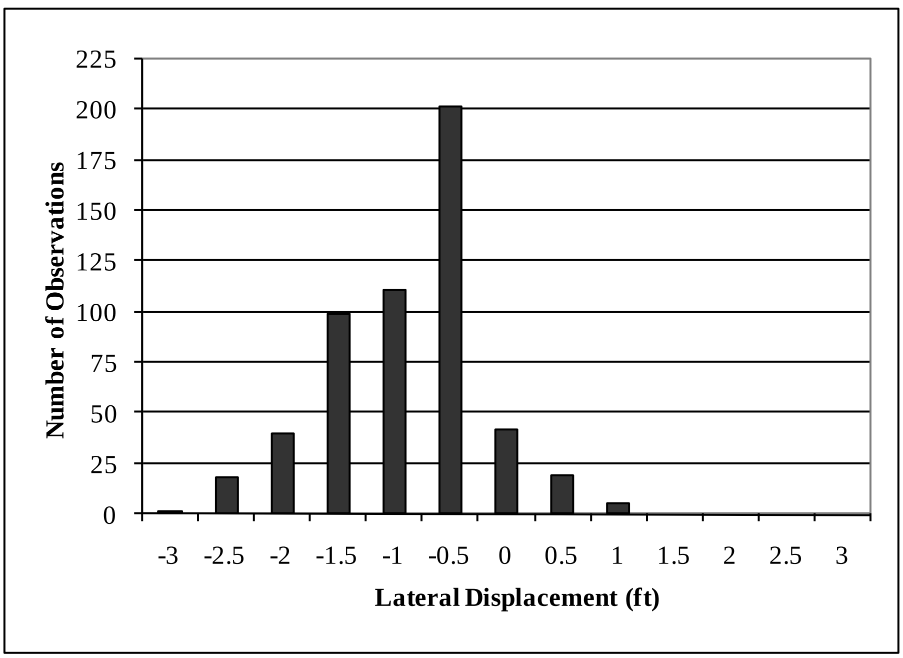

Figure C.3 Lincoln West Distribution at Location 2

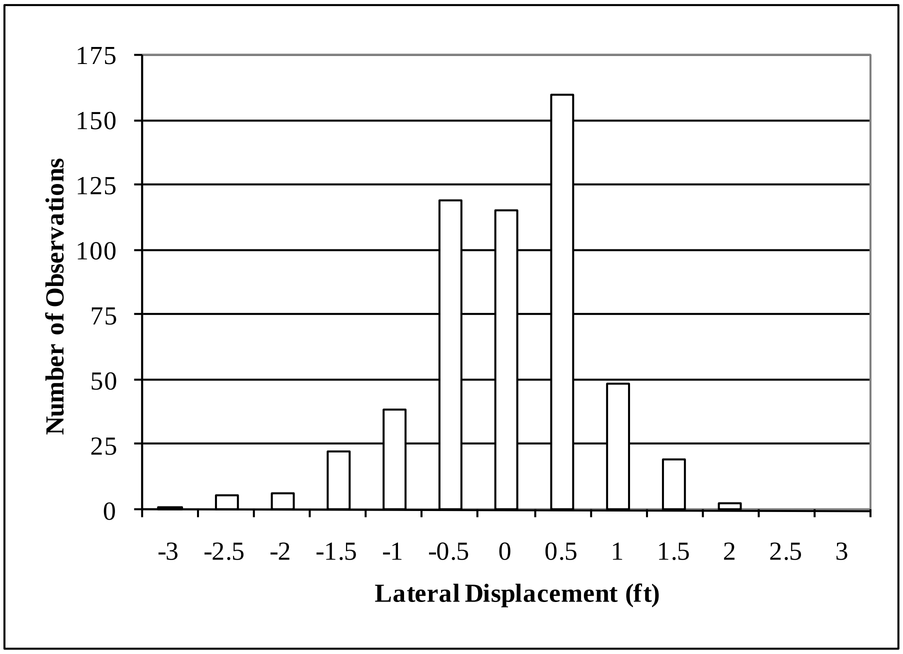

Figure C.4 Lincoln West Distribution at Location 3

Springfield North Study Site – Entrance Crossover

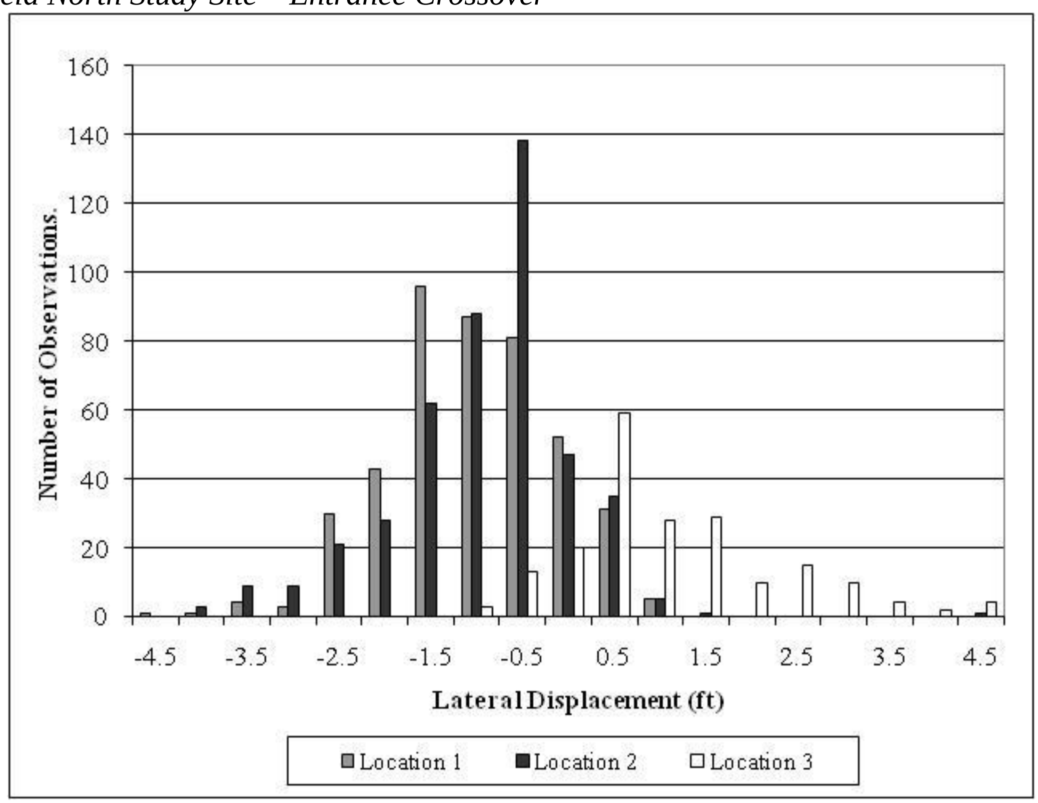

Figure C.5 Springfield North Entrance Crossover Distribution for All Locations

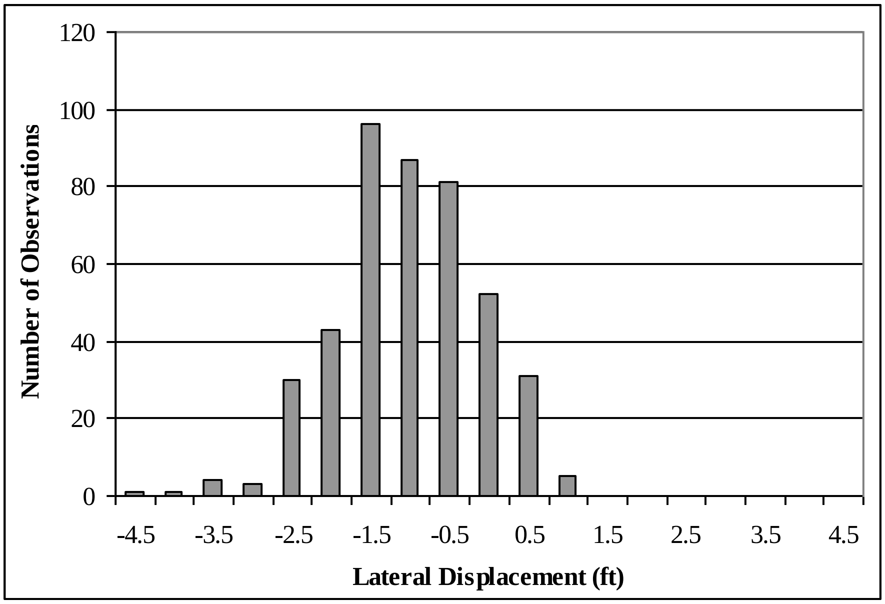

Figure C.6 Springfield North Entrance Crossover Distribution at Location 1

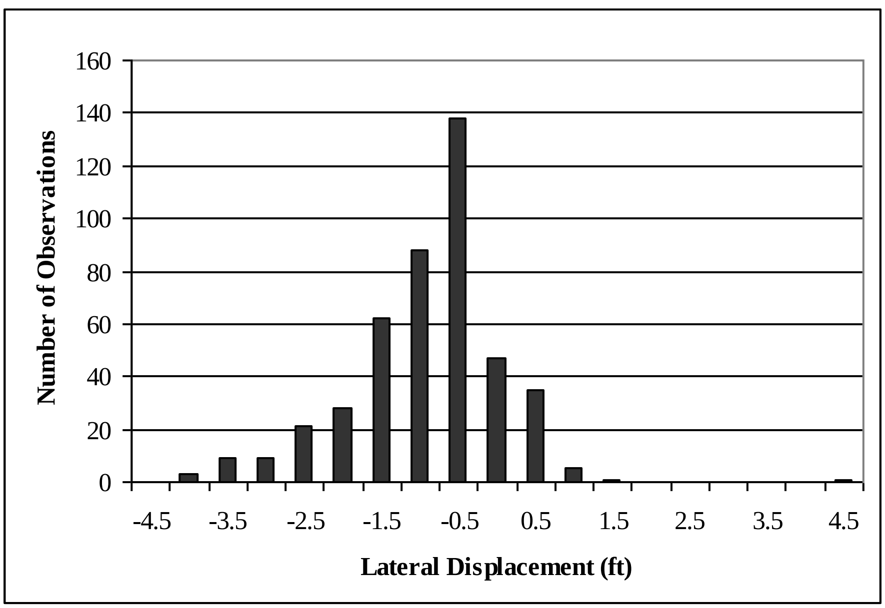

Figure C.7 Springfield North Entrance Crossover Distribution at Location 2

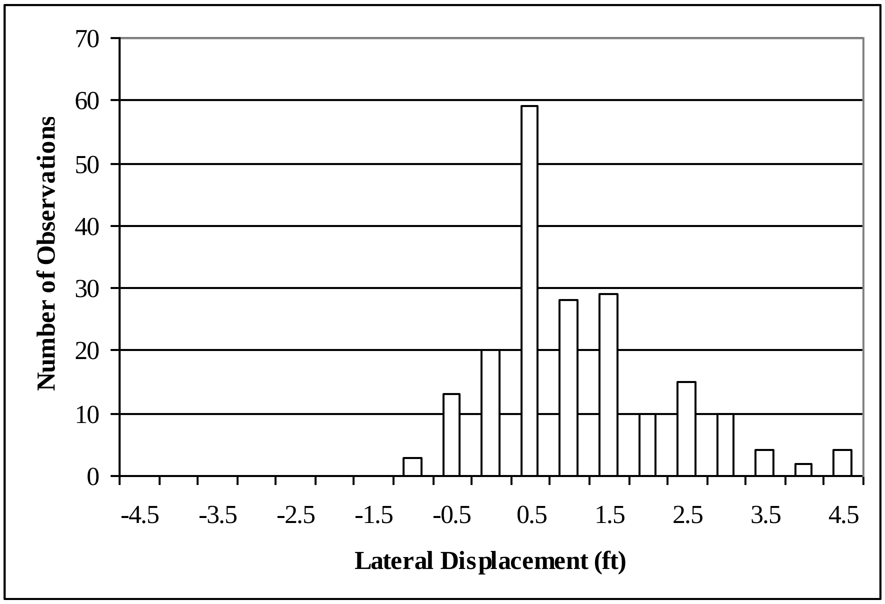

Figure C.8 Springfield North Entrance Crossover Distribution at Location 3

Springfield North Study Site – Exit Crossover

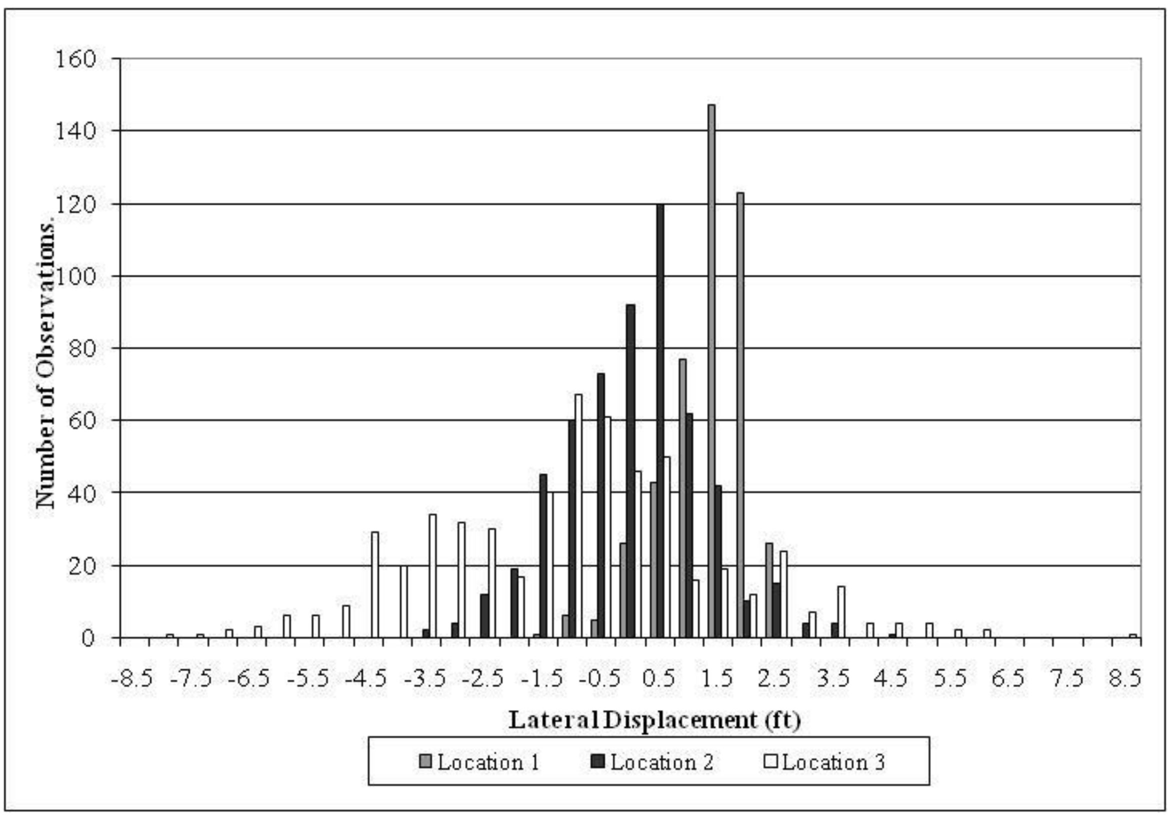

Figure C.9 Springfield North Exit Crossover Distribution for All Locations

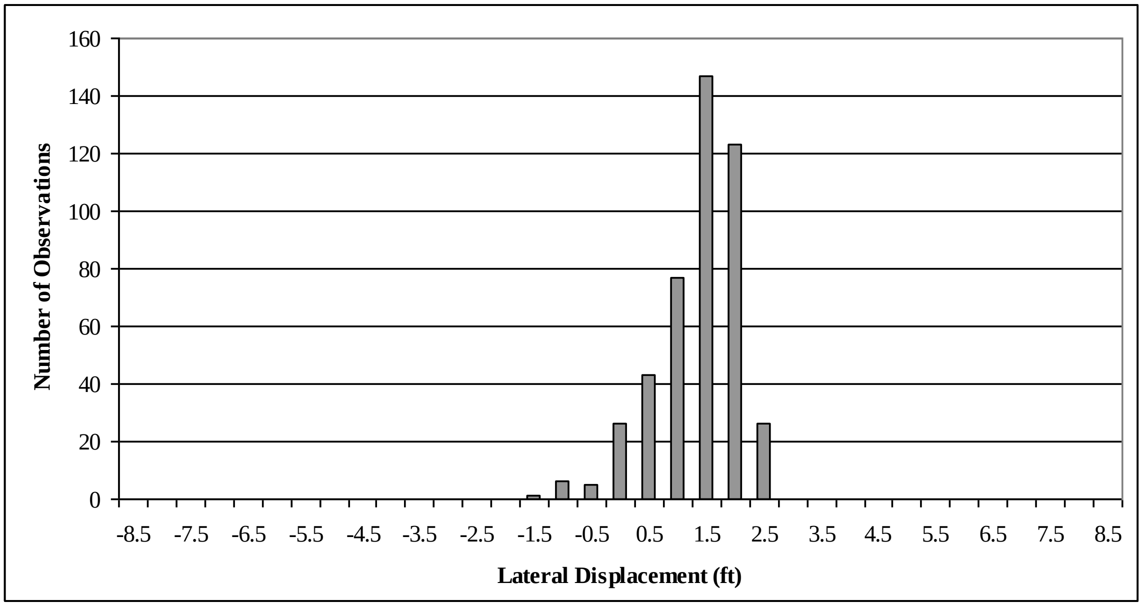

Figure C.10 Springfield North Exit Crossover Distribution at Location 1

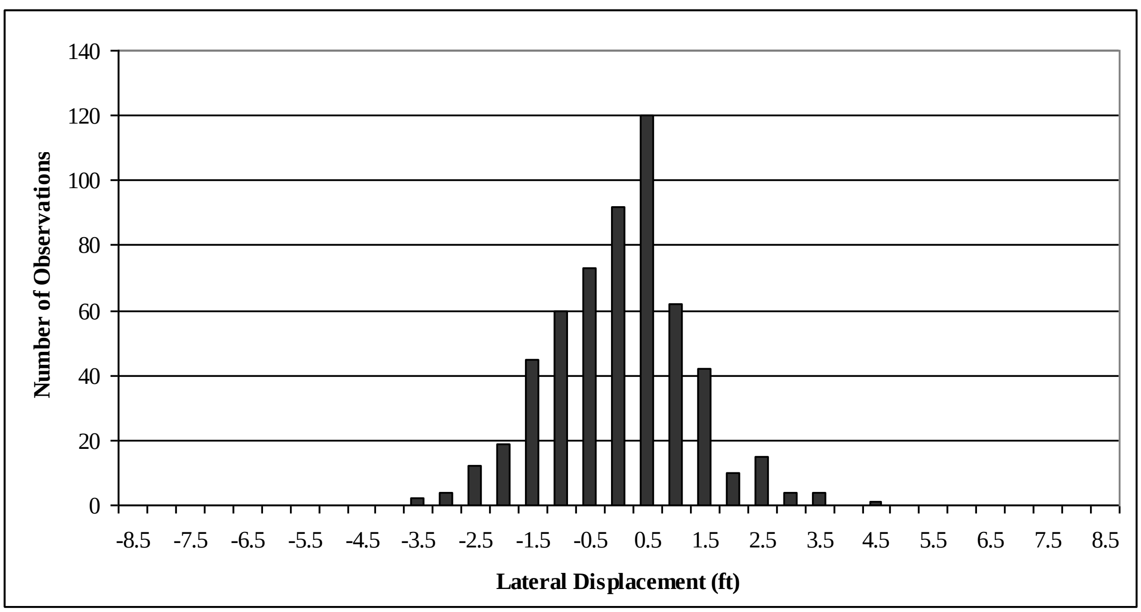

Figure C.11 Springfield North Exit Crossover Distribution at Location 2

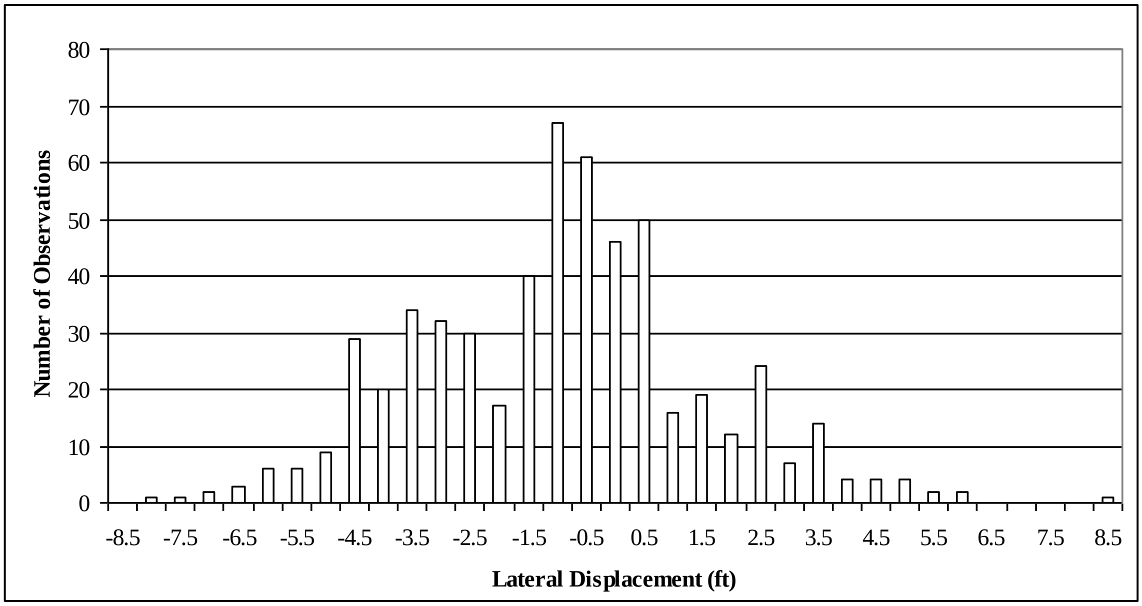

Figure C.12 Springfield North Exit Crossover Distribution at Location 3

<u>Central Limit Theorem</u>

The distributions appear to be approximately normal in shape. Following visual review of the distributions, the Central Limit Theorem was used to make a final decision on the normality of the data. The Central Limit Theorem states that a mean $\overline{X}$, of a random sample size, *n*, taken from a population with mean, μ , and standard deviation, σ can be used to determine the Z-statistic which is limiting form of the distribution in EQUATION c1 as the sample size approaches infinity is (27):

$$Z = \frac{\overline{X} - \mu}{\sigma / \sqrt{n}} \qquad \text{(C.1)}$$

Applying the Central Limit Theorem to the lateral displacement datasets allows for the assumption that the data collected was normally distributed. This theorem was applied to the datasets as it was believed that a sample size that would approach infinity would lead to a distinctively normal distribution for each data set.

Appendix D Lateral Displacement Data Dependence

The presence of other vehicles near observed vehicles may have influenced the lateral displacements that were measured. This had the potential to create dependence within the data sets. To determine if this dependence was present, the data sets were separated into two groups. These two groups consisted of observations collected under free-flow conditions and non-free-flow conditions. A t-test was then conducted using equation C.1 for each data set pairing to determine if the two groups were significantly different.

$$t' = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad \text{(D.1)}$$

Where:

t' = Calculated t-statistic
$\bar{x}$ = Sample mean
s^2 = Sample variance
n = Sample size

This test was analyzed with a 95% level of confidence which meant that any test with a calculated t' value less than -1.96 or greater than 1.96 would indicate that the two groups were significantly different. For the nine sets of data, only one location had a significant difference between free-flow and non-free-flow lateral displacements. This was Location 1 at the Springfield North exit crossover.

Table D.1 Calculated t' Values

Crossover Site	Location	Free-Flow Conditions	Mean	Standard Deviation	Sample Size	Calculated t'
Lincoln West (Entrance Crossover)	1	Yes	-0.283	0.674	281	0.52
		No	-0.313	0.636	256	
	2	Yes	-0.835	0.661	279	1.58
		No	-0.929	0.715	255	
	3	Yes	-0.009	0.548	279	-0.54
		No	0.027	0.650	256	
Springfield North (Entrance Crossover)	1	Yes	-1.016	0.762	284	0.19
		No	-1.033	0.932	150	
	2	Yes	-0.836	0.920	292	1.79
		No	-1.010	0.982	155	
	3	Yes	1.035	1.402	128	-1.32
		No	1.254	1.122	69	
Springfield North (Exit Crossover)	1	Yes	1.235	0.763	198	-3.38
		No	1.467	0.671	256	
	2	Yes	-0.028	1.222	-251	-1.18
		No	0.092	1.186	314	
	3	Yes	-0.898	2.626	249	0.61
		No	-1.027	2.344	314	

Appendix E Autotrack Analysis

The goal of applying AutoTrack to analyze the studied crossovers was to discern if ample geometrics were provided to allow drivers to maintain a driving path that followed the centerline of the driving lane within the crossover. The computer program AutoTrack has the ability to plot vehicular driving paths within the computer programs of Microstation and AutoCAD. These driving paths show the footprint of a vehicle as it follows maneuvers specified by the user.

As points were selected along a continuous path, AutoTrack created the footprint of the specified design vehicle at a set driving speed. For any driving path that would not conform to the preset capabilities of the design vehicle, the driving path was not created. These preset abilities are based on international guidelines dependent on the type of design vehicle. For the U.S. design vehicles, the AutoTrack program refers to stored presets based on Green Book guidelines (29).

Crossover Plans

To analyze the studied crossovers with AutoTrack, design plans were obtained from the Nebraska Department of Roads. These plans were used in conjunction with measurements taken in the field to construct layouts of each crossover in Microstation. At each crossover, three lines were added along the width of the driving lane to identify the three observation locations used in data collection.

All of the developed figures were arranged with traffic traveling from right to left across the figure. During this process, it was noted that the lane width at Lincoln West was less than 16 ft (as required by the NDOR Roadway Design Manual). Instead, the crossover was designed and built for a lane width of 14 feet. The plan view of this crossover is shown in figure E.1.

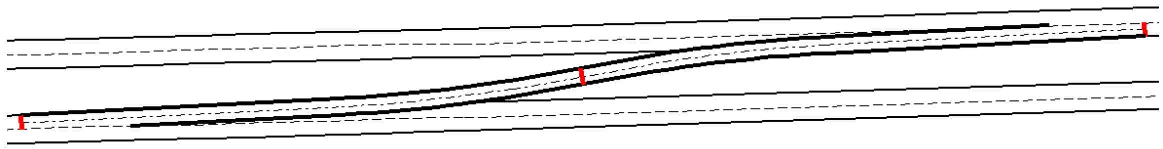

Figure E.1 Plan View of Lincoln West Crossover

At the Springfield North site, both crossovers were designed within the confines of the median, so estimations were made for these crossover layouts. For the entrance crossover figure E.2, drivers approached on a four-lane roadway in the right lane and had to cross through the closed left lane before reaching the median. This required an extension of the crossover through the closed driving lane at the beginning of the crossover.

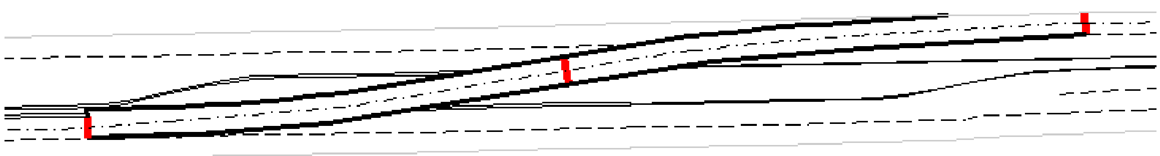

Figure E.2 Plan View of Springfield North Entrance Crossover

At the exit crossover for Springfield North figure E.3, the layout had to accommodate the expansion into two lanes of traffic. This created a unique case as the crossover widened from beginning to end. In this case, a path could have been created along the centerline of the crossover, but any vehicle path following that centerline would exit the crossover in a position that would be centered along two separate driving lanes downstream of the crossover.

In figure E.3, the approximated centerline of the crossover is shown. In addition, two thicker centerlines were drawn through the crossover that started at centerline of the crossover entrance. As the centerlines progress through the crossover, they are then connected to the centerlines of the downstream driving lanes.

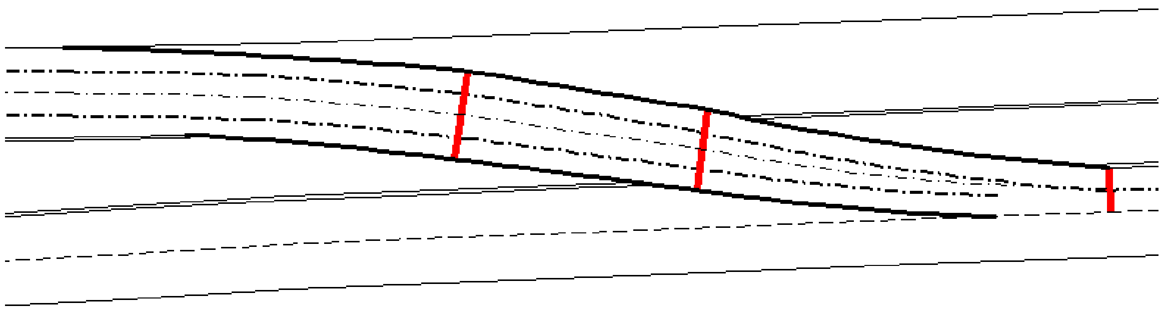

Figure E.3 Plan View of Springfield North Exit Crossover

The presence of two driving lanes downstream of the crossover means that each vehicle traversing the crossover would select a driving path that would lead it to the desired downstream driving lane. As the width of the crossover lane allows drivers to take their time in directing their vehicle towards the desired lane, it would not be suitable to judge a true path of minimum displacement through the crossover.

Development of Driving Paths

Once the crossover layouts were developed, each crossover was tested using a WB-62 design vehicle. A WB-62 was selected over shorter vehicle types because it would most readily display any evidence of offtracking at the rear of the vehicle and it is a vehicle type used consistently in roadway design. The driving paths were created with the goal of minimizing lateral displacements from the lane centerline throughout the crossover. Points along the driving paths were located along the lane centerline whenever possible to achieve this goal.

At each crossover location, two driving paths were created. Two paths were used to reflect the posted speed limit of the work zone and posted advisory speed of the crossover. Table E.1 shows the list of speed limits and advisory speeds for the three studied crossovers.

Table E.1 Speed Limits and Advisory Speeds at Study Locations

Crossover Site	Work Zone Speed Limit (mi/h)	Posted Advisory Speed (mi/h)
Lincoln West (Entrance Crossover)	50	35
Springfield North (Entrance Crossover)	50	40
Springfield North (Exit Crossover)	50	40

At the Lincoln West crossover, the two driving paths provided similar vehicle footprints. Both of the created driving paths were able to maintain a course that followed the centerline of the driving lane. Offtracking was negligible along the 35 mi/h path, and showed a small increase for the 50 mi/h path. Offtracking was measured throughout the driving paths, and it was determined to be less than 0.30 ft for both the 35 mi/h and 50 mi/h cases.

As the two driving paths had similar results, images of the 50 mi/h driving path are included. These driving paths show the vehicle footprint in light gray with the crossover in dark black and the existing driving lanes in thin black lines.

At the entrance crossover of Springfield North, the AutoTrack paths showed that it was possible for a WB-62 to maintain a path that followed the crossover lane centerline. In a similar case to the Lincoln West AutoTrack paths, the offtracking increased slightly between the advisory speed path (40 mi/h) and the posted speed limit path (50 mi/h). All offtracking measurements were below 0.35 ft.

Comparison of AutoTrack Results to Observed Displacements

The goal of this chapter was to discern if the studied crossovers provided ample geometrics to maintain a driving path that followed the crossover centerlines. While the exit crossover at the Springfield North site was not able to be analyzed directly for this instance, both the Lincoln West and Springfield North entrance crossovers were determined to have geometric designs that allowed drivers to maintain paths along their respective centerlines. This means that the minimum lateral displacement values that could be expected was 0.00 ft which supports the use of the lane centerline as the point of 0.00 ft of displacement.

Appendix F Speed Data Dependence

The presence of other vehicles in front of observed vehicles may have influenced the speeds that were measured. This had the potential to create dependence within the data sets. To determine if a significant level of dependence was present in the data, the data sets were separated into two groups. These two groups consisted of observations collected in free-flow conditions and observations collected in non-free-flow conditions. Equation C.1 from Appendix D was used to conduct t-tests to determine if there were any significant differences between the free-flow and non-free-flow conditions which would indicate dependence in the non-free-flow data grouping.

Table F.1 shows the calculated t-values. Four locations showed a significant difference between free-flow and non-free-flow conditions. These four locations included Location 1 and 2 for the Lincoln West crossover and Location 1 and 3 at the Springfield North exit crossover. All other locations did not have a significant difference between the two groups of data except for Location 2 at the Springfield North exit crossover. This crossover did not have speed data available, so no calculation was needed.

Table F.1 Calculated t' Values

Crossover Site	Location	Free-Flow Conditions	Mean	Standard Deviation	Sample Size	Calculated t'
Lincoln West (Entrance Crossover)	1	Yes	48.427	5.962	281	3.81
		No	46.580	5.287	257	
	2	Yes	50.267	6.286	281	3.58
		No	48.340	6.166	256	
	3	Yes	47.770	9.371	278	1.57
		No	46.587	8.014	252	
Springfield North (Entrance Crossover)	1	Yes	37.193	9.505	290	1.84
		No	35.583	8.271	151	
	2	Yes	47.617	9.345	290	1.77
		No	45.948	9.492	154	
	3	Yes	47.118	9.553	288	0.70
		No	46.442	9.800	154	
Springfield North (Exit Crossover)	1	Yes	37.382	6.167	251	5.51
		No	34.663	5.374	315	
	2	Yes	N/A	N/A	N/A	N/A
		No	N/A	N/A	N/A	
	3	Yes	48.157	11.565	236	4.13
		No	44.175	10.278	292	

Appendix G. Model Estimation

Linear Regression Model

Table 7.14 in Chapter 7 shows the model output for significant variables using least squares regression. In table G.1, the model including all of the independent variables is shown.

Table G.1 Linear Regression Model with All Variables

Variable Name	Coefficient	t	Significance
(Constant)	-0.377	-3.187	0.001
Direction of Displacement	0.004	0.404	0.686
Free Flow Conditions	0.002	2.190	0.029
Headway	0.001	1.599	0.110
Speed	-0.009	-4.307	0.000
Vehicle Type	-0.712	-12.628	0.000
Vehicle Type * Direction of Displacement	0.852	7.841	0.000
Lincoln West - Location 1	0.561	8.308	0.000
Lincoln West - Location 3	0.859	12.681	0.000
Springfield North Entrance - Location 1	-0.139	-1.808	0.071
Springfield North Entrance - Location 2	0.070	0.982	0.326
Springfield North Entrance - Location 3	1.851	19.609	0.000
Springfield North Exit - Location 1	2.096	26.697	0.000
Springfield North Exit - Location 3	-0.236	-3.440	0.001

n	R^2	SSR	SSE	SSTotal	F	Significance
3642	0.391	2824.202	4398.401	7222.604	179.195	0.000

Panel Model

The panel analysis in Limdep used a multiple step process to estimate lateral displacement. A panel analysis applies least squares regression, fixed effects models, and random effects models. To select the most applicable model, two statistics are used. First, the Lagrange multiplier is calculated by Limdep to determine if least squares regression is more suitable than the two effects models. If the Lagrange multiplier value indicates that least squares is the best model, then the models for fixed and random effects are not selected (31). If the least squares model is not the best model, then the Hausman statistic is consulted. This statistic is used to determine if the fixed effects or random effects model would be the most suitable model (31).

For the analysis of the crossover data, the Lagrange multiple value of 2282.53 indicated that the least squares model was not suitable. The Hausman statistic value of 9.58 indicated that the fixed effects model was the best fit for the data. Table G.2 shows the fixed effects model including all of the estimatable variables. Table 7.14 includes all of the R^2 values from each of the estimated models.

Table G.2 Fixed Effects Model Using All Variables

Variable Name			Coefficient	t	Significance
(Constant)			-1.106	-18.087	0.000
Direction of Displacement			2.236	60.540	0.000
Free Flow Conditions			0.042	1.311	0.190
Speed (Reciprocal)			2.483	1.077	0.282
Vehicle Type			-0.198	-4.548	0.000
n	R^2	SSE	F		Significance
3638	0.551	3239.748	742.830		0.000

Table G.3 Panel Analysis R^2 Values

Model	R^2 (Percent)
(1) Constant term only	0.0
(2) Group effects only	2.5
(3) Independent Variables only	53.0
(4) Independent Variables & Group Effects	53.9
(5) Independent Variables, Group Effects, & Time Effects	55.1