Pedestrian Operations at Single Point Interchanges

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Abstract

Single Point Interchanges (SPI's) are becoming increasingly popular throughout the state of North Carolina. There is potential for pedestrian movements across SPI's due to adjacent land uses typically built near these locations, such as malls, hotels, restaurants, and regional shopping centers. This research is a proactive effort to help alleviate potential pedestrian access issues that could arise in the future at these types of facilities.

The recommendations of this research effort are based on observations of both positive and negative design elements at single point interchanges throughout North Carolina. Based on these observations, the following design elements are essential at SPI's to provide pedestrians with a safer, more comfortable crossing: 90° ± 20° crosswalk orientation; proper curb ramp orientation; high visibility crosswalks (in conjunction with abutting pedestrian facilities); stop bar placement; pedestrian separation; and appropriate barrier heights. In addition, lighting and the provision of adequate sight distance are attributes that the research team recommends to include in an underpass SPI design. Last, during the design of a SPI, future pedestrian traffic and corridor improvements should be considered so that curb cuts, raised walkways, higher guardrails, separation from traffic, etc., do not need retrofitting at a later date.

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EXECUTIVE SUMMARY

Single Point Interchanges (SPI's) are becoming increasingly popular throughout the state of North Carolina. Although more expensive to construct than a traditional diamond interchange, their primary benefit of decreasing vehicular delay by bringing all ramp movements into a single point is very attractive. This is especially true where key corridors cross, such as a major thoroughfare and freeway. However, the large expanse of pavement required for the SPI has raised concerns for pedestrian use through the facility. The increased pavement area and lack of signal control for pedestrian crossing movements does little to promote pedestrian safety, and it appears to the general public that there is nothing being done to accommodate pedestrian movements.

ADA compliance issues are already becoming a problem for many states and municipalities. Because SPI's are typically built at freeway/arterial or freeway/loop locations, there is potential for pedestrian movements along the minor highway due to adjacent land uses typically built at these locations, such as malls, hotels, restaurants, regional shopping centers, and high density housing. Many transportation related facilities built to reduce vehicular delay, such as roundabouts and channelized right turn lanes, are now coming under pressure to make changes for pedestrians that will costs taxpayers millions of dollars to renovate. These facilities are built with the same goal in mind as that of a single point interchange. This research is a proactive effort to help alleviate potential pedestrian access issues that could arise in the future at these types of facilities.

The recommendations of this research effort are based on observations of both positive and negative design elements at single point interchanges throughout North Carolina, with some additional recommendations and considerations based on like facilities throughout the nation. Based on our observations, the following design elements are essential at SPI's to provide pedestrians with a safer, more comfortable crossing: 90° ± 20° crosswalk orientation; proper curb ramp orientation; high visibility crosswalks (in conjunction with abutting pedestrian facilities); proper stop bar placement; pedestrian

separation; and appropriate barrier heights. In addition, lighting and the provision of adequate sight distance are attributes that the research team recommends to include in an underpass SPI design. Last, during the design of a SPI, future pedestrian traffic and corridor improvements should be considered so that curb cuts, raised walkways, separation from traffic, higher guardrails, etc., do not need retrofitting at a later date.

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INTRODUCTION

One issue that is a concern to NCDOT is the increased difficulty of pedestrians trying to cross Single Point Interchanges (SPI). Many SPI's are constructed in areas with retail shopping, hotels, restaurants, and other pedestrian oriented facilities in the nearby vicinity. The high concentration of vehicular and potential pedestrian traffic causes concern. While there have been no pedestrian deaths so far, a pedestrian has to negotiate significant open pavement area to get across the interchange. Motorists do not expect to see many pedestrians, if any, which only compounds the problem. Because the central pavement area is larger than a traditional intersection area, including minimum pedestrian timing for the signal could increase the overall delay for the motorists moving through the signals.

Another concern is for pedestrians with visual or physical impairments. Already, some advocacy groups are pushing for roundabouts and channelized right turn lanes to become signalized under ADA guidelines, thus defeating the main benefit of continuous vehicular movement and reduced overall average delay for all motorists using either facility. This same push could be directed at SPI's in the near future. NCDOT is seeking information to be responsive to the needs of individuals or groups that might express difficulties for pedestrians to cross these interchanges, especially pedestrians with special needs.

As an example, the SPI located at I-40 and Fayetteville Road near Durham serves the Streets at Southpoint Mall and other retail establishments and housing developments to the north, south and east of the mall. Many individuals might choose to walk or bicycle to the mall if a safe and convenient path was available across the interchange. If such a path is not available, the only option is to travel by some form of vehicular mode. For visually-impaired pedestrians, this may severely limit their ability to function independently since they would be relying on another individual to drive or use public transportation services to get to the mall.

ADA compliance may become an issue in the future as advocacy groups push for reasonable designs that allow individuals with disabilities the opportunity for safe passage through these types of interchanges. NCDOT is concerned that pedestrian crossings at SPI's are not well-defined or well-understood by the general public. There is a large expanse of pavement at these interchanges and signal heads are lined up for traffic flow and not pedestrian crossings. Turning vehicles are following different paths than in conventional interchange designs. This causes increased difficulty in determining when it is safe to cross, and actually where the crossing should be made. This research will look at pedestrian designs at these facilities across the country and compile a recommendation of best practices for future implementation in North Carolina.

The research team incorporates a working knowledge of needs from populations with visual and physical impairments for this research effort. One of the researchers is currently involved in two national projects studying access for pedestrians with visual impairments: *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities* (National Cooperative Highway Research Program) and *Blind Pedestrians' Access to Complex Intersections* (National Institute of Health, Bioengineering Research Program). These projects include collaboration with orientation and mobility specialists, experienced accessibility designers, and pedestrians with vision disabilities which provides current thinking for the examination of SPI's in this project. Another researcher has a parent who is a wheelchair user with seven years of experience. Through input and experience of traversing various pedestrian facilities, relevant information about the needs of wheelchair users at SPI's can be represented.

LITERATURE REVIEW & SITE OBSERVATIONS

INTRODUCTION

The NCDOT has invested millions of dollars constructing Single Point Interchanges (SPI's) in many locations across the state. SPI's offer advantages to the motorist in simplicity of operation and reduced travel delay. They have been used on interstates and strategic highway corridors as a means of promoting increased mobility for both highway facilities located at the interchange. Documentation of the best practices for pedestrian accommodation at SPI's will help in future designs by NCDOT.

The majority of published information about pedestrians at SPI's is from State Departments of Transportation. Although there are SPI installations outside of the United States, no international literature was found on pedestrian operation at these interchanges. Some of the available information conflicts with other publications. A useful task of the project involved observations made during field visits to SPI's in North Carolina and reviewing aerial photographs from SPI's across the United States and internationally.

STATE OF THE PRACTICE

Design specifications and options available to the designers vary from state to state and differ greatly. Crossings of the ramps are of key concern for designers because of the conflicting movements of pedestrians and vehicles. Some state design specifications, recommendations, and general summary information include:

- Acceptable gaps at the free flowing ramps should be analyzed for safe pedestrian crossing (NCDOT, 2001)

- Crosswalks should be perpendicular to the ramp to minimize length, conflicting movements, and required signal time (MoDOT, 2008)
- Crosswalks should be located near the local street to meet driver expectation and provide good sight distance (MoDOT, 2008)
- Pedestrians may take up to 4 cycles to cross the ramps (CalTrans, 2001)
- Right turn ramps should be free-flowing only if pedestrian volumes are low (CalTrans, 2001)
- Minimizing the intersection size is beneficial (CalTrans, 2001)
- "To safely accommodate pedestrians, a pedestrian push button shall be installed" (CalTrans, 2001)
- If necessary, pedestrian movements across the crossroad (Y-line) could be two stage (Selinger & Sharp, 2000)
- Pedestrian safety could be increased by signalizing their crossing; however, the efficiency of SPI's could be degraded by including the pedestrian phase. Another remedy to further ensure pedestrian safety could be to construct an exclusive pedestrian bridge, but they are expensive to construct and maintain (MST, 2004).
- The New York State DOT described SPI's as potentially the most dangerous for pedestrians because crossings are longer, vehicles approach from behind, vehicular speeds are typically higher, and cycle times tend to be longer because of the large expanse of pavement in the intersection (NYSDOT, 2006)
- Another publication recommended that pedestrian movements should be discouraged at most SPI's (MST, 2004). However, the Missouri DOT described the SPI as being "very safe for pedestrians" with help from well-marked markings, structures, medians, and curbs (MoDOT FAQ, 2008).

Consensus at the municipal, state, and federal levels regarding pedestrian design at SPI's appears to be non-existent. A compilation of various sites throughout North Carolina and other states should provide more insight into design considerations for pedestrian facilities at SPI's.

SITE OBSERVATIONS

The research team made site visits to all fourteen SPI's in North Carolina and used aerial photographs to make site observations at locations across the United States, Canada, and Australia. The research team used a survey to gather information from State Departments of Transportation (see Appendix A) in the nation. Responses were obtained from twenty-eight departments, and other information was obtained from secondary sources that were verified from aerial photographs. As of May 2008, thirty-nine states have at least one SPI in operation and two other states have SPI's in the design stage with a total of 274 SPI's in the United States (Table 1). The research team found no SPI's in the other nine states (Table 2). Seven SPI's in Australia and five in Canada were also examined using aerial photographs.

Table 1 - States with Single Point Interchanges

STATE	Number of SPI's	STATE	Number of SPI's
Alabama*	1	Missouri	7 (1)
Alaska	3	Montana	18
Arizona*	38	Nebraska	8
Arkansas	0 (2)	Nevada	12
California	10	New Hampshire	2 (1)
Colorado*	4	New Mexico*	3
Connecticut	1	New York	3 (1)
Florida*	33	North Carolina	12 (2)
Georgia*	7	Ohio	1 (2)
Idaho*	1	Oklahoma	0 (1)
Illinois	10	Oregon	1 (1)
Indiana*	7	Pennsylvania*	9
Iowa*	1	South Carolina	4
Kansas	3	South Dakota	5
Kentucky*	4	Tennessee*	17
Louisiana	1	Texas*	4
Maryland	5	Utah*	14
Massachusetts*	1	Virginia	7
Michigan*	4	Washington*	6
Minnesota	3	Wisconsin*	1
Mississippi	2	**Total**	**274**

* Value not provided by Department of Transportation
(#) Number in parenthesis designates the number of SPI's that are under construction or in the design stage

Table 2 - States without Single Point Interchanges

Delaware*	New Jersey	Vermont
Hawaii	North Dakota*	West Virginia
Maine*	Rhode Island	Wyoming*

* No response from Department of Transportation and no secondary information to indicate SPI's in the state

Within North Carolina, and across the country, the pedestrian design characteristics at SPI's are highly inconsistent. In visits to North Carolina installations, the research team observed and recorded details of various pedestrian design characteristics. Overall, the team found that inconsistencies were most prominent in the design of pedestrian crossing areas, refuge areas, and underpass lighting and sight distance.

Crossing Areas

The crossing areas of SPI's are essential to allow pedestrians to safely traverse the interchange, especially those pedestrians with disabilities. Figure 1 shows a properly aligned crosswalk with curb ramps oriented approximately 90° to the gutter line. Notice also that the crosswalk is appropriately marked and contains a stop bar that is located just prior to the crosswalk. Figure 2 shows a crossing with curb ramp that is not oriented in the direction of the crossing and the crosswalk is not marked. A poorly oriented crossing can be a challenge for pedestrians with vision impairments because they would align to cross into dangerous situations (see Figure 2 crossing). For wheelchair users, a poorly aligned crossing inherently makes the crossing longer, adding pedestrian exposure time.

Figure 1 – Aligned Pedestrian Crossing
Wake Co., I-540 at Six Forks Rd

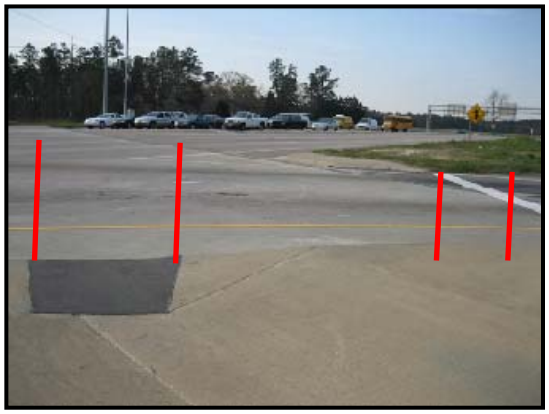

Figure 2 – Poorly Aligned Pedestrian Crossing
Wake Co., I-540 at US401

Refuge Areas

The type and degree of pedestrian separation from traffic in the refuge areas was a design feature that had significant variability between locations. Although each provides some degree of separation, there are trade-offs that should be considered. Figures 3 and 4 are two forms of pedestrian separation used along the mainline arterial. Figure 3 shows pedestrian separation with low height shrubs with curb separation while Figure 4 shows pedestrian separation with pavement markings. Although more expensive to construct and maintain, the first design alternative using landscaping features and curb and gutter provides a heightened sense of security while virtually eliminating roadway debris in the pedestrian travel way.

Figure 3 – Landscaped Pedestrian Separation Mecklenburg Co., I-85 at Freedom Dr

Figure 4 – Painted Pedestrian Separation Mecklenburg Co., I-85 at NC16

Figures 5 and 6 show two types of structural separation used primarily as a pedestrian refuge area between the on and off ramps. Figure 5 is unique in that it does not offer grade separation, but instead promotes a sense of security through a barrier treatment. Figure 6 is a more typical pedestrian treatment which uses vertical separation via a raised sidewalk. Both treatments accommodate the refuge area adequately by providing good spacing between the ramps and extension of the bridge outside the Y-line. Note that each of the four types of pedestrian separation shown in Figures 3-6 have distinct differences in terms of pedestrian comfort and debris accumulation (Table 3).

Figure 5 – Structural Pedestrian Separation
Mecklenburg Co., I-85 at NC16

Figure 6 – Vertical Pedestrian Separation
Wake Co., I-540 at Six Forks Rd

Table 3 – Figure Descriptions (Separation, Debris, Comfort)

	Figure 3	**Figure 4**	**Figure 5**	**Figure 6**
Type of Separation	Landscaping	Paint	Structural	Vertical
Roadway Debris	Eliminated	No Effect	Reduced	Eliminated
Pedestrian Comfort Level	High	Low	High	Average

Underpass Lighting and Sight Distance

In addition to the features of an overpass SPI, underpass SPI's have additional concerns with sight distance and lighting. Sight distance concerns can arise from any combination of issues with vegetation overgrowth, earthwork, small radius curves, and poor placement of pedestrian facilities, as examples. The off-ramp shown in Figure 7 demonstrates an unusual problem where sight distance is obstructed looking left while trying to cross in the direction of the SPI. Figure 8 shows the lack of sight distance looking at an exit ramp from underneath the access-controlled highway. This is a known problem with underpass SPI's, and it is hard to eliminate because of the difference in elevation between the two highways. However, in both figures the vegetation is further obstructing the pedestrian's view and ability to make a safe decision to cross the ramp.

Figure 7 – Underpass SPI Sight Distance
Durham Co., NC147 at Fulton St

Figure 8 – Underpass SPI Sight Distance
Mecklenburg Co., I-85 at Little Rock Rd

Lighting for an underpass SPI is important if pedestrians are expected to use the facility. Provided there is significant bridge separation like that shown in Figure 9, natural lighting provides increased visibility and situational awareness during daylight hours. However, in cases where pedestrian use is expected (especially during nighttime), underpass lighting is necessary for pedestrians to feel comfortable crossing through the SPI (Figure 10). Underpass lighting needs to be checked at night for non-functioning or broken lights.

Figure 9 – Underpass SPI Natural Lighting
Durham Co., NC147 at Fulton St

Figure 10 – Underpass SPI Lighting
Mecklenburg Co., I-85 at Little Rock Rd

SUMMARY

During the literature review, the team found that there is little published literature regarding pedestrian accessibility at SPI's. Many state agency and municipality SPI designs fell well short of accommodating the pedestrian; however, there is an obvious need for balance between pedestrian safety and vehicular efficiency. Aerial photographs and site visits provided the research team with design alternatives for three specific areas:

the pedestrian crossing area, refuge areas, and underpass lighting and sight distance. The crossing areas include attributes such as the crosswalk, curb ramp, and stop bar. The refuge areas are zones located on or near the interchange where interaction between pedestrians and vehicles is not desired. Underpass lighting and sight distance require the design engineer to think about pedestrian comfort and decisions made to safely cross an underpass SPI. The next section will present the most favorable design elements found during the literature review and site examinations.

DESIGN FEATURES

Accumulation of individual pedestrian design features at a single point interchange influences the overall pedestrian climate. A pedestrian's sense of security is significantly impacted by the various design features that were examined and observed during this study. The differences between vehicular and pedestrian travel modes lead to a desire of separation. The objective of this section is to provide engineers with knowledge and awareness of pedestrian needs at a SPI. Design features can be strategically utilized to increase pedestrian separation from the vehicle stream of traffic, which can lead to a more positive pedestrian climate and sense of security.

Design Elements

The following design elements should be incorporated at single point interchanges to provide pedestrians with a safer, more comfortable crossing. The elements include recommendations for design attributes of the crossing areas and refuge areas.

Crossing Areas

Crossing areas are the conflict points for pedestrians and vehicles. Although there is no simple design to remove the potential danger in this area, a good design can heighten pedestrian security. Characteristics that improve a pedestrian's experience include proper alignment of the curb ramp and crosswalk, proper pavement markings, and satisfactory stop bar placement. As Figure 11 demonstrates, the curb ramp should be oriented in the same direction as the crosswalk and follow the design guidelines of "Designing Sidewalks and Trails for Access" (FHWA, 1999). The figure also illustrates a perpendicular crossing of the ramp which reduces the exposure time for pedestrians. Appendix B contains sample designs of curb ramp layouts with proper orientation to the crosswalk. High visibility crosswalks could lead to greater recognition and respect of the

crosswalk area by drivers and are recommended in conjunction with abutting pedestrian facilities (Figure 12). To minimize the potential for pedestrian and vehicle interaction, the stop bar should be placed upstream of the crosswalk to prevent vehicles from stopping directly over the crosswalk (Figure 13).

Figure 11 – Properly Aligned Crosswalk
Wake County, I-540 at Six Forks Rd

Figure 12 – High Visibility Crosswalks
Fairfield County, CT, CT15 at CT111
(Image from Microsoft©)

Figure 13 – Proper Stop bar Placement
Wake County, I-540 at Six Forks Rd

Refuge Areas

The refuge area on SPI's should provide pedestrians with a safe and comfortable place to traverse the interchange and wait for the appropriate time to cross the ramps. Pedestrian separation from traffic in these areas is influential in a pedestrian's sense of security and comfort. Structural elements such as barriers (Figure 14), raised sidewalks (Figure 15),

or landscaping elements such as low-height, low-maintenance shrubs (Figure 16) can accomplish that goal. These separation elements have the added benefit of reducing the amount of roadway debris that can accumulate in pedestrian areas. An appropriate barrier height (chest high versus waist high) on the edge of the SPI structure can also increase pedestrian comfort (Figure 17).

Figure 14 – Structural Element
Mecklenburg Co., I-85 at NC16

Figure 15 – Raised Sidewalk
Wake Co., I-540 at Six Forks Rd

Figure 16 – Landscaping Element
Mecklenburg Co., I-85 at Freedom Dr

Figure 17 – Barrier Height
Mecklenburg Co., I-85 at Freedom Dr

Additional Design Considerations

The previous design elements are features that should be incorporated in SPI's, but the following design attributes should also be considered. Underpass SPI's are less common than overpass SPI's and have special needs for lighting and sight distance considerations. Lighting provides a more comfortable environment at nighttime, but maintenance must be a priority to keep lights operating. Sporadic lighting patterns do not provide adequate light for pedestrians. The earthwork and retaining walls for underpass SPI's create the potential for sight distance issues for pedestrians. To the extent possible, pedestrian

crossings should be located to avoid poor sight distance. The maintenance and type of vegetation around the interchange is important to maintain pedestrian lines of sight as well.

During the design of a SPI, future pedestrian traffic and corridor improvements should be considered. Future land use planning could affect the growth of pedestrian traffic and might have an impact on the design of pedestrian features. A site that currently experiences little-to-no pedestrian volumes could endure rapid growth with changes in land use over time.

The unique shape of a SPI can be utilized for aesthetic purposes along a special corridor. A SPI in St. Louis, Missouri was retrofitted to meet the streetscape designs of the corridor with stylized columns, landscaping, and other features (Figure 18). This SPI is an example of creating a consistent and appealing corridor and shows that a SPI's unique layout can be used in a dramatic manner.

Figure 18 – SPI in St Louis, Missouri: I-270 and MO 340 (Image from MoDOT)

SUMMARY OF FINDINGS

This research effort aimed to identify the operational characteristics of pedestrians crossing at SPI's. The effect of various design characteristics on pedestrians' comfort level and sense of security were of particular interest. There is a wide variety of pedestrian features across the state and nation, with no apparent standard.

CONCLUSIONS

From site visits across North Carolina, the research team found that SPI's are traversable for pedestrians. Although most SPI's have pedestrian facilities, the SPI's that implemented well-designed elements provide a more positive atmosphere for pedestrians. The following recommendations provide the design elements that provide a more favorable environment for pedestrians at SPI's.

RECOMMENDATIONS TO NCDOT AND OTHER STATES

The following design elements should be incorporated at single point interchanges to provide pedestrians with a safer, more comfortable crossing experience:

- Crosswalks should be within 20° of perpendicular to the ramps (90° ± 20°)

- Curb ramps should be oriented in the same direction as the crosswalk
- High visibility crosswalks are recommended in conjunction with abutting pedestrian facilities
- Stop bars should be located prior to the crosswalk
- Pedestrian separation from traffic should be provided in refuge areas through the utilization of structural elements or landscaping elements
- Appropriate barrier heights should be provided on the edge of the SPI structure

These design elements are features that should be incorporated in SPI's, but there are other factors that should be considered. Lighting and the provision of adequate sight distance are attributes that the research team recommends to include in underpass SPI design. During the design of a SPI, future pedestrian traffic and corridor improvements should be considered.

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APPENDIX A: EMAIL SURVEY FOR STATE DOT'S

Email survey sent to State Departments of Transportation:

> We're gathering literature and information on interchange design. Specifically, we're looking for the design features of Single Point Interchanges (SPIs) and the accommodation of pedestrians at these interchanges. If you've already responded, you can disregard this request.
>
> Does your state implement SPIs or Single Point Urban Interchanges (SPUIs)?
>
> If yes, we would appreciate your help with a couple of questions:
>
> How many SPIs have been constructed, are under construction, or are in the planning process (Location of the SPIs would also be appreciated)?
>
> How do you accommodate pedestrian movements at SPIs?
>
> Where are the crosswalks located? If the design templates are available online, we would appreciate that link or file.
>
> Do you have any observations about the interaction between pedestrians and vehicles at SPUIs that would aid future design of pedestrian crossings?

APPENDIX B: SAMPLE SPI CROSSWALK DESIGNS