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Assessing the Safety Impacts of Access Management Techniques

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ASSESSING THE SAFETY IMPACTS OF ACCESS

MANAGEMENT TECHNIQUES

by

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ABSTRACT

ASSESSING THE SAFETY IMPACTS OF ACCESS MANAGEMENT TECHNIQUES

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Access management techniques such as raised median installation and driveway consolidation improve safety conditions for motorists. Several locations where these access management techniques have been installed in the state of Utah were selected for analysis of the safety impacts. Although crash rates were not necessarily reduced as a result of the access management techniques, other safety improvements were observed. The raised medians generally reduced the more serious types of collisions, which resulted in a decrease in the severity of crashes. The fatality rates generally decreased as crashes became less severe. Because fatalities and the overall severity of crashes decreased, the overall cost of crashes was reduced. The cost of installing the raised medians was easily recouped by this reduction in the cost of crashes.

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1 INTRODUCTION

The purpose of this thesis is to present the results of a study conducted to assess the safety impacts of access management techniques in the state of Utah. The study was part of a research project funded by the Utah Department of Transportation (UDOT) and conducted by researchers at Brigham Young University (BYU) that began in March 2005. This chapter is divided into four sections including a problem statement section, a background section, an objectives section, and a thesis organization section.

1.1 Problem Statement

A number of research projects have been performed to assess the safety impacts of access management techniques. Typical findings of this research show that crash rates increase as access density increases. In addition, it has been shown that roadways with raised medians are generally safer than undivided roadways or those with two-way left-turn lanes (TWLTL). These results are based on studies performed in several states outside the state of Utah. To determine the safety benefits provided by access management techniques in the state of Utah, an evaluation of the safety performance of arterials in which access management techniques have been implemented was needed.

To complete the evaluation of the safety performance of arterials, a unique yet proven tool available through UDOT has been utilized. This tool is a geographic information system (GIS) enabled web delivered data almanac. This data almanac contains a crash database that allows researchers to evaluate crash data before, during, and after specified projects, changes to the network, and other noteworthy installations. This data almanac will be referred to as the crash database throughout this document.

A number of research studies have been conducted in the past utilizing the UDOT crash database establishing this tool as a proven and extremely useful technology. The crash database allows researchers the opportunity to establish a number of filters that can be used to obtain crash data, identify high crash locations, and establish crash trends. This information can then be utilized to evaluate the characteristics of the roadways in which these conditions occur, leading to the development of hypotheses on the possible reasons for such conditions. This information is invaluable in establishing relationships between geometric and/or traffic conditions and overall safety levels.

1.2 Background

In recent years there has been an increased emphasis on the implementation of access management principles and techniques in the state of Utah. UDOT has established state highway access management guidelines as part of the *Accommodation of Utilities and the Control and Protection of State Highway Rights of Way* (UDOT 2003). These guidelines establish the basis for including access management principles as a part of the issuance of driveway and street access permits.

One of the topics addressed in the state highway access management guidelines is that of raised median installation as an access management tool. The increase in congestion on arterial streets has led to the installation of raised medians as an alternative to reduce conflict points and improve safety.

A recent study completed at BYU began the process of evaluating raised medians as a proposed safety initiative in the state of Utah (Saito et al. 2004). The results of this research established a procedure to guide state engineers through the evaluation process of identifying the need for a raised median section on a given roadway segment. One of the factors identified in this procedure for the consideration of raised median installation is crashes. Crashes oftentimes form the basis for safety analysis of arterial streets and intersections.

1.3 Objective

The objective of this research was to estimate the safety impacts of access management treatments by investigating crash data from a representative sample of corridors across the state of Utah where access management techniques (e.g., raised medians and driveway consolidation) have been implemented. The primary method for estimating and quantifying the safety impacts was through the use of the UDOT crash database to compare crash rates before and after installation of access management techniques, along with comparative data from a number of corridor level control sites across the state.

Following the collection and analysis of the data, the effect of access management techniques (e.g., raised medians and driveway consolidation) were evaluated, including limited recommendations on the effectiveness of such techniques at improving safety across the state. These recommendations can be used by UDOT engineers and planners to establish policy and better quantify the benefits of proposed safety initiatives.

1.4 Thesis Organization

This thesis is organized into the following six chapters: 1) Introduction; 2) Literature Review; 3) Corridor Selection; 4) Analysis Procedure; 5) Results; and 6) Conclusions and Recommendations. After these chapters there is a reference section and an Appendix.

Chapter 2 is a literature review that outlines and defines various access management techniques and quantifies their safety impacts for both vehicles and pedestrians. The access management guidelines in the state of Utah are discussed as well as guidelines for raised medians. Finally, the background of the UDOT crash database is discussed.

Chapter 3 provides background regarding the corridors selected as locations of access management techniques and control sites. Maps and pictures are included in the discussion for each of the corridors selected.

Chapter 4 details the steps that were followed in the analysis of data for the selected corridors. The procedure followed in using the UDOT crash database is outlined in sufficient detail so that a similar analysis could be performed in the future for different corridors. Equations are also given for calculating various crash rates.

Chapter 5 presents the results of the analysis including tables and figures to aid in the presentation of the results. The chapter contains before and after data for each analysis location including: 1) overall crash rates; 2) access points data; 3) crash rates at intervals; 4) crash rates at intersections; 5) collision type results; 6) severity results; and 7) cost of crashes. Also included are results from the early and later periods for each control site including: 1) overall crash rates; 2) access points data; and 3) cost of crashes.

Chapter 6 provides conclusions summarizing the findings of the research as well as recommendations for future installations of access management techniques. The chapter also recommends future research possibilities related to the safety benefits of access management.

The Appendix includes the raw data that were used to generate the tables and figures displayed in Chapter 5.

2 LITERATURE REVIEW

A comprehensive literature review has been performed on aspects related to the safety impacts of various access management techniques. This process consisted of gathering all pertinent information that could contribute to this study. The literature review covers several different topics. First, access management techniques are defined and the safety impacts of each technique are analyzed. Next, the process of implementing access management guidelines in the state of Utah is summarized. Finally, the background on crash database tools as useful resources for crash safety analysis is given.

2.1 Safety Impacts of Access Management Techniques

Traffic volumes continue to increase dramatically, causing major congestion and delays for motorists. This trend will likely continue as the number of vehicle-miles traveled continues to grow at a much faster rate than population or roadway capacity. The increase in traffic volume has a particularly detrimental effect on arterial streets. The primary purpose of arterial streets is to move vehicles at a high operating speed and level of service. Some degree of access control is desirable to enhance mobility on an arterial because access to abutting property is not the major function of an arterial (AASHTO 2001). Unlimited access onto arterial streets has a negative effect on the arterial because it causes the capacity to diminish, average speeds to decrease, and provides more locations for potential conflicts of vehicles (Eisele et al. 2004).

A possible solution to the problem of diminishing capacity on arterial streets is the application of access management to the roadway. Access management is the systematic control of the location, spacing, design, and operation of driveways, medians and median openings, interchanges, and street connections to a roadway (TRB 2003). Access management techniques include raised medians, median opening spacing, auxiliary lanes, turn lanes, and driveway spacing. The safety and operational impacts of these access management tools are emphasized throughout the literature.

Access management techniques typically have a positive impact on the safety of a roadway corridor for both vehicles and pedestrians. The impacts of access management on vehicle and pedestrian safety will be discussed in the following sections.

2.1.1 Vehicle Safety

Access management has been shown to be an effective tool in improving vehicle safety. Some of the access management techniques that will be discussed in relation to vehicle safety are as follows:

1. traffic signal spacing;
2. unsignalized access spacing;
3. corner clearance;
4. median alternatives;
5. U-turns as alternatives to direct left turns;
6. access separation at interchanges; and
7. frontage roads.

2.1.1.1 Traffic Signal Spacing. The proper spacing of traffic signals can have a positive effect on reducing vehicle crashes. Several studies have shown that crash rates decrease as traffic signal spacing increases. A study performed in Georgia recorded a 40 percent increase in crash rates when traffic signal density increased from two to four signals per mile (Squires and Parsonson 1989). A study in Florida revealed that an increase in traffic signals of two to four per mile caused the crash rate to increase by 2.5 times (Millard 1993).

2.1.1.2 Unsignalized Access Spacing. Driveways and unsignalized access points create friction and disrupt mainline traffic flow as through traffic must slow for vehicles entering and exiting the roadway. Crash potential often increases due to this speed differential between through and turning traffic. The American Association of State Highway and Transportation Officials (AASHTO) states that "Driveways are, in effect, intersections and should be designed consistent with their intended use…. The number of crashes is disproportionately higher at driveways than at other intersections; thus their design and location merit special consideration" (AASHTO 2001).

In the National Cooperative Highway Research Program (NCHRP) Report 420 (1999), Gluck et al. reported that doubling the number of access points on a roadway from 10 to 20 per mile would increase crash rates by 40 percent. Additionally, a road with 60 access points per mile would have triple the crash rate as compared to a road that has 10 access points per mile.

In a recent study on corridors in Texas and Oklahoma, Eisele et al. (2004) reported that the crash rate increased as the number of access points per mile increased. Figure 2-1 shows this graphical relationship found in their study. The relationship clearly shows an upward relationship in the crash rate as the number of access points per mile increases. An example of a typical arterial with high access density in Provo, Utah is shown in Figure 2-2.

2.1.1.3 Corner Clearance. Major safety problems arise on roadways with inadequate corner clearances, where corner clearances represent the distances that are required between intersections and driveways (Gluck et al. 1999). AASHTO states that "…driveways should not be located within the functional area of an intersection or in the influence area of an adjacent driveway" (AASHTO 2001). The functional area of an intersection is shown in Figure 2-3. The functional area of an intersection comprises the area beyond the physical intersection of two roadways. It is the area near an intersection where decisions and maneuvers are made with regards to the intersection. The functional area includes portions of the road both upstream and downstream of the physical intersection (CTRE 2005e).

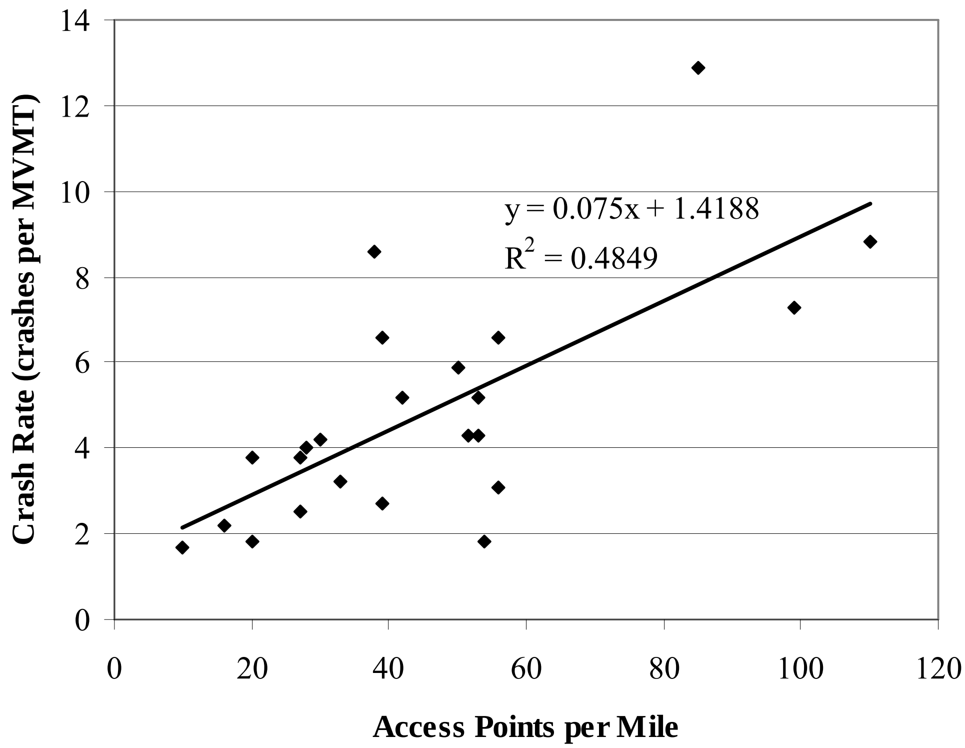


Figure 2-1. Relationship between access points and crash rate (adapted from Eisele et al. 2004).

Figure 2-2. Arterial with high access density.

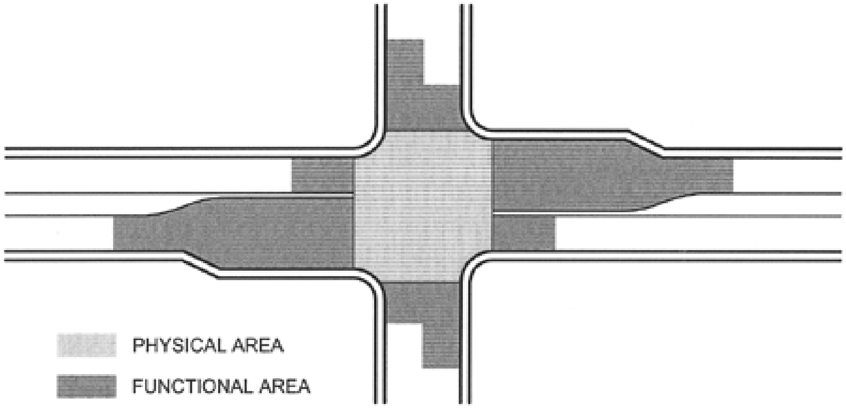


Figure 2-3. Functional area of an intersection (TFHRC 2005).

Most accident reports do not contain sufficient information or level of detail to identify driveway-related crashes. Consequently, it is difficult to measure the effects of corner clearances on crash rates. However, several studies report that a number of safety problems result from inadequate corner clearance (Gluck et al. 1999). These problems include:

- confusion and conflicts resulting from dual interpretation of right-turn signals when approaching a driveway/intersection;
- weaving maneuvers by vehicles leaving a driveway and crossing lanes of traffic to get to the left-turn lane; and
- other types of weaving maneuvers involving vehicles making turns into or out of driveways with insufficient weaving distances.

2.1.1.4 Median Alternatives. All major roadways have some type of center median. These median types can be classified as follows (TRB 2003):

1. undivided median – a traversable median, including painted medians, that do not physically prevent vehicles from crossing over it;

2. TWLTL – a continuous lane located between traffic traveling in opposite directions that provides a refuge area for vehicles to make left turns from both directions; and
3. raised median – a divided median or physical barrier in the roadway that separates opposing lanes of traffic, such as a concrete barrier or landscaped island.

An undivided, traversable median is not an effective access management measure because it does not provide control over vehicles entering upon it.

Roadways with a TWLTL are considered to be safer than undivided roadways. In the Access Management Manual (TRB 2003) published by the Transportation Research Board (TRB) it is reported that roadways with a TWLTL have average crash rates that are 35 percent lower than those of undivided roadways. Gluck et al. (1999) compiled several studies on median treatments and found that reductions in total crashes were reported in 9 out of 10 cases, with a median reduction of 33 percent. Reductions in crash rates were reported in 10 out of 12 cases.

Welch (2005) performed a study that evaluated the safety effects of reducing a four-lane urban roadway to two travel lanes with a center TWLTL. The results of this research found that urban corridors with less than 20,000 vehicles per day (vpd) experience an increase in traffic safety when reduced from four lanes to three lanes. The study reported that the conversion resulted in a 20 to 30 percent reduction in crashes while still maintaining an acceptable level of service. The reduction in crash rates can be attributed to fewer conflict points and improved sight distance for crossing and turning traffic along the corridor. Another safety benefit of the TWLTL is that it provides a storage area for left-turning vehicles as they wait to turn, removing them from the traffic stream (ITE 2005).

The effectiveness of a TWLTL begins to drop when traffic volumes on a roadway increase. A Georgia Institute of Technology study indicates that these volume thresholds are between an average annual daily traffic (AADT) value of 24,000 to 28,000 vpd. TWLTLs also experience higher crash rates in areas of high access point density (CTRE 2005c).

It is not recommended to install TWLTLs for roadways where there are more than two through lanes in each direction. In the southeastern United States several seven lane urban arterials where one lane is a TWLTL have crash rates as high as 11 crashes per hundred million vehicle miles traveled (VMT). Many of these crashes occur because drivers may have to cross several lanes (with traffic moving in several directions) to enter or exit a business, which can be a very complex situation for drivers as evidenced by the high crash rate (CTRE 2005c).

Raised medians provide more safety for arterials than do undivided roadways. Raised medians present a physical barrier that cannot easily be traversed. This treatment is helpful in limiting mid-block left turns to established openings in the median or at signalized intersections (ITE 2005). Raised medians also separate opposing directions of travel, which nearly eliminates the possibility of head-on collisions.

Researchers have shown that roadways with raised medians and other physically divided highways experience lower crash rates than undivided highways. A raised median reduces the possibility of conflicts and erratic movements. In the NCHRP Report 420, several studies were compiled comparing undivided highways to highways with medians. This comparison is displayed graphically in Figure 2-4. The mean crash rate for 10 undivided highways was 5.29 crashes per million VMT. The crash rate for the roadways with raised or divided medians was 3.34 crashes per million VMT (Gluck et al. 1999).

In the study on Texas and Oklahoma corridors, Eisele et al. (2004) studied three corridors that were converted from an undivided median to a raised median. All three roadways experienced reductions in crash rates after the installation of a raised median. The reductions in crash rates ranged from 21 to 53 percent.

A detailed crash study in Minnesota between 1991 and 1993 showed that four-lane urban arterials with raised medians are 40 percent safer than urban arterials that are undivided. Furthermore, a raised median was installed along Highway 28 in Des Moines, Iowa. The result was a 51 percent reduction in crash rate (CTRE 2005b).

Many highway agencies have experienced reductions in crashes after replacing TWLTLs with raised medians. Most agencies agree that roadways with a raised median are safer than roadways with a TWLTL when volumes exceed 24,000 to 28,000 vpd.

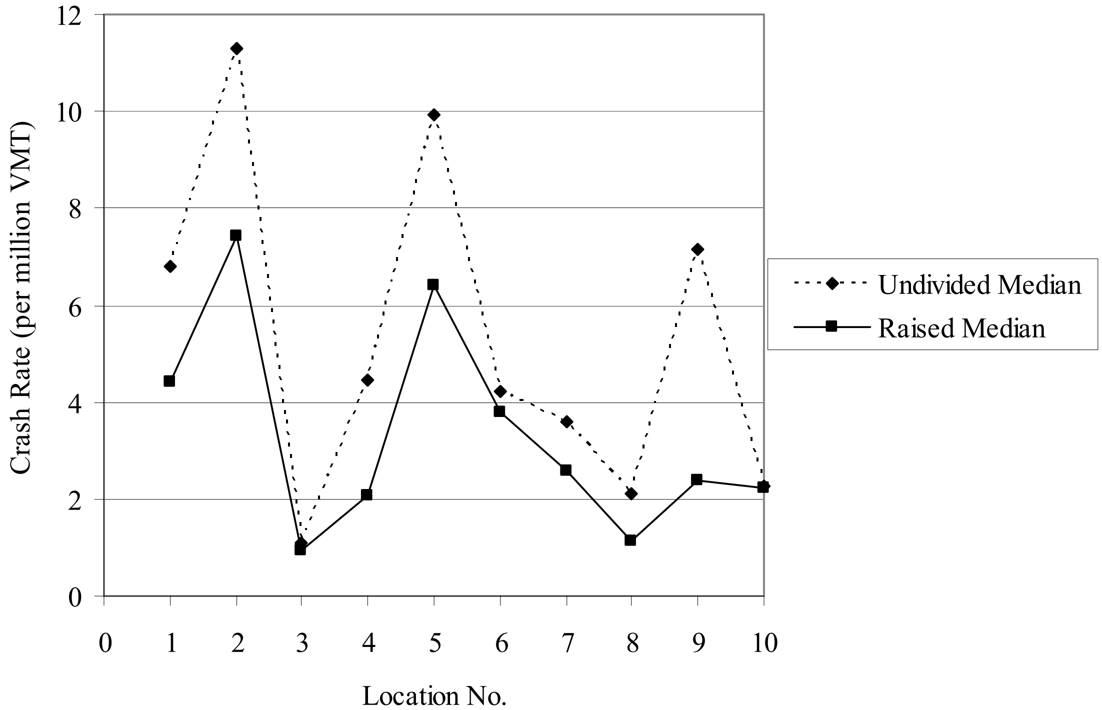


Figure 2-4. Crash rates comparing undivided and raised medians at ten locations (adapted from Gluck et al. 1999).

Certain crash types are likely to be reduced in situations where a raised median replaces a TWLTL. These crash types include sideswipe, rear-end, right-angle, left-turn, head-on, and pedestrian crashes (Gluck et al.1999). Several comparison studies have been performed to evaluate the before and after impacts on the same roadway for raised median replacements, while other studies compare crash rate for the two types of roads. Examples of these studies are provided in the following paragraphs.

The Georgia Department of Transportation completed a study of the crash statistics for all of the divided highways on the State Highway System from 1995 to 1998. The study found that raised medians had a 45 percent lower crash rate than that of TWLTLs. It was also found that raised medians helped reduce the injury rate by 43 percent and the fatality rate by 4 percent (Parsonson et al. 2000).

Eisele et al. (2004) analyzed two roads in Texas on which raised medians replaced TWLTLs. Texas Avenue in College Station, with an AADT of 41,000 vpd, experienced a 58 percent reduction in crash rate after the replacement. The number of incapacitating injuries was also reduced by 93 percent. Loop 281 in Longview, with an AADT of 23,500 vpd had a 17 percent reduction in overall crash rate.

In 1990 the Georgia DOT replaced 4.34 miles of TWLTL with a raised median on Memorial Drive in Atlanta. In the first year after completion there was a 37 percent reduction in total crash rate and a 48 percent reduction in the injury rate (TRI 1997). As of 1997, despite increases in crash rates throughout the surrounding DeKalb County, the crash rate was still reduced 17 percent from the years before construction. As of 1998, no fatalities had occurred in the seven years since the raised median was installed. In the 11.6 years before the project began there were 15 fatalities.

TRB (2003) compiled a list of situations for which a raised median is more desirable than a TWLTL. These situations are as follows:

- all new multilane urban arterial roadways;
- existing multilane urban arterial roadways with ADT in excess of 24,000 to 28,000 vpd, depending on local conditions;
- rural multilane roadways;
- bypass of an urban area;
- multilane roadways with a high level of pedestrian activity; and
- high crash location or areas where it is desirable to limit left turns to improve safety.

The Institute of Transportation Engineers (ITE) reported that a raised median can be a potential safety hazard on streets with high-speed traffic flow (ITE 2005). If the raised median is struck by a vehicle, it could cause the driver to lose control. Another problem caused by raised medians occurs at night when the medians are difficult to detect without the aid of some sort of permanent lighting device.

2.1.1.5 U-Turns as Alternatives to Direct Left-Turns. Raised medians eliminate many left turns from driveways along a roadway, which reduces the number of conflicts and improves safety. The diverted traffic from a driveway must be accommodated to make a right turn onto the arterial followed by a U-turn at the next median opening—an indirect left turn—to complete the desired movement. This movement is more manageable for drivers because it requires obtaining a sufficient gap in only one direction at a time, instead of finding a gap in both directions simultaneously. Figure 2-5 shows the movement of a right turn followed by a U-turn.

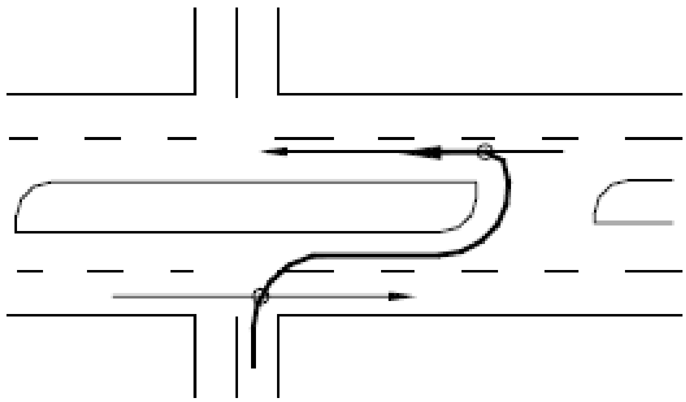


Figure 2-5. A right-turn movement followed by a U-turn (Huaguo, et al., 2000).

U-turns as an alternate to direct left turns have been studied to estimate their impact on safety. On US-1 in Florida, where left turns out of driveways onto major arterials are prohibited, the indirect left turn has resulted in a 22 percent crash rate reduction (Gluck et al. 1999).

In a separate study in Tampa Bay, Florida, a comparison of crash rates resulted in an 18 percent reduction when comparing direct left turns to indirect left turns. The same study found that indirect left turns experienced 27 percent fewer injuries and fatalities than direct left turns (Lu et al. 2001).

Left turn and U-turn lanes that are provided downstream of a signalized intersection are often called "Michigan U-turns" because many such lanes have been installed on Michigan's boulevard arterials. These lanes are typically provided about 660 feet downstream of a signalized intersection, as illustrated in Figure 2-6.

A study was performed on 123 boulevard segments in Michigan regarding the safety effects of the Michigan U-turn. The results show that the highway segments with a Michigan U-turn had a slightly higher crash rate than those segments without the Michigan U-turn when there were no traffic signals on the corridor. However, when

Figure 2-6. Aerial photograph of Michigan U-turn lanes (Answers 2005).

there were traffic signals on the corridor, the highway segments with a Michigan U-turn had a 49 percent lower crash rate than the segments without the Michigan U-turn (Gluck et al. 1999).

2.1.1.6 Access Separation at Interchanges. Freeway interchanges provide a transition between freeways and arterials and usually create large volumes of traffic. These interchanges can be a safety hazard if arterial street intersections are located too close to the end of the interchange ramp. Safety problems arise due to weaving distances that are inadequate. Gluck et al. (1999) summarize the guidelines used by the Oregon Department of Transportation for freeway interchanges as follows:

- the nearest major cross route intersection with a street on both sides of the interchange should not be less than 1,320 feet;
- the distance to the first access on a two-lane road ranges from 750 to 1,320 feet; and
- on a four-lane road, the distance to a median opening should be 990 to 1,320 feet.

2.1.1.7 Frontage Roads. A frontage road can be used as an access management technique to reduce conflicts along the main through lanes of a roadway. Through traffic is separated from local land-service traffic, thus protecting the through traffic from encroachment and conflicts.

Frontage roads run parallel to the mainline route and offer alternative access to commercial developments. The frontage road accesses the arterial by means of a cross road, reducing the number and density of conflict points associated with strip development. TRB recommends a separation of at least 300 feet between frontage road outlets and intersections between cross streets and arterials. A visual representation of this recommendation is shown in Figure 2-7. An actual frontage road is shown in Figure 2-8 (CTRE 2005d).

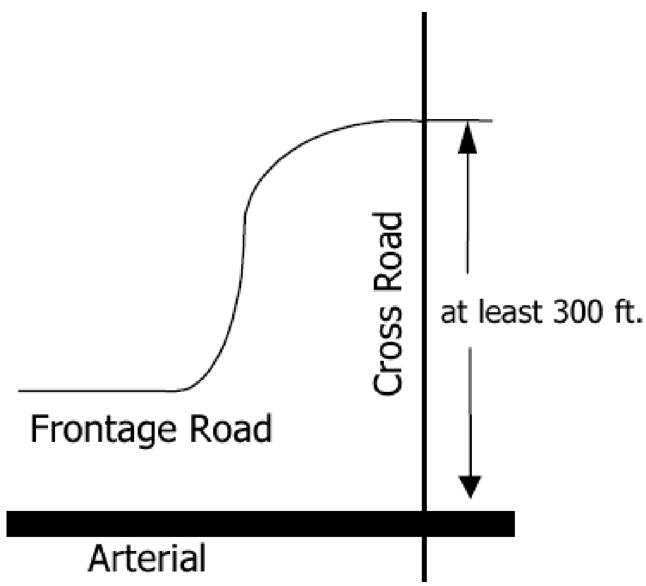


Figure 2-7. Visual representation of a frontage road (CTRE 2005d).

2.1.2 Pedestrian Safety

Research shows that specific access management techniques are valuable in providing safety for pedestrians. These techniques include (CTRE 2005a):

- reducing the number of driveways within a given distance (per mile or block);
- providing for greater distance separating driveways; and

Figure 2-8. A frontage road in Urbandale, Iowa (CTRE 2005d).

- providing raised medians as a refuge for pedestrian crossings.

Each of these techniques will be discussed in the sections that follow.

2.1.2.1 Reducing the Number of Driveways. When a sidewalk crosses a driveway it creates at least four potential conflict points between pedestrians and vehicles. As the number of driveways per block is reduced, the number of conflict points is reduced proportionally.

2.1.2.2 Providing for Greater Driveway Separation. Pedestrian safety also increases with greater separation of driveways because it reduces overlap of the operational areas of driveways. This increased separation of driveways helps drivers (and pedestrians) to concentrate on one conflict point at a time (CTRE 2005a).

2.1.2.3 Providing Raised Medians as a Refuge for Pedestrians. Research studies indicate that raised medians provide more safety for pedestrians than other types of medians. Raised medians provide pedestrians an "island" in the middle of the roadway that offers protection from vehicular traffic. This refuge does not exist on highways with no medians or those with TWLTLs (TRB 2003). Pedestrians need only concentrate on crossing one direction of travel lanes at a time rather than having to find a gap in the traffic in both directions. The difference between the two crossing maneuvers is shown in Figures 2-9 and 2-10.

In Figure 2-11, the pedestrians are using the raised median as a refuge while crossing the street. This island in the middle of the roadway helps to break up the crossing maneuver into two segments: 1) one segment to cross from the near side to the center median, and 2) one segment to cross from the center median to the far side of the street. Figure 2-12 shows pedestrians crossing a road that has no raised median. The TWLTL offers no refuge for the pedestrians, forcing them to perform one single crossing maneuver across both directions of traffic.

A Georgia Department of Transportation study evaluating all of the divided highways in the state found that raised medians provided considerably better pedestrian safety than TWLTLs. Roadways with raised medians had 78 percent less pedestrian fatalities than roadways with TWLTLs. This number represents the total crashes at both the mid-block and intersection (Parsonson et al. 2000).

Another study in Georgia on Memorial Drive in Atlanta found that before the raised median was installed there were six pedestrian fatalities in almost 12 years. After completion of the project, not a single fatality had occurred in seven years (Parsonson et al. 1998).

Another study comparing pedestrian safety for different median types shows similar results. As reported in Table 2-1, crash rates for four-lane roads that have no median are very similar to five-lane roads that have a TWLTL. However, divided four-lane roads with raised medians are approximately twice as safe for pedestrians when compared to roads with no medians or TWLTLs. These findings hold true for crash rates at both the mid-block and the intersection. The study found that a median must be at least four feet wide to be considered an effective refuge for crossing pedestrians. Also, a depressed grass median with no raised curb would be a slightly less effective pedestrian refuge than a raised median (CTRE 2005a). Where pedestrian traffic is heavier than just

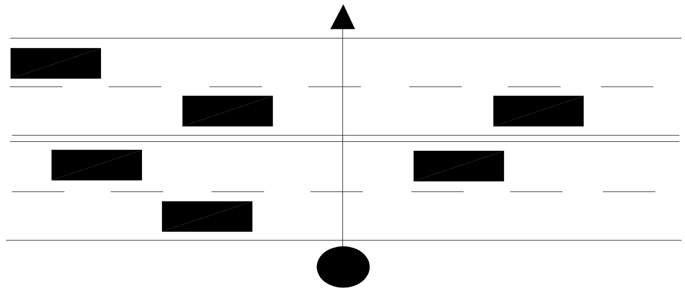


Figure 2-9. Pedestrian crossing at mid-block without raised median (adapted from FHWA 2005).

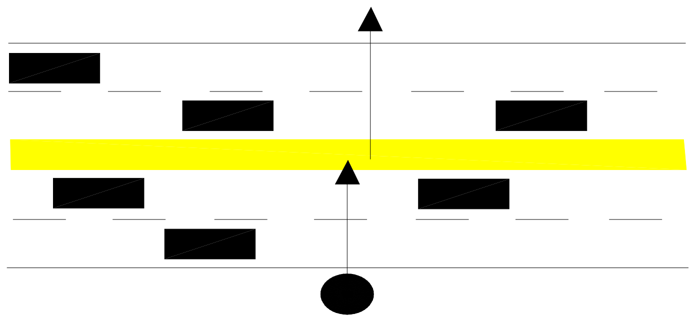


Figure 2-10. Pedestrian crossing at mid-block with raised median (adapted from FHWA 2005).

Figure 2-11. Pedestrians crossing road with raised median (FHWA 2005).

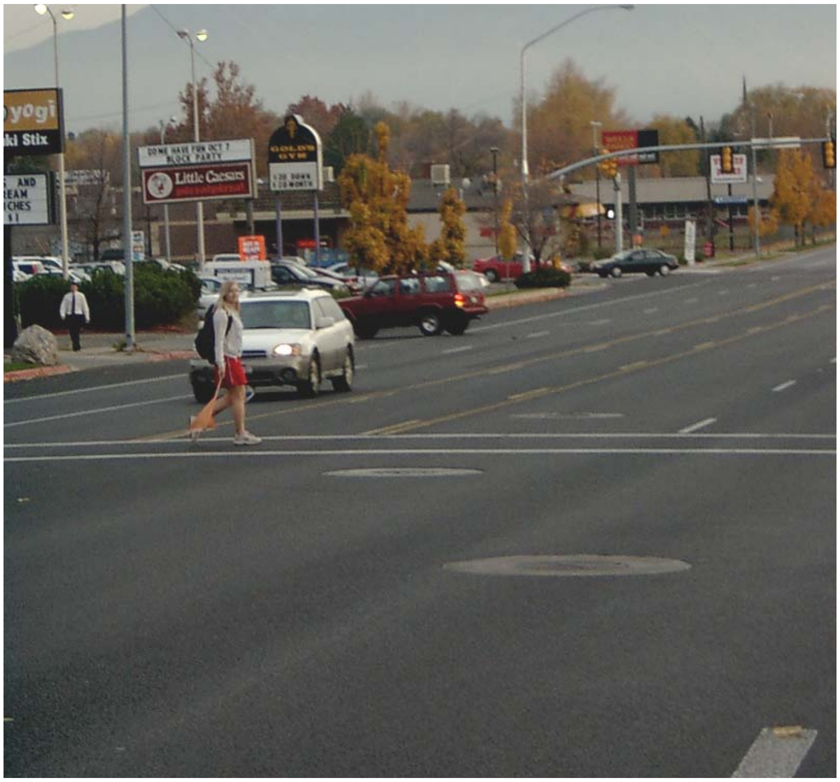


Figure 2-12. Pedestrian crossing road without a raised median.

an occasional pedestrian, the recommended median width is at least 8.5 feet (FDOT 1997).

Access management techniques have been defined in this section. As noted, each technique has safety benefits that improve the vehicle and/or pedestrian safety of a roadway.

Table 2-1. Mid-block and Intersection Crash Rates by Median Type (CTRE 2005a)

Roadway Type	**Median**	**Mid-block Pedestrian Crash Rate[1]**	**Intersection Pedestrian Crash Rate[2]**
Undivided 4 lane	None	6.69	2.32
5 lane (TWLTL)	Painted	6.66	2.49
Divided 4 lane	Raised	3.86	0.97

[1] per million VMT,
[2] per million entering vehicles

2.2 Access Management Guidelines in Utah

UDOT has an obligation and responsibility to preserve and maintain the state highway system. UDOT is also responsible for ensuring that the state highway system meets regional and local transportation needs. When proper care is not taken with regards to access management, the traveling public is exposed to higher crash rates and other hazards.

In this section, access management guidelines and principles in the Utah Administrative Rule are discussed. The Rule assists in the access management of Utah state highways. A brief discussion on raised median guidelines in the state of Utah is also included.

2.2.1 Utah Administrative Rule

It is essential to manage access to and from state highways. In the current Utah Administrative Rule R930-6 (UDOT 2003), access management principles are used to provide uniformity in the issuance of driveway and street access permits. Property owners who own land adjacent to state highways maintain the right to have reasonable access to their land uses. In the Rule, standards are established to balance the need of owners for reasonable access to land uses with the need to preserve the smooth flow of traffic on the state's highways. By implementing the guidelines set forth in the Rule, UDOT intends to prevent congestion and traffic crashes and improve public safety on its highways. These guidelines include techniques to "limit the number of conflict points at driveway locations, separate highway conflict areas, reduce the interference of through traffic, space at-grade signalized intersections, and provide for adequate on-site circulation and storage" (UDOT 2003).

The guidelines in the Rule are intended to be implemented statewide to ensure uniform and consistent application of the access management standards. In order to facilitate the statewide implementation of these standards, road segments have been categorized into "classifications of highways that have similar traffic movement purposes and objectives" (UDOT 2003). Every segment of state highway has been assigned one of nine highway classifications. The nine highway classifications are summarized in Table 2-2.

Table 2-2. State Highway Access Management Classifications (UDOT 2003)

Category	Assignment	Description
1	I	Freeway/Interstate
2	S-R	Statewide Rural
3	S-U	Statewide Urban
4	R-R	Regional Rural
5	R-UF	Regional Urban Fluid
6	R-US	Regional Urban Static
7	C-R	Community Rural
8	C-U	Community Urban
9	O	Other

UDOT intends to work closely with property owners and local governments in making access management decisions. In order to obtain access to a state highway system, property owners must apply for a permit through UDOT. Administrative employees look at each application and "review the balance of private property rights of reasonable access versus the public need to preserve the smooth flow of traffic on the State Highway system" (UDOT 2003). The permit is required to construct, modify, relocate, or close a vehicular access that connects to the state highway right-of-way.

Property owners must follow certain standards in the design and location of driveway accesses. The standards for street and access spacing are listed in Table 2-3. As noted in the table street spacing standards vary from 150 feet to 5,280 feet depending on access category and intersection control.

The intent of the Rule is to establish and formalize guidelines that will assist in the access management of state highways. These guidelines will help maintain a balance between the rights of property owners to reasonable access and the need to preserve a smooth and safe flow of traffic. By keeping consistent standards, it is easier to oversee access management on the State Highway system.

Table 2-3. State Highway Access Management Standards (UDOT 2003)

	Category	Minimum Signal Spacing (feet)	Minimum Street Spacing (feet)	Minimum Access Spacing (feet)	Minimum Interchange-to-Crossroad Access Spacing (feet)		
					to 1st R-in R-out "A"	to 1st Intersection "B"	from last R-in R-out "C"
1	I	Interstate/Freeway Standards Apply					
2	S-R	5,280	1,000	1,000	1,320	1,320	1,320
3	S-U	2,640	No Unsignalized Access Permitted		1,320	1,320	1,320
4	R-R	2,640	660	500	660	1,320	500
5	R-UF	2,640	660	350	660	1,320	500
6	R-US	1,320	350	200	500	1,320	500
7	C-R	1,320	300	150	Not Applicable		
8	C-U	1,320	300	150			
9	O	1,320	300	150			

Minimum interchange crossroad access spacing standards "A", "B", "C" are defined as follows:

1. Standard "A" refers to the distance from the interchange off-ramp gore area (point of widening) to the first right-in/out driveway intersection.
2. Standard "B" refers to the distance from the interchange off-ramp gore area (point of widening) to the first major intersection.
3. Standard "C" refers to the distance from the last right-in/out driveway intersection to the interchange on-ramp gore area (point of widening).

2.2.2 Raised Median Guidelines

In addition to street and access spacing requirements, another access management tool that can be used to reduce conflict points and improve safety is the installation of raised medians. A research study performed at BYU in 2004 evaluated raised medians as a safety improvement in the state of Utah. A procedure was developed that allows state engineers to identify the need for a raised median on a specific roadway and to make decisions on median installation (Saito et al. 2004).

2.3 Background of the UDOT Crash Database Tool

The recent study on raised medians that was performed at BYU began the process of analyzing raised medians in the state of Utah. To estimate the safety impacts of the raised medians, before and after crash data from the raised median corridors were evaluated. These crash records were extracted from UDOT's web-delivered crash database that can be used to evaluate crash statistics for all roads and intersections on the state highway system. The version that was used in the initial raised median study performed at BYU (Saito et al. 2004) was an early edition of the crash database that has been developed extensively since that time.

One of the main purposes of the crash database is to allow for rapid retrieval and analysis of crash data. The system is designed to enhance the analysis of the data in four ways (Anderson et al. 2005):

1. Custom tables and reports are created with only selected parameters, leaving off unneeded data. This simplifies the analysis by focusing on what is important.
2. Placing the data on a "smart map" allows the researcher to visually identify hot spots or deficient areas. The analysis can be further refined by extracting information from the map as needed.
3. Information extracted through a series of queries from different data sources can be saved into a single spreadsheet for analysis. For example wet weather crashes, skid index, and AADT could be acquired for a site from three different databases.
4. Researchers will have more time to analyze the data since it takes less time to gather and compile the information.

According to the UDOT Data Almanac User's Manual (Anderson 2005), the number of years of data selected in a query should be a function of: 1) how common the crash type is, 2) if the highway segment has undergone changes, and 3) a variety of other factors. In making a reliable, safety-related decision, it is important to obtain sufficient data without polluting it with inaccurate or old data. One to three years is a good sample if the crashes are reasonably common.

Crash analysis can be a very useful tool in the evaluation of the safety conditions of a highway. The number, type, and severity of crashes can lead to greater understanding of the causes of crashes on a roadway. This, in turn, can lead to effective solutions and ideas for improvements that can reduce crashes and improve safety. Crash analysis can be used to evaluate the impacts of roadway safety improvements that are already in place by analyzing before and after crash statistics. These types of studies can help identify effective safety improvements.

2.4 Literature Review Summary

In this chapter, a literature review was organized consisting of pertinent information regarding the safety impacts of access management techniques. Access management techniques were defined and the safety impacts of each technique were analyzed. Access management guidelines in the state of Utah were summarized and the background was given on the UDOT crash database tool.

In the following chapter, an overview is given regarding the locations where access management techniques are to be analyzed. An overview of the control sites for the study is also provided.

3 CORRIDOR SELECTION

In order to analyze the results of access management techniques, a representative sample of corridors from across the state of Utah was selected. In the process of corridor selection, and after coordinating with UDOT personnel, it was determined that there was insufficient data to select a statewide sample. Consequently, the corridors chosen for analysis are all located along the Wasatch Front with one control site in St. George. These corridors include locations where access management techniques (i.e., raised medians and/or driveway consolidation) have been installed within the past 12 years, as well as control sites that exhibit similar conditions to the study sites, only without the implementation of access management techniques.

In this chapter, the locations of access management techniques are described to provide an overview of the analysis sites. In addition, a description of the control sites for the study is provided. These descriptions include the study location, a background of the corridor, and reasons why the location was selected for the study.

3.1 Locations of Access Management Techniques

The locations that have been chosen for analysis where access management techniques have been installed are discussed in this section. The techniques that have been implemented at these locations consist exclusively of raised median installations. In addition to the raised median installation, however, driveway density data was also collected, indicating some locations where driveway consolidation has occurred.

In order to analyze data before and after median installation, the year in which the median was installed had to be determined. To determine the years that the raised medians were installed, UDOT's Roadview Explorer tool was utilized. This tool is located in the Photolog Section of the Systems Planning and Programming Division at the UDOT Complex located in West Valley City. To determine the year of installation, video of the state road under evaluation was viewed for past years until the raised median was identified in the photolog. Oftentimes the photolog showed the construction during the year of installation, with full median the following year. Other means of determining the year of installation can also be used. The simplest of which is when the region traffic engineers or field engineers can recall the year in which the raised median was installed.

The locations of the access management techniques selected for the study are as listed:

1. University Parkway (SR 265) − Milepoint 1.20 to 1.96.
2. Alpine Highway (SR 74) − Milepoint 2.40 to 4.29.
3. State Street (SR 89) − Milepoint 311.41 to 311.90.
4. 400/500 South (SR 186) − Milepoint 5.54 to 7.59.
5. 300 West (SR 89) − Milepoint 326.68 to 326.97.
6. Redwood Road (SR 68) − Milepoint 50.75 to 51.47.

Maps are included to illustrate the area where these locations are found. A map showing locations 1 and 2 in Utah County is provided in Figure 3-1. A map of locations 3 and 6 in southern Salt Lake County is shown in Figure 3-2, and a map of locations 4 and 5 in Salt Lake City is displayed in Figure 3-3.

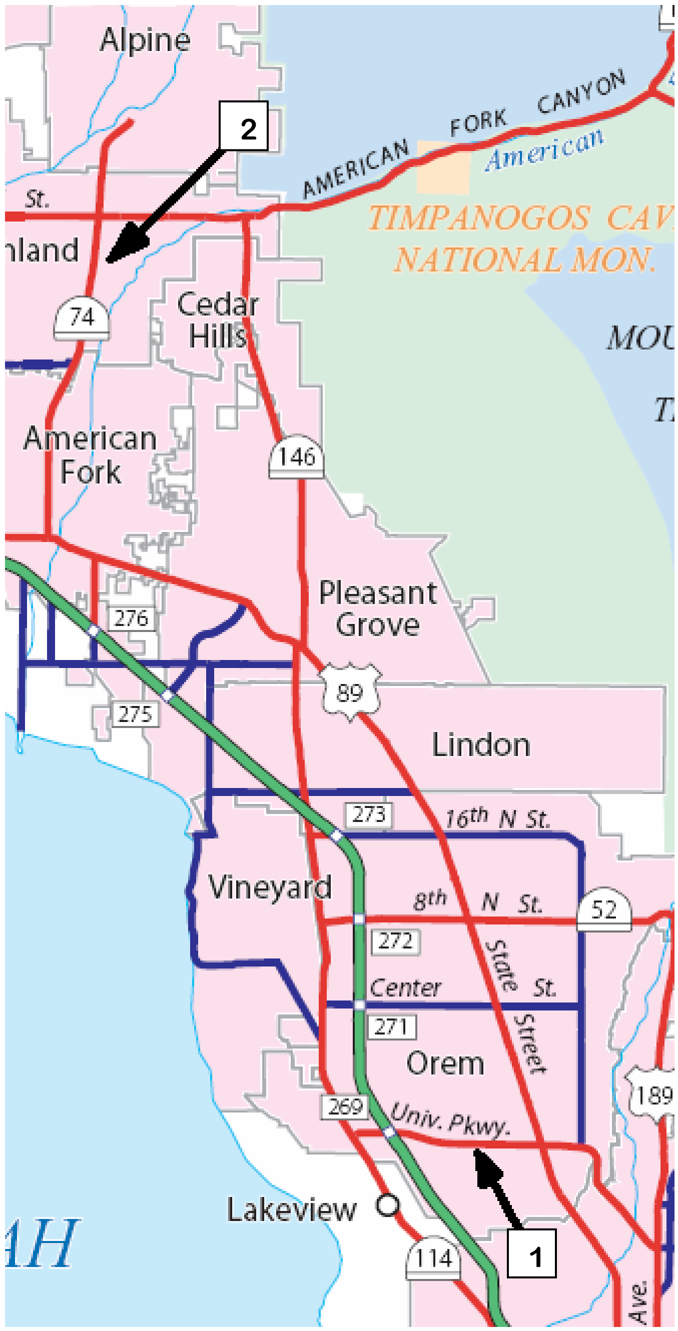


Figure 3-1. Map of locations 1 and 2 in Utah County (adapted from UDOT 2005c).

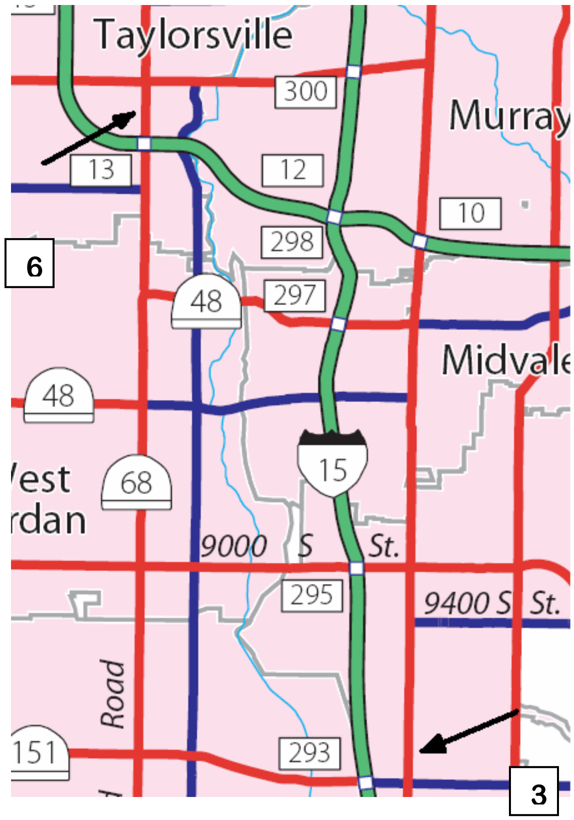


Figure 3-2. Map of locations 3 and 6 in southern Salt Lake County (adapted from UDOT 2005c).

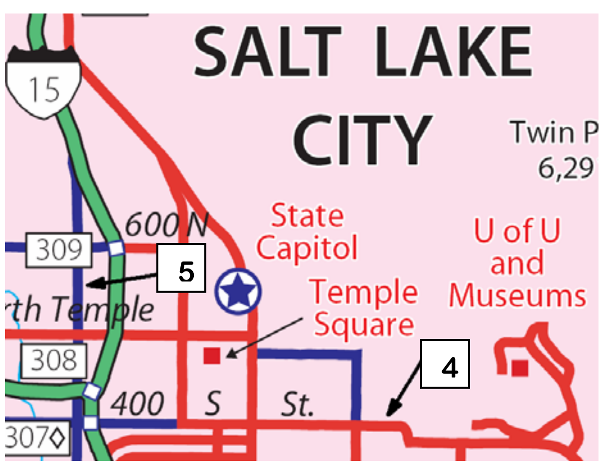


Figure 3-3. Map of locations 4 and 5 in Salt Lake City (adapted from UDOT 2005c).

3.1.1 University Parkway (SR 265)

University Parkway (SR 265) extends from Geneva Road on the west side of Interstate 15 to 900 East in Provo. SR 74 is a heavily-traveled six-lane arterial that connects the two major universities in Utah County; Utah Valley State College (UVSC) and BYU. On this corridor there are large businesses, a regional shopping mall, several restaurants, strip malls, and other entertainment destinations. A raised median was installed on University Parkway in Orem in 2002 between 400 West and 200 East. Prior to the raised median installation, University Parkway had a painted median that separated the three lanes of traffic in each direction. This segment was chosen for analysis due to the high traffic volumes (2004 AADT of 39,235) and the high number of access points along the corridor (UDOT 2005b). The raised median consists of a concrete curb with sections of landscaping as shown in Figure 3-4.

Figure 3-4. Raised median on University Parkway near 400 West intersection.

3.1.2 Alpine Highway (SR 74)

The Alpine Highway (SR 74) connects State Street (SR 89) in American Fork to the Highland/Alpine area. It is a two-lane collector that mostly traverses residential areas. The 2004 AADT for this segment of highway was 13,525 (UDOT 2005b). The roadway has a major intersection with SR 92 in Highland where a large supermarket, a gas station, and several strip mall developments are located. A raised median was installed in sections over a two-mile stretch from Hidden Drive (9840 North) to 11300 North in Highland. As shown in Figure 3-5, this segment of raised medians appears to be used more for beautification and to channel turn movements rather than to prohibit turns. This corridor was selected for analysis because of the unique design of the medians. There are access openings in the median at most of the residential streets that intersect with SR 74.

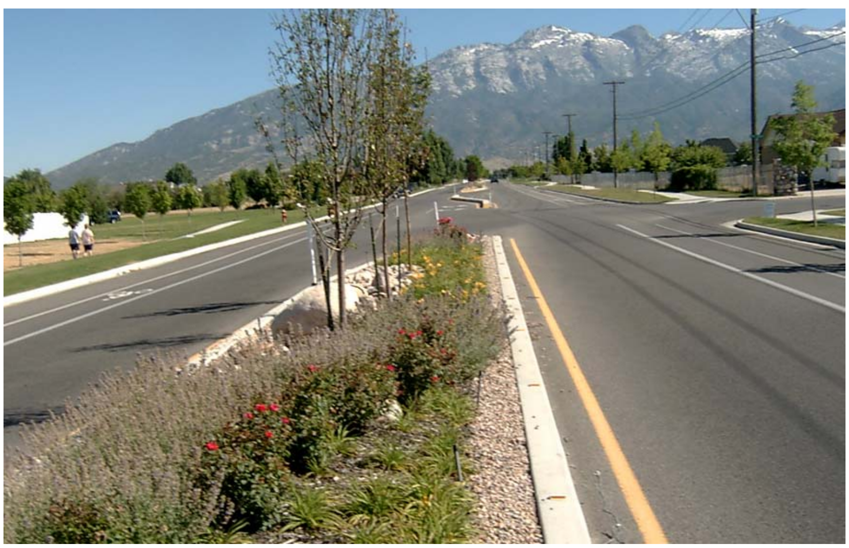


Figure 3-5. Raised median on SR 74 at 10000 North.

3.1.3 State Street (SR 89)

State Street (SR 89) is a major six-lane arterial that extends from north to south over nearly the entire length of the Salt Lake Valley. The corridor provides a direct route from Sandy to Salt Lake City's downtown area. Raised medians were installed in 1994 adjacent to the South Towne Mall from 10200 South to 10600 South. The segment was selected for analysis because it is a heavily-traveled corridor (2004 AADT of 29,640) with many strip malls and stores (UDOT 2005b). Figures 3-6 and 3-7 show the corridor during non-peak periods.

Figure 3-6. Raised median on State Street at 10400 South.

Figure 3-7. Raised median on State Street at 10600 South intersection.

3.1.4 400/500 South (SR 186)

During the years 1999-2001, a light rail line was constructed in the center of the 400/500 South (SR 186) corridor. This line is an east-west extension of the TRAX light rail system in Salt Lake City. As part of the light rail line on 400/500 South, a raised median was constructed to separate the rail lines from the automobile traffic lanes as illustrated in Figure 3-8. The light rail line, called the University Line, extends from Main Street to the University of Utah campus. Between 900 East and 1100 East, the corridor curves from 400 South to 500 South. This corridor is a heavily-traveled six-lane arterial (2004 AADT of 29,640) that serves as a major east-west corridor through the heart of Salt Lake City (UDOT 2005b). There are countless businesses, restaurants, stores, and office buildings on 400 South. The section of the roadway that turns into 500 South is more of a residential area, but high traffic volumes still exist. The segment of raised median analyzed in this research extends from Main Street to 1300 East. It was selected for analysis because it is a high-volume corridor in Salt Lake City with a unique raised median to serve light rail transit.

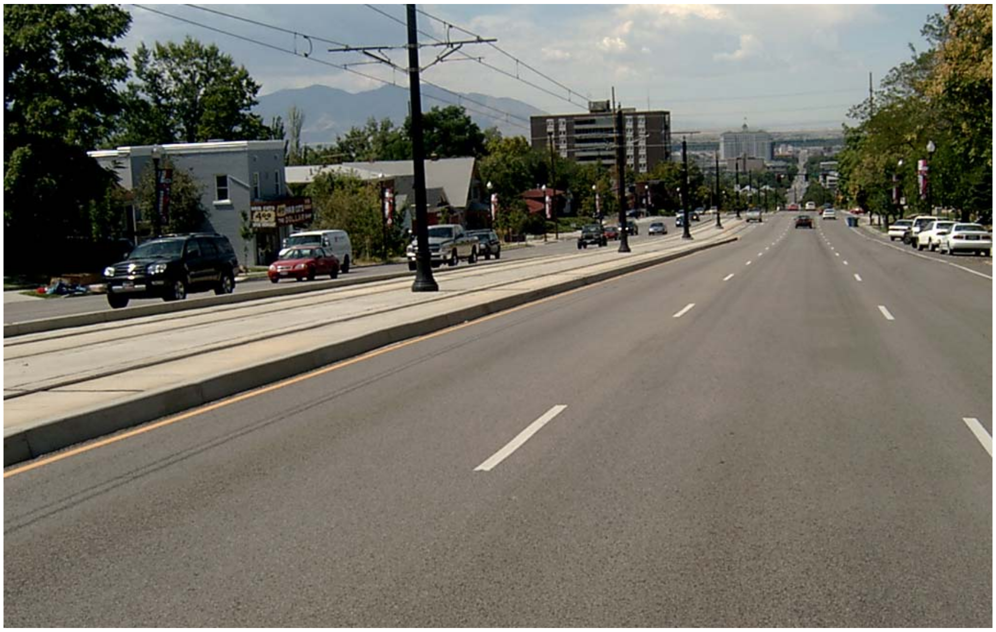


Figure 3-8. Raised median separating TRAX rail lines from traffic on 500 South.

3.1.5 300 West (SR 89)

As indicated previously, SR 89 is a major arterial in Salt Lake City. It serves as one of the only north-south corridors besides Interstate 15 that extends north from Salt Lake City to the Bountiful area. One segment of SR 89 extends along 300 West in the northern end of Salt Lake City. This six-lane segment of SR 89 had a 2004 AADT of 18,495 (UDOT 2005b). Along 300 West there are major sites that attract considerable traffic volumes including the Delta Center and the Triad Center. In 1999, a raised median was installed in the center of 300 West (SR 89), between North Temple and 300 North. West High School is located on the west side of the street between 200 and 300 North. Due to the high volume of pedestrian traffic at peak times during school days, a signalized pedestrian crossing was installed at approximately 200 North. The raised median is shown in Figure 3-9.

Figure 3-9. Raised median on 300 West near West High School at 200 North.

3.1.6 Redwood Road (SR 68)

Redwood Road (SR 68) is a major arterial that extends north and south over the entire length of Salt Lake County. Redwood Road is located approximately halfway between Interstate 15 and Bangerter Highway (SR 154), and serves several businesses, schools (including Salt Lake Community College) and other attractions. A raised median was installed on a six-lane segment of Redwood Road in 1994 from 5400 South to 6000 South in what is now Taylorsville City. This area of Redwood Road is extremely retail-oriented including a Wal-Mart, a grocery store, several fast food restaurants, a large movie theater, and other retail developments. Taylorsville High School is located on the northeast corner of Redwood Road and 5400 South. The raised median on Redwood Road was selected for analysis because it has very high traffic volumes (2004 AADT of 62,880) along that segment of the corridor (UDOT 2005b). Figure 3-10 shows the raised median on Redwood Road.

Figure 3-10. Raised median on Redwood Road near 5400 South.

3.2 Control Sites

In addition to the study sites, several corridors were chosen as control sites in order to provide a comparison between those sites in which access management techniques were installed and those sites in which they were not. A number of criteria were used in determining the control sites. Some of the sites have recently had raised medians installed or are about to have them installed. Other sites exhibit similar characteristics as the study sites but do not have raised medians. All of the control sites will be evaluated for their “before” conditions and will be used for comparison with the analysis sites.

The locations of the control sites selected for the study are as listed:

1. 700 East (SR 71) − Milepoint 21.87 to 22.47.
2. 12300 South (SR 71) − Milepoint 4.56 to 5.46.
3. Redwood Road (SR 68) − Milepoint 49.46 to 49.96.
4. St. George Blvd. (SR 34) − Milepoint 0.00 to 1.74.
5. SR 36 − Milepoint 59.90 to 60.90.

Maps are included to illustrate the area where these control sites are found. A map of location 4 in St. George is shown in Figure 3-11, and a map of location 5 in Tooele County is displayed in Figure 3-12. Figure 3-13 shows a map of locations 1, 2, and 3 in Salt Lake County.

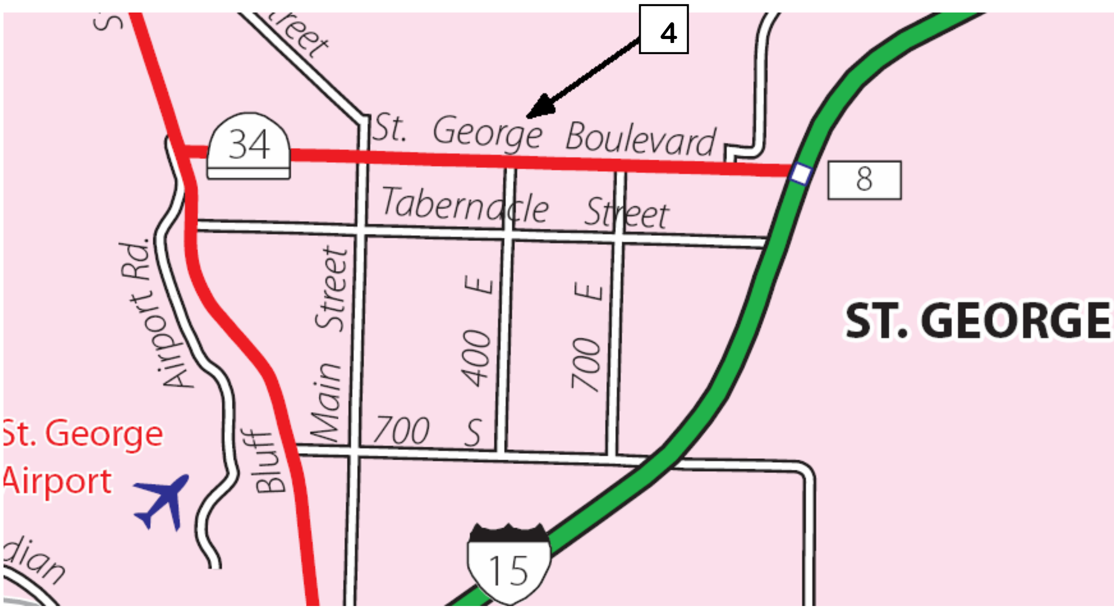


Figure 3-11. Map of control site location 4 in St. George (adapted from UDOT 2005c).

Figure 3-12. Map of location 5 in Tooele County (adapted from UDOT 2005c).

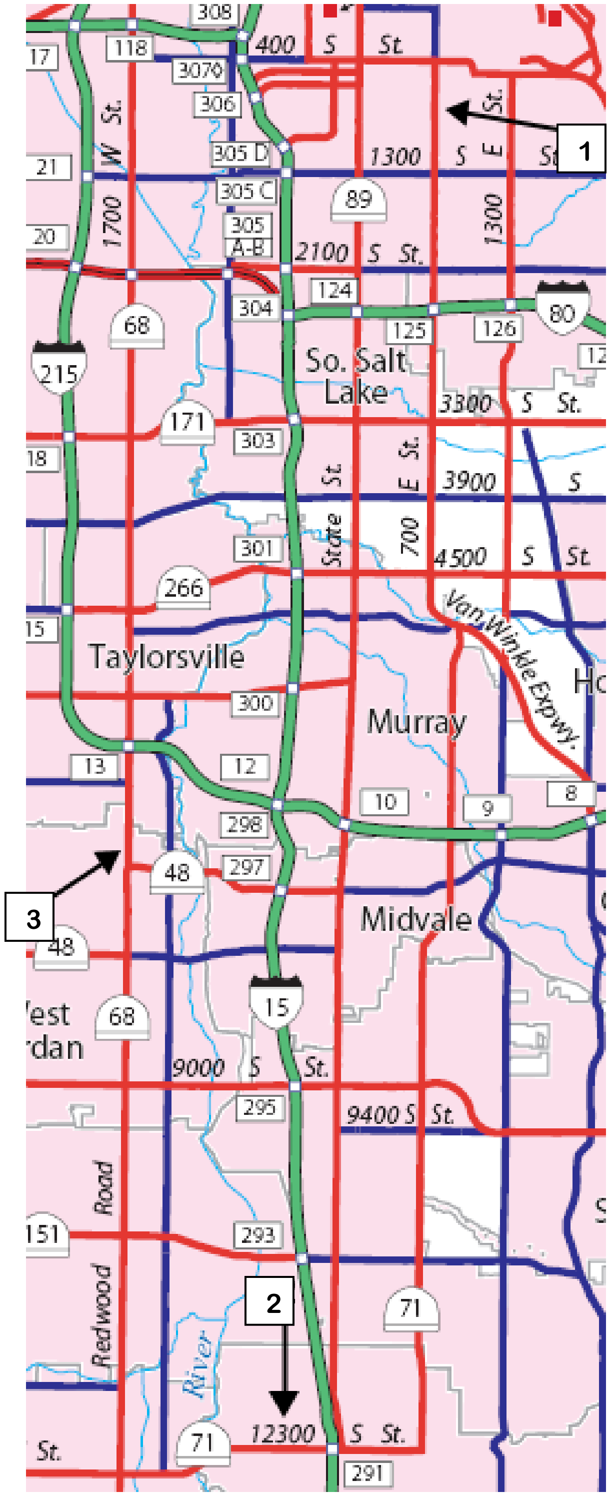


Figure 3-13. Map of control site locations 1, 2, and 3 in Salt Lake County (adapted from UDOT 2005c).

3.2.1 700 East (SR 71)

One of the major arterials that traverses much of the Salt Lake Valley parallel to State Street is 700 East (SR 71). This corridor experiences heavy traffic volumes (2004 AADT of 36,115) that are compounded by commuter traffic (UDOT 2005b). A new raised median was installed on a six-lane segment between 400 South and 800 South in 2002 that replaced an older raised median. The corridor was chosen for analysis as a road that has always had access management techniques in place. Figure 3-14 shows the raised median on 700 East.

Figure 3-14. Raised median on 700 East in Salt Lake City.

3.2.2 12300 South (SR 71)

A highway widening/improvement project was completed on 12300 South in Draper in November 2004. The project began in late 2002 and included widening the roadway to three lanes in each direction and installing a section of raised medians. The continuous stretch of raised medians from 300 East to 265 West was selected as a control site for analysis. This is a fast-growing area that has experienced large increases in traffic volumes (2004 AADT of 28,600) due to heavy development in the vicinity of the 12300 South interchange of Interstate 15 (UDOT 2005b). This area is shown in Figure 3-15 with the newly-installed raised medians on 12300 South. As a control site, crashes will be analyzed on this corridor for the time period leading up to the raised median installation.

Figure 3-15. Raised median on 12300 South in Draper.

3.2.3 Redwood Road (SR 68)

Several miles downstream from the raised median segment of Redwood Road outlined previously is a similar segment of roadway that does not include a raised median. The area has several large businesses, residential condominiums, and stores including a grocery store and a Target store. As shown in Figure 3-16, the only median treatment in this area is a TWLTL that extends over the entire corridor from 6670 South to 7000 South. The 2004 AADT for this segment of Redwood Road was 31,260 (UDOT 2005b). This seven-lane segment of corridor was selected as a control site to compare the safety impacts with the raised median segment of Redwood Road to the north.

Figure 3-16. TWLTL on Redwood Road near 7000 South.

3.2.4 St. George Blvd. (SR 34)

A highway improvement project has commenced on St. George Blvd. (SR 34) in St. George. The project began in April 2005 and is expected to be completed at the end of 2006. The project includes access improvements and pavement reconstruction as well as the installation of a landscaped raised median to replace the existing TWLTL. The project will convert the roadway from five lanes to four lanes. An airbrushed photograph of St. George Blvd. is shown in Figure 3-17 depicting the future raised median with landscaping. The raised median will extend over the entire project length from Bluff Street to 1000 East. The 2004 AADT for this segment of the project ranges from 19,230 on the west end to 33,960 at 700 East (UDOT 2005b). St. George Blvd. was chosen as a control site for analysis because it has a heavy concentration of hotels/motels, stores, and other businesses, and serves as a major arterial for this rapidly growing population.

Figure 3-17. Artistic rendition of the future raised median on St. George Blvd. (UDOT 2005a).

3.2.5 SR 36

A highway improvement project was recently completed on SR 36 in Tooele County. This corridor is the major artery for vehicle traffic between Tooele City and Salt Lake City. Traffic volumes have increased on SR 36 in recent years (2004 AADT of 20,475) as the area is becoming a bedroom community of Salt Lake City (UDOT 2005b). Along with the widening of the highway to two lanes in each direction, a raised median was installed on a one-mile stretch of the corridor in Erda. The project was completed in October 2005. This corridor has been selected as a control site to evaluate the safety of the corridor prior to the installation of the raised median.

3.3 Corridor Selection Summary

A summary of the corridors that were selected for analysis is shown in Table 3-1. The sites are divided into two groups: 1) analysis sites and 2) control sites. A summary of each site is provided including the state route, county, the year the median was installed (if applicable), the length of the study corridor, the access points per mile for the installation year, and the access points per mile for 2005.

Table 3-1. Summary of Corridors in the Analysis

	Location	State Route	County	Year Installed	Length (miles)	Access[a] Points/Mile in Installation Year	Access[a] Points/Mile in 2005
Analysis Sites	University Parkway	265	Utah	2002	0.77	23.4	18.2
	Alpine Highway	74	Utah	2002	1.90	8.9	8.9
	State St.	89	Salt Lake	1994	0.50	16.0	22.0
	400/500 South	186	Salt Lake	2001	2.06	74.3	73.3
	300 West	89	Salt Lake	1999	0.30	26.7	26.7
	Redwood Road	68	Salt Lake	1994	0.73	37.0	27.4
Control Sites	700 East	71	Salt Lake	2002	0.60	N/A[b]	101.7
	12300 South	71	Salt Lake	2004	0.90	N/A[b]	34.4
	Redwood Road	68	Salt Lake	N/A[b]	0.50	N/A[b]	24.0
	St. George Blvd.	34	Washington	2006	1.75	N/A[b]	93.1
	SR 36	36	Tooele	2005	1.00	N/A[b]	19.0

[a] Access points include both directions of travel along the corridor.
[b] N/A - Not Applicable

As illustrated in Table 3-1, there are two sites in Utah County, seven sites in Salt Lake County, one site in Washington County, and one site in Tooele County. The year of installation for the medians that have been installed varies from 1994 to 2006. The lengths of the segments being studied vary from 0.30 miles to 2.06 miles. The access points per mile range from 8.9 to 101.7. Several locations have experienced no change in access points per mile from the installation year until 2005. Three locations have experienced increases in access points per mile since the installation year, including State

Street, 300 West, and 700 East. The analysis site on Redwood Road has experienced a decrease in access points per mile since the median was installed.

4 ANALYSIS PROCEDURE

A set procedure is followed in the analysis of data for the selected corridors. This way, each corridor is analyzed in the same way and results are easily compared. The analysis presents an opportunity to estimate the safety impacts of access management techniques, particularly raised medians and driveway consolidation, in the state of Utah.

Chapter 3 outlined the corridors for analysis including a summary of the background information necessary for corridor analysis. In summary, each corridor was visited and inspected thoroughly, and the year that the raised median was installed on the corridor was determined. The exact beginning and ending mileage points of the segments in question were determined to match the crashes with the correct segment of roadway. All driveways and other access points were counted in order to determine the level of accessibility of the roadway. The reader is referred to Chapter 3 for a complete summary of the background information on each of the corridors chosen for analysis.

The key tool in analyzing the safety impacts of access management techniques such as raised medians is UDOT's web-delivered crash database. Valuable crash statistics for all of the roads on the State Highway system are available from this tool. The crash database allows for rapid retrieval and analysis of crash data. The database includes historic information for crashes dating back to 1992. The most recent crash data in the system is for calendar year 2004. This data was loaded onto the system in September 2005.

After arriving at UDOT's crash database website, the "Accidents" option is chosen from the "Select Application" drop-down box at the top right corner of the screen as illustrated in Figure 4-1. A set of five primary tabs appear at the top of the screen. These five tabs are used to assist in navigating through the crash database.

Several types of analysis are described in this chapter including segment analysis, intersection analysis, collision type analysis, and crash severity analysis. Following is a summary of the procedure that may be followed on the UDOT crash database to evaluate crash numbers and information for each type of analysis.

Figure 4-1. UDOT crash database homepage.

4.1 Segment Analysis

Segments of highways are analyzed in several ways using the crash database. The total number of crashes over an entire segment can be found, as well as the number of crashes in specified intervals over an entire segment. Crash rates can also be determined from the total crash numbers. Each of these items is discussed in depth in the following sections.

4.1.1 Simple Search

To find the overall number of crashes on a segment of a state road for a specific time period, the user inputs the required data into the appropriate fields of the crash database. This can be done as part of a "Simple Search" as shown in Figure 4-2. If available, the three years immediately before and after the median installation is used to compare the crash data for the segment of roadway that is to be analyzed. The "Simple Search" tool of the crash database produces a table that lists each crash that qualifies under the specified search limits and tallies the total number of crashes at the bottom of the list. The total number of crashes for the before and after conditions is used to calculate the crashes per year and the crashes per mile for the specified corridor. These before and after results can be easily compared to assist in determining the effectiveness of access management techniques.

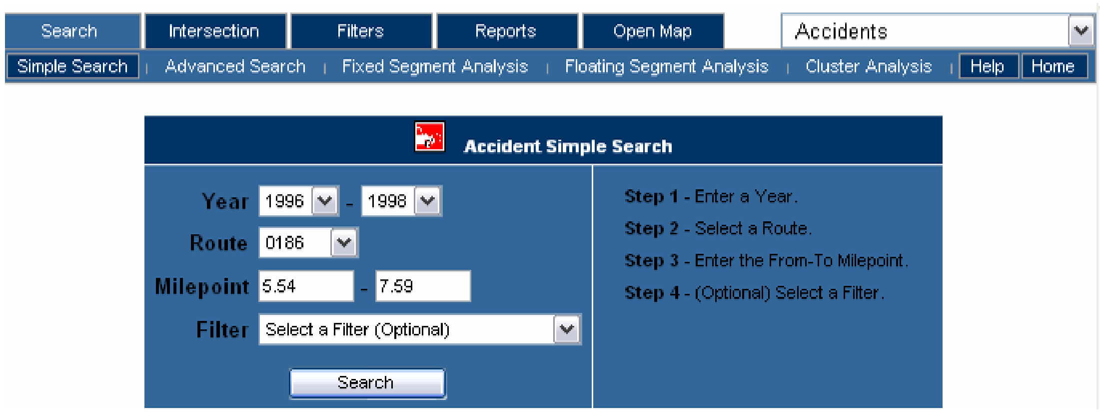


Figure 4-2. Example of a "Simple Search" performed using UDOT's crash database.

4.1.2 Fixed Segment Analysis

Along with the "Simple Search" option, there is another option under the search tab that is very useful for crash analysis. This is called the "Fixed Segment Analysis" option. This tool allows for crashes to be reported over short intervals of the segment being studied. The years to be studied and the state route are selected in the appropriate drop-down boxes, as well as the beginning and ending milepoints of the segment being analyzed. The next criteria that the tool asks for is the length of interval. The length of interval allows the user to summarize the data at the specified interval length along the entire corridor. Any length of interval can be chosen depending on how specific the desired analysis needs to be. As shown in Figure 4-3, a length of 0.1 miles is the default interval length for the fixed segment analysis. Below the interval input field, the user can specify the number of accidents to be used as a cutoff value for the search. The default for this entry is a zero (0) to satisfy the search requirements and identify all segments on the corridor. With these boxes filled with the essential search parameters, the search is performed by pressing the search button at the bottom of the input screen.

Figure 4-3. Example of a "Fixed Segment Analysis" search performed using the crash database tool.

The "Fixed Segment Analysis" search produces an output table like the one illustrated in Figure 4-4. The table lists each 0.1-mile interval and the corresponding number of crashes that occurred on that interval for the desired years. Overall crash rates (crashes per million VMT) and fatality rates (deaths per hundred million VMT) are also calculated and reported by the crash database using 2004 AADT volumes. As these rates were evaluated, it was determined that the rates calculated by the crash database do not account for multiple years of data. Therefore, it was determined through consultation with UDOT to calculate crash rates independent of the crash database so that average AADT values and multiple years could be included in the calculation. The following section provides a brief description of the calculation of crash rates.

Accident Search Results				
Route: 0186		Milepoint: 5.5 - 7.59		
Interval: 0.1		# of Accidents: 0		
Route	Milepoint Interval	# of Accidents	Accident Rate	Fatality Rate
0186	5.50 - 5.60	6	7.37	0.00
0186	5.60 - 5.70	10	12.26	0.00
0186	5.70 - 5.80	3	3.68	0.00
0186	5.80 - 5.90	5	6.13	0.00
0186	5.90 - 6.00	2	2.45	0.00
0186	6.00 - 6.10	9	11.04	0.00
0186	6.10 - 6.20	4	4.91	0.00
0186	6.20 - 6.30	9	11.04	0.00
0186	6.30 - 6.40	1	1.23	0.00
0186	6.40 - 6.50	6	8.19	0.00
0186	6.50 - 6.60	5	6.83	0.00
0186	6.60 - 6.70	0	0.00	0.00
0186	6.70 - 6.80	3	3.53	0.00
0186	6.80 - 6.90	2	2.35	0.00
0186	6.90 - 7.00	6	7.06	0.00
0186	7.00 - 7.10	9	10.59	0.00
0186	7.10 - 7.20	1	1.18	0.00
0186	7.20 - 7.30	4	4.71	0.00
0186	7.30 - 7.40	2	1.86	93.01
0186	7.40 - 7.50	0	0.00	0.00
0186	7.50 - 7.60	2	1.86	0.00
Total Records: 21				

Figure 4-4. Example table of results from the "Fixed Segment Analysis" search.

4.1.3 Crash Rate Statistics

Rates can be calculated for various highway crash statistics. Typically, rates are calculated for fatalities and for crashes at intersections and over specific segments of roadway. The crash rates for roadway segments, intersections, and fatalities are calculated using Equations 4-1, 4-2, and 4-3, respectively. Crash rates are generally a function of crashes per million or 100 million VMT and crashes per million entering vehicles (MEV).

$$RSEG = \frac{1{,}000{,}000 * A}{365 * T * V * L} \tag{4-1}$$

where: *RSEG* = crash rate for the segment (crashes per million VMT),

A = number of reported crashes for the time period,

T = number of years being analyzed,

V = AADT for the time period, and

L = length of the segment in miles.

$$RINT = \frac{1{,}000{,}000 * A}{365 * T * V} \tag{4-2}$$

where: *RINT* = crash rate for the intersection (crashes per MEV), and

V = the sum of the average daily approach volumes.

$$RFAT = \frac{100{,}000{,}000 * F}{365 * T * V * L} \tag{4-3}$$

where: *RFAT* = fatality rate for the segment (fatalities per 100 million VMT), and

F = number of fatalities for the time period.

The crash rates calculated using equations 4-1 through 4-3 are used for comparison in the before and after analysis of a segment or intersection. For some segments analyzed, AADT volumes are available at regular intervals along the segment. In such cases, the rates are calculated using available AADT data. Furthermore, AADT volumes vary each year. Consequently, the volumes for the specified year under analysis should be used when calculating multiple-year crash rates.

In many instances, AADT volumes vary throughout the analysis segment. In such cases a weighted AADT volume was calculated. Equation 4-4 shows how weighted AADT volumes were calculated for roadway segments that have sections of different AADT volumes. More specific information on the AADT volumes utilized in the analysis is provided in the section that follows.

$$AADT_{wt} = \frac{(AADT_1 * L_1) + (AADT_2 * L_2) + ... + (AADT_n * L_n)}{L_1 + L_2 + ... + L_n} \quad (4\text{-}4)$$

where: $AADT_{wt}$ = weighted AADT for analysis segment,

$AADT_n$ = AADT of each individual section within the analysis segment,

L_n = length of each individual section within the analysis segment, and

n = total number of AADT sections in analysis segment.

4.1.4 Average Annual Daily Traffic Data

AADT data are available on UDOT's website for the years 2000-2004 (UDOT 2005b). From UDOT's home page, the "Inside UDOT" tab is selected followed by the "Internal Groups and Divisions" and then "Planning and Programming." From there, the "Traffic Statistics" link on the left side of the page is selected from the list of "Subtopics." Finally, the "Traffic on Utah Highways" link towards the bottom of the page is selected. Once the AADT volumes for the chosen year are downloaded, the specified state route is found by scrolling down the PDF file. For any given year, "Traffic on Utah Highways" gives AADT volumes for the specified year plus the two years previous. An excerpt from "Traffic on Utah Highways" on UDOT's website is provided in Figure 4-5.

For AADT volumes from years prior to 2000, UDOT has published "Traffic on Utah Highways," that summarizes the data. These publications are readily available with AADT volumes for all years since 1991 with the exception of 1996 and 1997. When these two years are needed for the crash analysis, traffic volumes are calculated by interpolating the data from the previous and following years.

ROUTE NAME	BEG. ACCUM. MILEAGE	END ACCUM. MILEAGE	LOCATION DESCRIPTION	2003	2002	2001
0184	0.00	0.14	NORTH TEMPLE	17,450	17,450	16,350
0184	0.14	0.45	2ND NORTH ST VIA STATE ST	16,600	16,600	15,550
0184	0.45	0.72	MAIN ST VIA 2ND NORTH SLC	23,215	23,215	21,750
0184	0.72	1.94	500 NO VIA COLUMBUS-SR 89 VIA VICTORY	19,845	19,845	18,590
0186	0.00	1.18	BEGIN SR 186 AT JCT I 80	23,541	24,780	26,853
0186	1.18	1.50	2400 WEST STREET	23,541	24,780	26,853
0186	1.50	1.71	2200 WEST STREET	31,255	32,900	35,655
0186	1.71	2.24	JCT FAI 215 VIA NORTH TEMPLE	32,604	34,321	37,185
0186	2.24	3.46	REDWOOD RD VIA NORTH TEMPLE	22,670	23,765	29,185
0186	3.46	4.36	900 WEST ST	25,185	25,185	27,295
0186	4.36	5.10	300 WEST ST VIA NORTH TEMPLE IN SLC	25,950	25,950	28,125
0186	5.10	5.55	400 SOUTH ST VIA 300 WEST	20,830	21,415	23,205
0186	5.55	5.70	MAIN ST VIA 400 SOUTH	22,308	22,308	27,885
0186	5.70	6.60	STATE ST	22,340	22,340	27,925
0186	6.60	6.90	700 EAST VIA 400 SOUTH ST	23,143	20,065	32,375
0186	6.90	7.60	900 EAST VIA 400 SOUTH	22,860	23,273	34,737
0186	7.60	8.05	1300 EAST ST	28,930	29,455	41,085
0186	8.05	8.56	GUARDSMAN WAY VIA 500 SOUTH	28,294	28,725	31,130
0186	8.56	9.09	WASATCH BLVD	33,078	33,078	35,838
0186	9.09	9.45	SUNNYSIDE AVE	45,870	45,715	46,930
0186	9.45	9.76	2100 EAST ST VIA FOOTHILL BLVD	42,450	43,910	47,590
0186	9.76	9.99	FOOTHILL VILLAGE	40,240	40,970	44,400
0186	9.99	12.41	2300 EAST ST-FAI 215	40,538	41,155	41,916

Figure 4-5. Example of AADT volumes from Traffic on Utah Highways.

Once the data has been collected for the analysis segment, graphs and tables are generated to visually display and compare crash statistics. The data from the results table illustrated previously in Figure 4-4 can be copied and pasted into a computer spreadsheet, allowing for the columns and rows of data to maintain their original form. For the "Fixed Segment Analysis," tables are constructed to show the before and after number of crashes and the crash rate for each 0.1-mile segment of roadway. The percent change in the crash rate before and after the installation of access management techniques are also calculated and reported in the table. The tabulated values are plotted as charts that include both the before and after conditions to make comparisons simple.

4.2 Intersection Analysis

In a crash analysis it is also important to evaluate crashes at or near intersections. Crashes at or near intersections can also be analyzed utilizing UDOT's crash database. To begin an intersection crash analysis, the "Intersections" tab is selected from the set of five primary tabs at the top of the webpage. Within the "Intersections" tab there are two options: 1) "State Road Intersections" and 2) "Points of Interest."

4.2.1 State Road Intersections

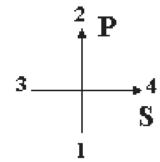
The "State Road Intersections" option allows the user to analyze the crashes at an intersection of two state roads. When analyzing crashes along a primary state route, the user simply inputs the year, route, and milepoints into the proper fields as illustrated in Figure 4-6. The "Radius" field is used in this analysis to set the parameters for the intersection crash search. The radius entered in this box represents the distance, in feet, from the intersection. All crashes within this radius are included in the crash search results. For the analysis performed as part of this thesis, the radius is set to 250 feet. At the bottom of Figure 4-6 is a list of intersection types that can be selected to help narrow the search to only include specific types of intersections. A typical table of search results for the "State Road Intersections" option is illustrated in Figure 4-7.

In Figure 4-7, the total number of intersection crashes for each state road intersection is displayed under the "Total All Legs" heading. As described previously, the rate corresponding to the number of crashes must be calculated by hand. Therefore, crash rates are calculated using the equation for intersection crash rates shown earlier as Equation 4-2. The calculation of crash rates can be easily performed if the lower table of Figure 4-7 is copied into a computer spreadsheet. The column for total crash rate under the "Total All Legs" heading can be altered to calculate the crash rate. As stated previously, when analyzing crashes over multiple years, the AADT volume of each of the study years is used in the equation for calculating crash rates.

Figure 4-6. Example of a "State Road Intersections" search performed using the crash database.

Intersection Analysis	
Criteria:	SELECT all route_intsections WHERE accident data is (Year BETWEEN 1996 AND 1998) AND radius = 500 AND Total Accidents >= 0 AND (Route = 0089) AND (Milepoint BETWEEN 319 AND 326)

Update Radius			
Leg 1:	500	Leg 2:	500
Leg 3:	500	Leg 4:	500
Update Radius			



Primary Route	MP 1	Secondary Route	MP 2	Type	Score	Total All Legs		Fatal All Legs		Primary Route (P)				Secondary Route (S)				Analyze			
										Leg 1		Leg 2		Leg 3		Leg 4					
						#	Rate	#	Rate	#	Rate	#	Rate	#	Rate	#	Rate				
0089	319.38	0266	3.53	Signal	417.2	138	5.88	0		26	4.93	50	9.47	31	4.80	31	4.80	Info	Acc	Veh	Tot
0089	321.14	0171	10.75	Signal	572.3	172	7.75	0		60	11.89	24	4.76	63	10.41	25	4.13	Info	Acc	Veh	Tot
0089	325.04	0269	0.90	Signal	601.6	35	1.54	0		21	4.06	6	1.16	7	1.13	1	0.16	Info	Acc	Veh	Tot
0089	325.19	0269	0.90	Signal	1082.8	53	2.37	0		27	5.44	18	3.63	7	1.13	1	0.16	Info	Acc	Veh	Tot
0089	325.33	0186	5.70	Signal / Trax Xing	2267.7	106	5.87	0		19	3.83	51	10.28	30	7.36	6	1.47	Info	Acc	Veh	Tot

Figure 4-7. Example of a table of results from a "State Road Intersections" search.

To compare before and after crashes, charts and tables are generated to display and compare the crash data at the intersection before and after installation of the access management technique. The percent change in the crash rate before and after the installation of the access management technique is also included in the tables. The total number of crashes and crash rates are plotted as charts to illustrate graphically the change in crashes from before to after. These charts and tables are included in the next chapter as part of the analysis.

The example results illustrated previously in Figure 4-7 also identify both "Primary Routes" and "Secondary Routes" at the intersection. The primary route is the main route being analyzed and the secondary route is each intersecting road along the main route. The total number of crashes is separated for each leg of the intersection according to the primary and secondary routes.

4.2.2 Points of Interest

The "Points of Interest" option allows the user to obtain the number of crashes at any intersection along the primary route where data is available, not just at intersections with other state roads. To proceed with the data search, the input data are entered into the fields as outlined previously for the "State Road Intersections" analysis. For the analysis performed as part of this thesis, the radius is set to 250 feet. The database tool performs a search on all known roadways or "Points of Interest" and produces a summary table as illustrated in Figure 4-8. The information provided in the table includes the milepoint, type of intersection, and description of each intersection along the segment of primary route. For each of these intersections, the number of crashes is shown for each of the two legs of the primary route, as well as the combined number of crashes from these two legs. For the "Points of Interest" analysis, the crashes from the two legs of the intersection on the secondary route are not tallied. Typically in calculating intersection crash rates, Equation 4-2 is used with approach volumes from all four legs of the intersection. Because the "Points of Interest" option only provides crash data from the two legs of the primary route, a note must be made in the analysis that these crash rates are calculated using approach volumes from only two of the four approaches of the intersection.

The total number of crashes for each intersection is displayed under the "Total" heading. The rate corresponding to the number of crashes needs to be recalculated independent of the crash database to account for multiple years of analysis and actual year AADT, as stated earlier. Therefore, crash rates are calculated using the equation for intersection crash rates shown in Equation 4-2. The calculation of crash rates for each intersection is performed by copying the data table of Figure 4-8 into a computer spreadsheet and using Equation 4-2 to calculate the rates for the "Total" rate column.

The crash rates for the intersections are compared using charts and tables that compare the crash data at the intersections before and after installation of the access management techniques. The percent change between the before and after crashes and rates are also included in the tables. The before and after crash rates are plotted as charts to illustrate graphically the change in rates. Tables and charts similar to those described here are included in Chapter 5 as part of the analysis.

Within the "Points of Interest" option there is an additional feature that can be used to assist in the analysis of intersection-related crashes. A checkbox may be selected called "Display as Radius of Influence," as illustrated in Figure 4-9. This option separates the crashes into user defined increments. The length of 50 feet is the default

Points of Interest Analysis

Criteria: SELECT all route_intsections WHERE accident data is (Year BETWEEN 1996 AND 1998) AND radius = 500 AND Total Accidents >= 0 AND (Route = 0186) AND (Milepoint BETWEEN 5.54 AND 7.59)

1 ⟶ 2

Route	Milepoint	Point Description	Type	Score	Total		Fatal		Leg 1		Leg 2		Analyze			
					#	Rate	#	Rate	#	Rate	#	Rate				
0186	5.54	Crossing - Main Street (FR 2148)	Signal / Trax Xing	696.4	25	3.07	0		6	1.47	19	4.67	Info	Acc	Veh	Tot
0186	5.69	Crossing - State Street (SR-89)	Signal	2424.9	36	4.41	0		18	4.41	18	4.41	Info	Acc	Veh	Tot
0186	5.84	Crossing - 200 East (FR 2308)	Signal	615.2	15	1.84	0		1	0.25	14	3.43	Info	Acc	Veh	Tot
0186	5.99	Crossing - 300 East (FR 2264)	Signal	1091.9	24	2.94	0		5	1.23	19	4.66	Info	Acc	Veh	Tot
0186	6.06	Right - Blair Street (340 East)	Stop Sign	1810	33	4.05	0		19	4.66	14	3.43	Info	Acc	Veh	Tot
0186	6.14	Crossing - 400 East	Signal	921.5	19	2.33	0		17	4.17	2	0.49	Info	Acc	Veh	Tot
0186	6.22	Crossing - Denver Street (440 East) - Divided by Trax	Stop Sign	2356.2	30	3.68	0		14	3.43	16	3.92	Info	Acc	Veh	Tot
0186	6.29	Crossing - 500 East (FR 2178)	Signal	1637.6	18	2.21	0		17	4.17	1	0.25	Info	Acc	Veh	Tot
0186	6.44	Crossing - 600 East	Signal	1377.4	18	2.21	0		17	4.17	1	0.25	Info	Acc	Veh	Tot
0186	6.59	Crossing - 700 East (SR-71 Right & FR 2356 Left)	Signal	1645.9	15	2.05	0		13	3.55	2	0.55	Info	Acc	Veh	Tot
0186	6.74	Crossing - 800 East	Signal / Schl Xwalk	542.7	11	1.50	0		3	0.82	8	2.18	Info	Acc	Veh	Tot
0186	6.90	Crossing - 900 East (FR 2180)	Signal / Schl Xwalk	1589.8	26	3.06	0		16	3.77	10	2.35	Info	Acc	Veh	Tot
0186	7.02	Crossing - 1000 East (SR-186 curves Right to 500 South) - Divided by Trax	Stop Sign	658.7	21	2.47	0		14	3.30	7	1.65	Info	Acc	Veh	Tot
0186	7.29	Crossing - 1100 East	Signal	2027.2	15	1.77	1	1.18	8	1.88	7	1.65	Info	Acc	Veh	Tot
0186	7.45	Crossing - 1200 East (Divided by Trax)	Stop Sign	323.4	3	0.35	0		1	0.24	2	0.47	Info	Acc	Veh	Tot
0186	7.52	Crossing - Douglas Street (1250 East) - Divided by Trax	Stop Sign	3210.4	42	4.94	0		2	0.47	40	9.42	Info	Acc	Veh	Tot
0186	7.59	Crossing - 1300 East (SR-181 Right & FR 2076 Left)	Signal	3330.3	43	4.00	0		5	0.93	38	7.07	Info	Acc	Veh	Tot

Figure 4-8. Example table of intersection crashes produced using the "Points of Interest" option.

setting for this analysis. This setting can be changed by the user to different length increments in the "Radius of Influence" field just below the checkbox.

The resulting table from the "Display as Radius of Influence" option is illustrated in Figure 4-10. The crashes are tabulated cumulatively as the radius of influence increases across the top of the table. This option is used to analyze the crashes near an intersection and to aid the analyst in determining the radius of influence where the crashes are most likely occurring for an intersection.

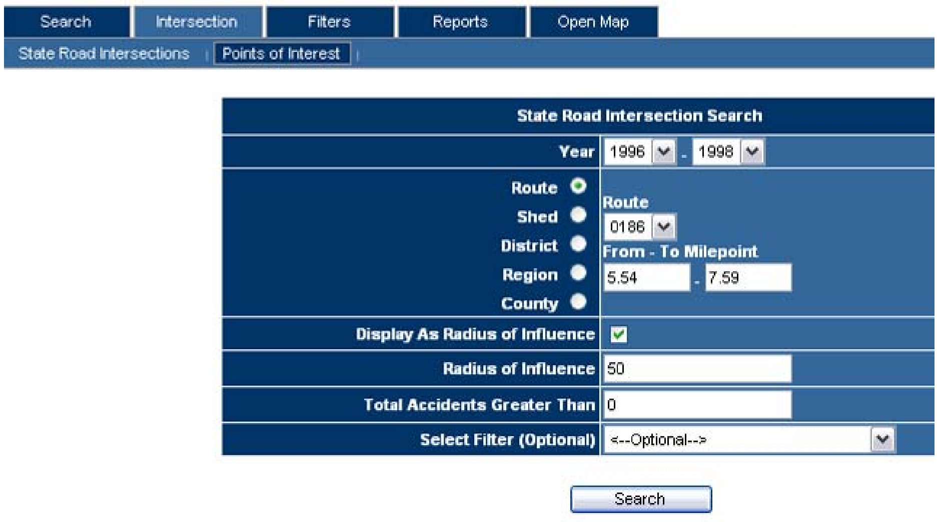


Figure 4-9. Example of a points of interest "Radius of Influence" intersection search performed using the crash database.

Radius of Influence Intersection Analysis

Criteria: SELECT all route_intsections WHERE accident data is (Year BETWEEN 1996 AND 1998) AND Radius Interval = 50 AND Total Accidents >= 0 AND (Route = 0186) AND (Milepoint BETWEEN 5.54 AND 7.69)

Route	Milepoint	50	100	150	200	250	300	350	400	450	500
0186	5.54	1	5	8	8	8	9	10	15	19	25
0186	5.69	3	15	19	19	21	25	31	34	36	36
0186	5.84	0	4	11	12	12	12	12	13	14	15
0186	5.99	2	16	16	16	16	16	20	21	24	24
0186	6.06	0	5	5	5	5	5	19	23	33	33
0186	6.14	10	12	12	12	12	13	13	16	16	19
0186	6.224	0	1	1	3	16	17	18	18	28	30
0186	6.29	1	2	15	16	16	17	17	17	18	18
0186	6.44	2	4	6	16	17	18	18	18	18	18
0186	6.59	0	0	0	12	14	14	15	15	15	15
0186	6.74	2	7	10	10	10	10	10	10	10	11
0186	6.9	14	18	19	19	21	22	22	22	26	26
0186	7.02	3	9	13	14	19	19	19	19	21	21
0186	7.29	0	5	5	6	7	8	9	13	14	15
0186	7.45	0	0	0	1	1	1	2	2	2	3
0186	7.523	0	1	1	1	3	3	3	6	40	42
0186	7.59	3	37	40	40	40	40	40	40	41	43
0186	7.68	2	2	2	2	2	2	2	4	39	42

Figure 4-10. Example of a table of intersection crashes produced by the "Display as Radius of Influence" option.

The types of intersections that are included in this crash analysis can be modified at the bottom of the field input page illustrated previously in Figure 4-6. By default, all intersection types are selected.

4.3 Collision Type Analysis

Crash analysis is also performed to quantify the effects of access management techniques on types of collisions. UDOT's crash database can be used to dissect this type of crash information for a specific corridor. In this section, the procedure is described for performing an analysis on collision types for segments and intersections.

4.3.1 Collision Type Analysis for Segments

The types of collisions for crashes on specific segments of roadway corridors can be evaluated from UDOT's crash database using filters to sort the crash data. To begin the collision type analysis, a filter needs to be created in the crash database. From the main page of UDOT's crash database, the "Filters" tab is selected, followed by the "Create a Filter" option. From the page that appears, "Route_Num" and "Milepoint" are double-clicked from the list of fields in the box on the left. Next, the "Build Search" button is selected, as illustrated in Figure 4-11. In the new page that appears, the filter is named and the filter type is left at "User Level." As an example, this filter will be referred to as "State Route A." On the same page, under the filter criteria heading, the years, state route, and milepoints being analyzed are chosen.

On the main page of the UDOT crash database, the "Search" tab is chosen followed by the "Advanced Search" option. In the new page that appears, "Collision Type" is double-clicked from the box on the left and the "Build Search" button is selected. From the page that appears, both the year and the collision type that are desired for the analysis are selected. Then the "State Route A" filter that was created previously is selected from the list at the bottom of this page, and the search is performed as

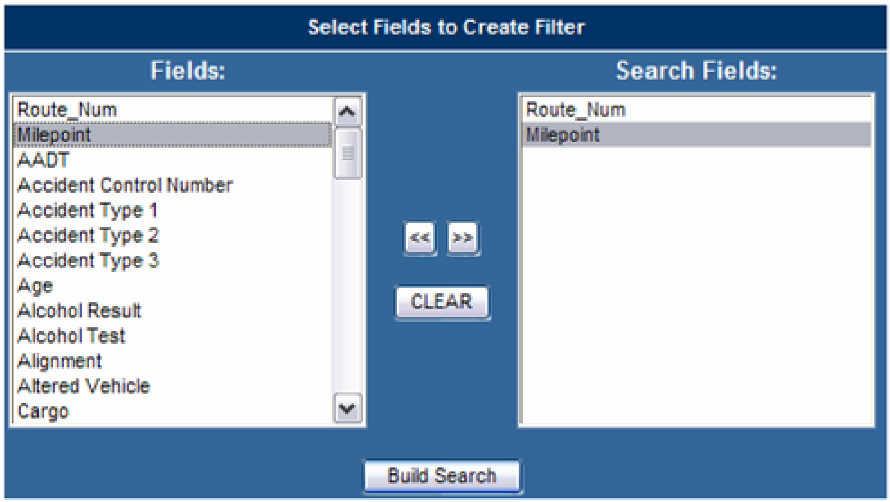


Figure 4-11. Example of creating a filter in UDOT's crash database.

illustrated in Figure 4-12. A new table appears that lists all the crashes that meet the criteria of state route, milepoints, year, and type of collision specified. As illustrated in Figure 4-13, a total count of the crashes is tabulated at the bottom of the table. This number can be compared with all the other collision type values for the corridor. In the crash database, each collision type is broken down very specifically; therefore many of the possible collision types can be combined for analysis purposes. For example, a search can be performed to tabulate the number of rear end crashes. However, there are three collision types in the list that are considered rear end crashes. Thus, all three are needed to tally a number for total rear end crashes.

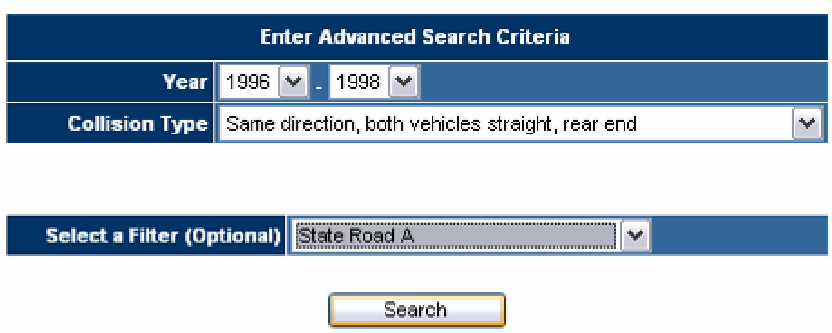


Figure 4-12. Example of a "Collision Type" search.

1998	0186	11.03	2	Info
1998	0186	11.06	2	Info
1996	0186	11.07	2	Info
1998	0186	11.28	3	Info
1996	0186	11.32	4	Info
1998	0186	11.37	2	Info
1998	0186	11.45	2	Info
1998	0186	11.48	2	Info
1997	0186	11.49	2	Info
1997	0186	11.53	2	Info
1996	0186	11.54	2	Info
1997	0186	11.58	2	Info
1998	0186	11.58	4	Info
1998	0186	11.65	2	Info
1998	0186	11.68	2	Info
1997	0186	11.73	3	Info
1998	0186	11.75	2	Info
1997	0186	11.95	2	Info
1998	0186	11.95	3	Info
1997	0186	11.95	2	Info
1997	0186	11.96	2	Info
				Total Accidents: 357

Figure 4-13. Example of a table that tallies specified collision types.

The most common types of collisions are compiled for both the before and after conditions. The collision types that are desired for the analysis include head-on collisions, rear-end crashes, right-angle crashes, sideswipes, and single vehicle crashes. These collision types can be calculated as percentages of total crashes. The before and after percentages can then be plotted in a chart to compare how collision types have changed. Charts that show collision type comparisons for before and after are included in the Chapter 5 as part of the analysis.

4.3.2 Collision Type Analysis for Intersections

The collision types for crashes at or near intersections can also be determined from UDOT's crash website. Once again, the "Intersections" tab is selected from the main page of the UDOT crash database, followed by the "Points of Interest" option. From this point, the user can select appropriate fields with the specified input criteria. With the radius at 500 feet (or some other user defined radius) the search can be performed. For the analysis performed as part of this thesis, the radius was set to 250 feet. The results table is produced similarly to that outlined previously in Figure 4-8. In this table, the "Info" option under the "Analyze" heading is selected. A summary table is produced, as shown in Figure 4-14, that lists each individual crash within the user defined radius of the intersection.

Accident Search Results

Criteria: SELECT accident_id FROM mainAccident WHERE Year BETWEEN '1996' AND '1998' AND (route_num='0186' AND milepoint between 5.46 AND 5.62)

Year	Route	Milepoint	Vehicles	
1996	0186	5.47	2	Info
1996	0186	5.47	2	Info
1998	0186	5.47	2	Info
1997	0186	5.48	2	Info
1997	0186	5.54	3	Info
1996	0186	5.55	2	Info
1996	0186	5.55	2	Info
1996	0186	5.55	3	Info
1996	0186	5.55	1	Info
1996	0186	5.56	1	Info
1998	0186	5.56	2	Info
1997	0186	5.56	1	Info
1996	0186	5.59	1	Info
1996	0186	5.61	2	Info
1996	0186	5.61	2	Info

Total Accidents: 1[illegible]

Figure 4-14. Example of a results table using the "Info" option within the "Points of Interest" table.

Because the table in Figure 4-14 lists the milepoint where each crash occurred, the range of milepoints is noted by the user. This table can be closed and the "Info" option for the next intersection of the "Points of Interest" table is selected. Another table similar to Figure 4-14 appears that shows the range of milepoints for the crashes at the next intersection. The new range of milepoints can be examined to determine if they overlap with the milepoints from crashes at the previous intersection. If the crashes overlap, a trial-and-error technique can be performed by changing the "Radius" field on the "Intersections" input page until each intersection considers only its own related crashes and not those of the upstream or downstream intersection.

Once the proper intersection radius is determined, the analysis continues. The final column of the "Points of Interest" intersection search illustrated previously in Figure 4-8 identifies several options under the "Analyze" heading. The "Tot" option is quite helpful for crash analysis as it creates tables for the specified intersection that list the number of crashes in which specific crash characteristics occurred. A sample table of the collision types is illustrated in Figure 4-15. This figure displays the number of crashes that occurred for each collision type and the corresponding percentages. The total crashes are shown as well as crashes separated by leg of intersection. The "Tot" option must be selected for each intersection that is desired to be included in the analysis. These crash numbers for each collision type may be tallied or copied to a computer spreadsheet for further analysis.

Analyzed Item: Collision Type	Leg 1	%	Leg 2	%	Total	%
Opposite directions, one vehicle straight, one vehicle turning left	0	0.0	2	100.0	2	9.5
Same direction, both vehicles straight, rear end	1	16.7	5	83.3	6	28.6
Opposite directions, both straight, side swipe	1	100.0	0	0.0	1	4.8
Same direction, both straight, side swipe	1	100.0	0	0.0	1	4.8
Same directio, one vehicle straight, one turning right	0	0.0	1	100.0	1	4.8
One vehicle straight, one coming from right, turning right	0	0.0	1	100.0	1	4.8
One vehicle straight, one coming from right, turning left	0	0.0	2	100.0	2	9.5
Single vehicle	0	0.0	6	100.0	6	28.6
One vehicle straight, one vehicle making U-turn	1	100.0	0	0.0	1	4.8
	0	0.0	0	0.0	0	0.0
	4	**19.0**	**17**	**81.0**	**21**	

Figure 4-15. Sample table showing collision types for a specific intersection.

The collision type data obtained from the crash database using the "Points of Interest" intersection search only provides crash numbers from the legs of the intersection on the major road being analyzed. Any crashes that occurred on the legs of the intersection on the minor intersecting road are not included in the intersection collision type tally.

Once the numbers of crashes for each collision type are compiled for the desired sequence of intersections, the number of crashes before and after installation of the access management treatment can be compared. These before and after values and their corresponding percent changes can be tabulated and plotted to provide a graphical representation of the results.

4.4 Crash Severity Analysis

Crash analysis is also performed to quantify the effects of access management techniques on severity of crashes. UDOT's crash database can be used to provide this crash data for both segments and intersections as outlined in the following sections.

It should be noted that the crash database data for fatalities show the number of crashes in which fatalities occurred, rather than the actual number of fatalities. For this reason, the reader must interpret the fatality data cautiously.

4.4.1 Crash Severity Analysis for Segments

The analysis of crash severity for segments is performed in a similar manner to the analysis of collision types discussed previously in Section 4.3.1. The types of crash severity for segments of highways can be determined from UDOT's crash database. A filter is developed for the specified route and milepoint as was illustrated previously with the "State Route A" filter. After the filter is developed, an advanced search is executed to produce crash severity data using the filter. The "Advanced Search" option is selected, and in the new page that appears, "Severity" is double-clicked from the box on the left and the "Build Search" button is selected. From the page that appears, both the year and the severity that are desired for the analysis are selected. The "State Route A" filter that was created previously is then selected from the list at the bottom of this page, and the search is performed as illustrated in Figure 4-16. A results table appears that lists all the crashes that meet the criteria of state route, milepoints, year, and severity type specified.

In the crash database, there are only five possible types of crash severity. A total count of the crashes is tabulated at the bottom of the results table. This number can be compared with all the other values for crash severity types for the corridor. These numbers and percentage changes are compiled in order to develop the charts and tables that visually display the information. Charts and tables for this analysis are included in Chapter 5 as part of the analysis.

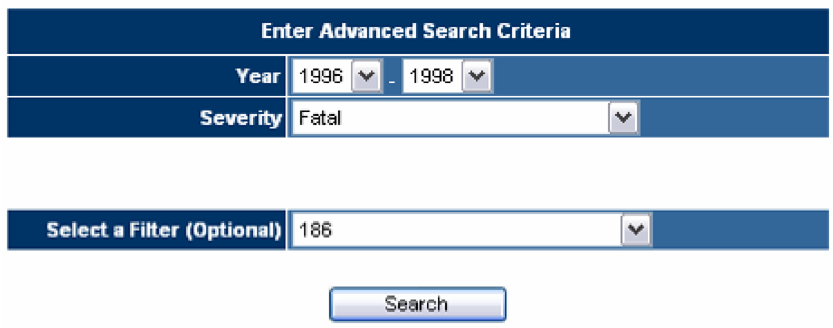


Figure 4-16. Example of a crash "Severity" search.

4.4.2 Crash Severity Analysis for Intersections

Crash severity for intersections is analyzed in a similar manner as collision types discussed previously in Section 4.3.2. The severity of crashes at or near intersections is determined from UDOT's crash database. Once again, the "Points of Interest" option is used to develop a list of crashes within a certain radius. From this point, the user can select appropriate fields with the specified input criteria. With the radius at 500 feet (or some other user defined radius) the search is performed. For the analysis performed as part of this thesis, the radius was set to 250 feet. The results table is produced similarly to that outlined previously in Figure 4-8. In this table, the "Info" option under the "Analyze" heading is selected. A summary table is produced, as illustrated previously in Figure 4-14, that lists each individual crash within the specified radius of the intersection. If this radius causes the crashes at adjacent intersections to be overlapping, or doublecounted, then a trial-and-error method is needed to determine an appropriate radius that will only consider the crashes related to one single intersection.

Once the proper intersection radius is determined, the analysis continues. With the proper information in the fields for the "Intersections" main page including the appropriate radius, the search is performed to bring up the "Points of Interest" page once again. For each intersection, the "Tot" option under the "Analyze" heading is selected as described and illustrated previously in Figure 4-8. This option creates tables for several key characteristics of crashes including "Severity." The "Severity" table lists the numbers of crashes in which each crash severity occurred, as illustrated in Figure 4-17. The "Tot" option must be selected for each intersection that is desired to be included in the analysis. These crash numbers for each crash severity may be tallied or copied to a computer spreadsheet for further analysis. Once again, the crash numbers are only from the legs of the intersection on the major road being analyzed.

Once the numbers of crashes for each crash severity are compiled for the desired sequence of intersections, the number of crashes before and after installation of the access management technique can be compared. These before and after values and their corresponding percent changes can be tabulated and plotted to provide a graphical representation of the results.

Analyzed Item: Severity

	Leg 1	%	Leg 2	%	Total	%
No Injury	4	44.4	5	55.6	9	36.0
Possible Injury	1	16.7	5	83.3	6	24.0
Bruises And Abrasions	0	0.0	8	100.0	8	32.0
Broken bones or bleeding wounds	1	50.0	1	50.0	2	8.0
	6	**24.0**	**19**	**76.0**	**25**	

Figure 4-17. Sample table showing crash severities for a specific intersection.

4.5 Analysis Procedure Summary

In order to estimate the safety impacts of access management techniques, a set procedure was outlined in this chapter for the analysis of specific corridors. This way, each corridor is analyzed in a consistent manner and the results can be easily compared. Using UDOT's crash database, several types of analysis can be performed. The procedure set forth in this chapter is used in Chapter 5 to analyze the corridors that have been selected and described in Chapter 3.

5 RESULTS

The set procedure for analyzing corridors described in Chapter 4 is followed in this chapter for the analysis of the predetermined corridors. Analysis details as well as results for the analysis sites and control sites are provided. The analysis results for each corridor include crash data, number of access points, and AADT volume data. The safety impacts of access management techniques such as raised medians and driveway consolidation can be estimated from the data in this chapter.

In this chapter results are summarized for both those sites where access management techniques have been implemented as well as for control sites. Prior to this discussion a summary of analysis details is provided, while following the presentation of results a summary of the results is presented.

5.1 Analysis Details

One of the metrics presented for each analysis location is a chart summarizing the collision types by percent of total crashes on each roadway segment. Because the crash database lists each collision type very specifically, many collision types were grouped together in the analysis to simplify the reporting process. The five resulting categories are rear end, right angle, sideswipe, head on, and single vehicle crashes. The specific collision types from the crash database and the categories that were grouped for the purposes of this analysis are summarized in Table 5-1.

It is a relatively well known fact that traffic crashes can cause many problems and bear a substantial cost for those involved and for society as a whole. In this analysis, a table was created for each analysis corridor summarizing the cost of crashes for the roadway segment. UDOT has assigned a dollar value to crashes depending on their severity. Table 5-2 shows the cost per crash for five different levels of severity as provided by the Systems Planning and Programming Division. It should be noted that constant dollars are used for all analyses. No reductions were made to the costs for year as the difference was assumed to be negligible.

Table 5-1. Categories of the Collision Types from the Crash Database

Category	Collision Type in Crash Database
Rear End	Same direction, both vehicles straight, rear end
	Same direction, one vehicle straight, one turning right, rear end
	Same direction, one vehicle straight, one turning left, rear end
Right Angle	Opposite directions, one vehicle straight, one vehicle turning left
	Both vehicles straight, approaching at an angle
	One vehicle straight, one coming from right, turning right
	One vehicle straight, one coming from left, turning left
	One vehicle straight, one coming from right, turning left
	Opposite directions, both vehicles turning left
	Approaching at an angle, both vehicles turning left
	Opposite directions, one turning left, one turning right
Sideswipe	Opposite directions, both straight, side swipe
	Same direction, both straight, side swipe
Head On	Opposite directions, both vehicles straight, head on
Single Vehicle	Single Vehicle

Table 5-2. Costs per Crash for Various Severities as Assigned by UDOT

Severity Description	Cost per Crash
Property Damage/No Injury	$4,500
Possible Injury	$25,000
Bruises and Abrasions	$48,000
Broken Bones or Bleeding Wounds	$228,000
Fatal	$2,720,000

As part of the cost analysis, the raised median installation costs were also estimated for each analysis location. UDOT's Systems Planning and Programming

Division compiled a Community Transportation Plan for 2005 that estimated the construction cost for a raised median. The cost for one direction of a raised median curb was reported as approximately $15 per linear foot. The cost for the median fill material was reported as approximately $5 per square foot. Assuming a 14-foot wide median and a curb for both directions, the cost of a raised median was assumed to be approximately $100 per linear foot. This value was multiplied by the length of the raised median segment to calculate an estimated construction cost. Because the raised median discontinues at intersections and other median openings, a factor of 0.9 was multiplied by the cost to represent the total cost of the raised median installation. For the analysis, this total cost was compared with the reduction in cost of crashes per year. Finally, the savings due to the reduction in crash costs were used to calculate how long after construction the cost of the raised median was recouped.

5.2 Analysis for Locations of Access Management Techniques

The safety impacts of the locations that have been chosen for analysis where access management techniques have been installed are discussed in this section. The techniques that have been implemented at these locations consist exclusively of raised median installations as defined previously in Chapter 3. Other details about these locations were also outlined and discussed in Chapter 3. In addition to the raised median installation, however, driveway density data were also collected, indicating some locations where driveway consolidation has occurred.

The locations of the access management techniques selected for the study are:

1. University Parkway (SR 265) − Milepoint 1.20 to 1.96.
2. Alpine Highway (SR 74) − Milepoint 2.40 to 4.29.
3. State Street (SR 89) − Milepoint 311.41 to 311.9.
4. 400/500 South (SR 186) − Milepoint 5.54 to 7.59.
5. 300 West (SR 89) − Milepoint 326.68 to 326.97.
6. Redwood Road (SR 68) − Milepoint 50.75 to 51.47.

Maps that show the locations of these corridors are found in Chapter 3. The following sections summarize the crash analysis results for each corridor where access management techniques were installed. Appendix A contains a summary of the raw crash numbers for all the analysis locations. The raw data were obtained from the UDOT crash database.

5.2.1 University Parkway (SR 265)

In 2002, a raised median was installed on University Parkway in Orem between 400 West and 200 East. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1999 to 2001 and the after period is from 2003 to 2004. Table 5-3 summarizes the before and after crashes on University Parkway including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-1 displays the crash rates at one-tenth-mile intervals for this segment of University Parkway. Figure 5-2 displays the intersection crash rate for all signalized intersections along the segment. Figure 5-3 illustrates the collision types on University Parkway by percentage of total crashes. Figure 5-4 shows the severity of crashes on University Parkway by percentage of total crashes. Finally, Table 5-4 shows the cost of crashes per severity type and the total cost of crashes on University Parkway for both the before and after periods.

As shown in Table 5-3, the crash rate for this segment of University Parkway increased after installation of the raised median. The crash rate increased from 6.37 to 9.13, a change of 43 percent. The fatality rate, however, was reduced from 4.75 to 0.00. The number of access points per mile was reduced by 22 percent, from 23.4 to 18.2. The average AADT for the segment increased from 34,978 to 37,985, an increase of 9 percent. This corridor is an area of rapid growth and a hot-spot for retail development. These factors contribute to worsening levels of service throughout this segment and at the signalized intersections, which may be causing crash rates to increase.

Table 5-3. Crash Data and Access Point Density for University Parkway

	Before (1999-2001)	**After (2003-2004)**
Crashes Per Year	62.7	97.5
Crash Rate (Crashes/MVMT[1])	6.37	9.13
Fatality Rate (Fatalities/100 MVMT[1])	4.75	0.00
Access Points	18	14
Length of Section (mi.)	0.77	0.77
Access Points per Mile	23.4	18.2
AADT[2]	34,978	37,985

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

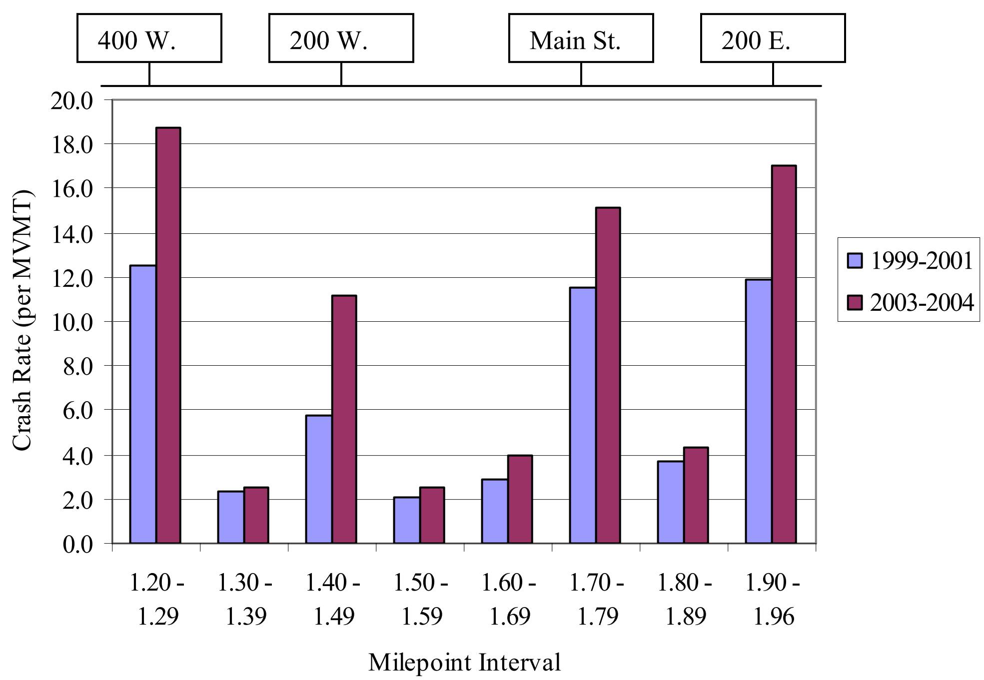


Figure 5-1. Crash rates for one-tenth-mile intervals of University Parkway.

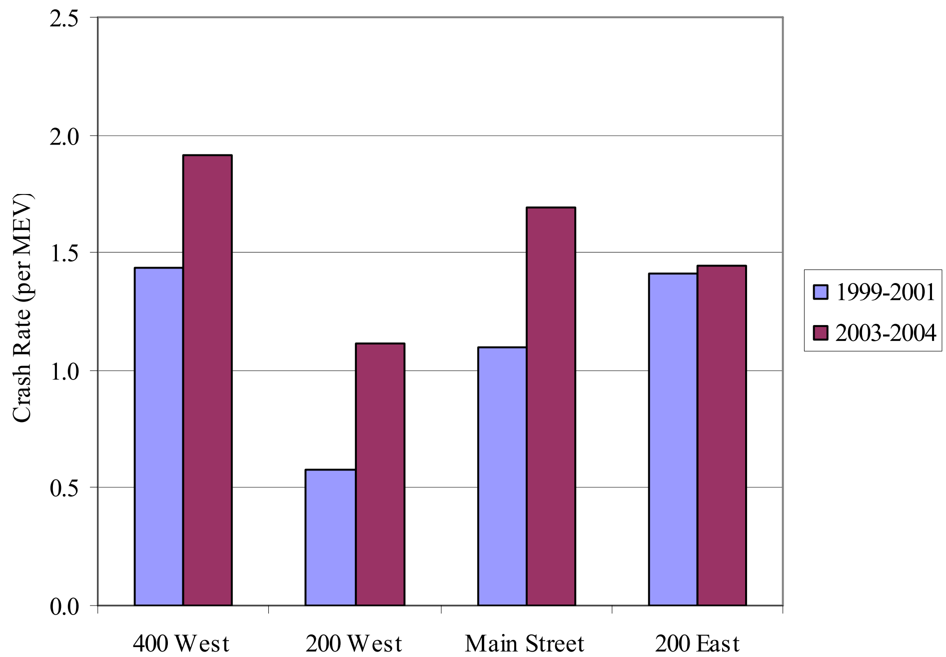


Figure 5-2. Intersection crash rates on University Parkway.

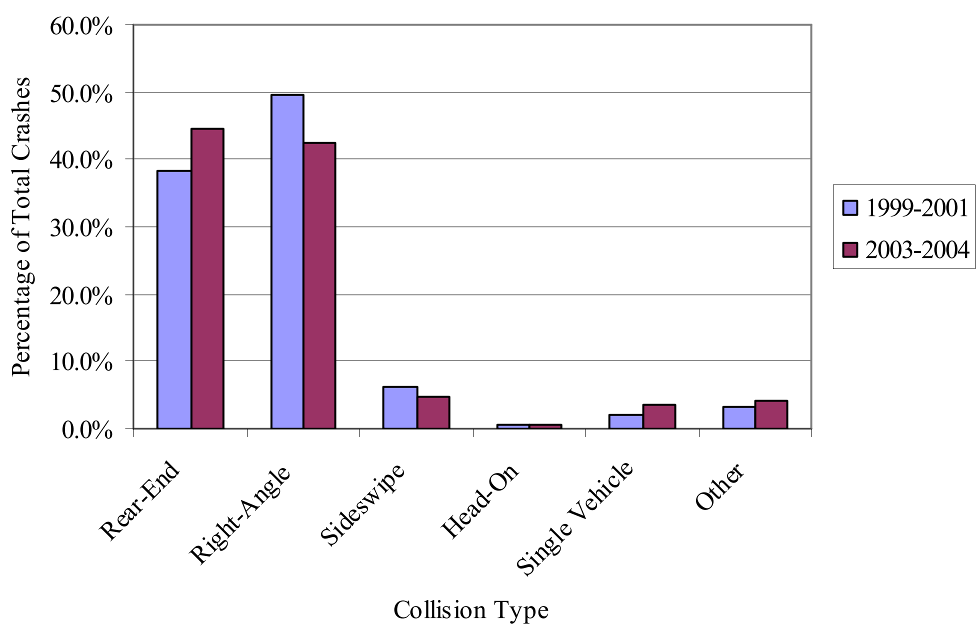


Figure 5-3. Collision types on University Parkway by percentage of total crashes.

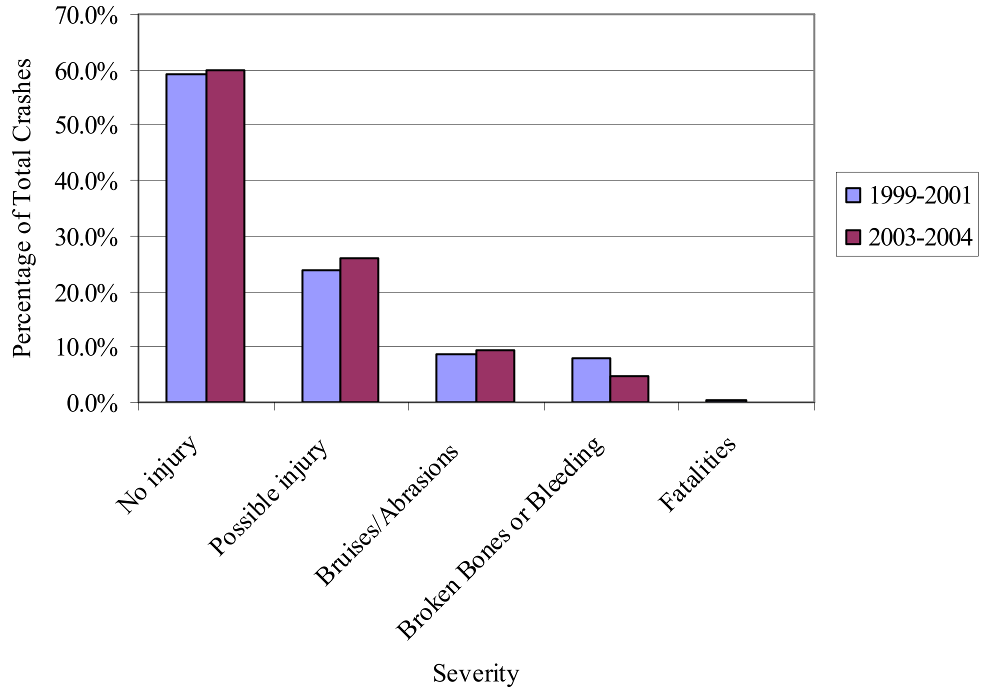


Figure 5-4. Severity of crashes on University Parkway by percentage of total crashes.

Table 5-4. Cost of Crashes on University Parkway

Crash Severity	Before (1999-2001)	After (2003-2004)
No injury	$499,500	$526,500
Possible injury	$1,125,000	$1,275,000
Bruises/Abrasions	$768,000	$864,000
Broken Bones or Bleeding Wounds	$3,420,000	$2,052,000
Fatalities	$2,720,000	$0
Total Cost of Crashes	$8,532,500	$4,717,500
Cost of Crashes Per Year	$2,844,167	$2,358,750

Figure 5-1 shows that crash rates increased at every one-tenth-mile interval along the segment. Figure 5-2 illustrates that intersection crash rates increased at every signalized intersection. Increases in crash rates at the signalized intersections may be caused by the fact that the raised medians force all left-turn movements to the signalized intersections.

Figure 5-3 indicates that rear-end and single vehicle crashes as percentages of total crashes both increased; the rear-end crashes increased from 38 percent to 45 percent of total crashes, and the single vehicle crashes increased from 2 percent to 4 percent of total crashes. An increase in rear-end crashes may be attributed to the turn pockets at intersections having insufficient storage length and causing left-turn vehicles to spill out into through lanes. Another potential cause of the increased rear-end crashes is the increase in left-turns and U-turns being made at intersections. The increase in single vehicle crashes may be attributable to the raised median being a new obstacle in the roadway that is easily struck by inattentive drivers.

The other categories of collision types in Figure 5-3, namely right-angle, sideswipe, and head-on crashes, were either unchanged or decreased as percentages of total crashes. Before the raised medians were installed, 50 percent of all the crashes were right-angle crashes. After, however, right-angle crashes made up only 43 percent of all crashes and were no longer the most common type of collision on this segment of University Parkway. Sideswipe crashes decreased from 6 percent to 5 percent of total crashes. Head-on crashes remained unchanged at 0.5 percent.

It is anticipated that right-angle crashes may have decreased due to the reduction in left turns created by the raised medians. Sideswipe crashes may have been reduced in this case because the raised median provides a physical barrier that prevents sideswipes from occurring between vehicles traveling in opposite directions. Head-on crashes are also typically prevented by the physical barrier that the raised median provides.

Figure 5-4 illustrates that the no injury, possible injury, and bruises/abrasions crashes all increased slightly as percentages of total crashes as follows: the no injury crashes increased from 59 percent to 60 percent of total crashes; the possible injury crashes increased from 24 percent to 26 percent of total crashes; and the bruises/abrasions crashes increased from 8 percent to 9 percent of total crashes.

The broken bones/bleeding and fatalities crashes both decreased as percentages of total crashes. The broken bones/bleeding crashes decreased from 8 percent to 5 percent of total crashes. The fatalities crashes were reduced from one-half percent to 0 percent.

These findings reflect the decreases in the more serious collision types. For example, right-angle and head-on crashes typically result in more severe crashes than do rear-end crashes. Since the percentage of right-angle crashes decreased on University Parkway, it is logical that the percentage of more severe crashes decreased as well.

Table 5-4 illustrates that the total cost of crashes per year decreased. The more severe crashes are much more costly than the less severe crashes. Since the more severe crashes decreased between the before and after periods, the total cost of crashes per year decreased by 17 percent.

The method discussed previously was used to compare the reduction in cost of crashes to the construction cost associated with installing a raised median. The cost to construct the raised median on University Parkway was estimated to be approximately $360,000. The reduction in cost of crashes as a result of the raised median was approximately $485,000 per year. As a result, the crash cost savings achieved by the raised median made up the cost of construction in less than nine months.

5.2.2 Alpine Highway (SR 74)

In 2002, a raised median was installed on the Alpine Highway in Highland between Hidden Drive and 11300 North. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1999 to 2001 and the after period is from 2003 to 2004. Table 5-5 summarizes the before and after crashes on the Alpine Highway including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-5 displays the crash rates at one-tenth-mile intervals for this segment of the Alpine Highway. Figure 5-6 illustrates the intersection crash rate for all signalized intersections along the segment. Figure 5-7 illustrates the collision types on the Alpine Highway by percentage of total crashes. Figure 5-8 displays the severity of crashes on the Alpine Highway by percentage of total crashes. Finally, Table 5-6 shows the cost of crashes per severity type and the total cost of crashes on the Alpine Highway for both the before and after periods.

Table 5-5. Crash Data and Access Point Density for the Alpine Highway

	Before (1999-2001)	**After (2003-2004)**
Crashes Per Year	16.7	13.5
Crash Rate (Crashes/MVMT[1])	1.76	1.46
Fatality Rate (Fatalities/100 MVMT[1])	0.00	0.00
Access Points	17	17
Length of Section (mi.)	1.90	1.90
Access Points per Mile	8.9	8.9
AADT[2]	13,653	13,317

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

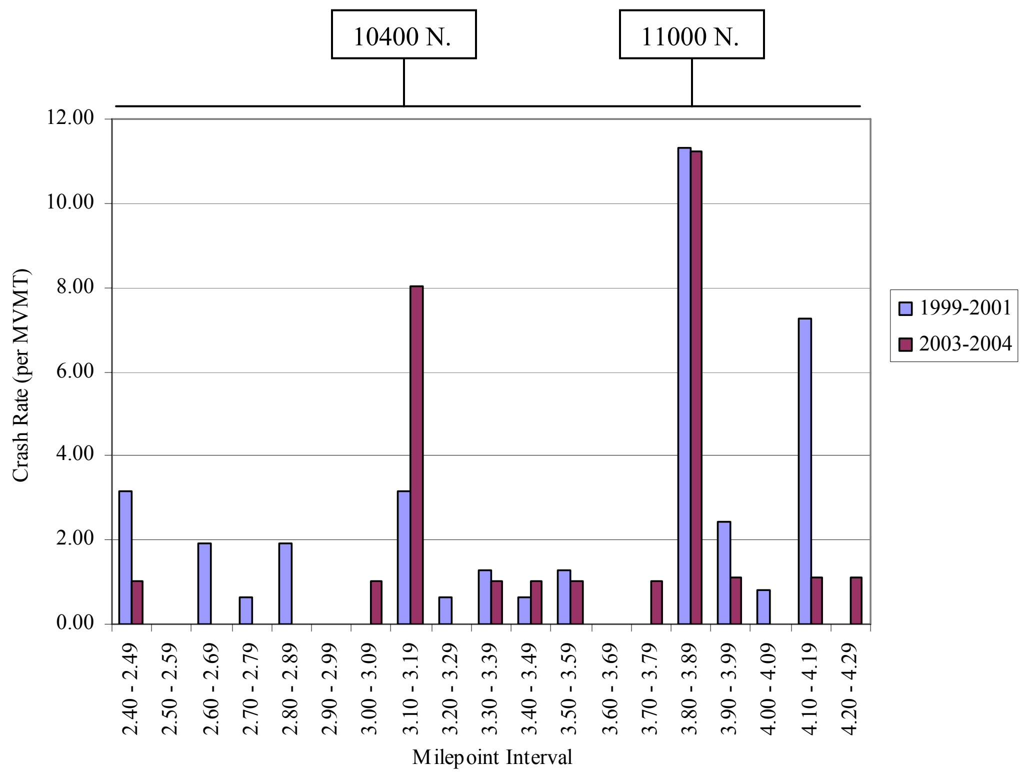


Figure 5-5. Crash rates for one-tenth-mile intervals of the Alpine Highway.

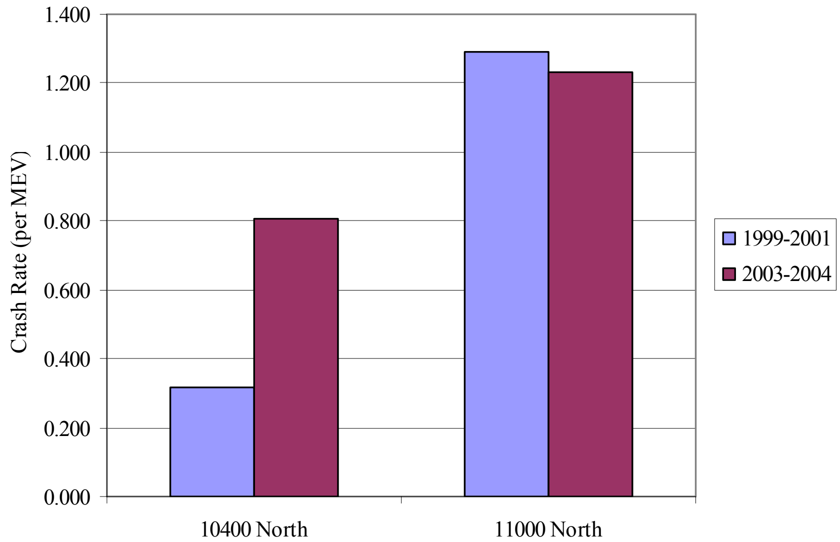


Figure 5-6. Intersection crash rates on the Alpine Highway.

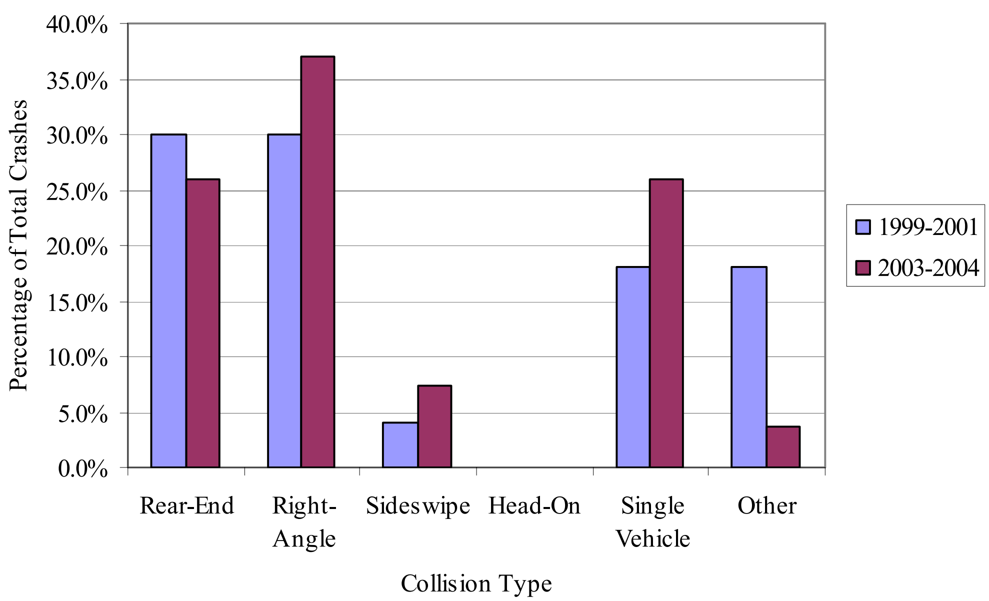


Figure 5-7. Collision types on the Alpine Highway by percentage of total crashes.

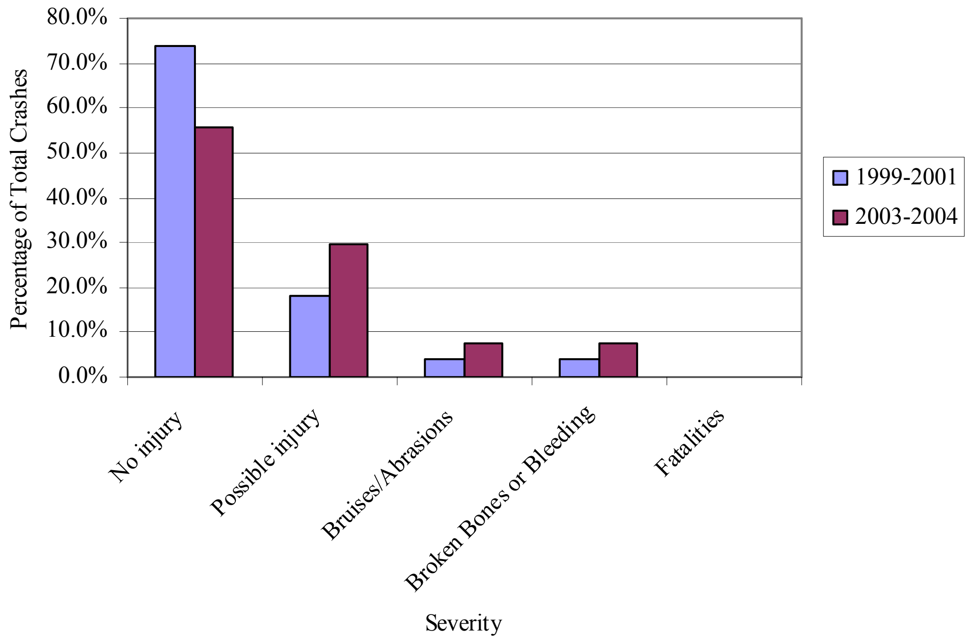


Figure 5-8. Severity of crashes on the Alpine Highway by percentage of total crashes.

Table 5-6. Cost of Crashes on the Alpine Highway

Crash Severity	**Before (1999-2001)**	**After (2003-2004)**
No injury	$166,500	$67,500
Possible injury	$225,000	$200,000
Bruises/Abrasions	$96,000	$96,000
Broken Bones or Bleeding Wounds	$456,000	$456,000
Fatalities	$0	$0
Total Cost of Crashes	$943,500	$819,500
Cost of Crashes Per Year	$314,500	$409,750

As shown in Table 5-5, the crash rate for this segment of the Alpine Highway decreased after installation of the raised median. The crash rate decreased from 1.76 to 1.46, a change of 17 percent. The fatality rate remained unchanged at 0.00 as there were no fatalities in either time period. The number of access points per mile also remained unchanged at 8.9. The average AADT for the segment decreased slightly from 13,653 to 13,317, a decrease of 2 percent.

Figure 5-5 shows that crash rates increased at some one-tenth-mile intervals and decreased at other one-tenth-mile intervals along the segment. Figure 5-6 illustrates that the intersection crash rate increased at the intersection of 10400 North by 154 percent. The dramatic increase in crash rate at this intersection may be due to the fact that a traffic signal was installed in 2002 as part of the raised median installation. Traffic signals typically bring added traffic volumes and may increase the likelihood of crashes. The intersection crash rate at the intersection of 11000 North decreased by 5 percent. It is difficult to determine how much the raised median affects crash rates at this intersection because the raise medians are discontinued within approximately 200 feet of the intersection to allow vehicles to access retail developments on the corners.

Figure 5-7 indicates that right-angle, sideswipe, and single vehicle crashes as percentages of total crashes all increased as follows: the right-angle crashes increased from 30 percent to 37 percent of total crashes; the sideswipe crashes increased from 4 percent to 7 percent of total crashes; and the single vehicle crashes increased from 18 percent to 26 percent of total crashes. An increase in right-angle crashes may be attributed to the new traffic signal that was installed at the intersection of 10400 North. The signalized intersection attracts more cross traffic and introduces the problems related to red-light running. It is difficult to explain the reason for the increase in sideswipe crashes. The increase in single vehicle crashes may be attributable to the raised median being a new obstacle in the roadway that is easily struck by inattentive drivers.

The other categories of collision types in Figure 5-7, rear-end and head-on crashes, were either unchanged or decreased as percentages of total crashes. Rear-end crashes decreased from 30 percent to 26 percent of total crashes. Head-on crashes remained unchanged at 0 percent of total crashes. Once again, it is difficult to explain the reason for the decrease in rear-end crashes.

Figure 5-8 illustrates that the possible injury, bruises/abrasions, and broken bones/bleeding crashes all increased as percentages of total crashes as follows: the possible injury crashes increased from 18 to 30 percent of total crashes; the bruises/abrasions crashes increased from 4 percent to 7 percent of total crashes; and the broken bones/bleeding crashes also increased from 4 percent to 7 percent of total crashes.

The no injury crashes decreased as a percentage of total crashes. The fatalities crashes remained unchanged at 0 percent. These findings reflect the fact that there are increases in the more serious collision types, such as right-angle crashes. It is difficult to explain, however, the reason why the raised medians might produce such results. One factor to consider is that this corridor has the lowest traffic volumes out of all of the analysis locations. In addition, most of the length of the segment is located in a residential area rather than a locale of heavy commercial development. Raised medians may not be as effective for areas of low traffic volumes and/or for areas of mostly residential development.

Table 5-6 illustrates that the total cost of crashes per year increased. The more severe crashes are much more costly than the less severe crashes. Since the more severe crashes increased between the before and after periods, the total cost of crashes per year increased by 23 percent.

The cost associated with installing a raised median was compared with the reduction in cost of crashes. The cost to construct the raised median on the Alpine Highway was estimated to be approximately $900,000. Since the cost of crashes per year increased by about $95,000 after the raised median was installed, the raised median installation did not result in cost savings. This analysis site was the only location where the cost of installing the raised median was not recouped by a reduction in cost of crashes.

This is the only analysis location where a raised median was installed on a corridor that traverses primarily through a residential area. Since the collision types and severity became more serious after the raised medians were installed, and the cost of crashes increased, it may be concluded that raised medians may not be as effective on roadways that are in primarily residential areas. The same may be said for roadways that serve only one lane of traffic in each direction.

5.2.3 State Street (SR 89)

In 1994, a raised median was installed on the State Street in Sandy between 10200 South and 10600 South. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1992 to 1993 and the after period is from 1995 to 1997. Table 5-7 summarizes the before and after crashes on State Street including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-9 illustrates the crash rates at one-tenth-mile intervals for this segment of State Street. Figure 5-10 displays the intersection crash rate for all signalized intersections along the segment. Figure 5-11 displays the collision types on State Street by percentage of total crashes. Figure 5-12 illustrates the severity of crashes on State Street by percentage of total crashes. Finally, Table 5-8 shows the cost of crashes per severity type and the total cost of crashes on State Street for both the before and after periods.

Table 5-7. Crash Data and Access Point Density for State Street

	Before (1992-1993)	**After (1995-1997)**
Crashes Per Year	14.0	39.0
Crash Rate (Crashes/MVMT[1])	3.97	8.83
Fatality Rate (Fatalities/100 MVMT[1])	14.16	0.00
Access Points	8	11
Length of Section (mi.)	0.50	0.50
Access Points per Mile	16.0	22.0
AADT[2]	19,345	24,215

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

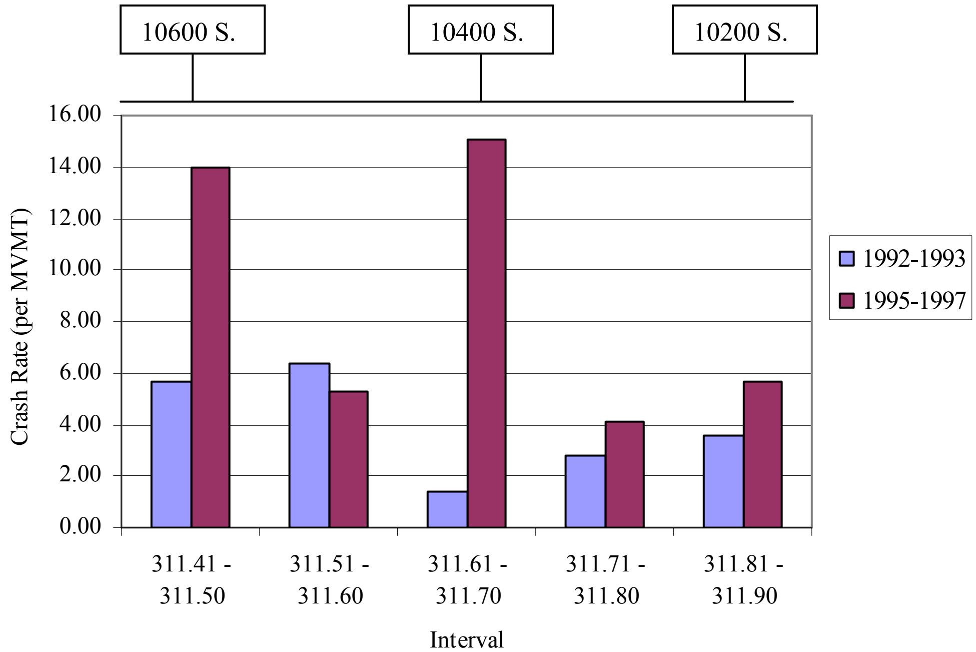


Figure 5-9. Crash rates for one-tenth-mile intervals of State Street.

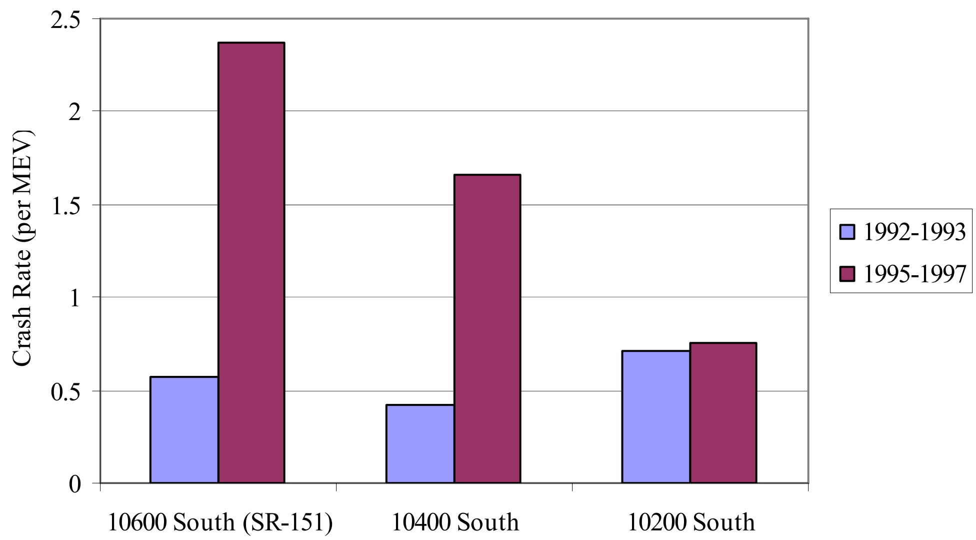


Figure 5-10. Intersection crash rates on State Street.

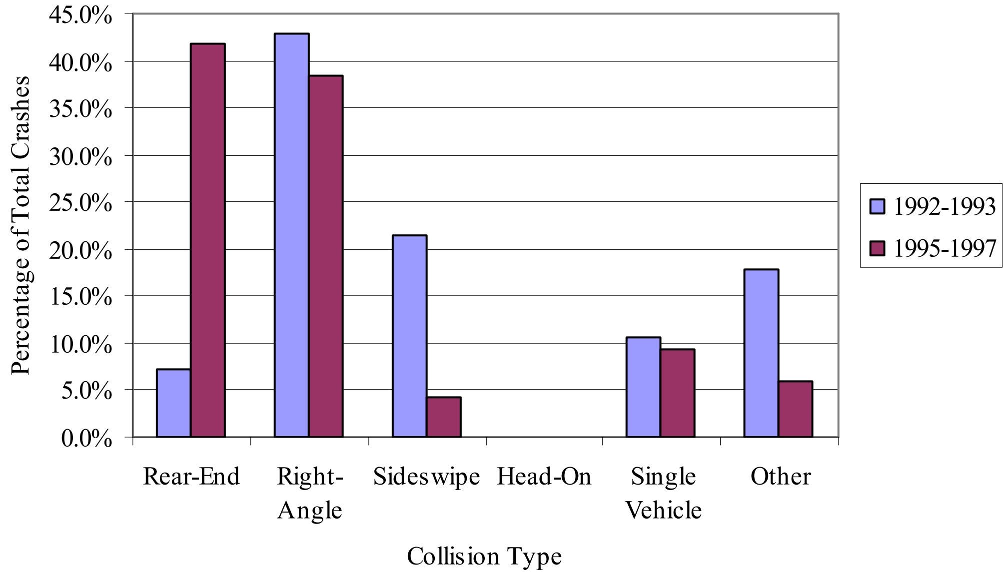


Figure 5-11. Collision types on State Street by percentage of total crashes.

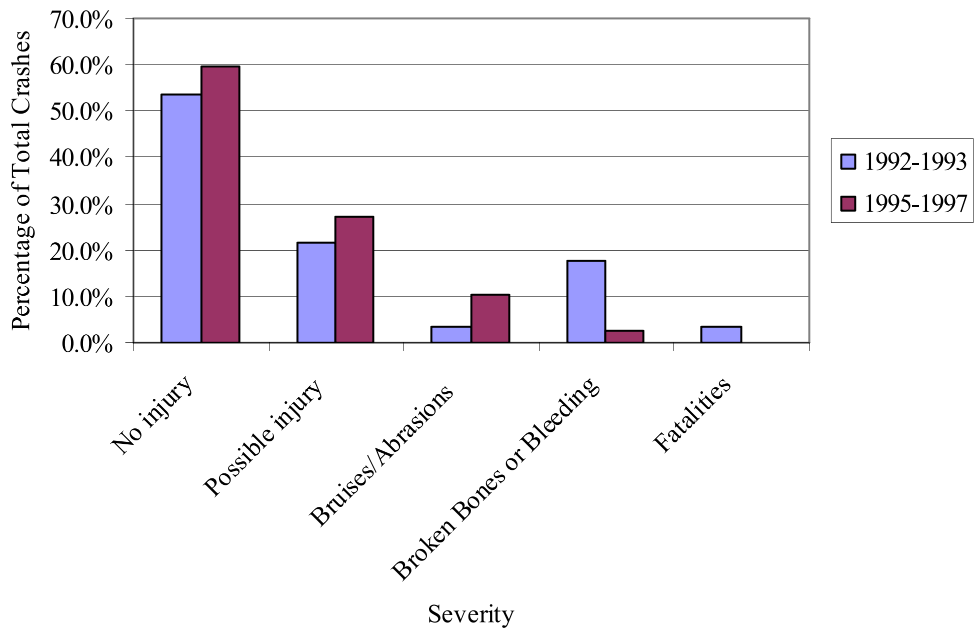


Figure 5-12. Severity of crashes on State Street by percentage of total crashes.

Table 5-8. Cost of Crashes on State Street

Crash Severity	Before (1992-1993)	After (1995-1997)
No injury	$67,500	$315,000
Possible injury	$150,000	$800,000
Bruises/Abrasions	$48,000	$576,000
Broken Bones or Bleeding Wounds	$1,140,000	$684,000
Fatalities	$2,720,000	$0
Total Cost of Crashes	$4,125,500	$2,375,000
Cost of Crashes Per Year	$2,062,750	$791,667

As shown in Table 5-7, the crash rate for this segment of State Street increased after installation of the raised median. The crash rate increased from 3.97 to 8.83, a change of 122 percent. The fatality rate decreased dramatically from 14.16 to 0.00 as there were no fatalities in the after time period. The number of access points per mile increased from 16.0 to 22.0, a change of 38 percent. The average AADT for the segment increased from 19,345 to 24,215, an increase of 25 percent.

The raised median was installed along this segment of State Street during the same time that the South Towne Centre Mall was constructed adjacent to the corridor. This mall is the largest of its kind in the entire state of Utah, and therefore, attracts a large number of trips. During the same time period many other retail developments were constructed along the corridor including restaurants and big box retail. This dramatic increase in development and traffic volumes along the roadway segment may be part of the reason for the increase in crash rates.

Figure 5-9 shows that crash rates increased at all but one of the one-tenth-mile intervals. Figure 5-10 illustrates that the intersection crash rate increased at all of the intersections along the segment. The two most dramatic increases were the 318 percent increase at the intersection of 10600 South and the 295 percent increase at the intersection of 10400 South. These two intersections received the brunt of the traffic volumes attracted by the South Towne Center Mall. In fact, a new traffic signal was installed at the 10400 South intersection as part of the construction of the mall. This is likely the cause of the increase in intersection crashes.

Figure 5-11 indicates rear-end crashes as a percentage of total crashes increased from 7 percent to 42 percent. Right-angle, sideswipe, and single vehicle crashes all decreased as percentages of total crashes as follows: right-angle crashes decreased from 43 percent to 39 percent of total crashes; sideswipe crashes decreased from 21 percent to 4 percent of total crashes; and single vehicle crashes decreased from 11 percent to 9 percent of total crashes. Such an increase in rear-end crashes may be attributed to the new traffic signal that was installed at the intersection of 10400 South. Raised medians often cause an increase in rear-end crashes because vehicles are required to make left-turns and U-turns only at the intersections, and left-turn pockets may not be sufficiently large enough to store all the vehicles. The lack of turn pocket storage causes vehicles to spill out into the through lanes and increases the potential of rear-end crashes. It is difficult to explain the reason for the decrease in single vehicle crashes. The decrease in right-angle and sideswipe crashes may be attributable to the raised median being a positive barrier that prevents these types of collisions. Head-on collisions remained unchanged at 0 percent.

Figure 5-12 illustrates that the no injury, possible injury, and bruises/abrasions crashes all increased as percentages of total crashes as follows: the no injury crashes increased from 54 percent to 60 percent of total crashes; the possible injury crashes increased from 21 percent to 27 percent of total crashes; and the bruises/abrasions crashes increased from 4 percent to 10 percent of total crashes. These findings reflect the increase in rear-end collisions, which are considered a less severe type of collision. Since more rear-end crashes are occurring at this location, the crashes have become less severe.

The broken bones/bleeding crashes and the fatalities crashes both decreased as percentages of total crashes. The broken bones/bleeding crashes decreased from 18 percent to 3 percent, and the fatalities decreased from 4 percent to 0 percent. These findings reflect the fact that there are decreases in the more serious collision types, such as right-angle crashes. Raised medians typically reduce the more severe crashes and improve the safety on a roadway.

Table 5-8 illustrates that the total cost of crashes per year decreased dramatically. Since the more severe crashes decreased between the before and after periods, the total cost of crashes per year decreased by 62 percent. Such a reduction in the cost of crashes is very beneficial for motorists and for society as a whole.

The cost associated with installing a raised median was compared with the reduction in cost of crashes. The cost to construct the raised median on State Street was estimated to be approximately $235,000. The reduction in cost of crashes as a result of the raised median was approximately $1,270,000 per year. As a result, the crash cost savings achieved by the raised median made up the cost of construction in less than two months.

5.2.4 400/500 South (SR 186)

Between 1999 and 2001, a raised median was installed on 400/500 South in Salt Lake City from Main Street and 1300 South. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1996 to 1998 and the after period is from 2002 to 2004. Table 5-9 summarizes the before and after crashes on 400/500 South including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-13 displays the crash rates at one-tenth-mile intervals for this segment of 400/500 South. Figure 5-14 displays the intersection crash rate for all signalized intersections along the segment. Figure 5-15 illustrates the collision types on 400/500 South by percentage of total crashes. Figure 5-16 displays the severity of crashes on 400/500 South by percentage of total crashes. Finally, Table 5-10 shows the cost of crashes per severity type and the total cost of crashes on 400/500 South for both the before and after periods.

As shown in Table 5-9, the crash rate for this segment of University Parkway increased after installation of the raised median. The crash rate increased from 2.75 to 4.03, a change of 47 percent. The fatality rate increased as well from 1.25 to 5.84. The number of access points per mile decreased slightly from 74.3 to 73.3. The average AADT for the segment decreased from 35,499 to 22,783, a decrease of 36 percent. This

Table 5-9. Crash Data and Access Point Density for 400/500 South

	Before (1996-1998)	After (2002-2004)
Crashes Per Year	73.3	69.0
Crash Rate (Crashes/MVMT[1])	2.75	4.03
Fatality Rate (Fatalities/100 MVMT[1])	1.25	5.84
Access Points	153	151
Length of Section (mi.)	2.06	2.06
Access Points per Mile	74.3	73.3
AADT[2]	35,499	22,783

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

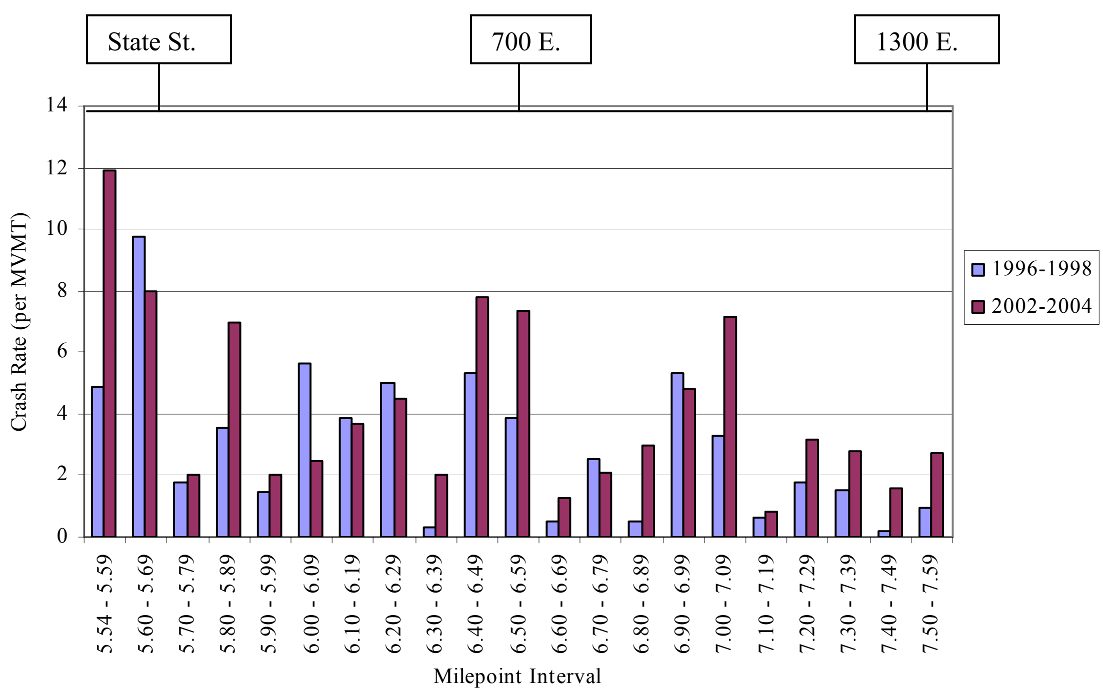


Figure 5-13. Crash rates for one-tenth-mile intervals of 400/500 South.

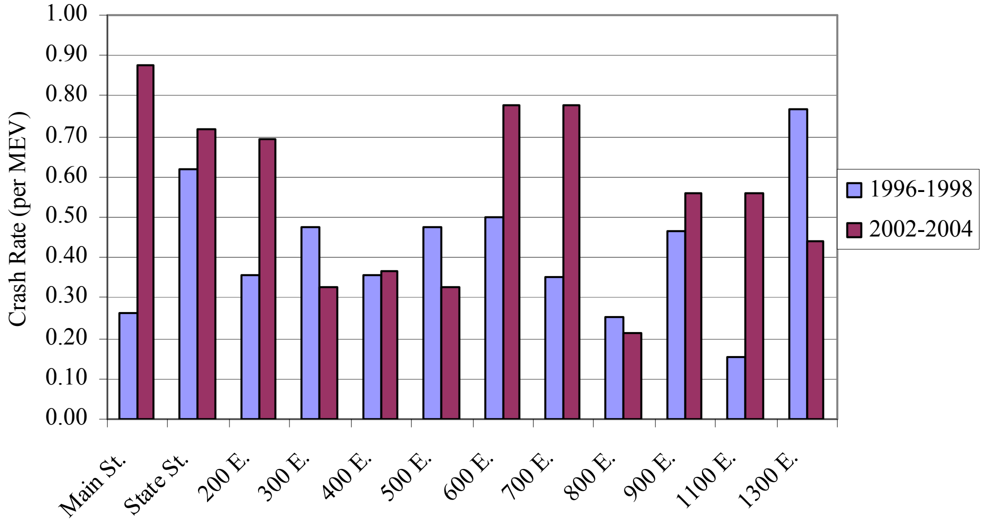


Figure 5-14. Intersection crash rates on 400/500 South.

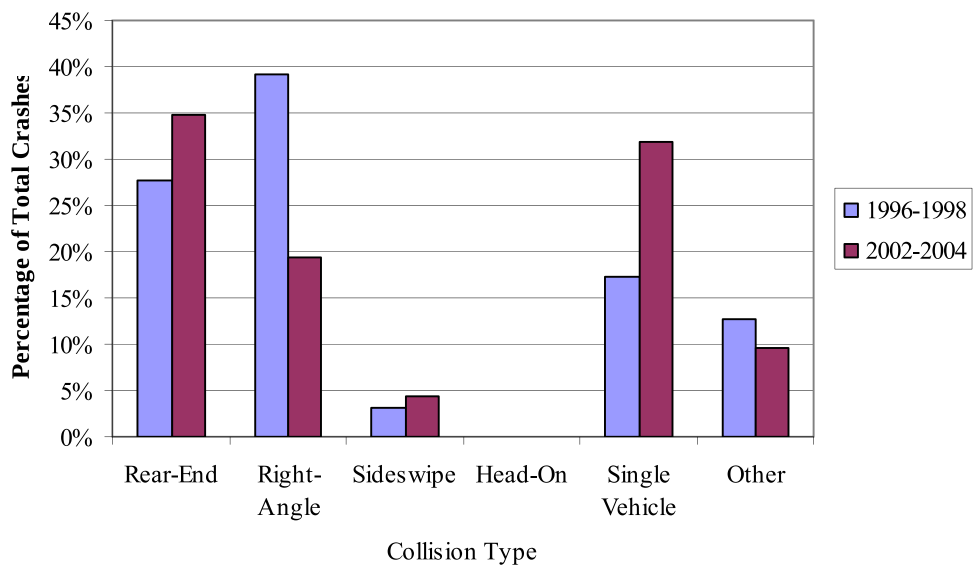


Figure 5-15. Collision types on 400/500 South by percentage of total crashes.

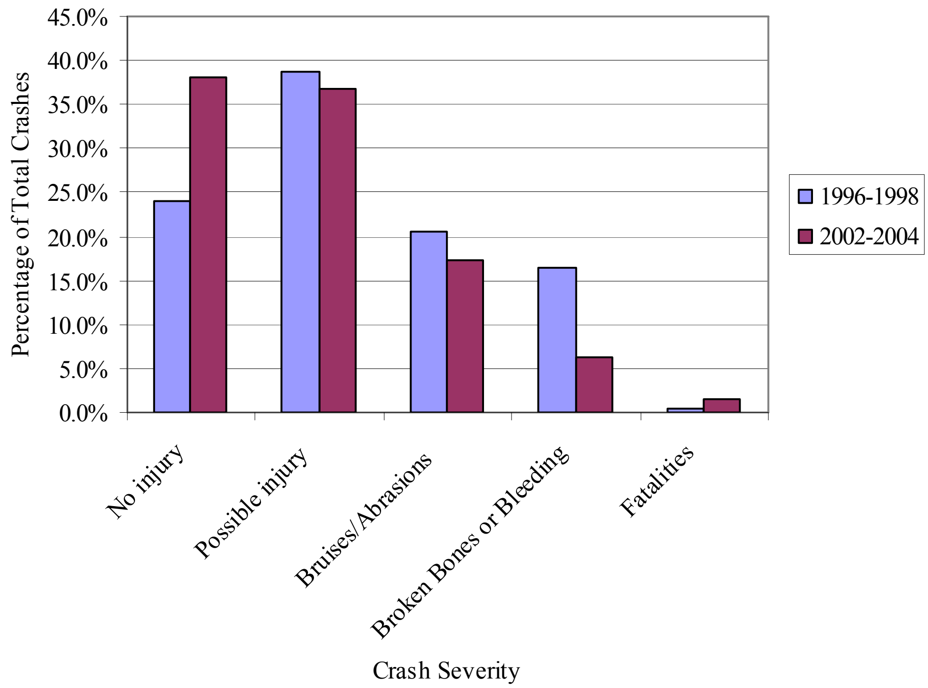


Figure 5-16. Severity of crashes on 400/500 South by percentage of total crashes.

Table 5-10. Cost of Crashes on 400/500 South

Crash Severity	Before (1996-1998)	After (2002-2004)
No injury	$238,500	$355,500
Possible injury	$2,125,000	$1,900,000
Bruises/Abrasions	$2,160,000	$1,728,000
Broken Bones or Bleeding Wounds	$8,208,000	$2,964,000
Fatalities	$2,720,000	$8,160,000
Total Cost of Crashes	$15,451,500	$15,107,500
Cost of Crashes Per Year	$5,150,500	$5,035,833

is a unique case of a raised median because it also serves as the site for the rail lines for the TRAX light rail system. The TRAX trains operate in the center of the road between raised medians that separate them from vehicular traffic. Since the TRAX line serves the area near the campus of the University of Utah, many vehicle trips on 400/500 South have been substituted for TRAX trips. Thus, the new TRAX system likely contributed to the reduction in traffic volume.

The fatality rate increased because of three separate fatality crashes that occurred in 2002. It is unfortunate that three fatalities occurred on this roadway segment in the same year, but each of the crashes occurred not as a result of the raised median but because of careless behavior on the part of drivers and pedestrians. One fatality occurred when a vehicle struck an 82 year-old person that was not crossing the street at an intersection or crosswalk. Another fatality occurred as a result of a motorcyclist speeding, losing control, and going off the right-side of the road. Finally, the last fatality was a result of a driver running a red light and colliding with an oncoming vehicle.

Figure 5-13 shows that crash rates increased at most one-tenth-mile intervals and decreased at other one-tenth-mile intervals along the segment. Figure 5-14 illustrates that intersection crash rates increased at eight of the twelve signalized intersection. Increases in crash rates at the signalized intersections are likely caused by the fact that the raised medians force all left-turn movements to the signalized intersections. There are five intersections where left-turns are prohibited for either the eastbound or westbound approach. These intersections are Main St., 200 East, 600 East, 900 East, and 1100 East. It is interesting to note that some of the most dramatic increases in intersection crash rates occurred at these intersections. This trend may be due to the fact that some drivers attempt to make a left-turn at one of these intersections, unaware of the left-turn restriction. This places them in a dangerous situation as they try to complete the maneuver.

Figure 5-15 indicates that rear-end, sideswipe, and single vehicle crashes as percentages of total crashes all increased as follows: the rear-end crashes increased from 28 percent to 35 percent of total crashes; the sideswipe crashes increased from 3 percent to 4 percent of total crashes; and the single vehicle crashes increased from 17 percent to 32 percent of total crashes. An increase in rear-end crashes may be attributed to the turn pockets at intersections having insufficient storage length and causing left-turn vehicles to spill out into through lanes. The increase in single vehicle crashes may be attributable to the raised median being a new obstacle in the roadway that is easily struck by inattentive drivers.

Figure 5-15 also shows that right-angle crashes decreased from 39 percent to 19 percent of total crashes. Head-on crashes remained unchanged at zero percent. Right-angle crashes are decreased likely because of the reduction in left turns created by the raised medians. A reduction in right-angle crashes typically reduces the severity of crashes as well. Head-on crashes are also a type of collision that, when prevented, improves the safety of the roadway.

Figure 5-16 illustrates that the no injury and fatalities crashes both increased as percentages of total crashes. The no injury crashes increased from 24 percent to 38 percent of total crashes, while the fatalities crashes increased from 0.5 percent to 1 percent of total crashes. As discussed previously, the increase in fatalities is a result of one year when abnormal fatality crashes occurred. The possible injury, bruises/abrasions, and broken bones/bleeding crashes all decreased as percentages of total crashes as follows: the possible injury crashes decreased from 39 percent to 37 percent, the bruises/abrasions crashes decreased from 21 percent to 17 percent, and the broken bones/bleeding crashes decreased from 16 percent to 6 percent of total crashes. These findings confirm the theory that raised medians typically help reduce the more severe crashes.

Table 5-10 illustrates that the total cost of crashes per year decreased. The more severe crashes are much more costly than the less severe crashes. With the exception of the fatalities crashes, the more severe crashes decreased between the before and after periods, and the total cost of crashes per year decreased by 2 percent.

The cost associated with installing a raised median was compared with the reduction in cost of crashes. The cost to construct the raised median on 400/500 South was estimated to be approximately $975,000. The reduction in cost of crashes as a result of the raised median was approximately $115,000 per year. As a result, the crash cost savings achieved by the raised median made up the cost of construction in approximately eight and a half years. It is important to note once again that this is a unique raised median installation because it was performed as part of a larger light rail construction project. As such, the cost estimates for this particular raised median are not necessarily representative of the actual costs. To be consistent with previous discussion, however, the same estimated per linear foot cost was used.

This segment of 400/500 South is only the second location in the state of Utah where a light rail line has been placed in the middle of the roadway along with raised medians. In order to know how to deal with similar light rail installations on state roads in the future, UDOT should utilize the lessons learned from the experience on 400/500 South and apply these lessons to future median light rail installations.

5.2.5 300 West (SR 89)

In 1999, a raised median was installed on 300 West in Salt Lake City between North Temple and 300 North. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1996 to 1998 and the after period is from 2000 to 2002. Table 5-11 summarizes the before and after crashes on 300 West including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-17 displays the crash rates at one-tenth-mile intervals for this segment of 300 West. Figure 5-18 illustrates the intersection crash rate for all signalized intersections along the segment. Figure 5-19 displays the collision types on 300 West by percentage of total crashes. Figure 5-20 displays the severity of crashes on 300 West by percentage of total crashes. Finally, Table 5-12 shows the cost of crashes per severity type and the total cost of crashes on 300 West for both the before and after periods.

As shown in Table 5-11, the crash rate for this segment of 300 West increased after installation of the raised median. The crash rate increased from 3.64 to 5.85, a change of 38 percent. The fatality rate remained unchanged at 0.00 as there were no fatalities in either time period. The number of access points per mile also remained unchanged at 26.7. The average AADT for the segment decreased from 25,065 to 20,287, a decrease of 19 percent. The decrease in AADT is likely a result of the I-15 reconstruction project that was mostly completed by the beginning of the after period. A large number of vehicles were using 300 West in the before period as an alternate to I-15, which had heavy lane restrictions due to the massive reconstruction project.

Table 5-11. Crash Data and Access Point Density for 300 West

	Before (1996-1998)	After (2000-2002)
Crashes Per Year	10.0	13.0
Crash Rate (Crashes/MVMT[1])	3.64	5.85
Fatality Rate (Fatalities/100 MVMT[1])	0.00	0.00
Access Points	8	8
Length of Section (mi.)	0.30	0.30
Access Points per Mile	26.7	26.7
AADT[2]	25,065	20,287

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

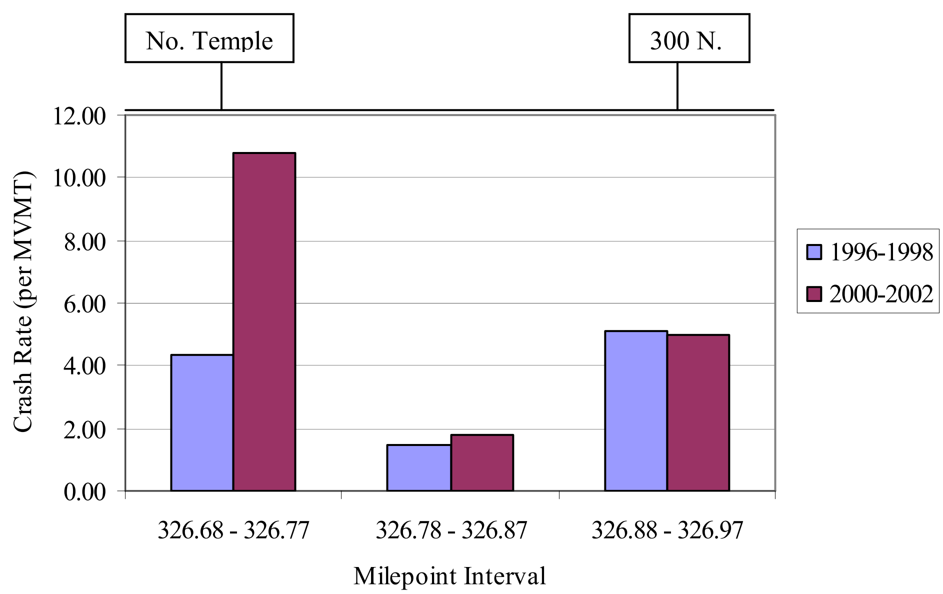


Figure 5-17. Crash rates for one-tenth-mile intervals of 300 West.

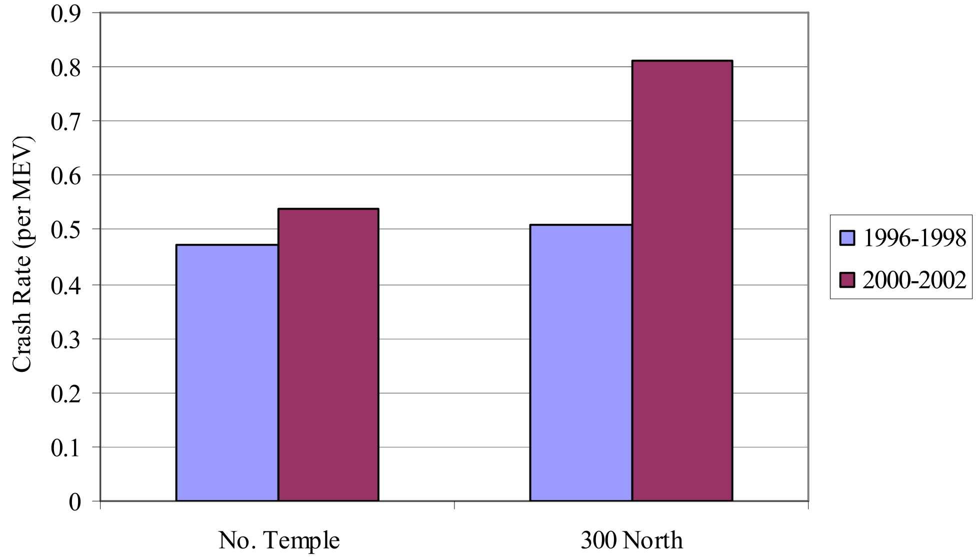


Figure 5-18. Intersection crash rates on 300 West.

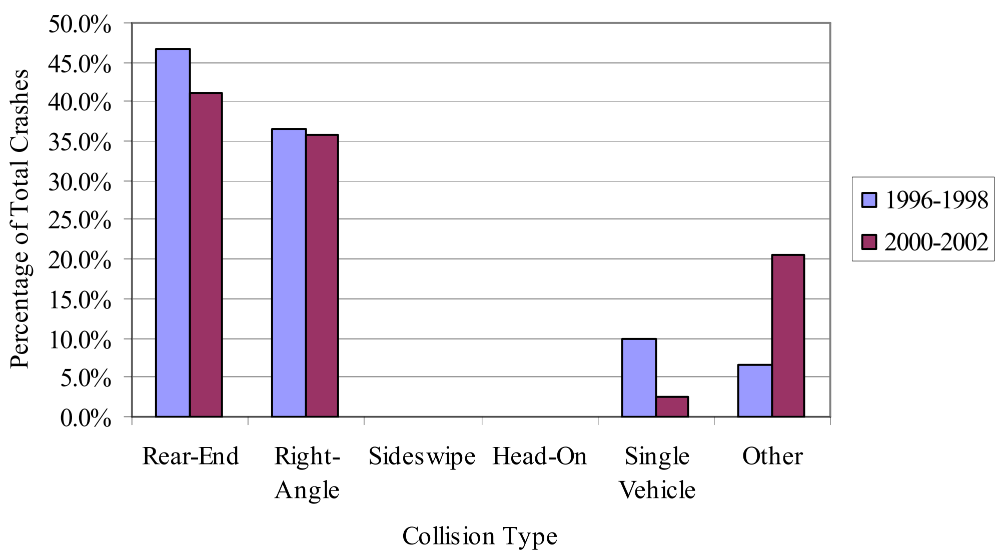


Figure 5-19. Collision types on 300 West by percentage of total crashes.

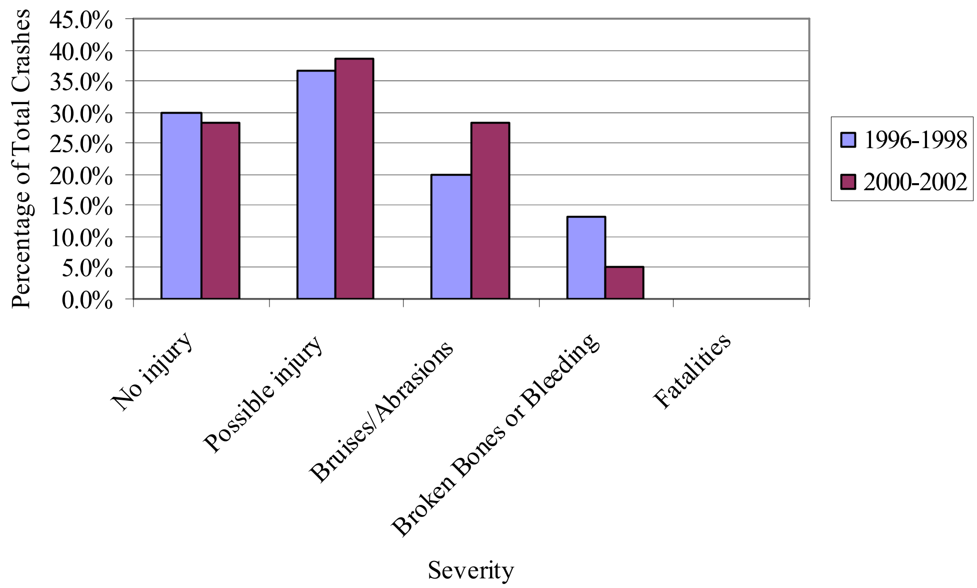


Figure 5-20. Severity of crashes on 300 West by percentage of total crashes.

Table 5-12. Cost of Crashes on 300 West

Crash Severity	**Before (1996-1998)**	**After (2000-2002)**
No injury	$40,500	$49,500
Possible injury	$275,000	$375,000
Bruises/Abrasions	$288,000	$528,000
Broken Bones or Bleeding Wounds	$912,000	$456,000
Fatalities	$0	$0
Total Cost of Crashes	$1,515,500	$1,408,500
Cost of Crashes Per Year	$505,167	$469,500

Figure 5-17 shows that crash rates increased at some one-tenth-mile intervals and decreased slightly at the other one-tenth-mile interval along the segment. Figure 5-18 illustrates that intersection crash rates increased at both signalized intersections along the segment, North Temple and 300 North. Increases in crash rates at the signalized intersections are likely caused by the fact that the raised medians force all left-turn movements to the signalized intersections.

Figure 5-19 indicates that "other" crashes were the only collision type in which crashes as a percentage of total crashes increased. Rear-end, right-angle, and single vehicle crashes as percentages of total crashes all decreased as follows: the rear-end crashes decreased from 47 percent to 41 percent of total crashes; the right-angle crashes decreased from 37 percent to 36 percent of total crashes; and the single vehicle crashes decreased from 10 percent to 3 percent of total crashes. Sideswipe and head-on crashes remained unchanged at 0 percent. It is anticipated that right-angle crashes may have decreased due to the reduction in left turns created by the raised medians. A decrease in right-angle crashes is the desired result for any roadway because it helps improve the safety conditions.

Figure 5-20 illustrates that the possible injury and bruises/abrasions crashes both increased slightly as percentages of total crashes as follows: the possible injury crashes increased from 37 percent to 39 percent of total crashes; and the bruises/abrasions crashes increased from 20 percent to 28 percent of total crashes. The no injury, broken bones/bleeding, and fatalities crashes either remained the same or decreased as percentages of total crashes. The no injury crashes decreased slightly from 30 percent to 28 percent of total crashes. The broken bones/bleeding crashes decreased from 13 percent to 5 percent of total crashes. The fatalities crashes remained unchanged at 0 percent. Other than the no injury crashes, which decreased slightly as a percentage of total crashes, the crash severities on this corridor follow the same pattern as most roadways on which raised medians have been installed. Namely, that the less severe crashes increase and the more serious crashes decrease as percentages of total crashes.

Table 5-12 illustrates that the total cost of crashes per year decreased. Since the more severe crashes were reduced in the after period, the total cost associated with the crashes is lower overall than the before condition. The total cost of crashes per year decreased by 7 percent.

The cost associated with installing a raised median was compared with the reduction in cost of crashes. The cost to construct the raised median on 300 West was estimated to be approximately $140,000. The reduction in cost of crashes as a result of the raised median was approximately $35,000 per year. As a result, the crash cost savings achieved by the raised median made up the cost of construction in less than four years.

5.2.6 Redwood Road (SR 68)

In 1994, a raised median was installed on Redwood Road between 5400 South and 6000 South. The following section summarizes the crash data for this roadway segment for both the before and after periods. The before period is from 1992 to 1993 and the after period is from 1995 to 1997. Table 5-13 summarizes the before and after crashes on Redwood Road including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. Figure 5-21 illustrates the crash rates at one-tenth-mile intervals of Redwood Road. Figure 5-22 displays the intersection crash rate for all signalized intersections along the segment. Figure 5-23 displays the collision types on Redwood Road by percentage of total crashes. Figure 5-24 shows the severity of crashes on Redwood Road by percentage of total crashes. Finally, Table 5-14 shows the cost of crashes per severity type and the total cost of crashes on Redwood Road for both the before and after periods.

Table 5-13. Crash Data and Access Point Density for Redwood Road

	Before (1992-1993)	**After (1995-1997)**
Crashes Per Year	112.5	110.3
Crash Rate (Crashes/MVMT[1])	8.36	7.25
Fatality Rate (Fatalities/100 MVMT[1])	0.00	0.00
Access Points	27	20
Length of Section (mi.)	0.73	0.73
Access Points per Mile	37.0	27.4
AADT[2]	50,490	57,082

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

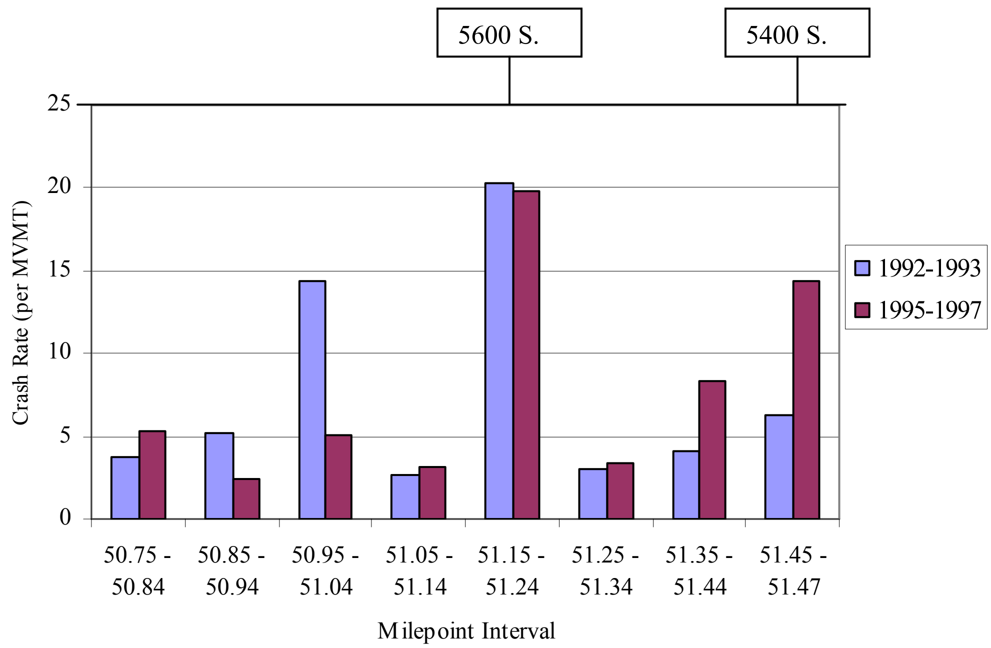


Figure 5-21. Crash rates for one-tenth-mile intervals of Redwood Road.

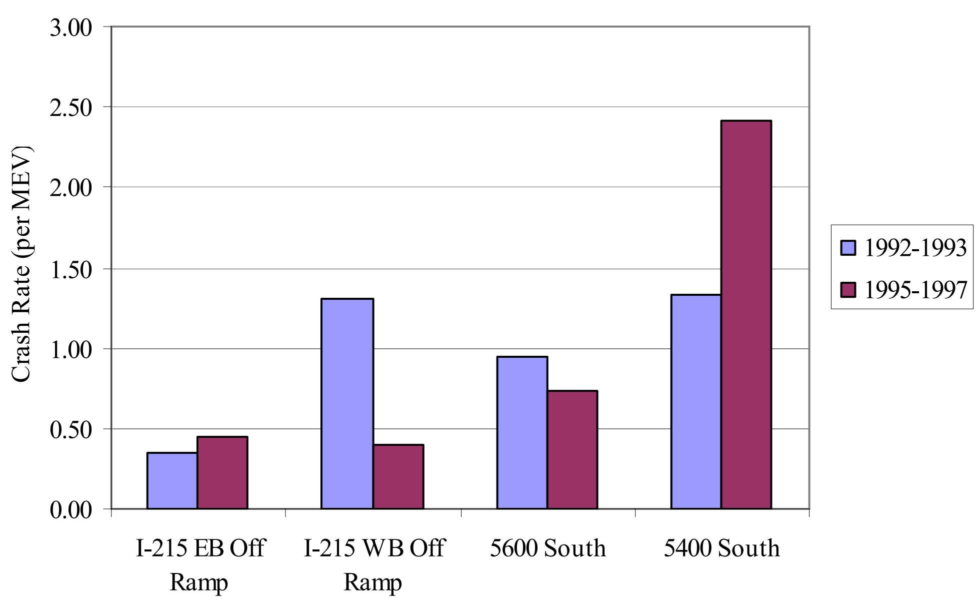


Figure 5-22. Intersection crash rates on Redwood Road.

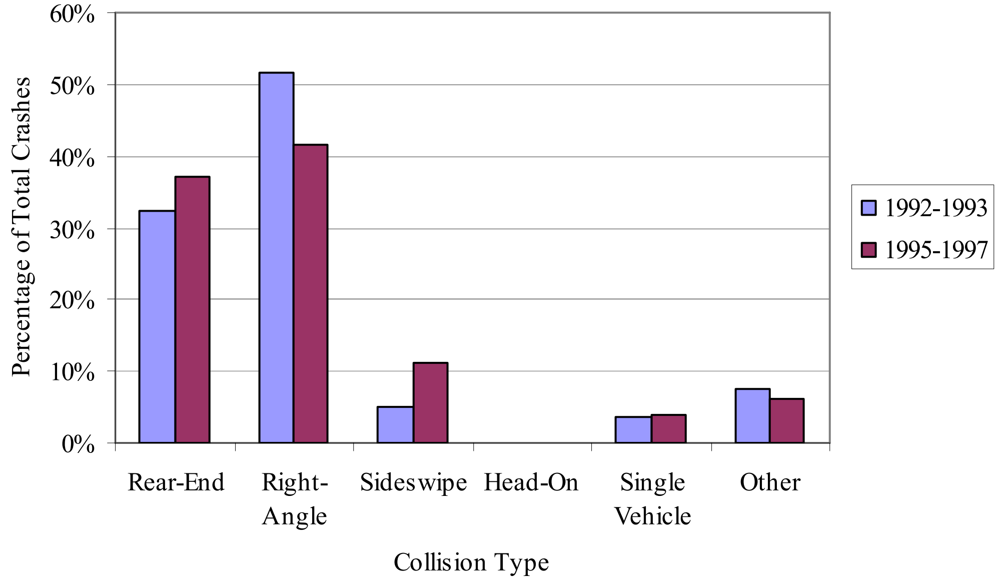


Figure 5-23. Collision types on Redwood Road by percentage of total crashes.

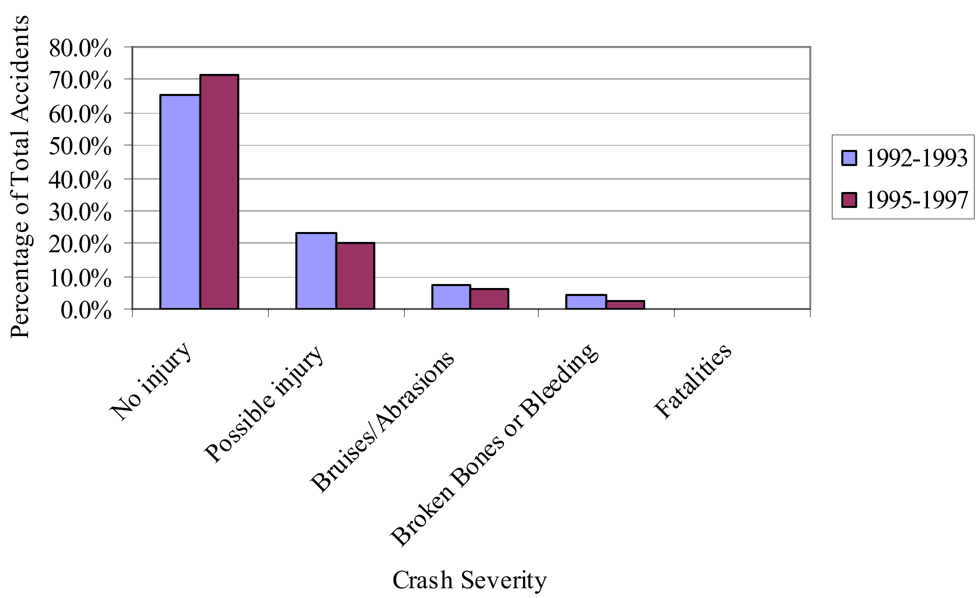


Figure 5-24. Severity of crashes on Redwood Road by percentage of total crashes.

Table 5-14. Cost of Crashes on Redwood Road

Crash Severity	Before (1992-1993)	After (1995-1997)
No injury	$661,500	$1,062,000
Possible injury	$1,300,000	$1,650,000
Bruises/Abrasions	$816,000	$1,008,000
Broken Bones or Bleeding Wounds	$2,052,000	$1,824,000
Fatalities	$0	$0
Total Cost of Crashes	$4,829,500	$5,544,000
Cost of Crashes Per Year	$2,414,750	$1,848,000

As shown in Table 5-13, the crash rate for this segment of Redwood Road decreased after installation of the raised median. The crash rate decreased from 8.36 to 7.25, a change of 13 percent. The fatality rate remained unchanged at 0.00 as there were no fatalities in either time period. The number of access points per mile decreased by 26 percent, from 37.0 to 27.4. The average AADT for the segment increased from 50,490 to 57,082, an increase of 12 percent. The increase in AADT may possibly be a result of the I-15 reconstruction project that was in progress during the after period. Hundreds of vehicles likely commuted north-south using Redwood Road as an alternate to I-15 in order to avoid the immense reconstruction project. The decrease in crash rate may be a result of the raised medians.

Figure 5-21 shows that crash rates increased at some one-tenth-mile intervals and decreased at other one-tenth-mile intervals along the segment. Figure 5-22 illustrates that intersection crash rates increased at two signalized intersections along the segment and decreased at the other two signalized intersections.

Figure 5-23 indicates that rear-end, sideswipe, and single vehicle crashes as percentages of total crashes all increased as follows: the rear-end crashes increased from 32 percent to 37 percent of total crashes; the sideswipe crashes increased from 5 percent to 11 percent of total crashes; and the single vehicle crashes increased from 3.5 percent to 4 percent of total crashes. An increase in rear-end crashes may be attributed to the turn pockets at intersections having insufficient storage length and causing left-turn vehicles to spill out into the through lanes. The increase in single vehicle crashes may be attributable to the raised median being a new obstacle in the roadway that is easily struck by inattentive drivers.

Figure 5-23 also shows that right-angle crashes decreased from 52 percent to 42 percent of total crashes. Head-on crashes remained unchanged at 0 percent. "Other" crashes decreased from 8 percent to 6 percent. Right-angle crashes may have decreased because of the reduction in left turns caused by the raised medians. A reduction in right-angle crashes typically reduces the severity of crashes. In this regard, this roadway segment follows the trend set forth by most roadways which have had a raised median installed.

Figure 5-24 illustrates that the no injury crashes were the only crash severity that increased as a percentage of total crashes. The no injury crashes increased from 65 percent to 71 percent. The possible injury, bruises/abrasions, broken bones/bleeding, and fatalities crashes either remained the same or decreased as percentages of total crashes as follows: the possible injury crashes decreased from 23 percent to 20 percent of total crashes; the bruises/abrasions crashes decreased from 8 percent to 6 percent of total crashes. The broken bones/bleeding crashes decreased from 4 percent to 2 percent of total crashes. The fatalities crashes remained unchanged at 0 percent.

The crash severities on this corridor follow the same pattern as most roadways on which raised medians have been installed. The less severe crashes increase and the more serious crashes decrease as percentages of total crashes. This is the desired effect that raised medians have on a roadway.

Table 5-14 illustrates that the total cost of crashes per year decreased. Since the more severe crashes were reduced in the after period, the total cost associated with the crashes is lower overall than the before condition. The total cost of crashes per year decreased by 23 percent.

The cost associated with installing a raised median was compared with the reduction in cost of crashes. The cost to construct the raised median on Redwood Road was estimated to be approximately $340,000. The reduction in cost of crashes as a result of the raised median was approximately $565,000 per year. As a result, the crash cost savings achieved by the raised median made up the cost of construction in less than eight months.

In the next section, the analysis of the safety impacts of the locations which were chosen as control sites is discussed.

5.3 Analysis for Control Sites

The safety impacts of the locations that have been chosen as control sites are discussed in this section. These sites provide a comparison between those sites in which access management techniques were installed and other typical roads throughout the state of Utah. Some control sites exhibit characteristics similar to the study sites. Three of the control sites (12300 South, St. George Blvd., and SR 36) were evaluated for the early period of 1999-2001 (Period 1) and again for the late period of 2002-2004 (Period 2). The other two control sites (700 East and Redwood Road) were evaluated for the early period of 1994-1996 (Period 1) and again for the later period of 2002-2004 (Period 2). These two sites are parallel to I-15 in Salt Lake County and serve as alternative north-south corridors to I-15. Since the reconstruction of I-15 occurred between 1997 and 2001, these two north-south alternatives had increased traffic volumes during that time. Consequently, the time periods for these two corridors were chosen deliberately to avoid the period of I-15 reconstruction. All five of the control sites are analyzed for two separate time periods in order to evaluate changes in traffic characteristics for typical roadways and to compare these changes with those of the analysis sites.

The locations of the control sites selected for the study are:

1. 700 East (SR 71) − Milepoint 21.87 to 22.47.
2. 12300 South (SR 71) − Milepoint 4.56 to 5.46.
3. Redwood Road (SR 68) − Milepoint 49.46 to 49.96.
4. St. George Blvd. (SR 34) − Milepoint 0.00 to 1.74.
5. SR 36 − Milepoint 59.90 to 60.90.

Maps are included in Chapter 3 that illustrate the locations of the control sites. The following sections summarize the crash analysis results for each control site.

Appendix B contains a summary of the raw crash numbers for all the control sites. The raw data were obtained from the UDOT crash database.

5.3.1 700 East (SR 71)

The segment of 700 East between 400 South and 800 South in Salt Lake City was chosen for a control site because it represents a road that has always had a raised median in place. The following section summarizes the crash data for this roadway segment for two time periods in an attempt to establish trends in crash rates. The early period is from 1994 to 1996 and the later period is from 2002 to 2004. Table 5-15 summarizes the before and after crashes on 700 East including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. The differences in the results from one time period to the next assist in showing traffic trends that are likely representative of the surrounding area. Table 5-16 shows the cost of crashes per severity type and the total cost of crashes on 700 East for Period 1 and Period 2.

As mentioned previously, the before period for this corridor was chosen in order to avoid the potentially misleading years of I-15 reconstruction. As shown in Table 5-15, the crash rate for this segment of 700 East decreased between the before and after periods. The crash rate decreased from 5.94 to 3.29, a change of 45 percent. The fatality rate increased from 0.00 to 4.01, because there were no fatalities in the before period and one fatality in the after period. The number of access points per mile remained unchanged at 101.7. The average AADT for the segment decreased from 42,270 to 37,988, a decrease of 10 percent.

As displayed in Table 5-16, the total cost of crashes per year on 700 East increased between Period 1 and Period 2. Since a fatality occurred in Period 2, the total cost associated with the crashes in Period 2 is higher overall than those in Period 1. The total cost of crashes per year increased by 10 percent.

Table 5-15. Crash Data and Access Point Density for 700 East

	Period 1 (1994-1996)	Period 2 (2002-2004)
Crashes Per Year	55.0	27.3
Crash Rate (Crashes/MVMT[1])	5.94	3.29
Fatality Rate (Fatalities/100 MVMT[1])	0.00	4.01
Access Points	61	61
Length of Section (mi.)	0.60	0.60
Access Points per Mile	101.7	101.7
AADT[2]	42,270	37,988

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

Table 5-16. Cost of Crashes on 700 East

Crash Severity	Period 1 (1994-1996)	Period 2 (2002-2004)
No injury	$252,000	$94,500
Possible injury	$1,600,000	$800,000
Bruises/Abrasions	$1,632,000	$912,000
Broken Bones or Bleeding Wounds	$2,508,000	$2,052,000
Fatalities	$0	$2,720,000
Total Cost of Crashes	$5,992,000	$6,578,500
Cost of Crashes Per Year	$1,997,333	$2,192,833

5.3.2 12300 South (SR 71)

The segment of 12300 South between 300 East and 265 West in Draper was chosen for a control site because it represents a road in a fast-growing area that was widened and had a raised median installed in the same project in 2005. The following section summarizes the crash data for this roadway segment for two time periods in an attempt to establish trends in crash rates. The early period is from 1999 to 2001 and the later period is from 2002 to 2004. Table 5-17 summarizes the before and after crashes on 12300 South including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. The differences in the results from one time period to the next assist in showing traffic trends that are likely representative of the surrounding area. Table 5-18 shows the cost of crashes per severity type and the total cost of crashes on 12300 South for Period 1 and Period 2.

Table 5-17. Crash Data and Access Point Density for 12300 South

	Period 1 (1999-2001)	Period 2 (2002-2004)
Crashes Per Year	73.3	96.7
Crash Rate (Crashes/MVMT[1])	8.75	10.03
Fatality Rate (Fatalities/100 MVMT[1])	0.00	3.50
Access Points	31	31
Length of Section (mi.)	0.90	0.90
Access Points per Mile	34.4	34.4
AADT[2]	24,938	29,032

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

Table 5-18. Cost of Crashes on 12300 South

Crash Severity	Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	$630,000	$850,500
Possible injury	$1,200,000	$1,900,000
Bruises/Abrasions	$1,008,000	$816,000
Broken Bones or Bleeding Wounds	$1,596,000	$1,596,000
Fatalities	$0	$2,720,000
Total Cost of Crashes	$4,434,000	$7,882,500
Cost of Crashes Per Year	$1,478,000	$2,627,500

As shown in Table 5-17, the crash rate for this segment of 12300 South increased between the before and after periods. The crash rate increased from 8.75 to 10.03, a change of 15 percent. The fatality rate increased in the after period from 0.00 to 3.50.

The number of access points per mile remained unchanged at 34.4. The average AADT for the segment increased from 24,938 to 29,032, an increase of 16 percent. The area surrounding this control site has grown rapidly in the past several years. New commercial development has occurred with many new businesses adjacent to the control site, likely causing the increase in AADT.

As displayed in Table 5-18, the total cost of crashes per year on 12300 South increased between Period 1 and Period 2. Since a fatality occurred in Period 2, the total cost associated with the crashes in Period 2 is higher overall than those in Period 1. The total cost of crashes per year increased by 78 percent.

5.3.3 Redwood Road (SR 68)

The stretch of Redwood Road between 6670 South and 7000 South is an area without raised medians that was chosen for a control site because it represents an area that can be compared to the analysis site on Redwood Road that has raised medians. The control site is in an area that has commercial activity similar to the analysis site. The following section summarizes the crash data for this roadway segment for two time periods in an attempt to establish trends in crash rates. The early period is from 1994 to 1996 and the later period is from 2002 to 2004. Table 5-19 summarizes the before and after crashes on the control site of Redwood Road including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. The differences in the results from one time period to the next assist in showing traffic trends that can be compared to the Redwood Road analysis site. Table 5-20 shows the cost of crashes per severity type and the total cost of crashes on Redwood Road for Period 1 and Period 2.

As mentioned previously, the before period for this corridor was chosen in order to avoid the years during I-15 reconstruction. As shown in Table 5-19, the crash rate for this segment of Redwood Road decreased slightly between the before and after periods. The crash rate decreased from 3.58 to 3.51, a change of 1 percent. The fatality rate also decreased in the after period from 5.87 to 0.00. The number of access points per mile

Table 5-19. Crash Data and Access Point Density for Redwood Road

	Period 1 (1994-1996)	Period 2 (2002-2004)
Crashes Per Year	20.3	22.0
Crash Rate (Crashes/MVMT[1])	3.58	3.54
Fatality Rate (Fatalities/100 MVMT[1])	5.87	0.00
Access Points	16	16
Length of Section (mi.)	0.50	0.50
Access Points per Mile	32.0	32.0
AADT[2]	31,115	34,078

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

Table 5-20. Cost of Crashes on Redwood Road

Crash Severity	Period 1 (1994-1996)	Period 2 (2002-2004)
No injury	$171,000	$189,000
Possible injury	$425,000	$350,000
Bruises/Abrasions	$192,000	$384,000
Broken Bones or Bleeding Wounds	$456,000	$456,000
Fatalities	$2,720,000	$0
Total Cost of Crashes	$3,964,000	$1,379,000
Cost of Crashes Per Year	$1,321,333	$459,667

remained unchanged at 32.0. The average AADT for the segment increased from 31,115 to 34,078, an increase of 9 percent.

This location is comparable to the analysis location on Redwood Road discussed in the previous section because only one mile separates the two locations. Both locations experienced similar decreases in crash rate.

As displayed in Table 5-20, the total cost of crashes per year on Redwood Road decreased between Period 1 and Period 2. Since a fatality occurred in Period 1, the total cost associated with the crashes in Period 2 is lower overall than those in Period 1. The total cost of crashes per year decreased by 65 percent.

5.3.4 St. George Blvd. (SR 34)

The segment of St. George Blvd. from Bluff Street to 1000 East was chosen as a control site because it represents a roadway in which raised medians are planned for installation, but the reconstruction project was not complete prior to this research study. The following section summarizes the crash data for this roadway segment for two time periods in an attempt to establish trends in crash rates. The early period is from 1999 to 2001 and the later period is from 2002 to 2004. Table 5-21 summarizes the before and after crashes on St. George Blvd. including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. The differences in the results from one time period to the next assist in showing traffic trends that are likely representative of the surrounding area. Table 5-22 shows the cost of crashes per severity type and the total cost of crashes on St. George Blvd. for Period 1 and Period 2.

Table 5-21. Crash Data and Access Point Density for St. George Blvd.

	Period 1 (1999-2001)	**Period 2 (2002-2004)**
Crashes Per Year	149.0	181.0
Crash Rate (Crashes/MVMT[1])	7.00	9.62
Fatality Rate (Fatalities/100 MVMT[1])	0.00	1.78
Access Points	163	163
Length of Section (mi.)	1.75	1.75
Access Points per Mile	93.1	93.1
AADT[2]	33,331	29,443

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

As shown in Table 5-21, the crash rate for this segment of St. George Blvd. increased between the before and after periods. The crash rate increased from 7.00 to 9.62, a change of 37 percent. The fatality rate also increased in the after period from 0.00

to 1.78. The number of access points per mile remained unchanged at 93.1. The average AADT for the segment decreased from 33,331 to 29,443, a decrease of 12 percent. The increasing crash rate for this segment was likely a factor in the decision made by UDOT to install raised medians at this location beginning in 2005.

Table 5-22. Cost of Crashes on St. George Blvd.

Crash Severity	Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	$1,341,000	$1,696,500
Possible injury	$2,625,000	$3,125,000
Bruises/Abrasions	$1,584,000	$1,584,000
Broken Bones or Bleeding Wounds	$2,508,000	$1,596,000
Fatalities	$0	$2,720,000
Total Cost of Crashes	$8,058,000	$10,721,500
Cost of Crashes Per Year	$2,686,000	$3,573,833

As displayed in Table 5-22, the total cost of crashes per year on St. George Blvd. increased between Period 1 and Period 2. Since a fatality occurred in Period 2, the total cost associated with the crashes in Period 2 is higher overall than those in Period 1. The total cost of crashes per year increased by 33 percent.

5.3.5 SR 36

A one-mile segment of SR 36 was chosen as a control site to see what conditions may have warranted raised medians to be installed for this one specific segment of the 10-mile widening project. The following section summarizes the crash data for this roadway segment for two time periods in an attempt to establish trends in crash rates. The early period is from 1999 to 2001 and the later period is from 2002 to 2004. Table 5-23 summarizes the before and after crashes on this stretch of SR 36 including crash rates, fatality rates, a summary of access points and segment length data, as well as weighted average AADT data for each period. The differences in the results from one time period to the next assist in showing traffic trends that are likely representative of the surrounding area. Table 5-24 shows the cost of crashes per severity type and the total cost of crashes on SR 36 for Period 1 and Period 2.

Table 5-23. Crash Data and Access Point Density for SR 36

	Period 1 (1999-2001)	Period 2 (2002-2004)
Crashes Per Year	6.7	9.3
Crash Rate (Crashes/MVMT[1])	1.06	0.93
Fatality Rate (Fatalities/100 MVMT[1])	0.00	0.00
Access Points	19	19
Length of Section (mi.)	1.00	1.00
Access Points per Mile	19.0	19.0
AADT[2]	17,255	27,487

[1]MVMT = Million Vehicle Miles Traveled

[2]AADT is a weighted average calculated using Equation 4-4

As shown in Table 5-23, the crash rate for this segment of SR 36 decreased between the before and after periods. The crash rate decreased from 1.06 to 0.93, a change of 12 percent. The fatality remained unchanged at 0.00. The number of access points per mile remained unchanged at 19.0. The average AADT for the segment increased from 17,255 to 27,487, an increase of 37 percent.

Table 5-24. Cost of Crashes on SR 36

Crash Severity	Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	$31,500	$90,000
Possible injury	$200,000	$150,000
Bruises/Abrasions	$144,000	$144,000
Broken Bones or Bleeding Wounds	$456,000	$456,000
Fatalities	$0	$0
Total Cost of Crashes	$831,500	$840,000
Cost of Crashes Per Year	$277,167	$280,000

As displayed in Table 5-24, the total cost of crashes per year on SR 36 increased between Period 1 and Period 2. The total cost associated with the crashes in Period 2 is similar to those in Period 1, but slightly higher. The total cost of crashes per year increased by 1 percent.

5.4 Chapter Summary

The analysis of the locations of access management techniques shows interesting results. Although most of the roadways in the analysis did not experience a reduction in crash rates as a result of raised median installation, other safety improvements were found in the results. For example, in most cases the fatality rates and severity of crashes decreased during the after period. Also, crashes are generally shifting from the mid-block to the signalized intersections.

Other trends were observed in the types of collisions that occurred at these locations. Generally, rear-end and single-vehicle crashes increased, while right-angle crashes decreased as a result of raised median installation. Table 5-25 displays the changes in types of collisions as percentages of total crashes for the analysis locations. As right-angle crashes are considered to be one of the most serious types of crashes, it is not surprising that a general decrease in the severity of crashes occurred as a result of raised median installation. In general, the no injury crashes increased and the more severe crashes involving injuries and fatalities decreased as percentages of total crashes. Table 5-26 displays the changes in crash severity as percentages of total crashes for the analysis locations.

The total cost of crashes per year decreased at all but one of the locations because of the general reduction in crash severity. Table 5-27 displays the comparison between the cost associated with raised median construction and the change in cost of crashes per year as a result of the raised median for each location. Also included in the table is an estimate of the time needed for the reduction in cost of crashes to make up the construction costs of the raised median.

Table 5-25. Changes in Collision Types as Percentages of Total Crashes at Analysis Locations

		Types of Collisions					
		Rear-End	Right-Angle	Sideswipe	Head-on	Single Vehicle	Other
Analysis Locations	University Parkway	●	○	○	-	●	●
	Alpine Highway	○	●	●	-	●	○
	State Street	●	○	○	-	○	○
	400/500 South	●	○	●	-	●	○
	300 West	○	○	-	-	○	●
	Redwood Road	●	○	●	-	●	○

"●" indicates an increase
"○" indicates a decrease
"-" indicates no change

Table 5-26. Changes in Crash Severity as Percentages of Total Crashes at Analysis Locations

		Crash Severity				
		No Injury	Possible Injury	Bruises/ Abrasions	Broken Bones or Bleeding	Fatalities
Analysis Locations	University Parkway	●	●	●	○	○
	Alpine Highway	○	●	●	●	-
	State Street	●	●	●	○	○
	400/500 South	●	○	○	○	●
	300 West	○	●	●	○	-
	Redwood Road	●	○	○	○	-

"●" indicates an increase
"○" indicates a decrease
"-" indicates no change

As shown in Table 5-27, the estimated cost of crashes per year was reduced as a result of raised median installation at every location except for the Alpine Highway. At the other five locations, the estimated cost of constructing raised medians is made up in no more than nine years due to the corresponding reduction in the cost of crashes.

Table 5-27. Comparison of Costs and Benefits of Raised Medians for the Analysis Locations

Analysis Locations	Estimated Cost of Raised Median Construction	Estimated Change in Cost of Crashes per year due to Raised Median	Time Needed to Make Up the Cost of Raised Median
University Parkway	$360,000	-$485,000	< 9 months
Alpine Highway	$900,000	$95,000	N/A
State Street	$235,000	-$1,270,000	< 2 months
400/500 South	$975,000	-$115,000	< 9 years
300 West	$140,000	-$35,000	< 4 years
Redwood Road	$340,000	-$565,000	< 8 months

The safety impacts of the locations that were chosen as control sites provided a comparison between those sites in which access management techniques were installed and other typical roads throughout the state of Utah. Some interesting comparisons can be made between the control sites and the analysis sites. For example, the fatality rate increased at three out of the five control sites. However, only one of the six analysis locations experienced an increase in the fatality rate. Even though the trends in typical roadways were showing a general increase in fatality rate, the analysis locations did not follow this general trend as the locations where raised medians were installed generally experienced a reduction in crash severity.

The reduction in cost of crashes at five of the six analysis locations is particularly notable considering what occurred at the control sites. For four of the five control sites, the cost of crashes increased during similar time periods. An increase in cost of crashes at the control sites aids in showing that the general trend in cost of crashes for typical roadways in Utah is increasing. As noted previously, constant dollar values were used for all crash costs. If inflation were included in this analysis, the increase would likely be greater. However, at locations where access management techniques have been implemented, the cost of crashes has generally decreased.

Changes in traffic volumes varied at the different analysis locations and control sites. It was apparent that traffic volumes were affected by the I-15 reconstruction project that lasted from 1997 to 2001. Primarily on north-south corridors, traffic volumes increased during the years of the project as motorists chose alternate routes to avoid the reconstruction project. These fluctuations in traffic volumes may have had an impact on the crash rates and overall trends at some of the chosen locations. Table 5-28 displays each location of access management technique and control site including a symbol for each traffic characteristic indicating the change between the early and later periods.

Table 5-28. Overall Changes in Traffic Characteristics at All Locations

		Crash Rate	Fatality Rate	Access Points per Mile	AADT	Total Cost of Crashes per Year
Analysis Locations	University Parkway	●	○	○	●	○
	Alpine Highway	○	-	-	○	●
	State Street	●	○	●	●	○
	400/500 South	●	●	○	○	○
	300 West	●	-	-	○	○
	Redwood Road	○	-	○	●	○
Control Sites	700 East	○	●	-	○	●
	12300 South	●	●	-	●	●
	Redwood Road	○	○	-	●	○
	St. George Blvd.	●	●	-	○	●
	SR 36	○	-	-	●	●

"●" indicates an increase
"○" indicates a decrease
"-" indicates no change

As outlined in Chapter 2, past research has generally shown that there is a positive relationship between the number of access points per mile and the crash rate on a roadway. To some extent, this is the case with the corridors in this study. Figure 5-25 displays the relationship between the number of access points per mile and the crash rate at all the analysis locations and control sites for the before and after conditions.

As shown in Figure 5-25, the relationship between the number of access points and the crash rate at the analysis locations and the control sites does not have very strong correlation. The R-squared value is very low at 0.005, and the *p*-value representing the relationship is rather high at 0.749. This relationship would indicate that the number of

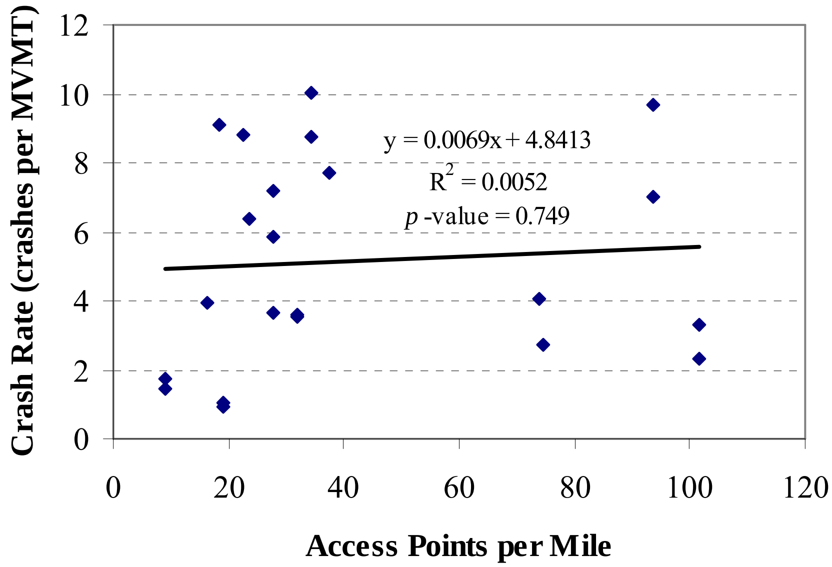


Figure 5-25. Relationship between the number of access points per mile and the crash rate at all the analysis locations and control sites for the before and after conditions.

access points per mile is not a strong indicator in the number of crashes on the corridor and that other factors play a stronger role in this relationship.

Upon further evaluation of the data it was noted that there are three corridors whose before and after data points are on the right side of the plot, apart from the other data points. It was determined that these three corridors have differing characteristics than the remaining sites and that these characteristics are inconsistent with what has been experienced with the other corridors. First, the corridor of 400/500 South is unique because it has a light rail line in the median. Factors related to the light rail line may contribute to unexpected results regarding crash rates and access point density. Second, the corridor of 700 East is an unusual corridor because so many of the access points within the segment are residential driveways serving historic homes that align the corridor. Finally, St. George Blvd. is an unusual corridor because of the geographic location of the corridor and the unique demographics of the surrounding area. St. George has a warm climate that appeals greatly to the elderly. Consequently, the proportion of elderly drivers in the area is much higher than average.

As a result of the differing characteristics of these three corridors, they were removed from the analysis and the relationship between the number of access points per mile and the crash rate without the three corridors was evaluated. Figure 5-26 displays the relationship between the number of access points per mile and the crash rate for the before and after conditions for the locations that showed characteristics that were consistent.

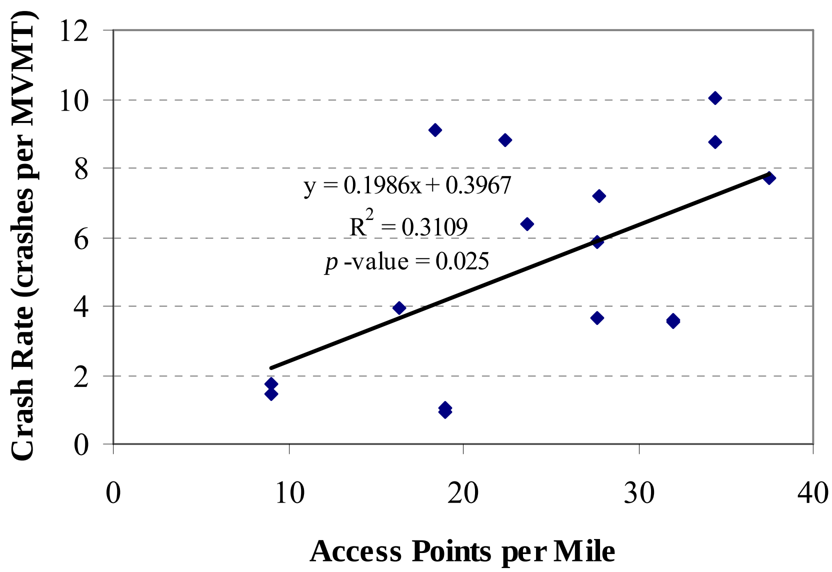


Figure 5-26. Relationship between the number of access points per mile and the crash rate for the before and after conditions for the locations that showed consistent characteristics.

Figure 5-26 indicates that there is a much stronger positive relationship between the number of access points and the crash rate at the analysis locations and the control sites after removing the corridors with differing characteristics. The R-squared value is higher, and the *p*-value representing the relationship has been reduced to 0.025. Although the R-squared value has increased, it is still relatively low, indicating that only 31 percent of the relationship can be attributed to the number of access point per mile. The significance of the relationship, however, has increased to the point where there is a statistically significant correlation. It is still difficult, however, to infer with complete confidence that the number of access points are causing the crash rate to increase in a linear fashion. A different relationship (e.g., log normal) may provide more accurate results as the crash rate tends to level off as the number of access points increases.

It is interesting to note from the analysis that there are other factors involved that may play a role in this correlation. Some of these factors include land use, demographics, geographic location, and geometric features. Although no conclusive results can be drawn from this analysis, the research is a starting point to form this relationship. It is recommended that more data be collected at sites throughout the state to develop more detailed relationships between these and other factors that can aid in a better understanding of the factors that affect crash rates.

6 CONCLUSIONS AND RECOMMENDATIONS

The preceding chapters have outlined the background of access management techniques as a procedure to improve safety conditions on a roadway. The analysis procedure using the UDOT crash database has been set forth, and the corridors selected for analysis have been discussed. The results show that while the overall crash rates for the locations of access management techniques were not reduced, other safety benefits resulted as a consequence of the access management techniques. This chapter summarizes the findings of the research and provides conclusions, offers recommendations for future use of access management techniques, and provides suggestions for future research possibilities.

6.1 Conclusions

The results of the study show that access management techniques (e.g., raised medians and driveway consolidation) are not necessarily effective in reducing overall crash rates. However, other safety improvements were observed that proved the techniques to be effective. Generally, fatality rates and severity of crashes decreased during the after period.

The lessening in the severity of crashes is anticipated to be a direct result of the change in the predominant types of collisions. Rear-end and single-vehicle crashes generally increased, while right-angle crashes decreased as a result of the raised median installation. The reduction in right-angle crashes directly resulted in a lessening of the severity of crashes and improved the safety on the roadways where raised medians were installed. This also resulted in a reduction in the fatality rate. In general, the no injury crashes increased and the more severe crashes involving injuries and fatalities decreased as percentages of total crashes. The results show that, in general, a safer roadway is created by the installation of raised medians.

The total cost of crashes per year generally decreased as a result of raised median installation. This is also attributable to the reduction in crash severity. The cost of crashes is reduced by such a degree that the cost reduction easily exceeds the cost of installing the raised median. As a result, raised medians can actually save money for the economy as a whole where the raised medians are installed.

The control sites chosen as part of the analysis provided insight regarding the general trends on typical roads throughout the state of Utah in recent years. Generally, the fatality rate for the control sites increased. The analysis locations experienced the opposite trend as locations where raised medians were installed generally experienced a reduction in fatality rate and crash severity.

The relationship between the number of access points per mile and the crash rates for the analysis locations and the control sites was slightly positive. However, the relationship was much more positive after removing three corridors whose characteristics were unique as compared to the remaining corridors. This analysis begins to provide the basis for identifying factors that affect crash rates; however, more data is needed to provide a better correlation.

6.2 Recommendations and Future Research

Access management techniques are recommended as a safety improvement for locations that are appropriate. An example of a location that may not be appropriate for access management techniques to improve safety is the Alpine Highway. The raised median on the Alpine Highway mainly traverses through a residential area. After the raised median installation, the collision types and severity became more serious, and the cost of crashes increased. It may be concluded that raised medians may not be as effective on roadways that primarily traverse residential areas. Raised medians may be more effective on roadways that primarily access commercial developments. UDOT should continue to monitor locations where raised medians have been installed to determine if this trend continues.

The unique raised median on 400/500 South where a light rail line is located in the median can serve as an excellent learning experience. There are plans for several new light rail lines in the near future for the state of Utah, so it is imperative for UDOT to pay attention to the results of the raised median on 400/500 South. UDOT should utilize the lessons earned from this experience and apply them to future raised median light rail installations.

Future research is recommended for the area of access management. Certain corridors are prime candidates for access management techniques while other locations are not. It would be valuable to develop more specific criteria to identify the characteristics of corridors that make these locations key candidates for access management techniques. It is suggested than a performance index be developed that accounts for such roadway characteristics as volume, crash rate, signal spacing, land use, projected development, level of service, number of lanes, turning frequency, and functional classification. This performance index could be used to evaluate corridors in the state of Utah to determine the need for access management techniques.

It is also recommended that UDOT continue to monitor locations where access management techniques (i.e., raised medians and driveway consolidation) are implemented. As was explained in this report, a number of factors may have contributed to the somewhat unexpected results in the crash rates before and after raised median installation. These include I-15 reconstruction, general traffic volume increases, and land use changes. As other raised median projects are installed, they should be carefully monitored to continue to quantify the overall safety benefits of access management treatments.

REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). (2001). *A Policy on Geometric Design of Highways and Streets.* Washington, DC.

Anderson, D., C. Glazier, and G. Perrett. (2005). UDOT Data Almanac User's Manual, Utah Department of Transportation, Research and Development Division, Salt Lake City, UT.

Answers Search Engine. (2005). Search Performed on Michigan U-turns, <http://www.answers.com/topic/michigan-left> (November 2005).

Center for Transportation Research and Education (CTRE). (2005a). *Access Management Toolkit: Answers to Frequently Asked Questions*, Access Management and Pedestrian Safety, No. 10. Iowa State University, Ames, IA. <http://www.ctre.iastate.edu/research/access/toolkit/10.pdf> (May 2005).

Center for Transportation Research and Education (CTRE). (2005b). *Access Management Toolkit: Answers to Frequently Asked Questions*, Continuous Raised Medians, No. 18. Iowa State University, Ames, IA. <http://www.ctre.iastate.edu/research/access/toolkit/18.pdf> (July 2005).

Center for Transportation Research and Education (CTRE). (2005c). *Access Management Toolkit: Answers to Frequently Asked Questions*, Continuous Two-Way Left-Turn Lanes, No. 15. Iowa State University, Ames, IA. <http://www.ctre.iastate.edu/research/access/toolkit/15.pdf> (June 2005).

Center for Transportation Research and Education (CTRE). (2005d). *Access Management Toolkit: Answers to Frequently Asked Questions*, Frontage and Backage Roads, No. 20. Iowa State University, Ames, IA. <http://www.ctre.iastate.edu/research/access/toolkit/20.pdf> (November 2005).

Center for Transportation Research and Education (CTRE). (2005e). *Access Management Toolkit: Answers to Frequently Asked Questions*, Functional Areas of Intersections, No. 5. Iowa State University, Ames, IA. <http://www.ctre.iastate.edu/research/access/toolkit/5.pdf> (November 2005).

Eisele, W. L., W. E. Frawley, and C. M. Toycen. (2004). *Estimating the Impacts of Access Management Techniques: Final Results.* Report 0-4221-2. Texas Transportation Institute, The Texas A&M University System, College Station, TX.

Federal Highway Administration (FHWA). (2005). FHWA Course on Bicycle and Pedestrian Transportation: Lesson 16. <http://safety.fhwa.dot.gov/ped_bike/univcourse/swless16.htm> (May 2005).

Florida Department of Transportation (FDOT). (1997). *Median Handbook*. Tallahassee, FL.

Gluck, J., H. S. Levinson, and V. Stover. (1999). *NCHRP 420: Impacts of Access Management Techniques*. TRB, National Research Council, Washington, DC.

Huaguo, Z., J. J. Lu, N. Castillo, and K. M. Williams. (2000). Operational Effects of a Right Turn Plus U-turn Treatment as an Alternative to a Direct Left Turn Movement from a Driveway. Published in the *Proceedings of the Fourth National Conference on Access Management*, Portland, OR.

Institute of Transportation Engineers (ITE). (2005). Median Treatments. *Traffic Information Progress Series*. Traffic Engineering Council, Washington, DC. <http://www.ite.org/pdf/twltl_1.pdf> (May 2005).

Lu, J., S. Dissanayake, N. Castillo, and K. Williams. (2001). *Safety Evaluation of Right Turns Followed by U-turns as an Alternative to Direct Left Turns*. University of South Florida College of Engineering. Submitted to Florida Department of Transportation, Tallahassee, FL.

Millard, W. (1993). *Accident Analysis Relating Crashes to Major Access Management Features* – US 41, Lee County, FL.

Parsonson, P. S., M. Waters, and J. S. Fincher (1998). Two-Way Left-Turn Lane With a Raised Median: Atlanta's Memorial Drive. Published in the *Proceedings of the Third National Conference on Access Management*, Fort Lauderdale, FL.

Parsonson, P. S., M. Waters, and J. S. Fincher. (2000). Georgia Study Confirms the Continuing Safety Advantage of Raised Medians Over Two-Way Left-Turn Lanes. Published in the *Proceedings of the Fourth National Conference on Access Management*, Portland, OR.

Saito, M., D. D. Cox, and T. G. Jin. (2004). *Evaluation of Four Recent Traffic and Safety Initiatives, Volume II: Developing a Procedure for Evaluating the Need for Raised Medians.* UDOT Report No. UT-04.11, Department of Civil and Environmental Engineering, Brigham Young University, Provo, UT.

Squires, C. A. and P. S. Parsonson. (1989). Crash Comparison of Raised Median and Two-Way Left-Turn Lane Median Treatments. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1239*. TRB, National Research Council, Washington, DC, pp. 30-40.

Transportation Research Board (TRB). (2003). *Access Management Manual*, Washington, DC.

Transportation Research Institute (TRI). (1997). *Medians: A Survey of the Literature*. Background Paper No. 4 prepared for the Oregon Department of Transportation, Salem, OR. Oregon State University.

Turner-Fairbank Highway Research Center (TFHRC). (2005). Intersection Safety Page. <http://www.tfhrc.gov/safety/pubs/04091/images/fig062.gif> (June 2005).

Utah Department of Transportation (UDOT). (2003). *Administrative Rule R930-6: Accommodation of Utilities and the Control and Protection of State Highway Rights of Way*, Division of Project Development, Railroads, and Utilities Section, Salt Lake City, UT.

Utah Department of Transportation (UDOT). (2005a). St. George Blvd. Project Website. <http://www.stgeorgeboulevard.com/index.php?page_id=14&page_cat_id=8&PHPSESSID=78111dd4f67698b6f31093da78fa0b48> (July 2005).

Utah Department of Transportation (UDOT). (2005b). Traffic on Utah Highways. <http://www.dot.utah.gov/index.php/m=c/tid=529> (July 2005).

Utah Department of Transportation (UDOT). (2005c). UDOT webpage: Highway Map. <http://www.dot.utah.gov/download.php/tid=346/WasatchFrontMap2005.pdf> (October 2005).

Welch, T. M. (2005). "The Conversion of Four-Lane Undivided Urban Roadways to Three-Lane Facilities." Walkable Communities, Inc. <http://www.walkable.org/4-3CON~1.PDF> (June 2005).

APPENDIX A: ANALYSIS LOCATION DATA

Table A-1. Crash and Volume Data for One-Tenth-Mile Intervals of University Parkway for the Before Period of 1999-2001

Route	Milepoint Interval	# of Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
265	1.20 - 1.29	48	12.53	35040	34810	35085
265	1.30 - 1.39	9	2.35	35040	34810	35085
265	1.40 - 1.49	22	5.74	35040	34810	35085
265	1.50 - 1.59	8	2.09	35040	34810	35085
265	1.60 - 1.69	11	2.87	35040	34810	35085
265	1.70 - 1.79	44	11.49	35040	34810	35085
265	1.80 - 1.89	14	3.66	35040	34810	35085
265	1.90 - 1.96	32	11.94	35040	34810	35085
Overall Section		188	6.37	35040	34810	35085

Table A-2. Crash and Volume Data for One-Tenth-Mile Intervals of University Parkway for the After Period of 2003-2004

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume
265	1.20 - 1.29	52	18.75	39235	36735
265	1.30 - 1.39	7	2.52	39235	36735
265	1.40 - 1.49	31	11.18	39235	36735
265	1.50 - 1.59	7	2.52	39235	36735
265	1.60 - 1.69	11	3.97	39235	36735
265	1.70 - 1.79	42	15.15	39235	36735
265	1.80 - 1.89	12	4.33	39235	36735
265	1.90 - 1.96	33	17.00	39235	36735
Overall Section		195	9.13	39235	36735

Table A-3. Crash and Volume Data for Intersections on University Parkway for the Before Period of 1999-2001

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
265	1.20	400 West	55	1.44	35040	34810	35085
265	1.45	200 West	22	0.57	35040	34810	35085
265	1.71	Main Street	42	1.10	35040	34810	35085
265	1.96	200 East	54	1.41	35040	34810	35085

Table A-4. Crash and Volume Data for Intersections on University Parkway for the After Period of 2003-2004

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	2004 Volume	2003 Volume
265	1.20	400 West	53	1.91	39235	36735
265	1.45	200 West	31	1.12	39235	36735
265	1.71	Main Street	47	1.69	39235	36735
265	1.96	200 East	40	1.44	39235	36735

Table A-5. Numbers of Crashes for Certain Collision Types on University Parkway for Before and After Periods

	Number of Crashes	
Collision Type	Before (1999-2001)	After (2003-2004)
Rear End	72	87
Right Angle	93	83
Sideswipe	12	9
Head On	1	1
Single Vehicle	4	7
Other	6	8
Total	188	195

Table A-6. Numbers of Crashes for Certain Crash Severities on University Parkway for Before and After Periods

	Number of Crashes	
Crash Severity	Before (1999-2001)	After (2003-2004)
No injury	111	117
Possible injury	45	51
Bruises/Abrasions	16	18
Broken Bones or Bleeding	15	9
Fatalities	1	0
Total	188	195

Table A-7. Crash and Volume Data for One-Tenth-Mile Intervals of the Alpine Highway for the Before Period of 1999-2001

Route	Milepoint Interval	# of Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
74	2.40 - 2.49	5	3.17	14420	14325	14435
74	2.50 - 2.59	0	0.00	14420	14325	14435
74	2.60 - 2.69	3	1.90	14420	14325	14435
74	2.70 - 2.79	1	0.63	14420	14325	14435
74	2.80 - 2.89	3	1.90	14420	14325	14435
74	2.90 - 2.99	0	0.00	14420	14325	14435
74	3.00 - 3.09	0	0.00	14420	14325	14435
74	3.10 - 3.19	5	3.17	14420	14325	14435
74	3.20 - 3.29	1	0.63	14420	14325	14435
74	3.30 - 3.39	2	1.27	14420	14325	14435
74	3.40 - 3.49	1	0.63	14420	14325	14435
74	3.50 - 3.59	2	1.27	14420	14325	14435
74	3.60 - 3.69	0	0.00	14420	14325	14435
74	3.70 - 3.79	0	0.00	14420	14325	14435
74	3.80 - 3.89	14	11.31	11330	11255	11340
74	3.90 - 3.99	3	2.42	11330	11255	11340
74	4.00 - 4.09	1	0.81	11330	11255	11340
74	4.10 - 4.19	9	7.27	11330	11255	11340
74	4.20 - 4.29	0	0.00	11330	11255	11340
Overall Section		50	1.76	13679	13589	13693

Table A-8. Crash and Volume Data for One-Tenth-Mile Intervals of the Alpine Highway for the After Period of 2003-2004

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume
74	2.40 - 2.49	1	1.01	13525	13705
74	2.50 - 2.59	0	0.00	13525	13705
74	2.60 - 2.69	0	0.00	13525	13705
74	2.70 - 2.79	0	0.00	13525	13705
74	2.80 - 2.89	0	0.00	13525	13705
74	2.90 - 2.99	0	0.00	13525	13705
74	3.00 - 3.09	1	1.01	13525	13705
74	3.10 - 3.19	8	8.05	13525	13705
74	3.20 - 3.29	0	0.00	13525	13705
74	3.30 - 3.39	1	1.01	13525	13705
74	3.40 - 3.49	1	1.01	13525	13705
74	3.50 - 3.59	1	1.01	13525	13705
74	3.60 - 3.69	0	0.00	13525	13705
74	3.70 - 3.79	1	1.01	13525	13705
74	3.80 - 3.89	10	11.21	12635	11800
74	3.90 - 3.99	1	1.12	12635	11800
74	4.00 - 4.09	0	0.00	12635	11800
74	4.10 - 4.19	1	1.12	12635	11800
74	4.20 - 4.29	1	1.12	12635	11800
Overall Section		27	1.46	13361	13274

Table A-9. Crash and Volume Data for Intersections on the Alpine Highway for the Before Period of 1999-2001

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	2001 volume	2000 volume	1999 volume
74	3.12	10400 North	5	0.32	14420	14325	14435
74	3.89	11000 North	16	1.29	11330	11255	11340

Table A-10. Crash and Volume Data for Intersections on the Alpine Highway for the After Period of 2003-2004

Route	Milepoint	Point Description	Total Crashes	Crash Rate	2004 Volume	2003 Volume
74	3.12	10400 North	8	0.80	13525	13705
74	3.89	11000 North	11	1.23	12635	11800

Table A-11. Numbers of Crashes for Certain Collision Types on the Alpine Highway for Before and After Periods

	Number of Crashes	
Collision Type	Before (1999-2001)	After (2003-2004)
Rear End	15	7
Right Angle	15	10
Sideswipe	2	2
Head On	0	0
Single Vehicle	9	7
Other	9	1
Total	50	27

Table A-12. Numbers of Crashes for Certain Crash Severities on the Alpine Highway for Before and After Periods

	Number of Crashes	
Crash Severity	Before (1999-2001)	After (2003-2004)
No injury	37	15
Possible injury	9	8
Bruises/Abrasions	2	2
Broken Bones or Bleeding	2	2
Fatalities	0	0
Total	50	27

Table A-13. Crash and Volume Data for One-Tenth-Mile Intervals of State Street for the Before Period of 1992-1993

Route	Milepoint Interval	# of Crashes	Crash Rate	1993 Volume	1992 Volume
89	311.41 - 311.50	8	5.66	19430	19260
89	311.51 - 311.60	9	6.37	19430	19260
89	311.61 - 311.70	2	1.42	19430	19260
89	311.71 - 311.80	4	2.83	19430	19260
89	311.81 - 311.90	5	3.54	19430	19260
Overall Section		28	3.97	19430	19260

Table A-14. Crash and Volume Data for One-Tenth-Mile Intervals of State Street for the After Period of 1995-1997

Route	Milepoint Interval	# of Accidents	Crash Rate	1997 Volume	1996 Volume	1995 Volume
89	311.41 - 311.50	37	13.95	28440	24215	19990
89	311.51 - 311.60	14	5.28	28440	24215	19990
89	311.61 - 311.70	40	15.09	28440	24215	19990
89	311.71 - 311.80	11	4.15	28440	24215	19990
89	311.81 - 311.90	15	5.66	28440	24215	19990
Overall Section		117	8.83	28440	24215	19990

Table A-15. Crash and Volume Data for Intersections on State Street for the Before Period of 1992-1993

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1993 Volume	1992 Volume
89	311.41	10600 South	8	0.57	19430	19260
89	311.65	10400 South	6	0.42	19430	19260
89	311.90	10200 South	10	0.71	19430	19260

Table A-16. Crash and Volume Data for Intersections on State Street for the After Period of 1995-1997

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1997 Volume	1996 Volume	1995 Volume
89	311.41	10600 South	63	2.38	28440	24215	19990
89	311.65	10400 South	44	1.66	28440	24215	19990
89	311.90	10200 South	20	0.75	28440	24215	19990

Table A-17. Numbers of Crashes for Certain Collision Types on State Street for Before and After Periods

	Number of Crashes	
Collision Type	Before (1992-1993)	After (1995-1997)
Rear End	2	49
Right Angle	12	45
Sideswipe	6	5
Head On	0	0
Single Vehicle	3	11
Other	5	7
Total	28	117

Table A-18. Numbers of Crashes for Certain Crash Severities on State Street for Before and After Periods

Crash Severity	Number of Crashes Before (1992-1993)	After (1995-1997)
No injury	15	70
Possible injury	6	32
Bruises/Abrasions	1	12
Broken Bones or Bleeding	5	3
Fatalities	1	0
Total	28	117

Table A-19. Crash and Volume Data for One-Tenth-Mile Intervals of 400/500 South for the Before Period of 1996-1998

Route	Milepoint Interval	# of Crashes	Crash Rate	1998 Volume	1997 Volume	1996 Volume
186	5.54 - 5.59	9	4.89	29110	27997	26883
186	5.60 - 5.69	30	9.79	29110	27997	26883
186	5.70 - 5.79	6	1.77	32085	30907	29728
186	5.80 - 5.89	12	3.55	32085	30907	29728
186	5.90 - 5.99	5	1.48	32085	30907	29728
186	6.00 - 6.09	19	5.61	32085	30907	29728
186	6.10 - 6.19	13	3.84	32085	30907	29728
186	6.20 - 6.29	17	5.02	32085	30907	29728
186	6.30 - 6.39	1	0.30	32085	30907	29728
186	6.40 - 6.49	18	5.32	32085	30907	29728
186	6.50 - 6.59	13	3.84	32085	30907	29728
186	6.60 - 6.69	2	0.50	37955	36312	34668
186	6.70 - 6.79	10	2.52	37955	36312	34668
186	6.80 - 6.89	2	0.50	37955	36312	34668
186	6.90 - 6.99	24	5.30	43550	41387	39223
186	7.00 - 7.09	15	3.31	43550	41387	39223
186	7.10 - 7.19	3	0.66	43550	41387	39223
186	7.20 - 7.29	8	1.77	43550	41387	39223
186	7.30 - 7.39	7	1.54	43550	41387	39223
186	7.40 - 7.49	1	0.22	43550	41387	39223
186	7.50 - 7.59	5	0.96	49967	47523	45079
Overall Section		220	2.75	37096	35499	33902

Table A-20. Crash and Volume Data for One-Tenth-Mile Intervals of 400/500 South for the After Period of 2002-2004

Route	Milepoint Interval	# of Crashes	Crash Rate	2002 Volume	2003 Volume	2004 Volume
186	5.54 - 5.59	18	11.94	22308	22308	24235
186	5.60 - 5.69	20	7.96	22308	22308	24235
186	5.70 - 5.79	5	2.04	22340	22340	22340
186	5.80 - 5.89	17	6.95	22340	22340	22340
186	5.90 - 5.99	5	2.04	22340	22340	22340
186	6.00 - 6.09	6	2.45	22340	22340	22340
186	6.10 - 6.19	9	3.68	22340	22340	22340
186	6.20 - 6.29	11	4.50	22340	22340	22340
186	6.30 - 6.39	5	2.04	22340	22340	22340
186	6.40 - 6.49	19	7.77	22340	22340	22340
186	6.50 - 6.59	18	7.36	22340	22340	22340
186	6.60 - 6.69	3	1.27	20065	23143	21675
186	6.70 - 6.79	5	2.11	20065	23143	21675
186	6.80 - 6.89	7	2.96	20065	23143	21675
186	6.90 - 6.99	12	4.79	23273	22860	22555
186	7.00 - 7.09	18	7.18	23273	22860	22555
186	7.10 - 7.19	2	0.80	23273	22860	22555
186	7.20 - 7.29	8	3.19	23273	22860	22555
186	7.30 - 7.39	7	2.79	23273	22860	22555
186	7.40 - 7.49	4	1.60	23273	22860	22555
186	7.50 - 7.59	8	2.70	29455	28930	22655
Overall Section		207	4.03	22734	23038	22578

Table A-21. Crash and Volume Data for Intersections on 400/500 South for the Before Period of 1996-1998

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1996 Volume	1997 Volume	1998 Volume
186	5.54	Main Street	8	0.26	26883	27997	29110
186	5.69	State Street	21	0.62	29728	30907	32085
186	5.84	200 East	12	0.35	29728	30907	32085
186	5.99	300 East	16	0.47	29728	30907	32085
186	6.14	400 East	12	0.35	29728	30907	32085
186	6.29	500 East	16	0.47	29728	30907	32085
186	6.44	600 East	17	0.50	29728	30907	32085
186	6.59	700 East	14	0.35	34668	36312	37955
186	6.74	800 East	10	0.25	34668	36312	37955
186	6.90	900 East	21	0.46	39223	41387	43550
186	7.29	1100 East	7	0.15	39223	41387	43550
186	7.59	1300 East	40	0.77	45079	47523	49967

Table A-22. Crash and Volume Data for Intersections on 400/500 South for the After Period of 2002-2004

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	2002 Volume	2003 Volume	2004 Volume
186	5.54	Main Street	22	0.88	22308	22308	24235
186	5.69	State Street	18	0.72	22308	22308	24235
186	5.84	200 East	17	0.69	22340	22340	22340
186	5.99	300 East	8	0.33	22340	22340	22340
186	6.14	400 East	9	0.37	22340	22340	22340
186	6.29	500 East	8	0.33	22340	22340	22340
186	6.44	600 East	19	0.78	22340	22340	22340
186	6.59	700 East	19	0.78	22340	22340	22340
186	6.74	800 East	5	0.21	20065	23143	21675
186	6.90	900 East	14	0.56	23273	22860	22555
186	7.29	1100 East	14	0.56	23273	22860	22555
186	7.59	1300 East	13	0.44	29455	28930	22655

Table A-23. Numbers of Crashes for Certain Collision Types on 400/500 South for Before and After Periods

	Number of Crashes	
Collision Type	Before (1996-1998)	After (2002-2004)
Rear End	61	72
Right Angle	86	40
Sideswipe	7	9
Head On	0	0
Single Vehicle	38	66
Other	28	20
Total	220	207

Table A-24. Numbers of Crashes for Certain Crash Severities on 400/500 South for Before and After Periods

	Number of Crashes	
Crash Severity	Before (1996-1998)	After (2002-2004)
No injury	53	79
Possible injury	85	76
Bruises/Abrasions	45	36
Broken Bones or Bleeding	36	13
Fatalities	1	3
Total	220	207

Table A-25. Crash and Volume Data for One-Tenth-Mile Intervals of 300 West for the Before Period of 1996-1998

Route	Milepoint Interval	# of Crashes	Crash Rate	1998 Volume	1997 Volume	1996 Volume
89	326.68 - 326.77	12	4.37	26235	25065	23895
89	326.78 - 326.87	4	1.46	26235	25065	23895
89	326.88 - 326.97	14	5.10	26235	25065	23895
Overall Section		30	3.64	26235	25065	23895

Table A-26. Crash and Volume Data for One-Tenth-Mile Intervals of 300 West for the After Period of 2000-2002

Route	Milepoint Interval	# of Crashes	Crash Rate	2002 Volume	2001 Volume	2000 Volume
89	326.68 - 326.78	24	10.80	18385	17225	25250
89	326.78 - 326.88	4	1.80	18385	17225	25250
89	326.88 - 326.98	11	4.95	18385	17225	25250
Overall Section		39	5.85	18385	17225	25250

Table A-27. Crash and Volume Data for Intersections on 300 West for the Before Period of 1996-1998

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1998 Volume	1997 Volume	1996 Volume
89	326.68	North Temple	13	0.47	26235	25065	23895
89	326.97	300 North	14	0.51	26235	25065	23895

Table A-28. Crash and Volume Data for Intersections on 300 West for the After Period of 2000-2002

Route	Milepoint	Point Description	Total Crashes	Crash Rate	2002 Volume	2001 Volume	2000 Volume
89	326.68	North Temple	12	0.54	18385	17225	25250
89	326.97	300 North	18	0.81	18385	17225	25250

Table A-29. Numbers of Crashes for Certain Collision Types on 300 West for Before and After Periods

	Number of Crashes	
Collision Type	Before (1996-1998)	After (2000-2002)
Rear End	14	16
Right Angle	11	14
Sideswipe	0	0
Head On	0	0
Single Vehicle	3	1
Other	2	8
Total	30	39

Table A-30. Numbers of Crashes for Certain Crash Severities on 300 West for Before and After Periods

	Number of Crashes	
Crash Severity	Before (1996-1998)	After (2000-2002)
No injury	9	11
Possible injury	11	15
Bruises/Abrasions	6	11
Broken Bones or Bleeding	4	2
Fatalities	0	0
Total	30	39

Table A-31. Crash and Volume Data for One-Tenth-Mile Intervals of Redwood Road for the Before Period of 1992-1993

Route	Milepoint Interval	# of crashes	Crash Rate	1993 Volume	1992 Volume
68	50.75 - 50.84	14	3.80	51500	49480
68	50.85 - 50.94	19	5.15	51500	49480
68	50.95 - 51.04	53	14.38	51500	49480
68	51.05 - 51.14	10	2.71	51500	49480
68	51.15 - 51.24	75	20.35	51500	49480
68	51.25 - 51.34	11	2.98	51500	49480
68	51.35 - 51.44	15	4.07	51500	49480
68	51.45 - 51.47	7	6.33	51500	49480
Overall Section		225	8.36	51500	49480

Table A-32. Crash and Volume Data for One-Tenth-Mile Intervals of Redwood Road for the After Period of 1995-1997

Route	Milepoint Interval	# of Crashes	Crash Rate	1997 Volume	1996 Volume	1995 Volume
68	50.75 - 50.84	33	5.28	58468	57082	55695
68	50.85 - 50.94	15	2.40	58468	57082	55695
68	50.95 - 51.04	32	5.12	58468	57082	55695
68	51.05 - 51.14	20	3.20	58468	57082	55695
68	51.15 - 51.24	124	19.84	58468	57082	55695
68	51.25 - 51.34	21	3.36	58468	57082	55695
68	51.35 - 51.44	52	8.32	58468	57082	55695
68	51.45 - 51.47	27	14.40	58468	57082	55695
Overall Section		331	7.25	58468	57082	55695

Table A-33. Crash and Volume Data for Intersections on Redwood Road for the Before Period of 1992-1993

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1993 Volume	1992 Volume
68	50.75	I-215 EB Off Ramp	13	0.35	51500	49480
68	51.01	I-215 WB Off Ramp	48	1.30	51500	49480
68	51.21	5600 South	35	0.95	51500	49480
68	51.47	5400 South	49	1.33	51500	49480

Table A-34. Crash and Volume Data for Intersections on Redwood Road for the After Period of 1995-1997

Route	Milepoint	Intersection Description	Total Crashes	Crash Rate	1997 Volume	1996 Volume	1995 Volume
68	50.75	I-215 EB Off Ramp	28	0.45	58468	57082	55695
68	51.01	I-215 WB Off Ramp	25	0.40	58468	57082	55695
68	51.21	5600 South	46	0.74	58468	57082	55695
68	51.47	5400 South	151	2.42	58468	57082	55695

Table A-35. Numbers of Crashes for Certain Collision Types on Redwood Road for Before and After Periods

	Number of Crashes	
Collision Type	**Before (1992-1993)**	**After (1995-1997)**
Rear End	73	123
Right Angle	116	138
Sideswipe	11	37
Head On	0	0
Single Vehicle	8	13
Other	17	20
Total	225	331

Table A-36. Numbers of Crashes for Certain Crash Severities on Redwood Road for Before and After Periods

	Number of Crashes	
Crash Severity	**Before (1992-1993)**	**After (1995-1997)**
No injury	147	236
Possible injury	52	66
Bruises/Abrasions	17	21
Broken Bones or Bleeding	9	8
Fatalities	0	0
Total	225	331

APPENDIX B: CONTROL SITE DATA

Table B-1. Crash and Volume Data for One-Tenth-Mile Intervals of 700 East for Period 1 (1994-1996)

Route	Milepoint Interval	# of Crashes	Crash Rate	1996 Volume	1995 Volume	1994 Volume
71	21.87 - 21.96	57	12.31	42970	42270	41570
71	21.97 - 22.06	19	4.10	42970	42270	41570
71	22.07 - 22.16	15	3.24	42970	42270	41570
71	22.17 - 22.26	24	5.19	42970	42270	41570
71	22.27 - 22.36	37	7.99	42970	42270	41570
71	22.37 - 22.46	13	2.81	42970	42270	41570
Overall Section		165	5.94	42970	42270	41570

Table B-2. Crash and Volume Data for One-Tenth-Mile Intervals of 700 East for Period 2 (2002-2004)

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume	2002 Volume
71	21.87 - 21.96	19	4.57	36115	38495	39355
71	21.97 - 22.06	5	1.20	36115	38495	39355
71	22.07 - 22.16	22	5.29	36115	38495	39355
71	22.17 - 22.26	3	0.72	36115	38495	39355
71	22.27 - 22.36	21	5.05	36115	38495	39355
71	22.37 - 22.46	12	2.88	36115	38495	39355
Overall Section		82	3.29	36115	38495	39355

Table B-3. Numbers of Crashes for Certain Crash Severities on 700 East for Period 1 and Period 2

Crash Severity	Number of Crashes Period 1 (1994-1996)	Number of Crashes Period 2 (2002-2004)
No injury	56	21
Possible injury	64	32
Bruises/Abrasions	34	19
Broken Bones or Bleeding	11	9
Fatalities	0	1
Total	165	82

Table B-4. Crash and Volume Data for One-Tenth-Mile Intervals of 12300 South for Period 1 (1999-2001)

Route	Milepoint Interval	# of Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
71	4.56 - 4.65	9	3.67	23040	21030	23080
71	4.66 - 4.75	14	5.71	23040	21030	23080
71	4.76 - 4.85	30	12.24	23040	21030	23080
71	4.86 - 4.95	34	11.20	27647	27647	27870
71	4.96 - 5.05	82	28.40	27647	27647	23810
71	5.06 - 5.15	3	1.04	27647	27647	23810
71	5.16 - 5.25	2	0.69	27647	27647	23810
71	5.26 - 5.35	16	5.54	27647	27647	23810
71	5.36 - 5.45	25	8.93	27647	27647	21405
Overall Section		215	8.75	25907	25147	23762

Table B-5. Crash and Volume Data for One-Tenth-Mile Intervals of 12300 South for Period 2 (2002-2004)

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume	2002 Volume
71	4.56 - 4.65	17	5.35	28600	28985	29510
71	4.66 - 4.75	62	19.50	28600	28985	29510
71	4.76 - 4.85	11	3.46	28600	28985	29510
71	4.86 - 4.95	50	15.73	28600	28985	29510
71	4.96 - 5.05	33	10.38	28600	28985	29510
71	5.06 - 5.15	73	22.96	28600	28985	29510
71	5.16 - 5.25	8	2.52	28600	28985	29510
71	5.26 - 5.35	17	5.35	28600	28985	29510
71	5.36 - 5.45	16	5.03	28600	28985	29510
Overall Section		287	10.03	28600	28985	29510

Table B-6. Numbers of Crashes for Certain Crash Severities on 12300 South for Period 1 and Period 2

Crash Severity	Number of Crashes Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	140	189
Possible injury	48	76
Bruises/Abrasions	21	17
Broken Bones or Bleeding	7	7
Fatalities	0	1
Total	215	287

Table B-7. Crash and Volume Data for One-Tenth-Mile Intervals of Redwood Road for Period 1 (1994-1996)

Route	Milepoint Interval	# of Crashes	Crash Rate	1996 Volume	1995 Volume	1994 Volume
68	49.46 - 49.55	8	2.35	32235	31115	29995
68	49.56 - 49.65	13	3.82	32235	31115	29995
68	49.66 - 49.75	20	5.87	32235	31115	29995
68	49.76 - 49.85	5	1.47	32235	31115	29995
68	49.86 - 49.95	15	4.40	32235	31115	29995
Overall Section		61	3.58	32235	31115	29995

Table B-8. Crash and Volume Data for One-Tenth-Mile Intervals of Redwood Road for Period 2 (2002-2004)

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume	2002 Volume
68	49.46 - 49.55	18	4.82	31260	32669	38305
68	49.56 - 49.65	20	5.36	31260	32669	38305
68	49.66 - 49.75	12	3.22	31260	32669	38305
68	49.76 - 49.85	11	2.95	31260	32669	38305
68	49.86 - 49.95	5	1.34	31260	32669	38305
Overall Section		66	3.54	31260	32669	38305

Table B-9. Numbers of Crashes for Certain Crash Severities on Redwood Road for Period 1 and Period 2

	Number of Crashes	
Crash Severity	Period 1 (1994-1996)	Period 2 (2002-2004)
No injury	38	42
Possible injury	17	14
Bruises/Abrasions	4	8
Broken Bones or Bleeding	2	2
Fatalities	1	0
Total	61	66

Table B-10. Crash and Volume Data for One-Tenth-Mile Intervals of St. George Blvd. for Period 1 (1999-2001)

Route	Milepoint Interval	# of Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
34	0.00 - 0.09	55	21.44	20125	24983	25160
34	0.10 - 0.19	17	6.63	20125	24983	25160
34	0.20 - 0.29	31	12.09	20125	24983	25160
34	0.30 - 0.39	6	2.34	20125	24983	25160
34	0.40 - 0.49	11	4.29	20125	24983	25160
34	0.50 - 0.59	23	5.61	36095	37995	38295
34	0.60 - 0.69	16	3.90	36095	37995	38295
34	0.70 - 0.79	20	4.88	36095	37995	38295
34	0.80 - 0.89	15	3.66	36095	37995	38295
34	0.90 - 0.99	14	3.41	36095	37995	38295
34	1.00 - 1.09	39	9.51	36095	37995	38295
34	1.10 - 1.19	13	3.17	36095	37995	38295
34	1.20 - 1.29	24	5.85	36095	37995	38295
34	1.30 - 1.39	29	7.07	36095	37995	38295
34	1.40 - 1.49	24	5.67	38585	38585	38890
34	1.50 - 1.59	19	4.49	38585	38585	38890
34	1.60 - 1.69	47	11.09	38585	38585	38890
34	1.70 - 1.74	44	20.77	38585	38585	38890
Overall Section		447	7.00	31586	34073	34335

Table B-11. Crash and Volume Data for One-Tenth-Mile Intervals of St. George Blvd. for Period 2 (2002-2004)

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume	2002 Volume
34	0.00 - 0.09	54	23.79	19230	21473	21473
34	0.10 - 0.19	26	11.46	19230	21473	21473
34	0.20 - 0.29	27	11.90	19230	21473	21473
34	0.30 - 0.39	8	3.53	19230	21473	21473
34	0.40 - 0.49	10	4.41	19230	21473	21473
34	0.50 - 0.59	27	7.65	29380	28747	38513
34	0.60 - 0.69	12	3.40	29380	28747	38513
34	0.70 - 0.79	12	3.40	29380	28747	38513
34	0.80 - 0.89	22	6.24	29380	28747	38513
34	0.90 - 0.99	17	4.82	29380	28747	38513
34	1.00 - 1.09	47	13.32	29380	28747	38513
34	1.10 - 1.19	20	5.67	29380	28747	38513
34	1.20 - 1.29	21	5.95	29380	28747	38513
34	1.30 - 1.39	53	15.03	29380	28747	38513
34	1.40 - 1.49	35	8.85	33960	33227	41170
34	1.50 - 1.59	44	11.13	33960	33227	41170
34	1.60 - 1.69	50	12.64	33960	33227	41170
34	1.70 - 1.74	58	29.33	33960	33227	41170
Overall Section		543	9.62	27171	27456	33702

Table B-12. Numbers of Crashes for Certain Crash Severities on St. George Blvd. for Period 1 and Period 2

	Number of Crashes	
Crash Severity	Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	298	377
Possible injury	105	125
Bruises/Abrasions	33	33
Broken Bones or Bleeding	11	7
Fatalities	0	1
Total	447	543

Table B-13. Crash and Volume Data for One-Tenth-Mile Intervals of SR 36 for Period 1 (1999-2001)

Route	Milepoint Interval	# of Crashes	Crash Rate	2001 Volume	2000 Volume	1999 Volume
36	59.90 - 59.99	1	0.53	17410	17230	17126
36	60.00 - 60.09	1	0.53	17410	17230	17126
36	60.10 - 60.19	1	0.53	17410	17230	17126
36	60.20 - 60.29	2	1.06	17410	17230	17126
36	60.30 - 60.39	1	0.53	17410	17230	17126
36	60.40 - 60.49	1	0.53	17410	17230	17126
36	60.50 - 60.59	1	0.53	17410	17230	17126
36	60.60 - 60.69	4	2.12	17410	17230	17126
36	60.70 - 60.79	4	2.12	17410	17230	17126
36	60.80 - 60.89	4	2.12	17410	17230	17126
Overall Section		20	1.06	17410	17230	17126

Table B-14. Crash and Volume Data for One-Tenth-Mile Intervals of SR 36 for Period 2 (2002-2004)

Route	Milepoint Interval	# of Crashes	Crash Rate	2004 Volume	2003 Volume	2002 Volume
36	59.90 - 59.99	6	1.99	28080	26990	27390
36	60.00 - 60.09	1	0.33	28080	26990	27390
36	60.10 - 60.19	6	1.99	28080	26990	27390
36	60.20 - 60.29	2	0.66	28080	26990	27390
36	60.30 - 60.39	5	1.66	28080	26990	27390
36	60.40 - 60.49	2	0.66	28080	26990	27390
36	60.50 - 60.59	2	0.66	28080	26990	27390
36	60.60 - 60.69	2	0.66	28080	26990	27390
36	60.70 - 60.79	1	0.33	28080	26990	27390
36	60.80 - 60.89	1	0.33	28080	26990	27390
Overall Section		28	0.93	28080	26990	27390

Table B-15. Numbers of Crashes for Certain Crash Severities on SR 36 for Period 1 and Period 2

	Number of Crashes	
Crash Severity	Period 1 (1999-2001)	Period 2 (2002-2004)
No injury	7	20
Possible injury	8	6
Bruises/Abrasions	3	3
Broken Bones or Bleeding	2	2
Fatalities	0	0
Total	20	28