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EVALUATION OF FOUR RECENT TRAFFIC AND SAFETY INITIATIVES

Volume II: Developing a Procedure For Evaluating the Need for Raised Medians

FINAL REPORT

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16. Abstract

Raised medians are a safety measure often used on highways to improve safety, maintain good traffic flow, and beautify the area. In this study, an extensive literature review was conducted to determine the advantages and disadvantages of raised medians. Raised medians were also compared to other median alternatives, such as two-way left-turn lanes (TWLTL) and undivided highways. Raised medians were found to provide better safety benefits than the other median types. A TWLTL tends to be a compromise between the raised median and the undivided highway because of the improvement in traffic flow and full property access. A survey was conducted on a principle arterial that recently installed a raised median. It was found that although raised medians may be perceived as an inconvenience, they do not keep customers from visiting adjacent businesses. Many also realized the safety benefits of raised medians. A crash analysis was also conducted on four highways in the greater Salt Lake City area. Raised medians were found to reduce severe crashes and right angle crashes in mid-blocks, while rear-end crashes increased in mid-blocks. Crashes did not necessarily shift to intersections. Right angle crashes at intersections either decreased or stayed the same, and rear-end crashes either increased or stayed the same. Using the information from the literature review, survey and crash analysis, a procedure for determining when to install a raised median was formulated. The procedure considers crash history, pedestrians, traffic volume, delays, number of driveways per mile, mid-block openings, and number of lanes. The procedure was applied to St. George Boulevard in St. George, Utah.

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1. INTRODUCTION

The Utah Department of Transportation (UDOT) selected a two-year research study of four recent traffic and safety initiatives in the Utah Transportation Research Advisory Committee (UTRAC) Workshop held at Brigham Young University in March 2002. Four traffic and safety initiatives that were included in the study were:

- Roundabouts,
- Raised Medians,
- Centerline rumble strips, and
- School zone policies.

This research report presents the findings of a study that evaluated traffic, safety and economic impacts of raised medians, especially those that have been constructed on segments of UDOT's highways. The main focus of the study was to develop a procedure for determining whether a raised median would be appropriate for a segment of a state highway under consideration.

1.1 Problem Statement

Recently, some cities in Utah that have state highways running through their central business districts (CBDs) have experienced congestion and have requested UDOT to install raised medians. Generally, raised medians improve through movements, provide refuge for pedestrians, and may or may not affect businesses negatively depending on the types of businesses on the adjacent land. They have been installed for various reasons, for instance, the improvement of traffic safety and traffic flow and the beautification of the area. UDOT currently does not have procedures for determining when to install a raised median; therefore, there is a need to develop such procedures that UDOT engineers can use at the time requests for raised medians on state highways are made by local agencies.

1.2 Objectives and Research Methodology

The objectives of this project are to:

1. Conduct a literature review,
2. Compare differences between different median types,
3. Conduct case studies of recent raised median installations in the local area, and
4. Develop a procedure for determining when to install raised medians in CBDs using the findings from objectives 1 through 3.

In the course of the study, two additional objectives were added, which are to:

1. Study crash data of four major arterials that have recently been treated with raised medians in Salt Lake County, and

2. Conduct a survey to evaluate impacts on travel behaviors of customers and consensus on economic impacts by store owners and managers.

The methodology of the study included a comprehensive literature review, customer and store manager/owner surveys, case study reviews, and crash analysis. From the findings of these tasks a procedure for evaluating the need for a raised median was developed.

1.3 Organization of the Report

Chapter 1 includes the background of this research topic, the problem that brought about the selection of raised medians as a study topic, and the objectives of this study. Chapter 2 consists of the literature review. The review covers the differences between the undivided median, the two-way left-turn lane (TWLTL), and the raised median (divided median). It also discusses eight topics relative to the median types with an emphasis on raised medians. Chapter 3 explains the findings of a customer and manager survey conducted at a principal arterial where UDOT recently installed a raised median. Chapter 4 discusses the results of a crash analysis conducted on four highways where UDOT has installed raised medians during the last 10 years. The analysis looked at severity, collision type, and location of crashes. Chapter 5 outlines the conclusions of the study. Appendix A contains a procedure for evaluating the need for a raised median and a sample evaluation. Appendix B, C, and D contain copies of the manager survey, customer survey, and manager and customer comments, respectively.

2. LITERATURE REVIEW

A comprehensive literature review was conducted through journal articles from the National Cooperative Highway Research Program (NCHRP), the Transportation Research Board (TRB) and Institute of Transportation Engineers (ITE) publications and other resources available on the Internet. Also, American Association of State Highway and Transportation Officials (AASHTO) and Federal Highway Administration (FHWA) statements were collected and reviewed. Furthermore, state department of transportation (DOT) practices were examined regarding raised median guidelines and design. The three main topics studied were: operations, safety, and economic impact. Special attention was placed to compare the differences among the three typical median treatments:

- Undivided median,
- TWLTL, and
- Raised median (divided median).

From the literature review, the principal differences and similarities among the three typical median types were enumerated in terms of requirements for right-of-way, safety, operations (particularly left-turn movements), and economic impact.

This section reports the findings from this literature search. It is comprehensive though not exhaustive insofar as time and resources were permitted and the scope is limited to CBDs. The emphasis of the literature search was on raised medians as the purpose of the study indicated.

The findings from the literature review are presented in the following eight sections:

1. Safety,
2. Operations,
3. Economics,
4. Aesthetics,
5. Cost,
6. Case Studies in Other States,
7. Models, and
8. Design Considerations.

2.1 Safety

2.1.1 Vehicle Safety

In general, previous studies indicate that both the TWLTL and raised median would provide an improvement in safety over an undivided median and that conversion from the TWLTL to the raised median would improve safety. For instance, Reish and Lalani (1987) reported on four different agencies that found crash rates were reduced with raised medians. These include:

- Georgia DOT found that the crash rate for a 6-lane roadway separated by a raised median was 4.4 crashes per million vehicle miles of travel lower than a similar facility with a TWLTL.
- The city of Arlington, Texas found a 66 percent reduction in crashes due to use of raised medians on 4-lane roadways.
- The New York State DOT reported crash rates for 6-lane undivided highways were 11.28 crashes per million vehicle miles of travel and 7.43 for divided highways, a difference of 34 percent.
- In a 1982 study by the FHWA, the implementation of raised medians resulted in a reduction of crash rates by 5 to as much as 80 percent.

Reish and Lalani (1987) stated that raised medians are an improvement over TWLTLs because mid-block crashes on roads with TWLTLs become higher on high volume streets.

Mukerjee, Chatterjee, and Margiotta (1993) compared the findings of various median-related studies. One of the studies conducted by Parsonson (1990) concluded that under all conditions a non-traversable median is safer than a TWLTL. However, when the model of Squires and Parsonson (1989) was compared to the models by Parker (1981) and Harwood (1986), they were conflicting in regard to crash rates. It was also reported that state design engineers did not come to a consensus when choosing between a TWLTL and a raised median when they were asked which median type they prefer.

Nevertheless, there are many findings in the literature indicating that raised medians are effective in reducing overall crash rates. In the NCHRP Report 420 (1999), Gluck, Levinson and Stover presented the average annual crashes per mile predicted from several safety models for the three types of median treatments as shown in Figure 1. In this figure crashes per mile are related to Average Daily Traffic (ADT). As shown in Figure 1, the raised median has fewer annual crashes per mile than either the TWLTL or the undivided road.

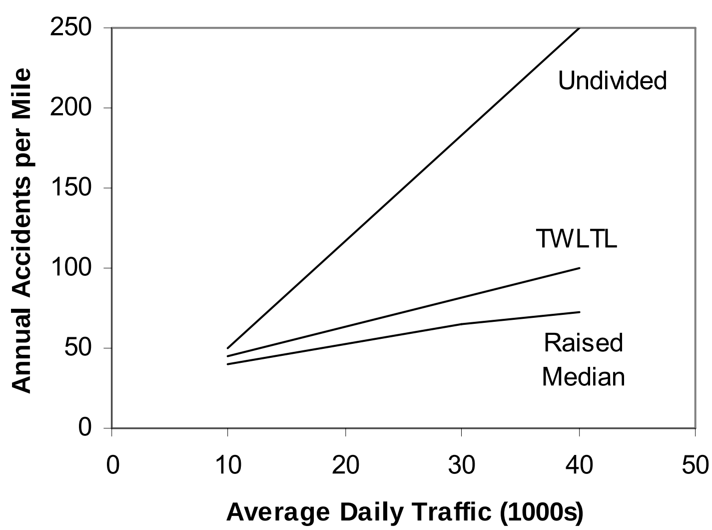

Figure 1: ADT versus annual crashes per mile
(Source: Gluck, Levinson and Stover 1999)

The Center for Transportation Research and Education (CTRE) reports that in addition to having more frequent crashes with higher traffic demand there are more frequent crashes with greater driveway densities, as cars make more frequent left-turns and right-turns (CTRE 2003d). Table 1 shows the relation between access points per mile and crash rate on undivided, TWLTL, and raised median roads presented by Bonneson and McCoy (1997).

Table 1: Crash rates by access points per mile

Access Points Per Mile	Undivided Roadway	TWLTL	Raised Median (RM)	Crash Rate Reduction TWLTL vs RM
<20	3.8	3.4	2.9	15%
20-40	7.3	5.9	5.1	14%
40-60	9.4	7.4	6.5	12%
>60	10.6	9.2	8.2	11%

Note: Crash rates per 100 million vehicle miles (MVM)
(Source: Bonneson and McCoy 1997)

Removing left-turning traffic from main-flow through lanes will improve traffic safety, which is accomplished by TWLTLs and by left-turn bays in raised medians. For the TWLTL, however, when traffic volumes become too high or if there are concentrated left-turns, safety may be compromised. Since TWLTLs have some of the benefits of both raised medians and undivided medians, they have been considered a compromise solution by Bonneson and McCoy (1998). One of the concerns for raised medians is that crashes may migrate to the surrounding neighborhoods, while one concern for TWLTLs is head-on collisions (Dixon, Hibbard, and Mroczka 1999).

Bonneson and McCoy (1998) reported that raised-curb medians are associated with fewer crashes than TWLTLs and undivided medians, but if U-turn activity increases, crashes may increase and reduce the safety margin between raised-curb medians and other median types.

In some studies, however, crash rates increased after the installation of raised medians. Dixon, Hibbard, and Mroczka (1999) stated in their study of three median improvement projects that the number of right angle crashes and overall crashes increased. However, the crash rates of the locations where raised medians were not installed were still higher, given the rapid growth of the area. Furthermore, they reported that median-related crashes would not migrate to the bounding signalized intersections as long as U-turns could occur at median openings.

As to the effect of the number of driveways on crash occurrence, Glennon et al. (1975a) found that when driveway density was 60 or more per mile, non-traversable medians were safer. In other situations, a TWLTL was safer.

Dixon, Hibbard, and Mroczka(1999) also reported that the general public still had concerns for TWLTLs and raised medians at the time their study was conducted. Safety concerns brought up by citizens concerning TWLTLs and raised medians were:

- The TWLTL would be a suicide lane,
- U-turns at intersections or mid-block openings would disrupt traffic flow, and
- Raised medians would encourage vehicles to travel at higher speeds.

Despite these general concerns, Gluck, Levinson, and Stover (1999) report that TWLTLs and raised medians have been found to reduce potential for rear-end crashes near intersections and reduced crashes by 35 percent in suburban areas and 70 to 85 percent in rural areas. Consistent reductions were reported in rear-end, sideswipe, head-on, fixed end crashes, and left-turn crashes.

2.1.2 Pedestrian Safety

As for pedestrian safety, previous studies show raised medians are advantageous for pedestrians because they provide pedestrian refuge areas in the middle of the highway. Islands, or raised medians, allow pedestrians to cross the road in two smaller segments, which allow them to focus in one direction of traffic at a time, instead of two. Also, pedestrians wait for a smaller gap to cross with raised medians because they only have to cross half as many lanes (FHWA 2003). Figures 2 and 3 show the difference in pedestrian safety in the crossing maneuvers.

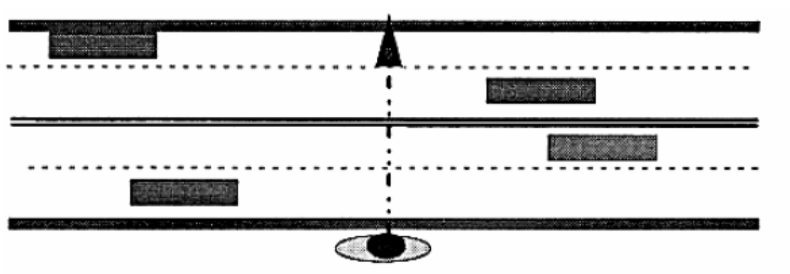

Figure 2: Mid-block pedestrian crossing without raised median
(Source: FHWA 2003)

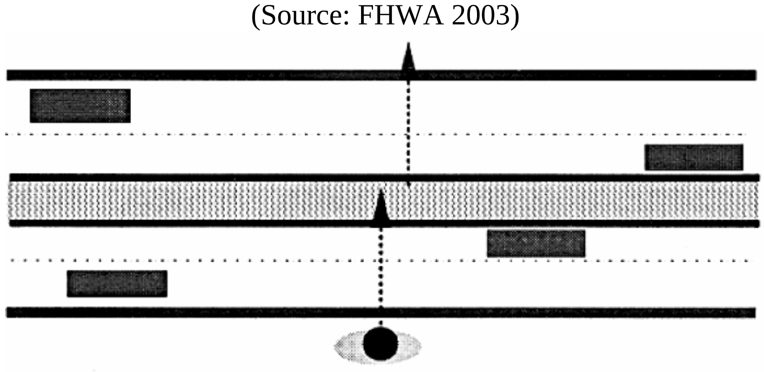

Figure 3: Mid-block pedestrian crossing with raised median
(Source: FHWA 2003)

As shown by Figures 2 and 3, raised medians reduce the number of conflict points that pedestrians encounter because vehicle maneuvers become more predictable. Raised medians are similar to reducing driveways or putting more distance between driveways, in that safety is improved as left-turns are reduced, making access points safer. With raised medians traffic will enter and exit driveways in one direction. Even if a mid-block opening is provided with a raised median, traffic movements are more predictable than before (CTRE 2003b). Figure 4 shows the effective use of raised medians for pedestrians crossing the street on a college campus. In the figure, pedestrians are able to wait as cars pass before crossing the street. Even though there are three lanes in each direction, pedestrians seem at ease.

Figure 4: Pedestrians cross road with raised median
(Source: FHWA 2003)

The Florida DOT recommends providing adequate pedestrian safety in high pedestrian zones. It also recommends that medians be considered in existing as well as new school zones, entertainment districts, tourist zones, residential neighborhoods, and other high volume pedestrian areas. They should especially be considered when these high pedestrian roadways have four or six lanes of traffic (FDOT 1995).

Table 2 shows pedestrian and crash rates by roadway type for mid-block and intersection locations. As shown in the table, pedestrian crash rates at the midblock are 1.7 times greater on undivided and TWLTL roads than on divided 4 lane roads. Moreover, pedestrian crash rates at intersections are 2.6 times greater on TWLTL roads and 2.4 times greater on undivided roads than on divided 4 lane roads. Also note that the pedestrian crash rate is similar for undivided and TWLTL cross-sections. At the midblock, pedestrian crash rate is 1.005 times greater on undivided 4 lane roads than on TWLTL roads. At intersections, pedestrian crash rate is 1.07 times greater on TWLTL roads than on undivided 4 lane roads. To experience these benefits, it is recommended that the median be at least 4 feet in width (CTRE 2003b). The CTRE also found that roads with raised medians are "roughly twice as safe for pedestrians" than roads with other median types. This is important for children and the elderly because they have less adequate gap assessment skills – skills needed to assess when to cross the street. It is also important for all pedestrians during the night, because people generally have reduced gap assessment skills at night and drivers have a more difficult time seeing pedestrians (FHWA 2003).

Table 2: Mid-block and intersection pedestrian crash rates by roadway type

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

a = crashes per million vehicle miles,
b = crashes per million entering vehicles
(Source: CTRE 2003b)

A similar statement was made by ITE (2003) that raised medians have been found to reduce crashes 25-40 percent and they can be used as a refuge for pedestrians. However, raised medians can be dangerous if struck at high speeds, and their visibility at night is an issue unless they are well lit.

The CTRE (2003b,d) list three advantages of raised medians over TWLTLs:

1. They prevent crashes caused by crossover traffic,
2. They reduce headlight glare, and
3. They provide pedestrian protection.

The CTRE recommends that raised medians be considered when pedestrian safety or serious crashes are a concern; however, TWLTLs may be adequate for serious crashes other than pedestrian crashes. Also, TWLTLs should be avoided on roads with more than two lanes in each direction because pedestrian crash rates increase dramatically (CTRE 2003b).

2.2 Operations

Traffic operations related to raised medians include access to adjacent businesses, delay, and traffic flow. Raised medians are more often preferred when safety is a concern, but they do have advantages that are important to recognize in terms of traffic operations. Table 3 shows the relative levels of access, delay, and separation of traffic for raised median, TWLTL, and undivided roads. For example, delay caused by left-turning vehicles is not a concern for raised medians when there are left-turn bays either at mid-block locations or at intersections. Also, raised medians are desirable for left turn storage when left-turn volumes are high (Van

Winkle 1988). Furthermore, traffic flows better on roadways that include raised medians because of separation of traffic. However, access to adjacent business is a concern because left-turns are blocked by raised medians at mid-block locations.

Table 3: Relative levels of access, delay and separation of traffic between median types

	Raised Median	TWLTL	Undivided Road
Access	low	high	high
Delay	low	low	high
Separation of traffic	high	medium	low

A TWLTL is usually the best alternative in terms of operations because it has the benefits of direct access provided by undivided roads and the benefits of decreased delay for through vehicles provided by raised medians (Gluck, Levinson, and Stover 1999; Dixon, Hibbard, and Mroczka 1999). As for delay, Bonneson and McCoy (1998) reported that raised medians and TWLTLs yield similar delays on arterials.

Other advantages offered by the TWLTL include (ITE 2003):

- Maneuverability and flexibility is much greater than the raised median,
- It does not have the penalty associated with hitting an object,
- TWLTLs may not be associated with increased U-turns,
- They provide a storage area for left-turning vehicles, and
- Drivers can take more direct routes when entering and exiting adjacent properties.

Also, TWLTLs are often preferred by fire fighters. Fire fighters have historically opposed raised medians for several reasons. A raised median "forces fire equipment to stop behind traffic at red lights since an apparatus is unable to detour to the other side of the street" (Los Angeles Evening Outlook 1962). In 1967, a report by chief engineer and general manager of the Board of Fire Commissioners, gave three reasons for opposing raised medians (Hill 1967):

- They slow emergency response to a high degree,
- In built-up areas, it is difficult to operate in the vicinity of large and extensive fires, and
- The above factors raise insurance rates to businesses.

U-turns are of another concern when median types are evaluated. A Circulation letter, No. 66-108 of the Division of Highways of the California Department of Public (1966) stated that continuous curbed medians should be avoided when streets are too narrow for U-turns. However, Bonneson and McCoy (1998) found that it might not matter if U-turns are possible. They concluded that U-turn activity would be a negligible issue for raised medians at the mid-block location because drivers either cannot make left-turns or they will be able to use the mid-block opening to arrive at their destination. Also, they prefer to take alternative routes where a right turn can be made instead of a left-turn. Bonneson and McCoy (1998) studied mid-block performance and found that incremental delay for an alternative route is less than making a U-turn at a downstream intersection.

Several reports encountered during the literature review cite advantages and disadvantages of raised medians. They included:

- Control of speed (Stover et al. 1982, CTRE 2003d),
- Decrease in conflicts (Stover et al. 1982, Parker 1983),
- Increase in capacity and safety (Stover et al.1982),
- Enhancement of traffic flow (Stover et al. 1982),
- Regulation of traffic (Stover et al. 1982),
- Clearer indications of travel lanes at intersections (Stover et al. 1982),
- Favor predominant movement (Stover et al. 1982),
- Increase area for traffic control devices (Stover et al. 1982),
- Increase area for pedestrian refuge (Stover et al. 1982),
- Encourage development of alternative access roads (Parker 1983),
- Concentrate left-turns at mid-block opening or intersection (ITE 2003),
- Discourage strip development (CTRE 2003d), and
- Control of land uses (CTRE 2003d).

In summary, raised medians effectively maintain speed and traffic flow because there are fewer conflicts for drivers to worry about. Traffic movements are regulated by the physical barriers of raised medians, as they clearly mark travel lanes. Raised medians can be tailored to a certain traffic movement. For example, raised medians can have mid block openings that allow left turns from the road but not from a driveway. Traffic engineers can use the unused surface of the raised median to erect traffic signs, signals, and other traffic control devices. The development of alternative access roads around the road with raised medians is an important step so that drivers can navigate to businesses through the streets around the road with raised medians. Also, strip mall development with unregulated accesses cannot only create an aesthetically unappealing streetscape, but also increases conflict points. Raised medians help discourage the development of such streetscape because raised medians force the developers to consider safe circulation of traffic to their developments.

There are obvious disadvantages of raised medians, such as:

- Undesirable conditions for turning movements (e.g. U-turns) (Parker 1983, ITE 2003, CTRE 2003d),
- Travel increases on local streets other than arterial with raised median (Parker 1983),
- Increase travel time and delay of some left-turning traffic (ITE 2003),
- Limit property access (CTRE 2003c,d), and
- Concentration of left-turns (CTRE 2003d).

In summary, raised medians can be frustrating to some drivers and they may have to travel extra to get to the destination. Second, traffic may increase on local streets nearby and the residents on those streets may complain. Third, as travelers use local streets and travel to intersections to reach their destinations due to limited direct access to properties instead of making direct left-turns on undivided roads or on TWLTL median, travel time and delay may increase. Fourth, the concentration of left-turns at mid-block openings and intersections could lead to spill-over from the left-turn bays that would eventually block vehicles on through lanes.

One benefit of raised medians is clear and for that reason raised medians are preferred to TWLTLs at intersections. When raised medians are installed at intersections, they separate slower left-turning traffic from through traffic and provide a protected space to decelerate and turn, as long as the length of a left turn bay is adequate. In contrast, roads with TWLTLs do not always provide protection for mid-block left-turning vehicles because of potential left-turning vehicles in the opposite direction sharing the lane. Another important advantage is raised medians do not allow left turns to or from driveways within the functional area of the intersection. This helps relieve congestion and significantly reduces the number of conflict points near or at intersections. These benefits are highest when the intersection approach volumes are high and traffic safety is low (CTRE 2003c).

2.3 Economics

Eisele and Frawley (2000) found that in the state of Texas the impacts of a raised median are less drastic than prior perceptions of business owners. However, they found the construction time period is most detrimental to businesses. To alleviate impacts on businesses during the construction, adequate and visible access must be ensured, construction time reduced, and construction performed in smaller segments. Public meetings can also alleviate some impacts of the construction phase (Eisele and Frawley 2000). Reish and Lalani (1987) reported that in Overland Park, Kansas, the installation of a raised median caused no known business failure.

Figures 5 and 6 were obtained from Eisel and Frawley’s study (2000) and present the raised median impacts for businesses. They give the percentage of managers that believed certain items relating to raised medians became better, stayed the same, or got worse. The items checked were:

- Traffic congestion,
- Traffic safety,
- Property access,
- Business opportunities,
- Customer satisfaction, and
- Delivery convenience.

Figure 5 shows the result of a survey done before median installation, while Figure 6 is the post-median installation survey done with those present before, during, and after the installation.

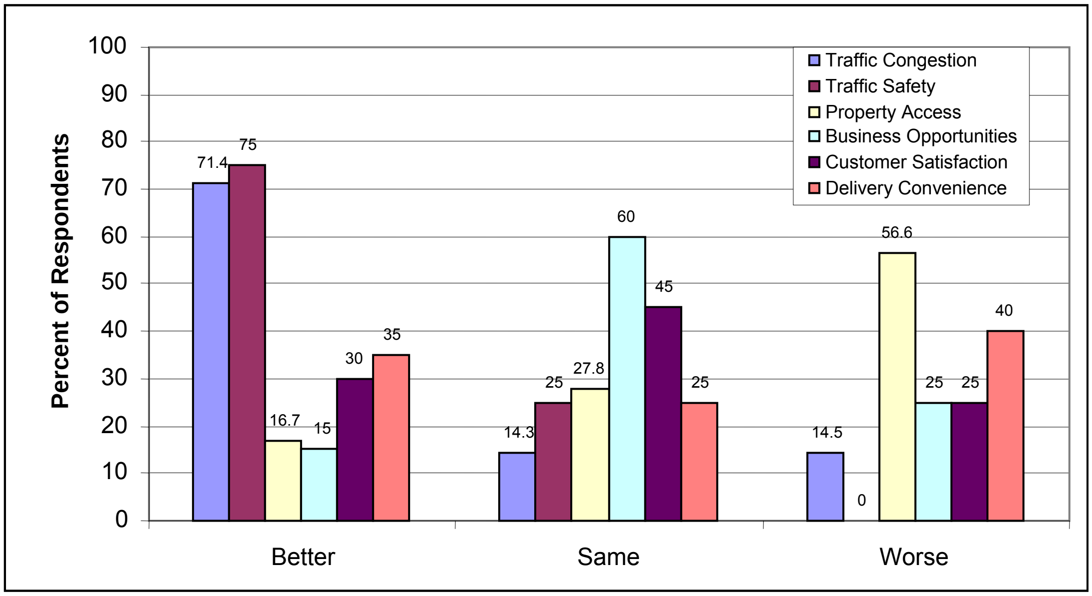

Figure 5: Raised median impacts for businesses interviewed before median installation
(Source: Eisele and Frawley 2000)

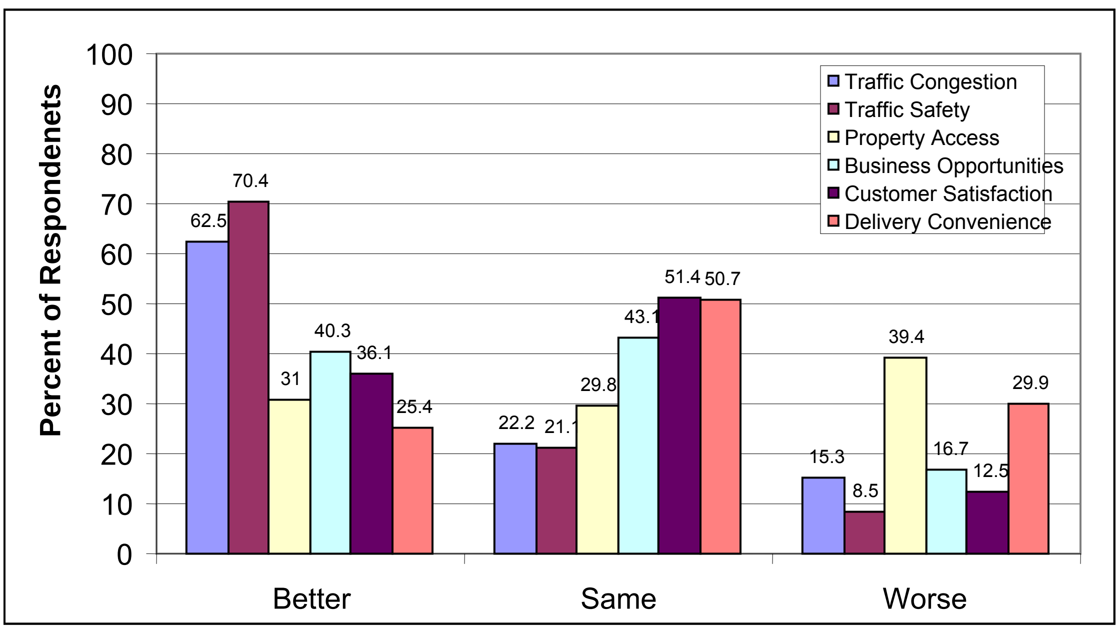

Figure 6: Raised median impacts for businesses present before, during, and after median installation
(Source: Eisele and Frawley 2000)

For businesses interviewed before median installation, the majority believed traffic congestion and traffic safety would be better. Also, the majority believed that business opportunities would be the same and property access would be worse. There was no decisive opinion either way concerning customer satisfaction or delivery convenience.

Opinions changed when asked after the median installation. For businesses present before, during, and after median installation, the percentage of businesses that believed traffic congestion and traffic safety would be better decreased slightly although it was still very high. Also, the percentage of business that believed property access would be worse decreased approximately 16 percent. Furthermore, the percentage of those that felt business opportunities would be better increased almost three times, from 15 percent to 40 percent.

Another business vitality study was conducted in Iowa on nine access management project locations (CTRE 2003a) Access-managed corridors generally had more rapid growth in retail sales once projects were completed. More business owners reported stability in sales or an increase in sales compared to those who reported a decrease after completion of an access management project. Traffic-dependant businesses, such as convenience stores and fast food restaurants, appeared not to be affected in a different manner than all the other businesses. Short-term losses for businesses were not found to be significant during the project. Over 80 percent of businesses found access management projects resulted in gains, stayed the same, or did not know; while 5 percent reported losses after the access management project. About 19 percent of business owners reported customer complaints, and half of those businesses were auto-oriented businesses (i.e., gas stations, convenience stores, fast-food restaurants, etc.). Over 80 percent of business owners reported no customer complaints. TWLTLs generally receive low levels of business owner complaints and customer complaints, while raised medians received low levels of customer complaints. Furthermore, auto-oriented businesses tend to be the least supportive of raised median projects (CTRE 2003a).

Very similar results were found in a 1996 study in Indiana (CTRE 2003a). The study indicated the average loss of business during construction of a major project is 13 percent. The biggest temporary losses came from gas stations, grocery stores, consumer electronic stores, hardware stores, and automotive sales and service firms. This study indicated that businesses recovered within two years and that 20 percent of businesses experienced long-term reduction in sales. Business types most likely to experience long-term detrimental impact were gas stations, car washes, and other automotive-related businesses. The majority of businesses reported that the projects benefited them, and the majority supported the projects (CTRE 2003a).

The CTRE (2003a) indicates one advantage and one disadvantage of raised medians in terms of economic impact. The advantage of a raised median is reduced fuel consumption and tailpipe emissions. This is due to the efficiency with which vehicles can travel on a separated roadway. The disadvantage is businesses and land owners may oppose a raised median project because they believe it will have large negative economic impacts. However, raised medians typically do not hurt business vitality. According to the findings, it is most likely that auto-oriented businesses will be the most opposed to raised median projects.

2.4 Cost

Construction of the median type and the right-of-way required is always a concern of the builders. Estimated development costs for median types are provided in Table 4. Costs of changing from one type of median to another may also affect the decision of selecting a particular median type. This information is provided in Table 5.

As illustrated in Table 4, the total cost per mile for a TWLTL and a raised median with four through lanes is $6,109,000 and $6,320,000 respectively, which is considered a small difference. However, the cost for an undivided four lane road is 20 perent less than a TWLTL and 23 percent less than a raised median. The primary reason for the discrepancy in cost is the number of lanes required. To construct a four-lane road, an undivided road requires only four lanes, whereas a TWLTL and a raised median require the equivalent of five lanes. The requirement for additional lanes also increases the right-of-way. Besides the wider roadway, raised medians require curbs and sometimes landscaping in the raised median structure. However, even though undivided roadways are less expensive than raised medians, the cost of a raised median is insignificant with regards to total project cost when it is part of a large construction project (Dixon, Hibbard, and Mroczka 1999).

Table 4: Estimated development costs per mile for different median treatments

Cost Item	Built-Up Urban Area			Outlying Urban Area		
	Undivided	TWLTL	Raised	Undivided	TWLTL	Raised
Unit Costs (thousands of dollars per lane-mile)*						
Construction	745	769	980	901	925	1,136
Right-of-Way	472	472	472	191	191	191
Total	1,217	1,241	1,452	1,092	1,116	1,327
Cost for a Street with Four Through Lanes (thousands of dollars per mile)*						
Construction	2,980	3,749	3,960	3,604	4,529	4,740
Right-of-Way	1,888	2,360	2,360	764	955	955
Total	4,868	6,109	6,320	4,368	5,484	5,695

* The estimated construction costs per mile are in 1996 dollars.
(Source: Gluck, Levinson, and Stover 1999)

Table 5: Ranges in costs for mid-block left-turn treatments (in 1996 dollars)

Reconstruction (or conversion) Combination	Estimated Difference in Construction Costs (Thousands)	Annualized Costs	
		Dollars per Mile	Dollars per Quarter-Mile
Undivided to Raised Median	$1,452	$106,841	$27,000
Undivided to TWLTL	$1,241	$91,315	$23,000
TWLTL to Raised Median	$980	$72,110	$18,000

(Source: Gluck, Levinson, and Stover 1999)

2.5 Aesthetics

Landscaped medians are recommended for improved aesthetics and pedestrian activity (Reish and Lalani 1987, CTRE 2003b, CTRE 2004a). They can enhance the public's support for the project and improve safety in all aspects (CTRE 2004a). Dixon, Hibbard, and Mroczka (1999) report that an unattractive median may be a catalyst for uncontrolled commercialization. For instance, citizens of Atlanta were concerned about the future development of a road in a residential area because an unattractive raised median was installed. This road eventually became a strip of auto-oriented businesses. Such a rampant development of strip malls reduces the aesthetics of the area and decrease the value of the community as residential area. On the other hand, a beautified median can enhance the attractiveness of an area and increase land value. The following figures provide examples of how a median can be landscaped. Figure 7 illustrates how flowers, shrubs, and trees can enhance a raised median design. Similarly, Figure 8 shows effective use of grass in landscaping medians. Figures 9 and 10, however, show how poor landscaping can make the surrounding area look harsh and unpleasant.

Figure 7: Raised median with trees and flowers
(Source: City of Madera 2004)

Figure 8: Raised median with grass and rocks
(Source: CTRE 2004a)

Figure 9: Raised median without landscaping
(Source: Knoxville Street Master Plan 2004)

Figure 10: Raised median without pleasant landscaping
(Source: CTRE 2004a)

2.6 Learning from Previous Case Studies

Review of several previous case studies revealed different reasons and trends for installing raised medians. This section summarizes four cases from the literature.

2.6.1 Case Study 1

In the July 1993 edition of the ITE Journal, Mukherjee, Chatterjee, and Margiotta reported the results of an experiment where state design engineers were given hypothetical situations, of which they voted for the best remedy. Three cases were presented in this experiment. They were:

1. Rural area expected to become suburban,
2. Existing suburban commercial area, and
3. Existing suburban residential area.

Discussions on the first and third cases are skipped in this report since they do not fit into the scope of this study. In the second case, the existing conditions were:

- 4-lane undivided highway,
- 2 miles of strip commercial use,

- Numerous rear-end crashes and delay problems,
- Current ADT = 25,000,
- Design ADT = 30,000,
- Speed limit = 40 mph,
- 5 signalized and 10 unsignalized intersections, and
- 150 uncontrolled driveways.

Based on these conditions, design engineers were asked which median treatment they would prefer. Table 6 shows the percentage of design engineers that preferred different median treatments. Almost one half of the participants preferred a TWLTL in this situation, whereas about a quarter preferred the non-traversable (i.e., raised) median, even though there are a large number of driveways and the ADT is relatively high.

Table 6: Design engineers choice

Treatments	Percent choosing (%)
Non-traversable median	26
TWLTL	45
Traversable median	3
Other	3
No response	23

(Source: Mukherjee, Chatterjee, and Margiotta 1993)

The conditions from the second case "Existing Suburban Commercial Area" were input into three different median treatment models, created by Parker (1981), Squires and Parsonson (1989), and Harwood (1986). Table 7 outlines the median the models favored in terms of crash rates and delay. Two out of three models favored the TWLTL in terms of crash rates, and one out of two favored the TWLTL in terms of delay.

Table 7: Treatment favored by models

	Parker	Squires and Parsonson	Harwood
Crash rates	Median	TWLTL	TWLTL
Delay	Median	NA	TWLTL

(Source: Mukherjee, Chatterjee, and Margiotta 1993)

It is likely in this case that a TWLTL was more popular with the design engineers because the road was for commercial use. The non-traversable median was likely popular because of the ADT and for controlled access.

2.6.2 Case Study 2

This case study comes from the August 1987 edition of the ITE Journal (Reish and Lalani 1987). The Public Works staff of Lakewood, Colorado, looked into the possible ways to

widen Wadsworth Boulevard, a major arterial in Cobb County, Georgia in the greater Atlanta area that has seen significant growth in vehicular volume.
The details of the arterial are as follows:

- 4-lane arterial with TWLTL,
- Acceleration and deceleration lanes at high volume driveways,
- Afternoon peak-hour volume (PHV) = 4,100 vph, and
- 20-year projections predict continued growth.

This arterial was not adequate to serve the increased traffic volume. Therefore, a survey and a literature search were conducted in order to find the best solution to meet the demand. The results of the literature search provided three recommended improvements. These were:

1. Install a raised median throughout the length of the project,
2. Provide adequate street widths and signal phasing for U-turns at intersections, and
3. Construct a secondary circulation system which will allow drivers to get to adjacent land uses easier.

All three recommendations were to be simultaneous and were based on the following conditions:

- Volume greater than 25,000 vpd, which is the suggested threshold for TWLTLs,
- Crash rates indicate a need for the improved safety of raised medians,
- U-turns could be accommodated,
- Raised medians would improve aesthetics, and
- Lack of evidence that businesses would fail due to raised median.

2.6.3 Case Study 3

In Mason City, Iowa, a raised median was built at the intersection of US Highway 18 and Pierce Avenue that changed the number and configuration of driveways within the functional area of the intersection, where functional area is illustrated in Figure 11 (CTRE 2003c). The functional area of an intersection is defined by three primary distances:

1. Perception - reaction distance,
2. Maneuver distance (braking & lane changing), and
3. Queue - storage distance (accommodate longest queue expected).

During the three years after the raised median installation, the number of crashes decreased by 40 percent while volumes increased by 16 percent. The turning traffic to and from commercial driveways that were within the functional area of the intersection and turning traffic at the physical intersection were the primary reasons for the high crash rate before construction. Safety increases because the raised median blocks traffic from traversing several lanes and reduces conflict points. It also helps left-turning traffic separate from through traffic.

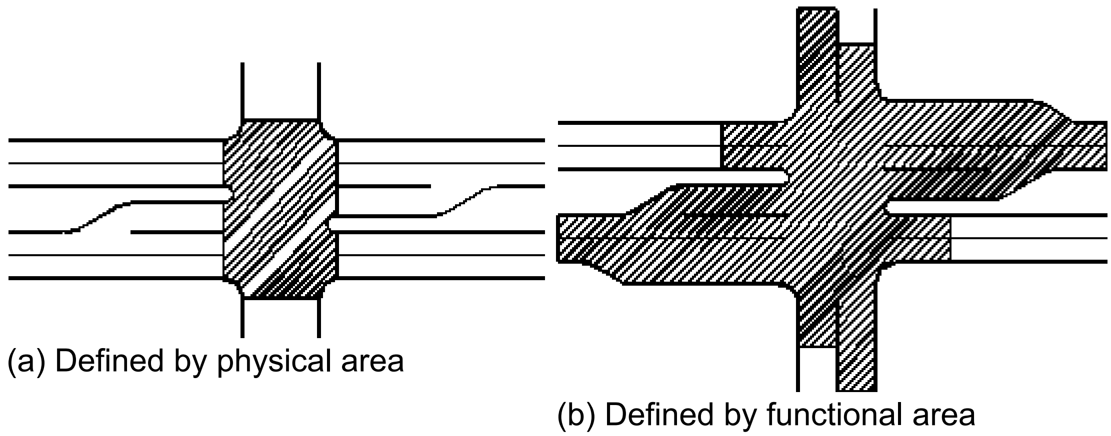

Figure 11: An intersection is defined by the (a) physical area and the (b) functional area
(Source: CTRE 2003)

2.6.4 Case Study 4

Dixon, Hibbard, and Mroczka (1999) reported a case where compromise was made and part of one road received a TWLTL and the rest a raised median. Wade Green Road in Cobb County of the greater Atlanta, Georgia area is characterized by two different land uses. North of Hickory Grove Road the land use is residential and south of Hickory Grove Road, the land use is commercial. Hickory Grove Road runs perpendicular to Wade Green Road. The Cobb County DOT recommended a TWLTL for the length of the project. In general, business owners and residents who lived directly on Wade Green Road favored the TWLTL. This is because a raised median would restrict access to the businesses and homes. Residents who did not live on Wade Green Road represented the majority, and they favored the raised median. The final outcome was a compromise. North of Hickory Grove Road became a raised median, and south of Hickory Grove Road became a TWLTL. After construction, rear-end collisions decreased from 36 percent to 15 percent, right-angle collisions increased from 16 percent to 44 percent, fixed object collisions decreased 28 percent to 10 percent, and sideswipe collisions increased from 10 percent to 24 percent. The average annual number of crashes also increased from 31 to 41 crashes.

2.7 Models

Bonneson and McCoy (1998) developed an Operations Analysis Model, which outputs capacity, delay, probability of bay overflow and queue length for all traffic movements at each intersection and arterial through movement travel speed. This model studies mid-block performance. The model consists of smaller component models, which include:

- Arterial through vehicle delay due to left-turn bay overflow,

- Arterial through vehicle delay due to left-turn or right-turning vehicles,
- Arterial through vehicle delay due to high traffic volume,
- Delay due to spillback from a downstream intersection, and
- Effect of signal-induced platoons on un-signalized intersection capacity and delay.

Overall, the model is based on Chapters 9 and 10 of the 1997 *Highway Capacity Manual* (TRB 1997). Figure 12 shows results of this model for one scenario, which has four through lanes, 10 percent left-turns per quarter mile, and 60 active access points per mile. An "active" access point is defined for this model as having an entering volume of 10 vehicles or more per hour.

As seen in Figure 12 the undivided cross section has the most delay. Figure 12 also shows that the raised curb median has slightly more delay than the TWLTL. This is probably due to concentrating the left-turns at intersections which may overflow into the through traffic.

Bonneson and McCoy (1998) also calibrated a regression model that predicts expected annual crash frequency based on its length, average daily traffic demand, median treatment, adjacent land use, and total access point density (active and non-active). The model was calibrated using data from Omaha, Nebraska and Phoenix, Arizona. The database includes 189 street segments that experienced 6,391 mid-signal street crashes in a three-year span.

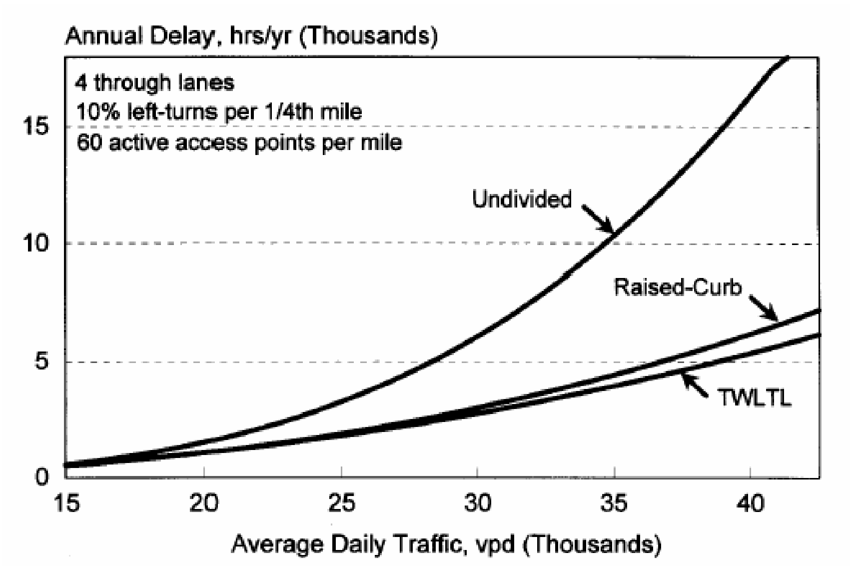

Figure 12: Annual delay versus average daily traffic
(Source: Bonneson and McCoy 1998)

Figure 13 presents the results of the safety model for a quarter-mile segment of an arterial street with 65 access points per mile and no parallel parking.

As illustrated in the figure, the annual crash frequency is similar for undivided and TWLTL median treatments. Bonneson and McCoy (1998) explained that this similarity was caused by the restriction on parallel parking on the streets in the database. The figure also shows that raised curb medians have lower crash frequency for both land uses.

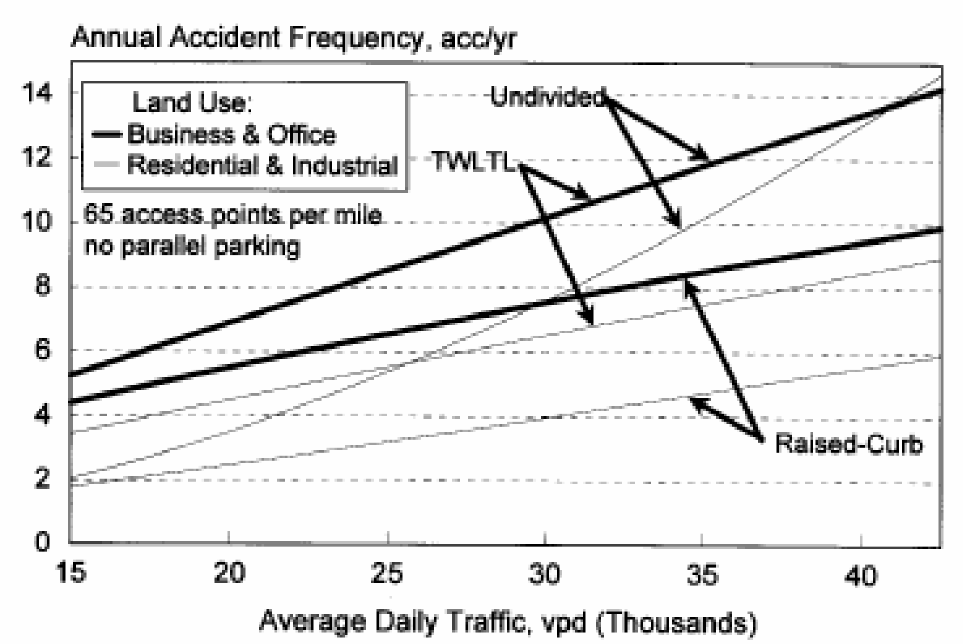

Figure 13: Average daily traffic versus annual crash frequency
(Source: Bonneson and McCoy 1998)

Bonneson and McCoy (1998) used their operations and safety models to determine the benefits of the median types using construction cost as a comparison factor. The results were tabulated for four-lane arterial streets in business and office areas as shown in Figures 14 and 15. The figures suggest when it may be appropriate to convert from one median type to another based on benefit-cost ratio. Bonneson and McCoy (1998) did not tabulate the conversion from a raised-curb median to an undivided road because the cost of conversion outweighed the benefits.

NCHRP Report 420 (Gluck, Levinson, and Stover 1999) summarizes the crash prediction models developed in the last 25 years. The results of these models support the relative safety of the three different median types, as follows:

- Safest: Raised median,
- Safe: TWLTL, and
- Least safe: Undivided.

They also support the 30 to 35 percent reduction in crashes found when converting from an undivided cross section to a TWLTL or raised median cross section. The raised median generally has the lowest predicted number of crashes, with the exception of the Harwood data mentioned in the report. The Bowman-Vecellio model suggests that the predicted number of crashes increases in a linear manner between an ADT of 10,000 and 40,000. The average of the various models generally results in fewer crashes for raised medians than for TWLTLs.

Average Daily Traffic (vpd)	Active Access Point Density[1] (ap/mi)	Left-Turn Percent per 1,320-ft Segment Length[2]					
		0	5	10	15	20	30
17,500	30						
	60						
	90						
22,500	30						
	60						
	90						
27,500	30						
	60	R	R	R			
	90	R	R	R	R	R	R
32,500	30	R	R	R	R	R	R
	60	R	R	R			
	90	R	R	R	R	R	
37,500	30	R	R	R	R	R	R
	60	R	R	R			T
	90	R	R	R	R		T
42,500	30	R	R	R	R	R	R
	60	R	R	R		T	T
	90	R	R	R			T

See Table 1 for Notes A and B.

T Stay with existing two-way left-turn lane.
Site-specific examination required.

R Consider adding a raised-curb median.
Volume levels may yield congested conditions.

Figure 14: When to consider converting from a 4-lane with TWLTL to a raised median
(Source: Bonneson and McCoy 1998)

Average Daily Traffic (vpd)	Active Access Point Density[1] (ap/mi)	Left-Turn Percent per 1,320-ft Segment Length[2]					
		0	5	10	15	20	30
17,500	30	U	U	U	U	U	
	60	U	U	U			
	90	U					
22,500	30	U					R
	60						R
	90					R	R
27,500	30			R	R	R	R
	60			R	R	R	R
	90		R	R	R	R	R
32,500	30		R	R	R	R	R
	60		R	R	R	R	R
	90		R	R	R	R	R
37,500	30		R	R	R	R	R
	60		R	R	R	R	R
	90	R	R	R	R	R	R
42,500	30	R	R	R	R	R	
	60	R	R	R	R	R	R
	90	R	R	R	R	R	R

Figure 15: When to consider converting from an undivided road 4-lane road to a raised median
(Source: Bonneson and McCoy 1998)

2.8 Design Considerations

Some of the design considerations for raised medians at intersections include:

- Length of turn/deceleration lane. Does it allow for safe deceleration and does it provide sufficient vehicle storage space?
- Minimum width of median at "nose." Is the nose visible?
- Visibility of the median. Is the median itself visible?
- Length of taper. Is the taper of the median appropriate for the approach speed? (CTRE 2003c)

In a similar volume related discussion CTRE (2003d) suggests when raised medians and TWLTLs should be considered from an operations standpoint. They recommend that a raised median should be considered when AADT is expected to exceed 28,000 vehicles per day (vpd) during the next 20 years or when it is difficult to predict future traffic volumes. Also, they report operations are typically better for raised medians than other cross-sections. On the other hand a TWLTL should be considered when AADT is between 10,000 and 28,000 vpd, the percentage of turning volumes is high, and the density of commercial driveways is low. Reish and Lalani (1987) report TWLTLs have been successful on streets with 8,000 to 31,000 vpd, however, the CTRE recommends that TWLTLs not be considered when traffic volumes are 24,000 to 28,000 vpd and when commercial driveway densities are high and closely spaced because the number of conflict points increases.

As for speed criterion *A Policy on Geometric Design of Highways and Streets* (the Green Book) by AASHTO (2001) states that a "[TWLTL] works well where the speed on the arterial highway is relatively low (25 mph to 45 mph) and there are no heavy concentrations of left-turn traffic," and that a "[TWLTL] should be used only in an urban setting…where there are no more than two through lanes in each direction."

As for factors in selecting median width for a divided highway the following factors are considered (AASHTO 2001):

- Area type: rural or suburban;
- Turning and through volumes from crossroads and vehicle mix;
- Volume and vehicle mix for turns from the highway;
- Design vehicle for crossing and turning;
- Type of traffic control: signalized intersection, unsignalized intersection with potential to be signalized, unsignalized intersection with little potential for signalization;
- Crossroad width and cross-section;
- Left-turn treatment; and
- U-turns on divided highway.

Median width should also be considered. Obviously increasing median width on divided highways provides multiple benefits when costs are not included in the discussion, including the following:

- Interference from opposing traffic is less,
- Drivers feel more freedom,
- More recovery area for out-of-control vehicles is available,
- More green space is kept,
- There will be less headlight glare ,
- There will be less need for median barrier,
- Right of way is available for construction of additional lanes,
- Right of way is available for left-turn lanes,
- There will be adequate width available for median acceleration lanes, and
- U-turns of large vehicles can be accommodated .

Table 8 presents feasible passenger car movements given particular median widths and the following statements summarize the relationship between median width and possible movements by passenger cars.

- 4 to 12 feet - not wide enough for left-turns,
- 14 to 24 feet - wide enough for left-turn lane but not wide enough to store a crossing or turning passenger car and be clear of through traffic,
- 26 to 44 feet - wide enough for turning or crossing passenger cars but not wide enough for a school bus,
- 46 to 80 feet - wide enough for a school bus but not wide enough for a large truck, and
- More than 80 feet - wide enough for all AASHTO vehicles.

2.9 Summary

There are many helpful reports available for the state engineers to reference. This chapter presented the findings for major issues related to using a particular type of median. The following references were found to be especially useful for writing this chapter.

- For design: NCHRP 395 (Bonneson and McCoy 1997), Florida DOT's Median Handbook (1997), Center for Transportation Research Report 1846 (O'Shea et al. 2001).
- Selecting a median treatment: NCHRP 395 (Bonneson and McCoy 1997), Access Management Manual (TRB 2003).
- Comparing median types: NCHRP 420 (Gluck, Levinson, and Stover 1999), Squires and Parsonson, (1989), Oregon DOT Median Guidelines (Transportation Research Institute 1997).
- Economic Impact: TTI Report 3904 (Eisele and Frawley 2000).

Table 8: Feasible left-turn treatments for various median widths

<table>
<tr><th>Median Width (ft)</th><th>No Left-Turn Lane</th><th>Single Left-Turn Lane</th><th>Double Left-Turn Lane</th><th>Parallel Offset Left-Turn Lane</th><th>Tapered Offset Left-turn Lane</th></tr>
<tr><td>4</td><td rowspan="19">FEASIBLE</td><td rowspan="5">NOT FEASIBLE</td><td rowspan="10">NOT FEASIBLE</td><td rowspan="6">NOT FEASIBLE</td><td rowspan="7">NOT FEASIBLE</td></tr>
<tr><td>6</td></tr>
<tr><td>8</td></tr>
<tr><td>10</td></tr>
<tr><td>12</td></tr>
<tr><td>14</td><td rowspan="2">MARGINAL</td></tr>
<tr><td>16</td><td rowspan="5">MARGINAL</td></tr>
<tr><td>18</td><td rowspan="12">FEASIBLE</td><td rowspan="4">MARGINAL</td></tr>
<tr><td>20</td></tr>
<tr><td>22</td></tr>
<tr><td>24</td><td rowspan="3">MARGINAL</td></tr>
<tr><td>26</td><td rowspan="8">FEASIBLE</td><td rowspan="8">FEASIBLE</td></tr>
<tr><td>28</td></tr>
<tr><td>30</td><td rowspan="6">FEASIBLE</td></tr>
<tr><td>32</td></tr>
<tr><td>34</td></tr>
<tr><td>36</td></tr>
<tr><td>38</td></tr>
<tr><td>40 and over</td></tr>
</table>

(Source: Harwood et al. 1997)

3. CUSTOMER AND STORE MANAGER SURVEYS

3.1 Introduction

University Parkway is an arterial that extends from 900 East in Provo to Geneva Road in Orem and intersects Interstate 15 (Exit 272) on the west side of Orem near Utah Valley State College (UVSC). There is a business district on the arterial in Orem and Provo with strip malls comprised mainly of large businesses and restaurants. In 2002, a raised median was installed along this arterial between 400 W and 200 E in Orem in order to reduce the number of severe crashes in this segment. Before the raised median was built in this segment, there were three lanes in each direction with a painted median that was intended to prohibit cross traffic. Because the median was painted, it did not adequately block vehicles from turning into and out of the median. Due to an increasing number of fatalities and other serious crashes the raised median was installed. In general many business owners believe that raised medians negatively affect their businesses. To ascertain the effect of the raised median on University Parkway between 400 W and 200 E in Orem, owner and customer surveys were conducted to ascertain the effect of the raised median on the businesses. This chapter presents the findings of these two surveys.

3.2 Methodology

Two surveys were created: one for the customers and the other for the managers of the businesses. Copies of these surveys can be found in Appendices B and C. A similar survey was done in Texas by Eisele and Frawley (2000) and the survey questions in this study are similar to those prepared by Eisele and Frawley, but tailored to the unique characteristics of University Parkway.

The customer survey has eleven questions. These eleven questions were aimed at obtaining information on five key aspects of the raised median construction. These are:

1. Have driving maneuvers changed when going into or out of a business?
2. If so, does this change in driving maneuver affect the likelihood of returning for business?
3. Was the trip planned or pass-by?
4. What is most important to the customers by ranking from 1 to 6, the importance of these six considerations, with 1 being most important:
    - Distance to travel,
    - Hours of operation,
    - Customer service,
    - Product quality,
    - Product price, and
    - Accessibility to store.
5. What effect does the raised median have on traffic congestion, traffic safety, property access, and customer satisfaction? Are these factors better, worse, or the same?

The manager survey has nine questions aimed at summarizing information on the following:

1. Opinion of how much business is pass-by versus planning to stop.
2. Opinion of whether customers are less likely to frequent the business because of the raised median.
3. Opinion of what is most important to customers by ranking (same as item 4 for the manager survey).
4. Opinion of how traffic congestion, traffic safety, property access, business opportunities, customer satisfaction, and delivery convenience have been affected (better, worse, or about the same) by the raised median.
5. Number of full-time and part-time employees before, during, and after construction of the raised median.
6. How has the number of customers per day, full-time employees or part-time employees changed during and after construction of the raised median? Has there been a percent increase, percent decrease, no change, or not sure?

3.2.1 Identifying the Business

It is important to identify the business in some way other than the actual name, so that any information received from managers concerning their employees and customers can be kept confidential. In order to do this, each store has been put into a category depending on its type of business. For example, instead of using the name Golden Corral, we code it with "restaurant". Fourteen different types of businesses were created to categorize the businesses on University Parkway between 400 W and 200 E in Orem, Utah. They are:

1. bank,
2. clothing,
3. dealership,
4. electric,
5. entertainment,
6. financial,
7. home,
8. hospital,
9. office,
10. restaurant,
11. specialty,
12. toys,
13. appliance, and
14. book.

The customer surveys are also represented in this way. The goal for the manager and customer surveys was to get representation from each type of business.

It was necessary to determine the type of business because businesses can be classified into two categories: pass-by oriented and planned stop oriented business. Some businesses depend on pass-by traffic and some depend on planned stop traffic. If a business is dependant on pass-by traffic, such as a fast-food restaurant or gas station, then its location is very important so that customers can easily enter and exit the business as they are passing by the store. However, if the business is dependent on customers making planned stops, such as a hardware store or furniture store, then location does not have to be easily accessible because customers are not deterred by the ease of access to the business because they have a specific reason to reach planned stop oriented businesses.

If the type of business is known, such as bank or clothing store, then it can be determined whether it is going to be a pass-by or planned stop business. It turns out that all of the businesses on the study segment of University Parkway can be justifiably classified as a planned stop business.

Not all businesses agreed to take the survey because their store policies did not allow us to administer the survey at those businesses. Out of the fourteen business types, twelve responses from eight business types were represented in the returned surveys, as follows:

- bank (1),
- clothing (1),
- dealership (1),
- financial (3),
- home (2),
- restaurant (2),
- hospital (1), and
- book (1).

3.2.2 Collecting the Surveys

Customer and manager surveys were administered differently. With the customer surveys, a call was made to the businesses in which a survey of the customers was desired. If the manager gave permission, a time to conduct surveys was established and conducted outside of the business. Survey takers would stand outside of the business as customers entered and ask if they would like to participate in a survey. If they were willing then they were asked the questions and the survey was filled out for them as they answered. In all, 173 customer surveys were collected.

With the manager surveys, a call was made to the manager and the manager was asked to fill out a survey about their business in the last few years, before and after the raised median was installed. As mentioned in the previous section, oftentimes the business declined the survey request per company policy, so our representation was limited to eight of the fourteen business types. If they accepted, a survey was faxed to or dropped off at their business. There were eleven completed and one partially completed surveys that were collected.

3.3 Results

Of the 173 customer surveys collected, there were 11 that came from a financial business, 84 that came from a clothing business, and 78 from a home business. Thus, there were three types of businesses represented by the customer surveys. Eleven manager surveys were collected. Eight business types were represented. Due to the small number of respondents, some business types had only one response.

The following subsections present the findings of these two surveys.

3.3.1 Customer Survey

First, descriptive statistics and short analyses of the eleven questions are presented, followed by their implications. Please note that 174 customers participated in the survey.

Q1. Of the 170 customers who responded to this question, 55 percent were aware that a raised had been built in 2002 and 45 percent were not aware that it had been built.

Q2. Of the 166 customers who responded to this question, 67 percent had patronized the business before while 33 percent had not patronized the business before.

Q3. Of the 168 customers who responded to this question, 37 percent will have to make a U-turn or series of right turns to get to their next destination, while 63 percent will not have to make one of these maneuvers.

Q4. Of the 111 customers who responded to this question, 48 percent of those that patronized this business before the raised median was built now have a different driving maneuver when they leave, while 52 percent have the same driving maneuver as before.

Q5 & Q7. Of the 142 customers who responded to this question, with respect to the raised median, 83 percent said they were just as likely to patronize the business as before the raised median was built, while 14 percent were less likely, and 3 percent were more likely.

Q6. Of the 165 customers who responded to this question, 79 percent of the customers were making a planned stop while 21 percent were pass-by. It was found that the percent of special-trip and passing-by customers did not change statistically between the three business types, after conducting a chi-square analysis at a 95 percent confidence level.

Q10. When selecting a business type, customers ranked six primary considerations as outlined in the survey. Number one is the most important reason to choose a particular business and number six is the least important reason. Of the 141 customers who ranked the considerations, product price was given a number one ranking most often, and accessibility to store was consistently selected as the least important of these six items. The final ranking based on the customer survey is as follows:

1. Product Price
2. Product Quality
3. Customer Service
4. Distance to travel
5. Hours of operation

6. Accessibility to store

Q11. Table 9 summarizes the responses by the customers. The number in parentheses below each heading represents the number of responses for each item.

Table 9: Percent of customers that felt the items below were made better, worse, or the same

	Traffic Congestion (165)	Traffic Safety (166)	Property Access (166)	Customer Satisfaction (162)
Better	15	49	8	10
Worse	33	20	58	20
Same	52	31	34	70

The feelings of how traffic congestion and traffic safety were affected by the raised median were similar among the different customer groups, according to a chi-square test at a 95 percent confidence level.

In summary, about one third of the surveyed customers now make a U-turn or series of right turns to get to their next destination, indicating the raised median in the study segment of University Parkway affected the travel patterns of some of the customers. Nearly one-half (48 percent) of those that had patronized the business before raised median construction had to modify their driving maneuvers because of the raised median. Despite these changes a very large percent of the customers (83 percent) said they were just as likely to visit the business even with the raised median. Moreover, only one-fifth of the customers that frequented the businesses were pass-by customers. When choosing a business, accessibility to store was the least important to the surveyed customers, while factors that would concern the customers most were product price, product quality, and customer service. One-third of surveyed customers believed that the raised median made traffic congestion worse, while half believed traffic safety improved. More than one-half believed that property access got worse, and seven out of ten felt customer satisfaction did not change. In summary, it can be said that the customers think their purchasing habits would not significantly change in this segment of University Parkway even though the raised medians may force them to change their travel patterns and traffic congestion might have resulted. This is understandable given most of the businesses on this segment of University Parkway are catering special-trip customers.

3.3.2 Manager Survey

First descriptive statistics and short analyses of the eleven questions are presented in the order of questions, followed by their implications. Please note that eleven store managers responded out of twelve businesses located in the studied segment of University Parkway. About 20 percent of businesses on University Parkway where the raised median was built in 2002 participated in this survey.

Q1. The year that businesses began operations was meant to screen out businesses that began after the raised median installation.

Q2. The average estimated percent of pass-by and planned stop traffic is 15 percent and 85 percent, respectively.

Q3. The managers were asked whether their regular customers were less likely or more likely to come to their business due to the raised median, or were they just as likely as before. Table 10 shows the distribution of customer satisfaction level as evaluated by store managers.

Table 10: Percent and number of managers that felt customers were less, same, or more likely to come to their business due to raised median

	Customers at Business		
	Less	Same	More
Managers	2	9	1
Percent of Managers	17%	75%	8%

Q4. The managers ranked the considerations outlined in the survey, with number one being the most important reason a customer chooses their store and number six is the least important. The ranking from the survey results are as follows:

1. Customer service, product quality, product price
2. Customer service
3. Distance to travel, product price
4. Distance to travel, hours of operation
5. Accessibility to store
6. Hours of operation

Customer service, product quality and product price were all ranked number 1 most often and customer service was also ranked number 2 most often.

Q5. Each manager was asked whether traffic congestion was made better, worse, or the same by the raised median. The percent of managers that gave a particular response for each consideration is given in Table 11. All 12 managers responded to this question.

Table 11: Percent that managers felt each consideration was made better, worse, or the same

	Traffic Congestion	Traffic Safety	Property Access	Customer Satisfaction	Business Opportunities	Delivery Convenience
Better	8	75	8	0	0	0
Worse	8	0	50	33	25	42
Same	84	25	42	67	75	58

Q6. Each manager estimated how many full-time and part-time employees were working at their business. The average number of employees for all businesses is given for each year in Table 12.

Table 12: Average number of employees each year at each business

	1997	1998	1999	2000	2001	2002	2003
Full-time	45	47	49	44	46	41	42
Part-time	3.3	3.0	3.0	2.7	2.3	4.5	4.5

Q7. Managers were asked whether there was a percent increase, decrease, or no change in their number of customers per day, full-time employees, and part-time employees during construction and after construction of the raised median. From the responses, a 95 percent confidence interval was developed for the percent change. Negative is percent decrease and positive is percent increase. Table 13 shows the 95 percent confidence intervals of the percent change based on manager responses. The 95 percent confidence intervals tell us that there was no significant change in customers per day, full-time employees, or part-time employees during or after construction of the raised median because the confidence intervals contain zero in them.

Table 13: 95 percent confidence intervals of the percent change based on manager responses

	During construction	After Construction
Customers per day	(-6.95, 0.70)	(-5.50, 1.83)
Full-time employees	(-13.88, 5.63)	Not Analyzed
Part-time employees	(0,0)	(0,0)

In summary, the answer to Question 2 (Q2) states that managers estimated that 85 percent of their business was from planned stops. Also, Table 10 shows that 75 percent of managers believed that their customers were just as likely to visit their store due to the raised median. Furthermore, the answer to question four shows that distance to travel, hours of operation, and accessibility to store were believed to be least important to customers, while product quality, customer service, and product price were the most important to them.

Table 11 shows that traffic safety was the only item that the majority of twelve managers surveyed felt raised medians had improved. The majority of managers believed that traffic congestion, customer satisfaction, and business opportunities had not been significantly affected. About half of the managers believed that customer satisfaction and delivery convenience had worsened. For the most part, the majority of the managers believed that the considerations in Table 11 had either gotten better or stayed the same, except for property access.

As shown in Table 12, there does not seem to be any pattern in the number of full-time employees, except that the number of full-time employees was lower in 2002 and 2003 than the previous years. Also, the number of part-time employees gradually decreases until 2001 and then spikes in 2002 and 2003. Full-time employees decreased while part-time employees increased. This may be because the raised median was built in 2002, but it could also be due to the recession at the time. From Table 13, the managers estimated that the number of customers per day during and after construction may have slightly decreased, while the number of full-time employees during construction may have slightly decreased. There seems to be no change in the number of part-time employees.

The data set in the manager survey had only twelve managers. This is a very small number to make meaningful conclusions or analyses. Hence, Tables 12 and 13 need to be interpreted with caution. In Table 12, the standard deviation is very large for both full-time and part-time employees. The responses that were used to base the 95 percent confidence intervals based on perceived changes and may be subjective.

What this survey implies is that most managers do not perceive a change in the volume of business. Also, the factors that affect customers the most are something that businesses have control over, such as customer service, product quality and product price. Over all, most managers felt that traffic safety had improved since the installation of the raised median, which was the most important reason to install a raise median at this section of University Parkway. The other factors seem to be an inconvenience but are not as important as traffic safety for the managers.

3.3.3 Comparing customer and manager surveys

Four questions were similar between the customer and manager surveys. They are:

- What is the percent planned stop versus pass-by?
- Are customers less, more, or just as likely to visit a business due to the raised median?
- Rank each consideration (distance to travel, hours of operation, etc.) from most important to least important when selecting a business of one type.
- Were certain considerations (traffic congestion, traffic safety, etc.) made better, worse, or the same by the raised median?

The percent of pass-by versus planned stop customers is compared in Table 14.

Table 14: Percentage of planned stop versus pass-by customers

	Percent (%)	
	Pass-by	Planned Stop
Customers	21	79
Managers	15	85

The likelihood of customers going to a particular store due to the raised median is given in Table 15. More than 85 percent of the surveyed customers and managers indicated the same or more. About one in six survey participants felt they are less likely to come to the store because of the raised median.

The rank of most important considerations when going to a store is given in Table 16. "Accessibility of store" turned out to be at the bottom rank of the concerned items for customers and only fifth of the concerned items for managers.

Table 15: How likely are customers to come to the store because of the raised median

	Percent (%)		
	Less	Same	More
Customers	14	83	3
Managers	17	75	8

Table 16: Ranking of most important considerations when going to a store

Rank	Customers	Managers
1	Product Price	Product Quality
2	Product Quality	Customer Service
3	Customer Service	Product Price
4	Distance to Travel	Distance to Travel
5	Hours of Operation	Accessibility to Store
6	Accessibility to Store	Hours of Operation

Managers and customers are asked whether certain considerations are better, worse, or stayed the same. Table 17 shows the results of this analysis.

Table 17: Customers and managers opinion of whether certain concerns have been made better, worse, or the same

		Traffic Congestion	Traffic Safety	Property Access	Customer Satisfaction
Customers	Better	15	49	8	10
	Same	52	31	34	70
	Worse	33	20	58	20
Managers		Traffic Congestion	Traffic Safety	Property Access	Customer Satisfaction
	Better	8	75	8	0
	Same	84	25	42	67
	Worse	8	0	50	33

In summary, the percent of customers that made special stops is slightly less than what was estimated by the manager surveys. Also, a larger percent of customers said the likelihood of visiting a store has not changed by the raised median.

The three most important and least important items to consider when selecting a store is the same for customers and managers. The three most important considerations are product price, product quality, and customer service, while the three least important items are distance to travel, hours of operation, and accessibility to store. Product price is most important to customers while managers felt that product quality was most important to customers. Also, accessibility to store is slightly less important than what managers perceived.

A large percentage of managers felt that traffic safety had improved for customers by the presence of a raised median, and one-fifth of all customers felt that traffic safety was actually worse. Also, a large percentage of customers felt that traffic congestion was worse. Furthermore, customers felt that property access was slightly worse than what managers had believed to be true of customers. Perhaps the differences in numbers are because customers are more sensitive to the changes in traffic control than the managers. Moreover, 10 percent of customers thought customer satisfaction was better while managers thought otherwise. Many customers liked the raised median because of safety despite the decline in convenience.

It should be noted that the surveys collected for the customers were from only three locations, that is, three business types, while the surveys collected from the managers were from twelve stores. The types of stores representing the customer surveys were clothing, financial, and furniture. The types of stores represented from the manger surveys were clothing, furniture, financial, medical, restaurant, book, and dealership.

Survey respondents were encouraged to add comments on the survey forms. Appendix D contains comments from the customer and manager surveys.

4. CRASH EXPERIENCE: BEFORE AND AFTER INSTALLATION OF RAISED MEDIAN

As outlined in the literature review, previous research suggests that raised medians improve safety. These findings, however, are from states other than Utah. As a result, the Utah Department of Transportation has requested a study of crash data on four arterials where raised medians were installed in the past few years. The purpose of this study is to identify noticeable effects that raised medians have on crashes. The main questions to answer are:

- Do raised medians reduce severity of crashes?
- Do raised medians reduce the frequency of crashes?
- Do raised medians increase or decrease certain types of collisions?

Because each arterial is different and because there are several factors other than the installation of raised medians that could affect crash severity, frequency, and crash type, it is important to recognize that raised medians may not be the only factor affecting crash dynamics. This is especially true because raised medians are usually not installed alone but with other road improvements.

The roads that were evaluated in the study are located in Salt Lake County and listed in Table 18.

Table 18: Road Sections Used for the Crash Analysis

Route Number	Section	Milepost*	Length (mile)	Number of Intersections	Analysis Period	
					Before	After
State Road 186	State Road 89 to 1300 East	5.65 - 7.55	1.90	11	1996-1998	2002-2003
State Road 89	10200 South to 10600 South	311.41 - 311.90	0.49	3	1992-1993	1995-1997
State Road 89	North Temple to 300 North	326.68 - 326.97	0.29	2	1995-1997	1999-2001
State Road 68	5400 South to 6200 South	50.46 - 51.47	1.01	6	1992-1993	1996-1997

* As appears in the UDOT Crash Records 2004.

Before and after data were compared for four different crash statistics:

- Crash rate,
- Location of crash,
- Severity of crash, and
- Crash type.

Three crash rates were used to compare the data, which are:

- Crash rate – crashes per 100 million vehicle miles of traveled (100 MVM) for mid-blocks or 100 million entering vehicles (100 MEV) for intersections,
- Crashes per mile – number of crashes divided by length of segment, and
- Crash percent share (%) – percent share of a specific crash type against the total number of crashes.

The data used in this crash analysis were extracted from UDOT's crash website, which is the property of the Division of Traffic and Safety of UDOT.

Note that all crash rates of 'before' and 'after' periods mentioned in this chapter are annual average crash rates of the number of years before or after the construction of raised median. A typical recommended length of analysis period for the 'before' and 'after' is three years. However, due to the insufficient dataset available at the time of the study for either 'before' or 'after' periods, rigorous statistical inferences cannot be made; in some cases only two years of data were available at the time of the analysis. The findings presented, therefore, should be cautiously interpreted.

Annual Average Daily Traffics (AADTs) were obtained from the Traffic on Utah Highways posted in UDOT Website (http://www.dot.state.ut.us/index.php/m=c/tid= 529); the AADTs for the study locations were compared to those found in the Utah traffic volume maps (1998 Traffic on Utah Highways, UDOT). There were some differences in the mileposts among the Traffic on Utah Highways, UDOT Bluebook, and UDOT's Crash Record website. The mileposts used in this study conform to the UDOT's Crash Record website in order to maintain uniformity in the milepost values, which may cause some discrepancies in AADT values; however, judging from the way AADTs are typically estimated, the effects on descriptive statistics would be minimal.

Before and after crash data were analyzed for the entire road sections, intersections and mid-blocks. The boundary of the intersection was defined by the number of lanes. The intersection boundary was measured from the center of the intersection and was bounded by the distance determined by multiplying the number of lanes by the average lane width. There were two types of intersections, signalized intersections and unsignalized intersections. The rest of the road section was defined as the mid-block. Figure 16 shows the road section, intersections and mid-blocks.

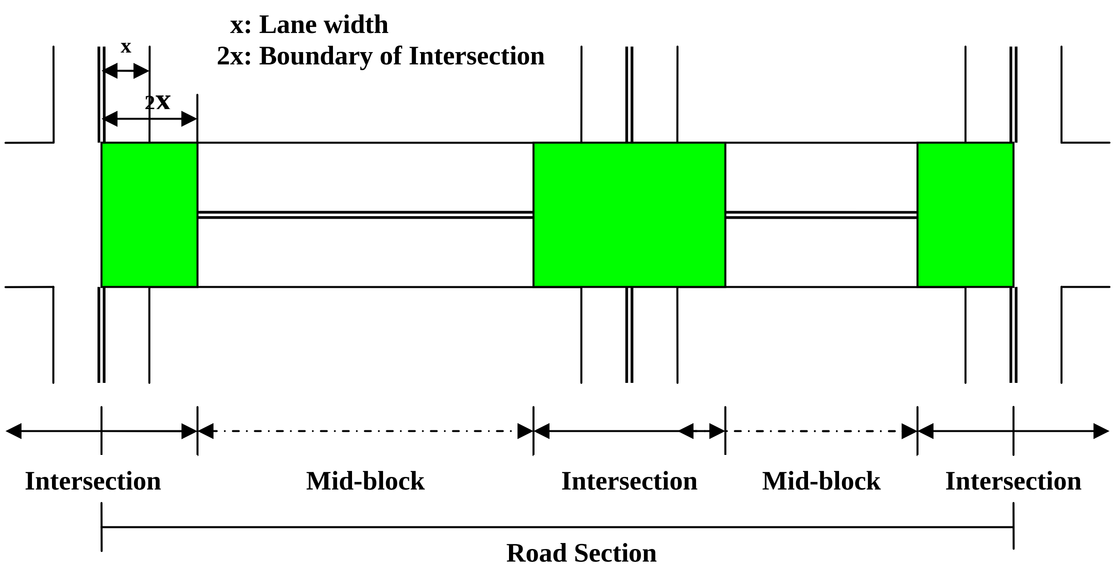

Figure 16 Road Section, Intersection and Mid-block

4.1 Highway 186, from SR 89 to 1300 East

A raised median was installed on Highway 186 between State Street (Highway 89) and 1300 East during the years 1999 to 2001 in Salt Lake City. As shown in Table 18, 'before' crash statistics were collected from 1996 to 1998, while 'after' crash statistics were collected in 2002 and 2003. Hence, the 'before' crash statistics were averaged over three years, and the 'after' crash statistics were averaged over two years. The reader must interpret the following comments cautiously because the 'after' data contains only two years of data. This is a type of unique raised median because it also serves as the location of train tracks for the light rail system (TRAX) in Salt Lake City. Figure 17 shows the starting and ending intersections of this segment on Highway 186.

State Street Looking East

1300 East Looking West

Figure 17 The Starting and Ending Intersection from State Street to 1300 East on Highway 186

Table 19 shows overall crashes and traffic data for the whole analysis segment on Highway 186. The average AADTs of 'before' and 'after' were 35,560 and 22,337, respectively. The average AADT decreased by 37.2 percent after raised median construction. While crashes per mile decreased from 33.7 to 30.0, crash rate increased from 263.75 per 100 MVM to 365.44 per 100 MVM. The increase of the crash rate was caused by the decrease in AADT not by the actual increase in the number of crashes.

Table 19: Overall Crashes and AADT from State Street to 1300 E on Highway 186

	Before	After	% Changes
The Annual Average Number of Crashes	64	57	-10.9%
Crashes per mile*/year	33.7	30.0	-11.0%
AADT	35,560	22,337	-37.2%
VMT	24,265,212	15,597,819	-35.7%
Crash Rates for Entire Segments (100MVM)	263.75	365.44	+38.3%

* Segment Length: 1.9 miles.

As shown in Table 20, crash rates both at intersections (per 100 MEV) and in mid-blocks (per 100 MVM) increased by 36.4 percent and 40.0 percent, respectively.

Table 20: Crash Rates at Signalized Intersections and Mid-blocks on Highway 186

	Crash Rates		% Changes
	Before	After	
Intersections (100 MEV)	98.91	134.63	+36.4%
Mid-blocks (100 MVM)	164.85	230.80	+40.0%

One of the goals of installing a raised median is to reduce the occurrence of severe crashes. Taking a look at the severity of crashes in mid-blocks, the fatality rate increased to 6.41 per 100 MVM from 0.00 per 100 MVM, as seen in Table 21. The crash rate and percent share in 'broken bones' decreased by 76.7 percent and 83.2 percent, respectively. Also, the crash rate and percent share of 'bruise and abrasion' decreased by 12.5 percent and 39.0 percent, respectively. However, the crash rate and percent share of 'possible injury' and 'no injury' increased after raised median construction.

Table 21: Crash Rate and Percent Share by Crash Severity in Mid-blocks on Highway 186

	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Fatalities	0.00	6.41	0.0%	2.8%
Broken Bones	27.47	6.41	16.7%	2.8%
Bruises/Abrasions	32.97	28.85	20.0%	12.5%
Possible Injury	59.07	89.76	35.8%	38.9%
No Injury	45.33	99.37	27.5%	43.0%

As for the severity of crashes at intersections, the percent share of fatal crashes at intersections after raised median construction was 2.5 percent, up from 1.4 percent, as seen in Table 22. The crash rate of fatalities increased from 1.37 per 100 MEV to 3.21 per 100 MEV. While the crash rate and percent share of 'broken bones' decreased by 63.7 percent and 73.5 percent, respectively, the crash rates of the other crash severities such as 'bruise and abrasions', and 'no injury' significantly increased.

Table 22: Crash Rate and Percent Share by Crash Severity at Intersections on Highways 186

	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Fatalities	1.37	3.21	1.4%	2.5%
Broken Bones	17.86	6.41	18.1%	4.8%
Bruises/Abrasions	13.74	22.44	13.9%	16.7%
Possible Injury	45.33	51.29	45.8%	37.5%
No Injury	20.61	51.29	20.8%	37.5%

Unfortunately, the crash rate of fatalities increased from 0.00 per 100 MVM to 6.41 per 100 MVM at mid-blocks and from 1.37 per 100 MEV to 3.21 per 100 MEV at intersections after raised median construction (Table 21, 22). In regards to severity, there were three fatalities in 2002 after construction which made the fatality rates very high. It was unfortunate that three fatalities occurred in the same year, but each of the crashes occurred as a result of reckless driving or careless pedestrian crossing, not due to the raised median. One fatality occurred because an 82 year old person crossed the street in mid-block and was hit by a vehicle. The second fatality occurred because two youths were traveling too fast in a motorcycle and hit the curb as they ran off the road to the right and the vehicle flipped. The last fatality occurred at an intersection because one driver disregarded a traffic signal and hit a vehicle.

As for crash types in mid-blocks (see Table 23), all crashes classified as ‘turning left’, ‘U-turn’ and ‘approaching at an angle’ decreased in both rate and percent share. On the other hand, all crash types classified as ‘rear end with same direction’, ‘side swipe with same direction’, ‘single vehicle’ and ‘backing’ increased. These trends on crash types showed positive and potentially negative effects of raised medians.

The crash types classified as ‘same direction, both vehicles straight, rear end’, and ‘single vehicle’ showed large increases. The crash rate and percent share of the crash type ‘same direction, both vehicles straight, rear end’ increased by 152 percent and 61 percent, respectively. Also, the crash rates and percent share of ‘single vehicle’ increased by 135 percent and 50 percent, respectively.

On the other hand, the crash types classified as ‘opposite direction, one vehicle straight, one vehicle turning left’ and ‘both vehicle straight, approaching at an angle’ had large decreases in crash rate. The crash rate and percent share of ‘opposite directions, one vehicle straight, one vehicle turning left’ decreased by 42 percent and 61 percent, respectively. Table 23 also shows changes in the other crash types.

While some crash types that require passing median classified as ‘U-turn’, ‘left turn’, and ‘opposite direction collision’ disappeared completely or decreased after raised median construction, other crash types classified as ‘backing’ and ‘one vehicle straight, one coming from left turning right’ newly appeared after raised median construction. Changes in crash types in mid-blocks after raised median construction showed both positive and negative effects of raised median.

Table 23: Crash Rate and Percent Share by Crash Type in Mid-blocks on Highway 186

Crash Type	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	32.97	19.23	22.6%	8.6%
Same direction, both vehicles straight, rear end	32.97	83.34	22.6%	37.1%
Same direction, one vehicle straight, one turning right, rear end	4.12	6.41	2.8%	2.9%
Same direction, one vehicle straight, one turning left, rear end	1.37	0.00	0.9%	0.0%
Opposite directions, both straight, side swipe	1.37	0.00	0.9%	0.0%
Same direction, both straight, side swipe	2.75	6.41	1.9%	2.9%
Same direction one vehicle straight, one turning right	2.75	3.21	1.9%	1.4%
Same direction, one vehicle straight, one turning left	1.37	0.00	0.9%	0.0%
Same direction, both vehicles turning left	1.37	0.00	0.9%	0.0%
Both vehicles straight, approaching at an angle	27.47	19.23	18.9%	8.6%
One vehicle straight, one coming from right, turning right	1.37	0.00	0.9%	0.0%
One vehicle straight, one coming from left, turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from right, turning left	0.00	0.00	0.0%	0.0%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	34.34	80.14	23.6%	35.7%
Backing	0.00	3.21	0.0%	1.4%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	1.37	0.00	0.9%	0.0%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	3.21	0.0%	1.4%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

Table 24 shows the crash rate and percent share by crash type at intersections from State Street to 1300 East on Highway 186. All crash types in rate and percent share except ‘opposite directions, one vehicle straight, one vehicle turning left’ and ‘both vehicles straight, approaching at an angle’ increased or remained the same.

The crash rate and percent share of ‘opposite directions, one vehicle straight, one vehicle turning left’ decreased by 62 percent and 74 percent, respectively. Additionally, the crash rate and percent share of ‘both vehicles straight, approaching at an angle’ decreased by 57 percent and 71 percent, respectively. On the other hand, the crash rate and percent share of ‘single vehicle’ increased by 214 percent and 143 percent, respectively. Also, the crash rate and percent share of ‘same direction, both vehicles straight, rear end’ increased by 121 percent and 63 percent, respectively. The other crash types had small changes as seen in Table 24.

There are no special trends and characteristics on crash types at intersections after raised median construction. However, as left turns at intersections changed from unprotected or other methods to protected left turn after raised median construction, crash types related with left turning decreased or disappeared. Also, the crash types classified as 'single vehicle' and 'backing' disappeared completely in the analysis section. On the other hand, the crash types classified as 'same direction, one vehicle straight, one turning right' and 'one vehicle straight, one coming from right, turning right' newly appeared after raised median construction.

Table 24: Crash Rate and Percent Share by Crash Type at Intersections on Highway 186

Crash type	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.0	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	26.10	9.62	27.1%	7.3%
Same direction, both vehicles straight, rear end	28.85	64.11	30.1%	48.8%
Same direction, one vehicle straight, one turning right, rear end	1.37	3.21	1.4%	2.4%
Same direction, one vehicle straight, one turning left, rear end	0.00	0.00	0.0%	0.0%
Opposite directions, both straight, side swipe	0.00	0.00	0.0%	0.0%
Same direction, both straight, side swipe	5.49	12.82	5.7%	9.8%
Same direction, one vehicle straight, one turning right	0.00	3.21	0.0%	2.4%
Same direction, one vehicle straight, one turning left	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning left	0.00	0.00	0.0%	0.0%
Both vehicles straight, approaching at an angle	23.35	9.62	24.3%	7.3%
One vehicle straight, one coming from right, turning right	0.00	3.21	0.0%	2.4%
One vehicle straight, one coming from left, turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from right, turning left	0.00	0.00	0.0%	0.0%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	6.87	22.44	7.1%	17.1%
Backing	1.37	0.00	1.4%	0.0%
Same direction, both vehicles turning right	1.37	0.00	1.4%	0.0%
Approaching at an angle, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	1.37	3.21	1.4%	2.4%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

In regard to crash types, some trends emerged in the data. It appears that all crash types crossing median classified as 'U-turn', 'left turn', and 'opposite direction collision' in mid-blocks disappeared completely or decreased after the construction of raised median, while some crash types classified as ‘opposite directions’, ‘turning left’, and ‘approaching at an angle’ at intersections decreased.

The crash types in mid-blocks classified as ‘rear end with same direction’, ‘side swipe with same direction’, ‘single vehicles’ and ‘backing’ increased; the crash types ‘single vehicle’, and ‘same direction, both vehicles straight, rear end’ experienced a large increase in crash rate and percent share at intersections. In mid-block and at intersection, ‘single vehicle’ crashes increased after raised median installation.

Some crash types classified as ‘backing’ and ‘one vehicle straight, one coming from left turning right’ newly appeared in mid-blocks. On the other hand, some crash types classified as ‘same direction, one vehicle straight, one turning right’ and ‘one vehicle straight, one coming from right, turning right’ newly appeared at intersections.

Perhaps the following explanation can give some insight into these trends. First, with raised medians, left turn movements are restricted in mid-blocks and concentrated at intersections. Hence, ‘left-turn’ and ‘opposite direction’ related crashes would decrease in mid-blocks but may increase at intersections.

Second, raised medians do not permit vehicles to make crossing movements except at intersections or mid-block openings. This prevents right angle crashes from occurring in mid-blocks.

Third, ‘single vehicle’ crashes may increase when there is a raised median with curbs or barriers. These crashes are not likely to be serious, but they may occur more often after a raised median is installed.

Lastly, some crash types like ‘right turning movement’ may appear newly with raised medians both in mid-blocks and at intersections.

4.2 Highway 89 (State Street), from 10200 South to 10600 South

A raised median was installed between 10200 South and 10600 South on Highway 89, adjacent to the South Towne Center in 1994. ‘Before’ data were gathered from 1992 to 1993, while ‘after’ data were gathered from 1995 to 1997. Figure 18 shows the starting and ending intersections of this segment on Highway 89.

10200 South Looking South   10600 South Looking North

Figure 18: The Starting and Ending Intersection from 10200 S to 10600 S on Highway 89

Table 25 shows overall crashes and traffic data for the whole analysis segment from 10200 South to 10600 South on Highway 89. The average AADTs of ‘before’ and ‘after’ were 23,545 and 26,918, respectively. The average AADT increased by14.3 percent after raised median installation. With the increase of crashes per mile from 29.8 to 82.3, the crash rate increased from 332.46 per 100 MVM to 803.17 per 100 MVM. The crashes per mile for the whole segment increased by 176.2 percent. With a small increase in AADT, increases in crash rates were directly caused by the increase in the number of crashes.

Table 25: Overall Crashes and AADT from 10200 S to 10600 S on Highway 89

	Before	After	% Changes
The Annual Average Number of Crashes	14	39	+178.6%
Crashes per mile*/year	29.8	82.3	+176.2%
AADT	23,545	26,918	+14.3%
VMT	4,211,023	4,814,284	+14.3%
Crash Rates for Entire Segments (100 MVM)	332.46	803.17	+141.9%

* Segment Length: 0.49 miles.

Crash rates for both mid-blocks and intersections are displayed in Table 26. The crash rate at intersections increased by 763.0 percent from 59.37 per 100 MEV to 512.36 per 100 MEV. On the other hand, the crash rate in mid-blocks had small changes with the increase of 9.0 percent, from 273.09 per 100 MVM to 297.73 per 100 MVM.

Table 26: Crash Rates and Percent Share at Intersections and Mid-blocks from 10200 S to 10600 S on Highway 89

	Crash Rates		% Changes
	Before	After	
Intersections (100 MEV)	59.37	512.36	+763.0%
Mid-blocks (100 MVM)	273.09	297.73	+9.0%

Table 27 shows the crash rate and percent share by crash severity in mid-blocks from 10200 South to 10600 South on highway 89. As far as crash severities are concerned, the two most severe crash types decreased remarkably in crash rate and percent share in mid-blocks. The fatality rate decreased by 100 percent, while crashes resulting in 'broken bones' decreased by 89.2 percent. Out of all crashes, the percent of fatal crashes decreased from 5.6 percent to 0.0 percent, and the percent share of crashes resulting in 'broken bones' decreased from 22.2 percent to 2.4 percent. Clearly, the mid-block became a much safer place to drive than before the raised median was constructed at this site.

Table 27: Crash Rates and Percent Share by Crash Severity in Mid-blocks from 10200 S to 10600 S on Highway 89

	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Fatalities	12.38	0.00	5.6%	0.0%
Broken Bones	49.52	7.22	22.2%	2.4%
Bruises/Abrasions	12.38	21.66	5.6%	7.1%
Possible Injury	49.52	72.18	22.2%	23.8%
No Injury	99.03	202.12	44.4%	66.7%

Table 28 shows the crash rates and percent share at intersections in the study site. As shown in Table 28, there were no fatalities at intersections before and after raised median construction. Crashes at intersections resulting in 'broken bones' were 2.7 percent after raised median construction. While there were not crashes before raised median installation at this site, they cannot be compared with before raised median construction because there were no signalized intersections before raised median construction.

Table 28: Crash Rates and Percent Share by Crash Severity at Intersections from 10200 S to 10600 S on Highway 89

	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Fatalities	0.00	0.00	0.0%	0.0%
Broken Bones	0.00	14.44	0.0%	2.7%
Bruises/Abrasions	0.00	64.97	0.0%	12.0%
Possible Injury	0.00	158.81	0.0%	29.3%
No Injury	0.00	303.18	0.0%	56.0%

Table 29 shows the crash rate and percent share by crash type in mid-blocks. The crashes classified as ‘left turn’, ‘U-turn’, and ‘turning movement with an angle’ decreased or disappeared completely in mid-blocks. On the other hand, the crashes classified as ‘single vehicle’, ‘rear ends’ with same direction and ‘right angles’ increased.

After raised median construction, the crashes classified as ‘opposite direction, both straight, side swipe’, ‘both vehicles straight, approaching at an angle’, ‘opposite directions, both vehicles turning left, approaching at an angle’, ‘both vehicles turning left’, and ‘one vehicle straight, one vehicle making U-turn’ disappeared completely. Also, crashes classified as ‘same direction, one vehicle straight, one turning right, rear end’, ‘same direction, both straight, side swipe’, ‘same direction, one vehicle straight, one turning right’, and ‘one vehicle straight, one coming from right, turning left, decreased between 40 percent and 80 percent in crash rate.

On the other hand, the crash classified as ‘same direction, both vehicles straight, rear end’ increased by 1,167 percent and its percent share increased from 5.0 percent to 47.7 percent. The crashes classified as ‘opposite directions, one vehicle straight, one vehicle turning left’ and ‘single vehicle’ increased slightly. Also, the crashes classified as ‘’one vehicle straight, one coming from right, turning right’ and ‘one vehicle straight, one coming from left, turning left’ newly appeared after the installation of a raised median.

Table 29: Crash Rates and Percent Share by Crash Type in Mid-blocks from 10200 S to 10600 S on Highway 89

Crash Type	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	23.21	43.31	10.0%	13.6%
Same direction, both vehicles straight, rear end	11.60	151.59	5.0%	47.7%
Same direction, one vehicle straight, one turning right, rear end	11.60	7.22	5.0%	2.3%
Same direction, one vehicle straight, one turning left, rear end	0.00	0.00	0.0%	0.0%
Opposite directions, both straight, side swipe	23.21	0.00	10.0%	0.0%
Same direction, both straight, side swipe	34.81	7.22	15.0%	2.3%
Same direction, one vehicle straight, one turning right	11.60	7.22	5.0%	2.3%
Same direction, one vehicle straight, one turning left	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning left	0.00	7.22	0.0%	2.3%
Both vehicles straight, approaching at an angle	11.60	0.00	5.0%	0.0%
One vehicle straight, one coming from right, turning right	0.00	14.44	0.0%	4.5%
One vehicle straight, one coming from left, turning left	0.00	7.22	0.0%	2.3%
One vehicle straight, one coming from right, turning left	34.81	7.22	15.0%	2.3%
Opposite directions, both vehicles turning left	11.60	0.00	5.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	34.81	64.97	15.0%	20.5%
Backing	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	11.60	0.00	5.0%	0.0%
One vehicle straight, one vehicle making U-turn	11.60	0.00	5.0%	0.0%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

Shifting gears to intersections, ‘opposite directions, one vehicle straight, one vehicle turning left’ (right angle) (35.6 percent), ‘all crash types of rear end’ (37.0 percent) and ‘both vehicles straight, approaching at an angle’ (9.6 percent) crashes were the most common crash types after the construction of a raised median as shown in Table 30. Unfortunately, these data cannot be compared to before the construction of raised medians. ‘Right angle’ and ‘with an angle crashes’ are generally more common at signalized and unsignalized intersections than in mid-blocks because drivers encounter vehicles in conflicting movements.

Table 30: Crash Rates and Percent Share by Crash Type at Intersections from 10200 S to 10600 S on Highway 89

Crash Type	Crash Rates per 100 MEM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	0.00	187.68	0.0%	35.6%
Same direction, both vehicles straight, rear end	0.00	151.59	0.0%	28.8%
Same direction, one vehicle straight, one turning right, rear end	0.00	36.09	0.0%	6.8%
Same direction, one vehicle straight, one turning left, rear end	0.00	7.22	0.0%	1.4%
Opposite directions, both straight, side swipe	0.00	0.00	0.0%	0.0%
Same direction, both straight, side swipe	0.00	28.87	0.0%	5.5%
Same direction, one vehicle straight, one turning right	0.00	0.00	0.0%	0.0%
Same direction, one vehicle straight, one turning left	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning left	0.00	0.00	0.0%	0.0%
Both vehicles straight, approaching at an angle	0.00	50.53	0.0%	9.6%
One vehicle straight, one coming from right, turning right	0.00	7.22	0.0%	1.4%
One vehicle straight, one coming from left, turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from right, turning left	0.00	7.22	0.0%	1.4%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	0.00	14.44	0.0%	2.7%
Backing	0.00	7.22	0.0%	1.4%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	0.00	28.87	0.0%	5.5%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

In summary, the overall trends are that more crashes have occurred at intersections due to a large amount of traffic generated by the South Town Center and other business along the stretch concentrated at a smaller number of intersections

In mid-blocks, while crash types classified as ‘left turn’, ‘U-turn’, and ‘turning movement with an angle’ decreased or disappeared completely, crash types classified as ‘single vehicle’, ‘rear ends with same direction’, and ‘right angles’ increased after the installation of raised median.

Overall, however, safety has improved as evidenced by decreases in both crash rate and percent share of ‘fatalities’ and ‘broken bone’ crashes in mid-blocks.

4.3 Highway 89 (State Street), from North Temple to 300 North

A raised median was installed between North Temple and 300 North in 1998 on Highway 89. Before data were gathered from 1995 to 1997, while after data were gathered from 1999 to 2001. This site has comparable amounts of 'before' and 'after' data. The average AADTs of 'before' and 'after' were 23,318 and 22,641, respectively. Figure 19 shows the starting and ending intersections of this segment on Highway 89.

North Temple Looking North

300 North Looking South

Figure 19: The Starting and Ending Intersection from North Temple to 300 N on Highway 89

Table 31 displays overall crashes and traffic data for the study segment. While the crashes per mile increased by 60.7 percent from 32.2 to 51.7, AADT in this segment experienced a slight decline (-2.9%). Crash rates in this segment increased by 65.6 percent from 378.15 per 100 MVM to 625.91 per 100 MVM after raised median installation.

Table 31: Overall Crashes and AADT on Highway 89 from N Temple to 3rd North

	Before	After	% Changes
The Annual Average Number of Crashes	9	15	+66.7%
Crashes per mile*/year	32.2	51.7	+60.7%
AADT	23,318	22,641	-2.9%
VMT	2,468,175	2,396,515	-2.9%
Crash Rates for Entire Segments (100MVM)	378.15	625.91	+65.6%

* Segment Length: 0.3 miles.

Table 32 shows crash rate and percent share of intersections and mid-blocks from North Temple to 300 North on Highway 89. Crash rate per 100 MEV at intersections and crash rate per 100 MVM in mid-blocks increased by 54.5 percent, from 216.08 per 100 MEV to 333.82 per 100 MEV, and 80.2 percent, from 162.06 per 100 MVM to 292.09 per 100 MVM, respectively.

Table 32: Crash Rates at Intersections and Mid-blocks from North Temple to 300 North on Highway 89

	Crash Rates		% Changes
	Before	After	
Intersections (100MEV)	216.08	333.82	+54.5%
Mid-blocks (100 MVM)	162.06	292.09	+80.2%

Another important factor for consideration is the crash severity. There were no fatalities on this stretch before or after raised median installation as shown in Table 33. However, it appeared that the severity of crashes was reduced because the crashes resulting in ‘broken bones’ decreased from 27.01 per 100 MVM to 0.00 per 100 MVM. Crash resulting in ‘bruises and abrasions’ also decreased by 31.3 percent from 40.50 per 100 MVM to 27.80 per 100 MVM and the percent share of this crash type reduced from 25.0 percent to 11.1 percent.

Table 33: Crash Rates and Percent Share by Crash Severity in Mid-blocks from North Temple to 300 N on Highway 89

	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Fatalities	0.00	0.00	0.0%	0.0%
Broken Bones	27.01	0.00	16.7%	0.0%
Bruises/Abrasions	40.50	27.80	25.0%	11.1%
Possible Injury	54.00	139.10	33.3%	55.6%
No Injury	40.52	83.45	25.0%	33.3%

However, crash severity at intersections showed a different trend. There were also no fatalities before or after, but crashes resulting in ‘broken bones’ slightly increased from 40.52 per 100 MEV to 41.73 per 100 MEV as shown in Table 34. On the other hand, the percent share of crashes resulting in ‘broken bones’ dropped from 12.8 percent to 11.1 percent at intersections in this segment, indicating most of the crashes were less severe than before.

Table 34: Crash Rates and Percent Share by Crash Severity at Intersections from North Temple to 300 N on Highway 89

	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Fatalities	0.00	0.00	0.0%	0.0%
Broken Bones	40.52	41.73	12.8%	11.1%
Bruises/Abrasions	27.00	166.90	8.6%	44.4%
Possible Injury	181.00	83.50	57.3%	22.3%
No Injury	67.53	83.45	21.3%	22.2%

The next category to look at is crash type. Table 35 shows a listing of crash types, crash rates and percent share. Like the previous two highway segments, the crash rate for ‘rear end’ and its percent share increased, while the crash rates for ‘right angle’ and ‘angle’ and their percent shares decreased in mid-blocks.

There are some special characteristics of crash types at this section. While the crash rate per 100 MVM of 'same direction, both vehicles straight, rear end' increased by 41.6 percent from 108.04 to 153.00, the percent share of this crash type decreased by 17.5 percent from 66.7 percent to 55.0 percent because a couple of new crash types took place. Crash types classified as 'same direction, one vehicle straight, one turning right' and 'both vehicles straight, approaching at an angle' newly appeared after raised median installation. On the other hand, crash types classified as 'opposite directions, one vehicle straight, one vehicle turning left', 'same direction, one vehicle straight, one turning left, rear end' and 'single vehicle' disappeared after raised median construction. This is a newly positive outcome of raised median construction.

As shown in Table 35, the crash type classified as 'left turning movement' disappeared completely, which is a benefit of raised median construction.

Table 35: Crash Rate and Percent Share by Crash Type in Mid-blocks from North Temple to 300 N on Highway 89

Crash Type	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	13.50	0.00	8.3%	0.0%
Same direction, both vehicles straight, rear end	108.04	153.00	66.7%	55.0%
Same direction, one vehicle straight, one turning right, rear end	0.00	0.00	0.0%	0.0%
Same direction, one vehicle straight, one turning left, rear end	13.50	0.00	8.3%	0.0%
Opposite directions, both straight, side swipe	0.00	0.00	0.0%	0.0%
Same direction, both straight, side swipe	0.00	0.00	0.0%	0.0%
Same direction, one vehicle straight, one turning right	0.00	0.00	0.0%	0.0%
Same direction, one vehicle straight, one turning left	0.00	27.82	0.0%	10.0%
Same direction, both vehicles turning left	0.00	0.00	0.0%	0.0%
Both vehicles straight, approaching at an angle	0.00	97.36	0.0%	35.0%
One vehicle straight, one coming from right, turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left, turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from right, turning left	0.00	0.00	0.0%	0.0%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	27.01	0.00	16.7%	0.0%
Backing	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	0.00	0.00	0.0%	0.0%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

Table 36 shows crash types found at the intersections in this segment. Crashes classified as 'right angle', 'same direction, both vehicles straight, rear end', 'same direction', and 'sideswipe' increased, while crashes classified as 'right angle', 'single vehicle' and 'angle' decreased in crash rate and in percent share as shown in Table 36. It was encouraging to find that the crash percent shares of 'right angle' and 'angle' decreased because they usually resulted in serious types of crashes.

The crash rate and percent share of 'same direction, both vehicles straight, rear end' collision increased by 126.6 percent and 46.3 percent, respectively. While the crash rates classified as 'right angle' ('opposite directions, one vehicle straight, one vehicle turning left') and 'both vehicles straight, approaching at an angle' had slight increases, the percent shares of those crashes increased or did not change. Crashes classified as 'opposite directions, both straights, side swipe', 'same direction, both straight, side swipe', and 'same direction, both vehicles turning left' increased by 100% in crash rate, that is to say, they newly appeared after raised median installation.

On the other hand, the crash rate and percent share of 'single vehicle' decreased by 65.7 percent and 77.7 percent, respectively. Also, crashes classified as 'same direction, one vehicle straight, one turning right' and 'same direction, one vehicle straight, one turning right, rear end' disappeared completely after raised median installation.

Table 36: Crash rates and Percent Share by Crash Type at Intersections from North Temple to 300 N on Highway 89

Crash Type	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	40.52	55.64	19.0%	16.7%
Same direction, both vehicles straight, rear end	67.53	153.00	31.3%	44.8%
Same direction, one vehicle straight, one turning right, rear end	27.01	0.00	12.5%	0.0%
Same direction, one vehicle straight, one turning left, rear end	0.00	0.00	0.0%	0.0%
Opposite directions, both straight, side swipe	0.00	13.91	0.0%	4.2%
Same direction, both straight, side swipe	0.00	41.73	0.0%	12.5%
Same direction, one vehicle straight, one turning right	13.51	0.00	6.3%	0.0%
Same direction, one vehicle straight, one turning left	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning left	0.00	13.91	0.0%	4.2%
Both vehicles straight, approaching at an angle	27.01	41.73	12.5%	12.5%
One vehicle straight, one coming from right, turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left, turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from right, turning left	0.00	0.00	0.0%	0.0%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	40.52	13.91	18.8%	4.2%
Backing	0.00	0.00	0.0%	0.0%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	0.00	0.00	0.0%	0.0%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

It seems that crashes shifted from mid-blocks to intersections; however, crashes are becoming less serious both in mid-blocks and at intersections. Also, crashes classified as 'right angle', 'single vehicle' and 'angle' decreased in mid-blocks, while less serious crashes increased. These changes happened while the average number of crashes for this site changed significantly (see Table 32).

4.4 Highway 68 (Redwood Road), from 5400 South to 6200 South

A raised median was installed in this segment in 1994 and 1995. Before data were gathered from 1992 to 1993, while after data were gathered from 1996 to 1998. This raised median extended under Interstate 215. Note that the before data had only two years of crash data. Figure 20 shows the starting and ending intersections of this segment on Highway 68.

5400 South Looking South   6200 South Looking North

Figure 20: The Starting and Ending Intersection from 5400 S to 6200 S on Highway 68

Table 37 shows overall crash data and traffic data for the whole analysis section.   Crashes per mile increased by 27.9 percent from 126.7 per 100 MVM to 162.1 per 100 MVM. Also, AADT and crash rate increased by 13.6 percent and 12.6 percent, respectively.

Table 37: Overall Crashes and AADT from 5400 S to 6200 S on Highway 68

	Before	After	% Changes
Annual Average Number of Crashes	128	164	+28.1%
Crashes per mile*/year	126.7	162.0	+27.9%
AADT	41,243	46,840	+13.6%
VMT	15,642,842	17,764,288	+13.6%
Crash Rates for Entire Segments (100MVM)	818.27	921.32	+12.6%

* Segment Length: 0.3 miles.

Table 38 displays crash rates per 100 MVM or 100 MEV and percent changes by segment types. Crash rates at intersections and in mid-blocks increased by 25.6 percent and 4.2 percent, respectively, after raised median installation.

Table 38: Crash Rates at Intersections and Mid-blocks from 5400 S to 6200 S on Highway 68

	Crash Rates		% Changes
	Before	After	
Intersections (100 MEV)	319.64	401.55	+25.6%
Mid-locks (100 MVM)	498.63	519.77	+4.2%

Table 39 shows crash severities for this segment. There were no fatalities before or after construction of the raised median in this segment. Crash rates resulting in 'broken bones' and 'bruises/abrasions' had small changes after raised median installation. Property damage only crashes, on the other hand, increased by 13.2 percent in crash rate.

Table 39: Crash Rates and Percent Share by Crash Severity in Mid-blocks on Highway 68

	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Fatalities	0.00	0.00	0.0%	0.0%
Broken Bones	22.37	22.53	4.5%	4.3%
Bruises/Abrasions	31.96	26.27	6.4%	5.1%
Possible Injury	134.25	120.09	26.9%	23.1%
PDO	310.05	350.89	62.2%	67.5%

At the intersections, there were 1.88 fatal crashes per 100 MEV after raised median construction as shown in Table 40. This was caused by one fatality after raised median construction which accounts for less than one percent of all crashes. All severity level crash rates increased except for 'bruises/abrasion'. The percent share of crashes for both 'broken bones' and 'bruises/abrasions' decreased slightly at intersections in this site. The largest increase in percent share of crash was found for 'possible injury'.

Table 40: Crash Rates and Percent Share by Crash Severity at Intersections on Highway 68

	Crash Rates per 100 MEV		Percent Share	
	Before	After	Before	After
Fatalities	0.00	1.88	0.0%	0.5%
Broken Bones	9.59	11.48	3.0%	2.9%
Bruises/Abrasions	28.77	28.15	9.0%	7.0%
Possible Injury	63.93	106.96	20.0%	26.6%
PDO	217.35	253.32	68.0%	63.0%

As seen Table 41, there were no specific trends in crash reduction and increase among crash types in mid-blocks of this segment. Especially, all crash types except 'right angle' and 'left turning movement' type crashes experienced an increase. The crash rate and percent share of 'opposite directions, one vehicle straight, one vehicle turning left' ('right angle') decreased by 38.4 percent and 41.3 percent, respectively. Crash types related to left turns classified as 'same direction, one vehicle straight, one turning left' and 'same direction, both vehicles turning left' disappeared completely after raised median construction. Also, both the crash rate and percent share of the 'same direction, one vehicle straight, one turning right' decreased by 76.5 percent and 78.1 percent, respectively.

On the other hand, crash types classified as 'rear end', 'side swipe', 'movement with an angle', 'single vehicle', 'backing', and 'U-turn' experienced increase at various ranges from 20 percent to 200 percent. The most noteworthy change was the appearance of 'U-turn' related crashes after raised median installation. As for mid-blocks, it is very difficult to find definitive trends.

Table 41: Crash Rates and Percent Share by Crash Type in Mid-blocks on Highway 68

Crash Type	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	191.78	118.22	39.0%	22.9%
Same direction, both vehicles straight, rear end	153.43	197.03	31.2%	38.2%
Same direction, one vehicle straight, one turning right, rear end	6.39	16.89	1.3%	3.3%
Same direction, one vehicle straight, one turning left, rear end	6.39	5.63	1.3%	1.1%
Opposite directions, both straight, side swipe	0.00	1.88	0.0%	0.4%
Same direction, both straight, side swipe	28.77	46.91	5.8%	9.1%
Same direction, one vehicle straight, one turning right	15.98	3.75	3.2%	0.7%
Same direction, one vehicle straight, one turning left	3.20	0.00	0.6%	0.0%
Same direction, both vehicles turning left	6.39	0.00	1.3%	0.0%
Both vehicles straight, approaching at an angle	12.79	30.02	2.6%	5.8%
One vehicle straight, one coming from right, turning right	31.96	20.64	6.5%	4.0%
One vehicle straight, one coming from left, turning left	3.20	7.51	0.0%	0.0%
One vehicle straight, one coming from right, turning left	9.59	26.27	1.9%	5.1%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	15.98	20.64	3.2%	4.0%
Backing	3.20	9.38	0.6%	1.8%
Same direction, both vehicles turning right	3.20	1.88	0.6%	0.4%
Approaching at an angle, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	1.88	0.0%	0.4%
One vehicle straight, one vehicle making U-turn	0.00	7.51	0.0%	1.5%
Opposite directions, one turning left, one turning right	0.00	0.00	0.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

Table 42 shows crash rate and percent share by crash type at intersections. Most of the crash types at intersections were ‘right angle’, ‘rear end’ and ‘side swipe’ related crashes. Table 42 shows that all crash types except ‘same direction, one vehicle straight, one turning right, rear end’, ‘same direction, one vehicle straight, one turning right, ‘both vehicle straight, approaching at an angle’, and ‘single vehicle’ increased or newly appeared after raised median installation .

Some crash types such as ‘one vehicle straight, one vehicle making U-turn’ and ‘opposite directions, one turning left, one turning right’ disappeared completely. Crash types related to ‘turning left’ classified as ‘rear end’ and ‘same direction one or both vehicle tuning left’ newly appeared after raised median installation.

The largest increase and decrease in crash rate were found for 'same direction, both straight, side swipe' (222.8 percent increase) and 'same direction, one vehicle straight, one turning right' (70.6 percent decrease) crash types.

Table 42: Crash Rates and Percent Share by Crash Type at Intersections on Highway 68

Crash Type	Crash Rates per 100 MVM		Percent Share	
	Before	After	Before	After
Opposite directions, both vehicles straight, head on	0.00	0.00	0.0%	0.0%
Opposite directions, one vehicle straight, one vehicle turning left	86.43	93.82	27.0%	23.3%
Same direction, both vehicles straight, rear end	128.85	189.52	40.0%	47.0%
Same direction, one vehicle straight, one turning right, rear end	9,59	5.63	3.0%	1.4%
Same direction, one vehicle straight, one turning left, rear end	0.00	5.63	0.0%	1.4%
Opposite directions, both straight, side swipe	0.00	0.00	0.0%	0.0%
Same direction, both straight, side swipe	12.79	41.28	4.0%	10.2%
Same direction, one vehicle straight, one turning right	12.79	3.75	4.0%	0.9%
Same direction, one vehicle straight, one turning left	0.00	3.75	0.0%	0.9%
Same direction, both vehicles turning left	0.00	3.75	0.0%	0.9%
Both vehicles straight, approaching at an angle	9.59	7.51	3.0%	1.9%
One vehicle straight, one coming from right, turning right	15.98	11.26	5.0%	2.8%
One vehicle straight, one coming from left, turning left	3.20	5.63	0.0%	0.0%
One vehicle straight, one coming from right, turning left	9.59	13.14	3.0%	3.3%
Opposite directions, both vehicles turning left	0.00	0.00	0.0%	0.0%
Same direction, one vehicle turning right, one vehicle turning left	0.00	0.00	0.0%	0.0%
Single vehicle	19.18	15.01	6.0%	3.7%
Backing	3.20	3.75	1.0%	0.9%
Same direction, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, both vehicles turning left	0.00	0.00	0.0%	0.0%
One vehicle straight, one vehicle making U-turn	6.39	0.00	2.0%	0.0%
Opposite directions, one turning left, one turning right	3.20	0.00	1.0%	0.0%
One vehicle straight, one coming from left turning right	0.00	0.00	0.0%	0.0%
Approaching at an angle, one turning left, one turning right	0.00	0.00	0.0%	0.0%

In summary, the number of crashes increased after the raised median was installed. Also, crash rates in mid-blocks and at intersections increased. However, crashes in mid-blocks became less severe, while crashes at intersections stayed at about the same level of severity. The reduction in severity in mid-blocks may be attributed to the decrease in 'right angle' crashes. 'Right angle' crashes decreased in crash rate and percent share, while 'rear end' crashes increased in crash rate and severity. The percent share of individual crash types, however, stayed at about the same levels at intersections.

4.5 Overall Trends

The overall trends that were consistent among the four study sites after the installation of raised median are the following:

- Right angle crashes decreased in crash rate and percent share in mid-blocks,
- Rear end crashes increased in crash rate and percent share in mid-blocks,
- Crashes did not necessarily shift to intersections,
- Crash severities decreased in mid-blocks and at intersections,
- Crash rate and percent share of right angle crashes either decreased or stayed the same at intersections, and
- Crash rate and percent share of rear end crashes either increased or stayed the same at intersections.

This section discusses detailed characteristics and trends of each segment after raised median installation, focusing on crash frequencies, crash rates, crash severities and crash types.

4.5.1 Overall Crash rates

Crashes per mile for all four sites but Highway 186 increased after raised median installation although AADTs at the four segments experienced increases or decreases, as shown in Table 43. The crash rates of all four sites increased; especially, Highway 89 from 10200 S to 10600 S section had the largest increase in crash rate (by 142 percent). In summary, it can be concluded that crash rates of all four sites increased after a raised median was constructed.

Table 43: Overall Trends in Crash Rates the Four Sites after Raised Median Construction

	Highway 186	Highway 89-1 (10200S to 10600S)	Highway 89-2 (North Temple to 300N)	Highway 68
Crashes Per Mile	- (33.7 → 30.0)	+ (29.8 → 82.3)	+ (32.2 → 51.7)	+ (126.7 → 162.0)
AADT	- (35,560 → 22,337)	+ (23,545 → 26,918)	- (23,318 → 22,641)	+ (41,243 → 46,840)
Accident Rate (per 100 MVM)	+ (263.75 → 365.44)	+ (332.46 → 803.17)	+ (378.15 → 625.91)	+ (818.27 → 921.32)

4.5.2 Crash Rates by Mid-block and Intersection

As can be seen by comparing Table 43 with Table 44, crash rate per 100 MVM or 100MEV in the study segments are related to the crash rates of the entire segment. As crash rates at all four study segments increased, the crash rates by road segment increased. But the crash rates at intersections increased at four sites ranging from 25 percent to 137 percent, and their increases were larger than those of mid-blocks ranging from 4 percent to 80 percent. Therefore, crash rates per 100 MVM in mid-blocks and crash rates per 100MEV at intersections increased among the four segments. The increases in crash rates at intersections were much larger than those of mid-blocks.

Table 44: Crash Rates per 100MVM or 100 MEV by Road Segment at the Four Study Sites after Raised Median Construction

	Highway 186	Highway 89-1 (10200S to 10600S)	Highway 89-2 (North Temple to 300N)	Highway 68
Mid-Blocks (per 100 MVM)	+ (164.85→230.80)	+ (273.09→297.73)	+ (162.08→292.09)	+ (498.63→519.77)
Intersections (per 100 MEV)	+ (98.91→134.63)	+ (59.37→512.36)	+ (216.08→333.82)	+ (319.64→401.55)

4.5.3 Crash Severity

Table 45 summarizes the changes in crash severities by mid-block and intersection after raised median construction. Crash severity in mid-blocks is lower after median construction at three sites. On the other hands, crash severity at intersections is more severe at two sites, safer at one site, or not known at one site due to lack of data. There's no pattern in crash severity changes at intersections.

Table 45: Changes of Crash Severity at the Four Study Sites after Raised Median Installation

	Highway 186	Highway 89-1 (10200S to 10600S)	Highway 89-2 (North Temple to 300N)	Highway 68
Mid-blocks	No changes	Safer	Safer	Safer
Intersections	More Dangerous	*	Safer	More dangerous

* Not compared.

4.5.4 Crash Types

After raised median installation, there are many changes in crash types in mid-blocks as mentioned in previous sections. Table 46 shows crash types that experienced decrease in crash rates in mid-blocks at the four study segments. Crash types that experienced a decrease in crash rate are defined as such 'when a decrease in crash rate happened at least at two sites and no change took place at one site' or 'one decrease site and three no change sites' were identified as the crash types that experienced positive effects of raised median installation as shown in bold font in Table 46. With this criterion, crash types of decreasing crash rate in mid-blocks are as follows:

- Opposite directions, one vehicle straight, one vehicle turning left;
- Same direction, one vehicle straight, one turning left, rear end;
- Opposite directions, both straight, side swipe;
- Same direction, one vehicle straight, one turning right;
- Same direction, one vehicle straight, one turning left;
- Same direction, both vehicles turning left;
- One vehicle straight, one coming from right, turning right;
- Opposite directions, both vehicles turning left;

- Same direction, both vehicles turning right; and
- One vehicle straight, one vehicle making U-turn.

The crash types with deceasing crash rates in mid-blocks after raised median installation are related to ‘turning movements with left turn’, ‘right turn’ and ‘U-turn’ crashes. Raised medians prevent the drivers from turning anywhere in mid-blocks. Reducing or eliminating these crash types is one positive aspect of installing raised medians.

Table 46: Comparison of Changes in Crash Rate (The Decrease of Crash Rates per 100 MVM) by Crash Type in Mid-blocks

Crash Type	Highway 186	Highway 89-1	Highway 89-2	Highway 68
Opposite directions, one vehicle straight, one vehicle turning left	- (33→19)	+ (23→43)	- (14→0)	- (192→118)
Same direction, one vehicle straight, one turning right, rear end	+ (4→6)	- (12→7)	* (0→0)	+ (6→17)
Same direction, one vehicle straight, one turning left, rear end	- (1→0)	* (0→0)	- (14→0)	* (6→6)
Opposite directions, both straight, side swipe	- (1→0)	- (23→0)	* (0→0)	+ (0→2)
Same direction, both straight, side swipe	+ (3→6)	- (35→7)	* (0→0)	+ (29→47)
Same direction, one vehicle straight, one turning right	* (3→3)	- (12→7)	* (0→0)	- (16→4)
Same direction, one vehicle straight, one turning left	- (1→0)	* (0→0)	+ (0→28)	- (3→0)
Same direction, both vehicles turning left	- (1→0)	+ (0→7)	* (0→0)	- (6→0)
Both vehicles straight, approaching at an angle	- (27→19)	- (12→0)	+ (0→97)	+ (13→30)
One vehicle straight, one coming from right, turning right	- (1→0)	+ (0→14)	* (0→0)	- (32→21)
One vehicle straight, one coming from right, turning left	* (0→0)	- (35→7)	* (0→0)	+ (10→26)
Opposite directions, both vehicles turning left	* (0→0)	- (12→0)	* (0→0)	* (0→0)
Single vehicle	+ (34→80)	+ (35→65)	- (27→0)	+ (16→21)
Same direction, both vehicles turning right	* (0→0)	* (0→0)	* (0→0)	- (3→2)
Approaching at an angle, both vehicles turning left	* (0→0)	- (12→0)	* (0→0)	+ (0→2)
One vehicle straight, one vehicle making U-turn	- (1→0)	- (12→0)	* (0→0)	+ (0→8)

* No changes.

As for the negative effects of installing raised medians, crash rates of some crash types increased in mid-blocks. Table 47 shows crash types with increased crash rates in mid-blocks at the four sites. Just like the positive case, when the crash rates of a particular crash type increased at least at two sites or showed no changes at one site, it was labeled as “crash rate increase” as shown in bold font in Table 47. According to this criterion, crash types in mid-block whose crash rate “increased” are as follows:

- Same direction, both vehicles straight, rear end;
- Same direction, one vehicle straight, one turning right, rear end;
- Same direction, both straight, side swipe;
- One vehicle straight, one coming from left, turning left;
- Single vehicle;
- Backing; and
- One vehicle straight, one coming from left turning right.

The crash types with increased crash rates in mid-blocks after raised median construction are related to ‘vehicle movement in same direction’, ‘single vehicle’ and ‘backing’ crashes. Although raised medians prevent the drivers from turning anywhere in mid-blocks thus typically reducing the number of crashes, crashes classified as ‘same direction’ and ‘single vehicle’ increased. What is noteworthy is that a crash type ‘same direction, both vehicles straight, rear end’ increased at the four sites. Therefore, increasing certain crash types after raised median construction, as mentioned above, is one of the negative effects of raised medians.

Table 47: Comparison of Changes in Crash Rate (The Increase of Crash Rates per 100 MVM) by Crash Type in Mid-blocks

Crash Type	Highway 186	Highway 89-1	Highway 89-2	Highway 68
Opposite directions, one vehicle straight, one vehicle turning left	- (33→19)	+ (23→43)	- (14→0)	- (192→118)
Same direction, both vehicles straight, rear end	+ (33→83)	+ (12→152)	+ (108→153)	+ (152→197)
Same direction, one vehicle straight, one turning right, rear end	+ (4→6)	- (12→7)	* (0→0)	+ (6→17)
Same direction, one vehicle straight, one turning left, rear end	- (1→0)	* (0→0)	- (14→0)	* (6→6)
Opposite directions, both straight, side swipe	- (1→0)	- (23→0)	* (0→0)	+ (0→2)
Same direction, both straight, side swipe	+ (3→6)	- (35→7)	* (0→0)	+ (29→47)
Same direction, one vehicle straight, one turning left	- (1→0)	* (0→0)	+ (0→28)	- (3→0)
Same direction, both vehicles turning left	- (1→0)	+ (0→7)	* (0→0)	- (6→0)
Both vehicles straight, approaching at an angle	- (27→19)	- (12→0)	+ (0→97)	+ (13→30)
One vehicle straight, one coming from right, turning right	- (1→0)	+ (0→14)	* (0→0)	- (32→21)
One vehicle straight, one coming from left, turning left	* (0→0)	+ (0→7)	* (0→0)	+ (3→8)
One vehicle straight, one coming from right, turning left	* (0→0)	- (35→7)	* (0→0)	+ (10→26)
Single vehicle	+ (34→80)	+ (35→65)	- (27→0)	+ (16→21)
Backing	+ (0→3)	* (0→0)	* (0→0)	+ (3→9)
Approaching at an angle, both vehicles turning left	* (0→0)	- (12→0)	* (0→0)	+ (0→2)
One vehicle straight, one vehicle making U-turn	- (1→0)	- (12→0)	* (0→0)	+ (0→8)
One vehicle straight, one coming from left turning right	+ (0→8)	* (0→0)	* (0→0)	* (0→0)

* No changes.

Like in mid-blocks, there are many changes in crash types at intersections after raised median installation. Table 48 shows crash types that experienced decreases in crash rates at intersections at the three sites after raised median installation. Crash types that experienced a decrease in crash rate are defined as such ‘when a decrease in crash rate happened at least at two sites and no change took place at one site’ or ‘one decrease site and two no change sites’ were identified as the crash types that experienced positive effects of raised median installation as shown in bold font in Table 48. With this criterion, crash types of decreasing crash rates at intersections are as follows:

- Same direction, one vehicle straight, one turning right, rear end;
- Same direction, one vehicle straight, one turning right;

- Both vehicles straight, approaching at an angle;
- Single vehicle; and
- Same direction, both vehicles turning right.

The crash types at intersections with a decreasing crash rate after raised median construction are those involving ‘turning movement with same direction’ and ‘single vehicle’ collisions.

The raised median limits the driver to turning at intersections by preventing the driver from turning anywhere in mid-blocks. Hence, these turning related crash types experienced a decrease in crash rate after raised median construction.

Table 48: Comparison of Changes in Crash Rate (The Decrease of Crash Rates per 100 MVM) by Crash Type at Intersections

Crash Type	Highway 186	Highway 89-2	Highway 68
Opposite directions, one vehicle straight, one vehicle turning left	- (26→10)	+ (41→56)	+ (86→94)
Same direction, one vehicle straight, one turning right, rear end	+ (1→3)	- (27→0)	- (10→6)
Same direction, one vehicle straight, one turning right	+ (0→3)	- (14→0)	- (13→4)
Both vehicles straight, approaching at an angle	- (23→10)	+ (27→42)	- (10→8)
One vehicle straight, one coming from right, turning right	+ (0→3)	* (0→0)	- (16→11)
Single vehicle	+ (7→22)	- (41→14)	- (19→15)
Backing	- (1→0)	* (0→0)	+ (3→4)
Same direction, both vehicles turning right	- (1→0)	* (0→0)	* (0→0)
One vehicle straight, one vehicle making U-turn	+ (1→3)	* (0→0)	- (6→0)
Opposite directions, one turning left, one turning right	* (0→0)	* (0→0)	- (6→0)

* No changes.

Table 49 shows the crash types that experienced an increase at intersections. Just like the positive case, when the crash rates of a particular crash type increased at least at two sites or showed no changes at one site, it was labeled as “crash rate increase” as shown in bold font in Table 49. Based on this criterion, crash types at intersections that experienced an increase in crash rate are the following:

- Opposite directions, one vehicle straight, one vehicle turning left;
- Same direction, both vehicles straight, rear end;
- Same direction, one vehicle straight, one turning left, rear end;
- Opposite directions, both straight, side swipe;
- Same direction, both straight, side swipe;

- Same direction, one vehicle straight, one turning left;
- Same direction, both vehicles turning left;
- One vehicle straight, one coming from left, turning left; and
- One vehicle straight, one coming from right, turning left.

The crash types at intersections with increasing crash rates after raised median construction include ‘various vehicle movements in same and opposite direction with angle and turning’ crashes. As raised medians prevent the drivers from turning anywhere in mid-blocks, turning movements are concentrated at intersections. A few crash types like ‘same direction, both vehicles straight, rear end’ and ‘same direction, both straight, side swipe’ increased at the three sites after raised median construction.

Table 49: Comparison of Changes in Crash Rate (The Increase of Crash Rates per 100 MVM) by Crash Type at Intersections

Crash Type	Highway 186	Highway 89-2	Highway 68
Opposite directions, one vehicle straight, one vehicle turning left	- (26→10)	+ (41→56)	+ (86→94)
Same direction, both vehicles straight, rear end	+ (29→64)	+ (68→153)	+ (128→190)
Same direction, one vehicle straight, one turning right, rear end	+ (1→3)	- (27→0)	- (10→6)
Same direction, one vehicle straight, one turning left, rear end	* (0→0)	* (0→0)	+ (0→6)
Opposite directions, both straight, side swipe	* (0→0)	+ (0→14)	* (0→0)
Same direction, both straight, side swipe	+ (5→13)	+ (0→42)	+ (13→41)
Same direction, one vehicle straight, one turning right	+ (0→3)	- (14→0)	- (13→4)
Same direction, one vehicle straight, one turning left	* (0→0)	* (0→0)	+ (0→4)
Same direction, both vehicles turning left	* (0→0)	+ (0→14)	+ (0→4)
Both vehicles straight, approaching at an angle	- (23→10)	+ (27→42)	- (10→8)
One vehicle straight, one coming from right, turning right	+ (0→3)	* (0→0)	- (16→11)
One vehicle straight, one coming from left, turning left	* (0→0)	* (0→0)	+ (3→6)
One vehicle straight, one coming from right, turning left	* (0→0)	* (0→0)	+ (10→13)
Single vehicle	+ (7→22)	- (41→14)	- (19→15)
Backing	- (1→0)	* (0→0)	+ (3→4)
One vehicle straight, one vehicle making U-turn	+ (1→3)	* (0→0)	- (6→0)

* No changes.

4.6 Comparison with Non-Raised Median

A comparison of raised median sites with adjacent sites without raised medians was to study general trends in the changes of crash rates. If the crash rates of the non-raised median sites are similar to the raised median segments, then perhaps the raised median was not the cause of any changes in crash rates. Ideally, non-raised segments should have the same land use, number of lanes, traffic volume, and number of access points as those with raised median. Finding two sites with exactly the same conditions is practically impossible, but these factors were examined in the comparisons.

4.6.1 Highway 186, from State Street to 1300 East

The crash rates before and after median installation of a western segment of Highway 186 of equal length without a raised median between mileposts 3.75 and 5.65 were compared to the segment with a raised median. The crash rates at these segments are shown in Table 50.

Table 50: Comparison of Crash Rates of Raised Median Versus Non-Raised Median Segments of Highway 186

	Crash Rates per 100 MVM	
	Raised Median	Non-Raised Median
Before	263.75	463.88
After	365.44	430.45
Percent Change	+38.3%	-7.3%

After installation of the raised median, crash rates increased by 38.3 percent in the raised median segment and decreased by 7.3 percent in the non-raised median segment, respectively. There is a large difference in land use between the raised median segment and the non-raised median segment. The light rail transit (TRAX) extends along the length of the raised median segment; in fact, the light rail is the raised median. One block of the "non-raised" median segment does have TRAX and was excluded from the raised median analysis. However, most of the raised median segment has TRAX in the median. The AADTs for both sites before and after the raised median was installed is shown in Table 51.

It is noted that the raised median segment decreased in traffic volume by 37.2 percent and the non-raised median segment decreased by 18.2 percent, which was a reversal of what occurred with the crash rates. It seems that drivers were avoiding this route because of TRAX. One possible explanation for increased crash rates is land use. For example, the raised median segment is located in a highly commercialized area of downtown Salt Lake City and is adjacent to the University of Utah campus and much development took place after the construction of TRAX

Table 51: Comparison of AADTs of Raised Median Versus Non-Raised Median Segments of Highway 186

	AADT (vpd)	
	Raised Median	Non-Raised Median
Before	35,560	28,900
After	22,337	23,654
Percent Change	-37.2%	-18.2%

The non-raised median segment located west of the raised median segment is not lined with a light rail system, and there is less volume on the road. This makes the non-raised median site a little safer to begin with. Hence, no effort was made to form any hypotheses on the relationship between the two segments.

4.6.2 Highway 89, from 10200 S to 10600 S

The crash rates before and after median installation of a southern segment of Highway 89 of equal length without a raised median between mileposts 310.92 and 311.41 were compared with the segment with a raised median. Their crash rates are shown in Table 52.

Table 52: Comparison of Crash Rates of Raised Median Versus Non-Raised Median Segments of Highway 89

	Crash Rates per 100 MVM	
	Raised Median	Non-Raised Median
Before	332.46	809.98
After	803.17	517.64
Percent Change	+141.6%	-36.1%

The crash rate increased in the raised median segment by 141.6 percent after raised median installation. However, the non-raised median segment just south of the raised median segment experienced a 36.1 percent reduction in crash rate over the same time period.

The large increase in crash rate in the raised median segment is likely due to the opening of the South Towne Center in 1994, which is the same year the raised median was finished. AADTs were also checked to identify any trends in the data. The AADTs before and after raised median installation are shown in Table 53.

While the raised median section increased in volume, the non-raised median segment increased even more. It is not clear why the non-raised median segment decreased in crash rate while increasing in volume. Other safety improvements not identified in this study may have contributed to this safer condition.

Table 53: Comparison of AADTs of Raised Median Versus Non-Raised Median Segments of Highway 89

	AADT (vpd)	
	Raised Median	Non-Raised Median
Before	23,545	17,603
After	26,918	23,043
Percent Change	+14.3%	+30.9%

4.6.3 Highway 89, North Temple to 300 North

The non-raised median segment compared in this segment is on Highway 89 between 300 West and West Temple between mileposts 326.39 and 326.68. The results of the crash rates for both segments before and after raised median construction are shown in Table 54.

Table 54: Comparison of Crash Rates of Raised Median Versus Non-Raised Median Segments of Highway 89

	Crash Rates per 100 MVM	
	Raised Median	Non-Raised Median
Before	378.15	331.90
After	625.91	565.98
Percent Change	+65.5%	+70.5%

The crash rate on the raised median segment increased by 65.5 percent compared to by 70.5 percent on the non-raised median segment. This may mean that the raised median helped slightly to decrease the crash rates. However, the raised median segment had a higher crash rate from the beginning.

The AADTs for both segments before and after the raised median installation are shown in Table 55.

Table 55: Comparison of AADTs of Raised Median Versus Non-Raised Median Segments of Highway 89

	AADT (vpd)	
	Raised Median	Non-Raised Median
Before	23,318	26,567
After	22,641	26,707
Percent Change	-2.9%	+ 0.1%

Unfortunately, the segments are so short that traffic count was taken at a location in this study site on Highway 89 and considered the same for both segments.

Interestingly, the average number of traffic crashes actually increased for both segments while the average volume were practically the same. Much of the traffic runs east-west in this vicinity. The non-raised median segment is an east-west segment, whereas the raised median segment runs north-south to reach the 600 N interchange to I-15. Also, the raised median segment is more of an industrial/residential neighborhood, while the non-raised median segment is a commercial/tourist area due to the malls and the Salt Lake temple. At any given time during the year, there are out-of-town drivers coming to visit the LDS Temple and its vicinity, to see the Christmas lights, or go to a wedding. This draws a large volume of traffic on the non-raised median segment. This may be the reason why the non-raised median segment has seen an increase in crash rate.

4.6.4 Highway 68, from 5400 South to 6200 South

An adjacent segment of equal length evaluated is located at north of the raised median segment on Highway 68 between mileposts 49.45 and 50.46. The average crash rates before and after raised median installation for both segments are shown in Table 56.

Table 56: Comparison of Crash Rates of Raised Median Versus Non-Raised Median Segments of Highway 68

	Crash Rates per 100 MVM	
	Raised Median	Non-raised Median
Before	818.27	654.33
After	921.32	434.80
Percent change	+12.6%	-33.6%

Before the raised median was built, the crash rate was 818.27 and 654.33 crashes per 100 MVM in the raised median and non-raised median segments, respectively. After the raised median was built, the crash rate was 921.32 and 434.80 crashes per 100 MVM on the raised median and non-raised median segments, respectively. This translates into an increase of 12.6 percent in the raised median segment and a decrease of 33.6 percent in the non-raised median in crash rate.

The AADTs before and after raised median installation for both segments are shown in Table 57.

Table 57 Comparison of AADTs of Raised Median Versus Non-Raised Median Segments of Highway 68

	AADT (vpd)	
	Raised	Non-raised
Before	41,243	28,532
After	46,840	34,483
Percent Change	+13.6%	+20.9%

Both the raised median and non-raised median segments experienced an increase in traffic volume. While the raised median section increased in AADT, the non-raised median segment increased even more. It is not clear why the non-raised median segment significantly decreased in crash rate while increasing in traffic volume. Other safety improvements or access management measures not identified in this study may have contributed to this safer condition.

4.6.5 Summary of Comparisons

There are many factors affecting traffic safety such as road conditions, access management, traffic conditions, and human behavior. One of the goals of this comparison was to examine positive effects of raised medians on traffic safety. As shown in Table 58, one segment with a raised median experienced positive effects on traffic safety (Highway 89, from North Temple to 300 N), while the other three segments with raised median experienced negative effects on traffic safety. It was not clear to what extent segments with raised medians contributed more to traffic safety than those without raised medians.

Table 58: Changes of Crash rates and AADTs at All Raised Median Versus Non-Raised Median Segments

	Highway 186		Highway 89 (from 10200S to 10600S)		Highway 89 (from North Temple to 300N)		Highway 68	
	Raised Median	Non-Raised Median	Raised Median	Non-Raised Median	Raised Median	Non-Raised Median	Raised Median	Non-Raised Median
Crash Rates	+38.3%	-7.3%	+141.6%	-36.1%	+65.5%	+70.5%	+12.6%	-33.6%
AADTs	-37.2%	-18.2%	+14.3%	+30.9%	-2.9%	+0.1%	+13.6%	+20.9%

5. CONCLUSIONS

In conclusion, raised medians are recommended where appropriate. Raised medians are useful in decreasing the number of turning conflicts at midblock locations and hence, decrease crash severity. They also control traffic movements, provide pedestrian safety, beautify an area when properly landscaped, and maintain traffic flow.

TWLTLs may also be adequate for a highway depending on circumstances described in the literature review section, since they remove left-turning vehicles from through lanes, which improves safety, reduces delay, and maintains continuous access to businesses along the highway. TWLTLs are not appropriate in high pedestrian zones and they tend to attract businesses. Hence, they are probably not good for residential areas or where businesses are not desired.

With regards to the customer survey conducted at selected stores on University Parkway, about half of customers had to change their driving maneuver when going to a business. Also, one-third of customers felt traffic congestion got worse and that property access declined. On the other hand, more than half believed that traffic safety improved and customer satisfaction did not change for 7 out of 10 customers. With that, 83 percent said they were just as likely to visit the business. Moreover, accessibility to the store was least important to customers, while product price, product quality and customer service were most important. In all, the raised median may have caused some inconvenience but traffic safety is improved and purchasing habits did not change substantially.

According to the before-and-after findings of the manager survey referred from selected stores on University Parkway, most managers did not perceive a change in the volume of business after the raised median was installed. Also, similar to the customer survey, most managers felt that traffic safety had improved and that traffic congestion had stayed the same. Moreover, managers felt that the most important reason that customers came to their business was because of product price, product quality, and customer service, which are things that the manager has some control over.

According to the crash data analysis, six general trends were found. The trends that were consistent throughout all the studied highways are the following:

- Right angle crashes decreased in crash rate and percent share in mid-blocks,
- Rear end crashes increased in crash rate and percent share in mid-blocks,
- Crashes did not necessarily shift to intersections,
- Crash severities decreased in mid-blocks and at intersections,
- Crash rate and percent share of right angle crashes either decreased or stayed the same at intersections, and
- Crash rate and percent share of rear end crashes either increased or stayed the same at intersections.

The comparison of the four raised median sites with four adjacent sites without raised medians showed no definite trends. There are many factors affecting traffic safety such as road conditions, access management, traffic conditions, and human behavior. Also, finding two sites with exactly the same condition is practically impossible. One of the goals of this comparison was to examine positive effects of raised medians on traffic safety. One segment with a raised median experienced positive effects on traffic safety (Highway 89, from North temple to 300 N), while the other three segments with raised median experienced negative effects on traffic safety. It was not clear to what extent segments with raised medians contributed more to traffic safety than those without rasied median.

Based on these findings, a procedure for evaluating the need for raised medians was developed. To make it a stand-alone document, the procedure is included in Appendix A. Appendix A contains the case of St. George Boulevard in St. George, UT, as an example.

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APPENDIX A

APPENDIX A: PROCEDURE FOR EVALUATING THE NEED FOR RAISED MEDIANS

A.1 Procedure and Factors

The reasons for considering a raised median on an arterial segment vary. Possible reasons are to reduce severe crashes caused by lack of control, to provide room for light rail, to provide better channelization of traffic, or even to beautify a neighborhood. It is often difficult to decide when the appropriate time for installing a raised median would be because they typically serve very specific purposes. The procedure discussed herein consists of comparing the conditions of the site with seven criteria. The criteria given here are general suggestions for determining when to install raised medians. The UDOT engineers are encouraged to check these factors when they make a decision of selecting the type of median. A summary of the criteria and the primary factor associated with each criteria is found in Table A-1.

Table A-1: Raised Median Evaluation Criteria

Factors	Criteria
Crashes	If there are a high number of crashes that could be prevented with a raised median on a 4 or 6 lane roadway, then installing a raised median should be considered.
Pedestrians	If there are a high number of pedestrian crossings in the mid-block or at an intersection, a raised median should be provided, particularly on an arterial with four or more lanes.
Volume	If the volume exceeds 24,000 to 28,000 AADT on a principal arterial or minor arterial in urban areas, a raised median installation should be considered.
Delay	If there is excessive delay on an undivided roadway because of left-turns, then install a TWLTL or a raised median. If a TWLTL does not accommodate all the left-turning vehicles and causes backing up and delay, then install a raised median and route the traffic to an intersection where the traffic can be better accommodated.
Driveways per mile	If there are more than 60 driveways per mile, consider installing a raised median.
Mid-block opening	Mid-block openings can be considered if the distance constraints are met and the opening would help alleviate strain on nearby intersections when a large generator is present.
Number of lanes	A raised median should be given consideration when the number of through lanes is more than four.

The subsequent sections provide the rationale for these criteria.

Crashes: ***If there are a high number of crashes that could be prevented with a raised median on a 4 or 6 lane roadway, then installing a raised median should be considered.***

The majority of crashes that can be eliminated by raised medians are crossing crashes. Figures A-1 and A-2 show the reduction in conflict points when raised medians are introduced. When there are high crash rates, a raised median is preferred over Two-Way Left-Turn Lanes (TWLTLs), and TWLTLs are preferred over undivided roadways.

Several studies have indicated a decrease in crashes after installation of raised medians. A before-and-after crash study conducted on four highways in Utah where raised median treatments were installed in the past few years indicated that crash severity decreased, right angle crashes decreased at the midblock, and rear end collisions increased at the midblock. Also, at signalized intersections, right angle crashes either decrease or stay the same and rear end crashes either increase or stay the same. Furthermore, it was found that crashes do not necessarily shift to the signalized intersection.

It should be recognized though that TWLTLs may be adequate in some situations, if the original cross-section is undivided. Also note that there may be a conflict between vehicles and the raised median depending on the design features that could make a raised median inappropriate. Furthermore, it is not well understood whether raised medians cause an increase in crashes on parallel routes. Therefore, the engineer needs to carefully analyze the corridor as a system. Raised medians have been associated with less right angle, sideswipe and head-on collisions (Gluck, Levinson, and Stover 1999); however, the before and after study conducted in Utah does not give a solid trend regarding sideswipe and head-on collisions. It does show that right angle collisions decrease at the midblock and may decrease at the intersection or stay the same.

When installing a raised median, access to the businesses along the roadway is an issue. Most driveway related crashes are left-turning crashes as shown in Figure A-3. A raised median could remove that conflict because unrestricted left-turns will not be available with a raised median.

The findings of several studies on the safety of raised medians are presented here to further assist the engineer in understanding the safety effects of installing a raised median. According to Squires and Parsonson (1989) in Georgia, for every 100 crashes on a TWLTL road, there were 85 and 79 divided highway crashes on 4- and 6-lane roadways, respectively. In Michigan, there were 43 and 51 divided highway crashes on 4- and 6-lane roadways, respectively. In Florida, there were 75 and 75 divided highway crashes on 4- and 6-lane roadways, respectively. These values are summarized in Table A-2. Because contributing causes for crashes may not be simply one type of median, the statistics vary from state to state. For example, divided highways in Michigan have half as many crashes, but in Florida there are only 25 percent less crashes on divided highways. Even so, there seems to be a general reduction in crashes with divided highways over TWLTLs.

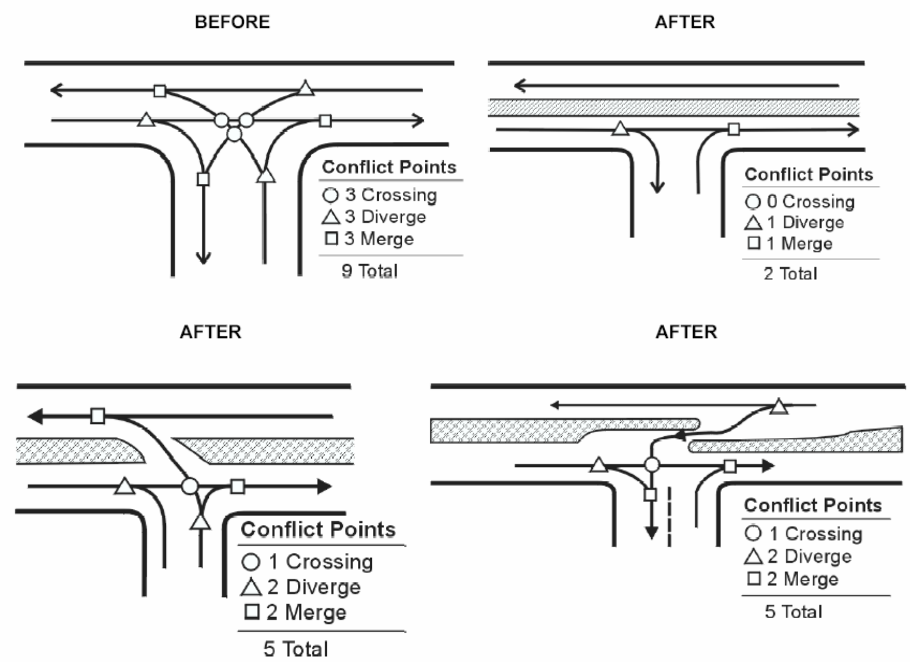

Figure A-1: Conflict points on a 3-leg intersection before and after raised median installation
(Source: CTRE 2004b)

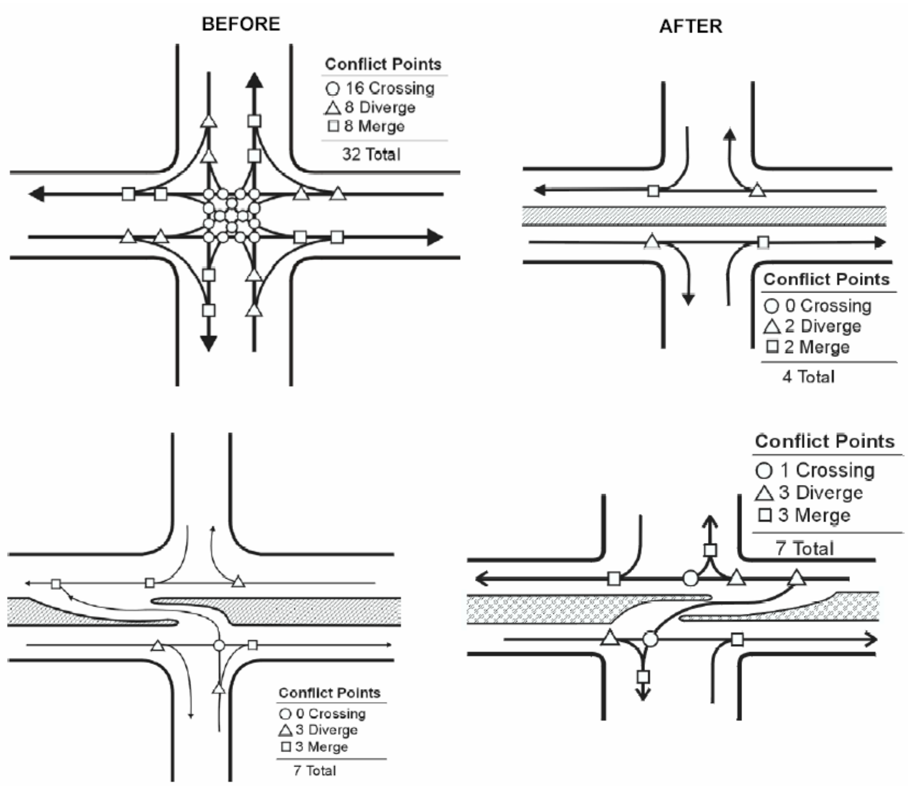

Figure A-2: Conflict points on a 4-leg intersection before and after raised median installation
(Source: CTRE 2004b)

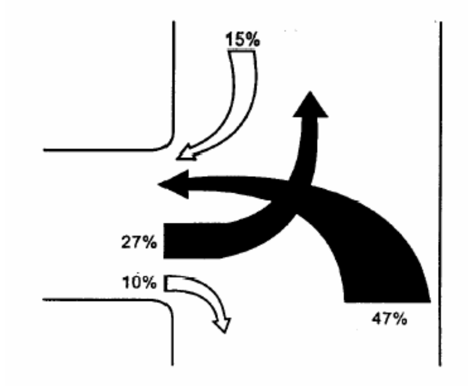

Figure A-3: Percentage of driveway crashes by movement
(Source: NHI 1992)

Table A-2: Percentage of divided highway crash rates as compared to highways with TWLTL

State	Cross Section	
	4-lane	6-lane
Georgia	85%	79%
Michigan	43%	51%
Florida	75%	75%

(Source: Squires and Parsonson 1989)

The Center for Transportation Research and Education (CTRE) has outlined several advantages of raised medians in terms of safety (CTRE 2003b,d). For example, they prevent crashes caused by crossover traffic, reduce headlight glare, and provide pedestrian protection. Raised medians should be used when safety is a concern; however, TWLTLs may be adequate if there are only 4 through lanes. Otherwise, crash rates have been shown to increase dramatically.

In Table A-3, Haguenauer et al. (1982) studied crash rates in crashes per million entering vehicles (MEV) at unsignalized and signalized intersections. They found that there tend to be fewer crashes when there is a left-turn lane. Also, there is a larger difference in crash rates for the unsignalized intersection.

Table A-3: Effect of left-turn bays on crash rates

	Crash per MEV			
	Unsignalized		Signalized	
Type of crash	No left-turn lane	Left-turn lane	No left-turn lane	Left-turn lane
Left turns	1.20	0.12	0.65	0.37
All other	3.15*	0.92*	1.82*	1.17
Total	4.35*	1.04*	2.47*	1.54*

* indicates statistically significant difference
(Source: Haguenauer et al. 1982)

Similarly in Tables A-4 and A-5, there is a larger percent change for unsignalized intersections than for signalized intersections when before and after crash rates are compared. These tables do not relate directly to raised medians but they have implications for TWLTLs and raised medians with left-turn bays.

Table A-4: Crash rates before and after construction of left-turn bays for signalized and unsignalized intersections

Crashes per MEV						
	Signalized			Unsignalized		
Light Conditions	Before	After	Percent Change	Before	After	Percent Change
Day	0.94	0.73	-22	1.12	0.5	-55
Night	1.12	1.00	-11	1.24	0.73	-41
Total	1.00	0.82	-18	1.16	0.58	-50

(Source: Hagenauer et al 1982)

Table A-5: Crash rates after construction of left-turn bays

Crashes per MEV						
	Signalized			Unsignalized		
Severity	Before	After	Percent Change	Before	After	Percent Change
Property Damage	0.62	0.48	-23	0.67	0.37	-45
Injury	0.37	0.34	-8	0.47	0.20	-57
Fatal	0.00	0.01	-0	0.02	0.01	-50

(Haguenauer et al. 1982)

Also, left-turn crashes tend to be the most severe because they are crossing lanes of traffic. A raised median at a three-leg (T) (Figure A-1) or four-leg intersection (Figure A-2), will either not allow left-turns or restrict left-turns to one direction, making them safer. The strictest scenario on the top-right of both Figures A-1 and A-2 do not allow left-turns, while the other two raised median scenarios on bottom allow only one left-turn, which results in only one crossing conflict point from a left-turn. Without a raised median (top-left), there are 9 conflict points at a T-intersection and 32 conflict points at a four-leg intersection. The presence of a raised median at a T-intersection will greatly simplify turning maneuvers.

Bowman and Vecellio (1994) studied the difference in crash rates involving personal injury between raised medians and TWLTLs in CBDs and suburban areas and reported a significant difference in personal injury related vehicular crash rates as shown in Tables A-6 and A-7. Table A-6 shows crash rates of five crash types of raised medians and TWLTLs at the midblock, while Table A-7 shows frequency, crash rate, and crash percentage of raised medians and TWLTLs for PDO, injury, and fatal crashes.

The results of Table A-6 shows rear-end, right angle, head-on, left-turn, and other crash rates per 100 MVM of raised medians to be less than corresponding crash rates of TWLTLs. The results of Table A-7 shows PDO, injury and fatal crash rates of raised medians are lower than corresponding crash rates of TWLTLs.

Table A-6: Summary of suburban midblock crash rates by median type and crash type

Crashes per 100 MVM		
Crash Type	Raised Median	TWLTL
Rear-End	80.98	139.61
Right Angle	35.05	63.26
Head-On	1.34	2.55
Left-Turn	24.35	52.50
Other	47.52	53.45

(Source: Bowman and Vecellio 1994)

Table A-7: Summary of suburban vehicle crash rate by severity and median type

Crashes per 100 MVM			
Severity	Variable	Raised Median	TWLTL
PDO	Frequency	2649	4855
	Crash rate	131.1	221.4
	Percent crashes	69.3	71.1
Injury	Frequency	1169	1962
	Crash rate	57.9	89.5
	Percent crashes	30.6	28.7
Fatal	Frequency	5	10
	Crash rate	0.3	0.5
	Percent crashes	0.1	0.2

(Source: Bowman and Vecellio 1994)

Table A-8: Crash rates on 4-lane urban arterials in Florida

Severity	Median Treatment	Crash Rate per Million Vehicle Miles[1]
Injury	Undivided	2.2
	TWLTL	1.7
	Flush Pavement	1.8
	Raised	1.3
Property Damage Only	Undivided	2.1
	TWLTL	1.5
	Flush Pavement	1.4
	Raised	1.1

[1] Values were estimated from bar graph
(Source: Bowman and Vecellio 1994)

Table A-8 shows injury and PDO crash rates on undivided, TWLTL, flush paved, and raised median treatments of 4-lane urban arterials in Florida. Table A-9 compares mean crash rates of three median types on suburban arterials. In Table A-8, undivided roadways exhibit the largest crash rate per MVM for both injury and PDO crashes. Raised medians exhibit the lowest crash rate for both injury and PDO crashes. In Table A-9, raised medians had the lowest mean crash rates and TWLTLs had the highest mean crash rates on suburban arterials.

Table A-9: Comparison of vehicular crash rates on suburban arterials

Comparison	Mean Crash Rates (100 MVM)	Significant Difference*
Raised median vs. TWLTL	373 vs. 676	yes
Raised median vs. Undivided	373 vs. 409	yes
TWLTL vs. Undivided	676 vs. 409	no

*95% confidence level, Scheffe multiple comparison test
(Source: Bowman and Vecellio 1994)

Pedestrians: ***If there are a high number of pedestrian crossings in the mid-block or at an intersection, a raised median should be provided, particularly on an arterial with four or more lanes.***

Long, Gan, and Morrison (1993) reported that non-traversable medians are associated with less pedestrian crash rates per 100 MVM as compared to TWLTLs and undivided roadways in urban areas as shown in Figure A-4. In a similar pedestrian related study, Oregon State University reported that mid-block pedestrian crash rates were found to be almost twice as much for undivided 4-lane roadways and 5-lane-with-TWLTL roadways than for divided 4-lane roadways as shown in Table A-10 (Bowman and Vecellio 1994). The table also shows that at intersections, there are about 2.5 times more pedestrian crashes for undivided 4-lane roadways and 5-lane with TWLTL roadways than for divided 4-lane roadways.

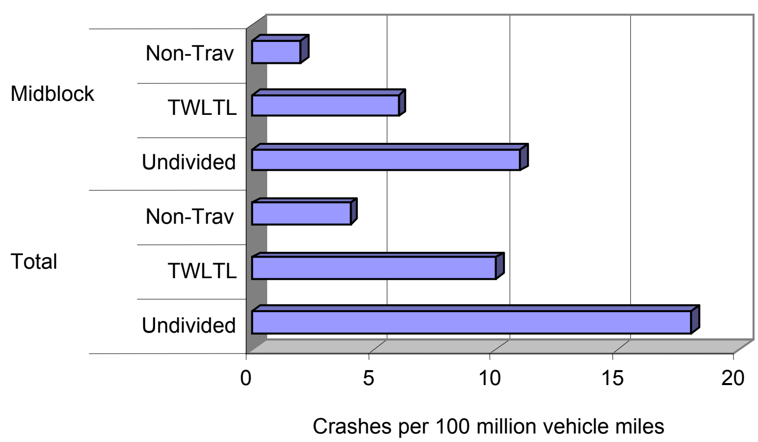

Figure A-4: Pedestrian crash rates in Florida urban areas, 4-lane highways
(Source: Harwood and Glennon 1978)

Table A-10: Pedestrian crash rates versus roadway type

Roadway Type	Median	Mid-block[1]	Intersection[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 MVM
2 Per MEV
(Source: Bowman and Vecellio 1994)

In another pedestrian related study Bowman and Vecellio (1994) found that pedestrian crashes were twice as common on TWLTLs as on raised medians in CBDs.

It is hypothesized that the reason for a lower mid-block and intersection pedestrian crash rates for divided 4-lane roadways may be because the divider, or raised median, allows pedestrians to cross the road in two segments rather than one as illustrated in Figure A-5. When there is not a raised median, pedestrians have to look both ways before crossing as illustrated in Figure A-6.

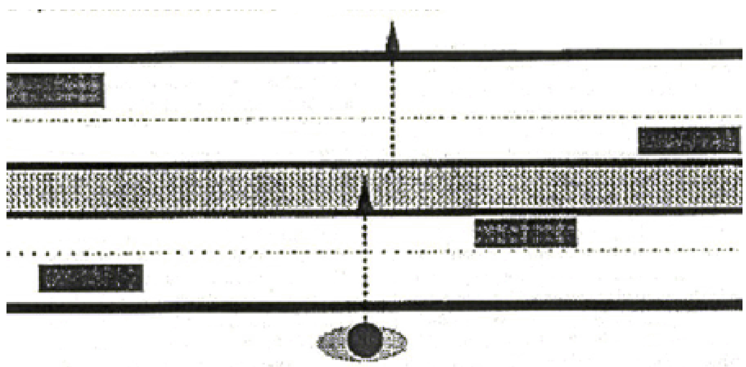

Figure A-5: Crossing maneuver for pedestrians with a raised median
(Source: FHWA 2003)

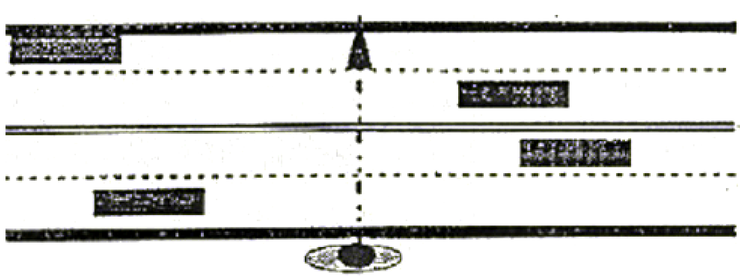

Figure A-6: Crossing maneuver for pedestrians without a raised median
(Source: FHWA 2003)

Two advantages for pedestrians when a raised median is present are:

1. Pedestrians have less distance to travel before reaching a safe zone, and
2. Pedestrians only have to look in one direction before crossing to a safe zone.

If the pedestrian is crossing a road without a raised median, four lanes of traffic must be crossed which requires a 12-second gap at 4 feet per second (fps). However, if the pedestrian is crossing a road with a raised median, two lanes of traffic must be crossed which only requires a 6-second gap. A raised median also simplifies the crossing maneuver by allowing the pedestrian to look just one direction before crossing, then wait, and look the other direction before crossing again as shown in Figure A-5. However, the raised median must be at least 4 feet in width in order for pedestrians to be safe. They also need to be clearly visible both day and night. In addition, non-mountable medians are better for pedestrian safety because out-of-control vehicles may be stopped by a 12-inch curb.

Table A-11, adapted from Bowman and Vecellio (1994) shows that there are almost twice as many pedestrian crashes on arterials with TWLTLs than on arterials with a raised median or no median. This may be due to the extra lane on an arterial with a TWLTL. There are three disadvantages of a road with a TWLTL: 1) There is an extra lane to cross, 2) there is no refuge, and 3) pedestrians must look in both directions before attempting to cross. A TWLTL arterial with 5 lanes takes one 15-second gap to cross the arterial after looking both ways, instead of 12 seconds for an undivided road and 6 seconds for a road with a raised median.

Table A-11: Comparison of median type pedestrian-vehicle crash rates at mid-block in CBDs

Comparison	Mean Crash Rates (Crashes per 100 MVM)
Raised vs. TWLTL	19.1 vs. 41.1
Raised vs. Undivided	19.2 vs. 87.3
TWLTL vs. Undivided	41.1 vs. 87.3

(Source: Bowman and Vocellio 1994)

Bowman and Vocellio (1994) reported that some pedestrians may use the TWLTL as a refuge. Five percent of pedestrians used a TWLTL as a refuge versus 18 percent on a raised median. Clearly, pedestrians feel safer using a raised median as a refuge than a TWLTL. This is especially important for the elderly because their walking speeds are significantly lower than typical middle-aged pedestrians. Most agencies believe that a 6-foot to 16-foot raised median width is suitable for pedestrian refuge.

Volume: ***If the volume exceeds 24,000 to 28,000 AADT or ADT on a principal arterial or minor arterial in urban areas, a raised median installation should be considered.***

Gluck, Levinson, and Stover (1999) found traffic volume to be a predictor of crashes as shown in Figure A-7. When the AADT is approximately 10,000 vpd, the differences in crashes per mile is negligible between the three cross sections (undivided, TWLTL, and raised median). However, as the AADT increases the number of crashes per mile increases much more for the undivided cross section than for either the TWLTL or raised median cross sections.

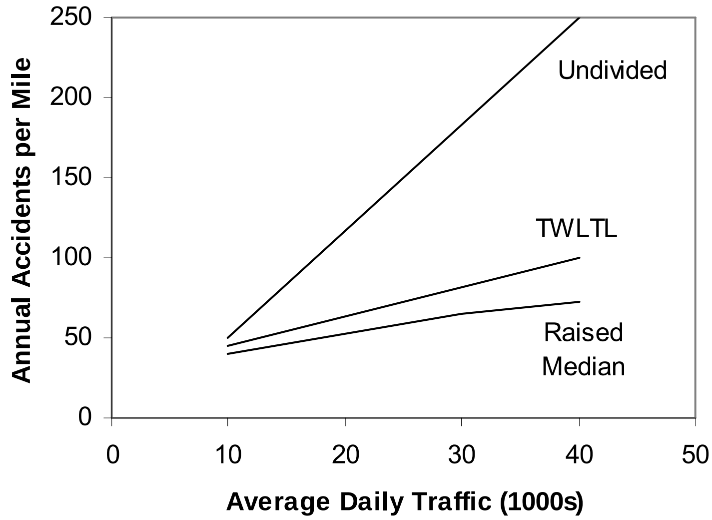

Figure A-7: ADT versus annual crashes per mile
(Source: Gluck, Levinson and Stover 1999)

Squires and Parsonson (1989) reported that in urban areas, raised medians are safer at an ADT of 30,000 vpd or more unless there are seven or more driveways per mile and/or two or more signals per mile. Also, TWLTLs are safer at an ADT of 10,000 vpd unless the driveways per mile are low. Squires and Parsonson found that when there are few driveways that attract high volume of traffic, raised medians are safer, but when there are several driveways that attract relatively little traffic, TWLTLs are safer. This finding is supported by Parker (1983) and Harwood and St. John (1985). It is contrary to the findings of Glennon et al. (1975a, 1975b, 1975c). Furthermore, with higher volumes of opposing traffic, raised medians provide concentrated areas to make left-turns which are safer than larger maneuver areas, such as found on TWLTLs.

Delay: ***If there is excessive delay on an undivided roadway because of left-turns, then install a TWLTL or a raised median. If a TWLTL does not accommodate all the left-turning vehicles and causes backing up and delay, then install a raised median and route the traffic to an intersection where the traffic can be better accommodated.***

Excessive delay is typically caused by left-turn vehicles on through lanes of undivided roadways. A TWLTL may be adequate for this type of delay, however, if a TWLTL does not provide an appropriate and safe turning maneuver, traffic may need to be rerouted with a raised median.

Figure A-8 (Bonneson and McCoy 1998) shows that delay for raised medians and TWLTLs are very similar when there are 4 through lanes, 10 percent left-turns per quarter mile and 60 access points per mile.

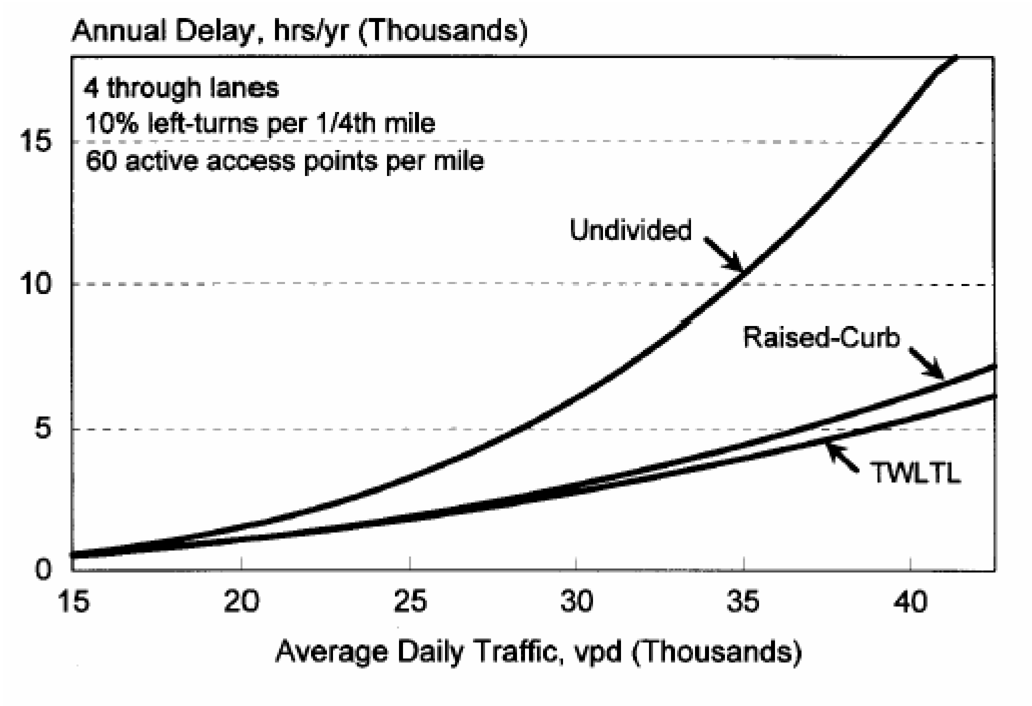

Figure A-8: Average annual delay to major-street left-turn and through vehicles
(Source: Bonneson and McCoy 1998)

Driveways per mile: ***If there are more than 60 driveways per mile, consider installing a raised median.***

Table A-12 shows that there is an associated increase in crashes as the number of driveways per mile increases. For example, there is a 74 percent increase in crashes when there are 20 to 40 driveways per mile compared to less than 20 driveways per mile.

Table A-12: Crash rate versus driveways per mile for an undivided multilane highway

Driveways per Mile	Approximate Driveways per 500 Feet	Representative Crash Rate	Increase in Crashes
Under 20	Under 2	3.4	--
20 to 40	2 to 4	5.9	+74%
40 to 60	4 to 6	7.4	+118%
Over 60	Over 6	9.2	+171%

(Source: Gluck, Levinson, and Stover 1999)

Table A-13 presents crash rates by median treatment as predicted by signalized access density. The signalized access density is divided into four categories. As the signalized access density increases, the overall crash rate increases. The undivided arterials experience the highest crash rates followed by the TWLTL arterials, and the non-traversable arterials have the lowest crash rates.

Table A-13: Crash rates by signalized access density and median treatment in urban and suburban areas per MVM

Signalized Access Density (Access Points per Mile)	Crash Rate (Crashes per MVM)			
	Undivided	TWLTL	Raised Median	Total
≤ 2	4	4.1	2.8	3.5
2.01 to 4	8.2	7	5.7	6.9
4.01 to 6	9.9	7.4	6	7.5
>6	9.5	9.1	8.3	9.1
Total	8.6	6.9	5.2	

(Source: Gluck, Levinson, and Stover 1999)

Table A-14 below shows the crash rates of median treatments as predicted by access density, which includes unsignalized and signalized access points. The overall crash rates increase with increased access density. Also, the undivided arterials experience the highest crash rates, followed by TWLTL arterials, while the raised median arterials experience the lowest crash rates.

Table A-14: Crash rates by access density and median treatment in urban and suburban areas per MVM

Access Density*	Crash Rate (Crashes per MVM)			
	Undivided	TWLTL	Raised Median	Total
≤20	3.8	--	2.9	3.2
20.01 to 40	8.3	5.9	5.1	5.9
40.01 to 60	9.4	7.4	6.5	7.4
>60	9.6	9.2	5.4	8.6
Total	8.6	6.9	5.2	

* Access density includes unsignalized and signalized access points per mile
(Source: Gluck, Levinson and Stover 1999)

Table A-15 shows the amount of crashes per mile that will be reduced for two scenarios. The first scenario has low roadside development (< 30 driveways per mile) and low ADT (< 5,000). The second scenario has high roadside development (> 60 driveways per mile) and high ADT (> 15,000). In the first scenario, the reduction in crashes per mile is much greater with the raised median, which suggests that TWLTLs are not as effective in low density areas. In the second scenario, the reduction in crashes per mile is about the same for raised medians and TWLTLs. This seems to suggest that raised medians and TWLTLs are effective at reducing crashes per mile in high density areas.

Table A-15: Estimated annual reduction in crashes per mile based on roadside development and ADT

Conditions		Estimated Annual Reduction in Crashes per Mile	
Level of roadside development	Highway ADT	Raised Median	TWLTL
Low, < 30 driveways per mile	Low, <5,000	22	4.4
High, >60 driveways per mile	High, >15,000	31.2	28.1

(Source: Glennon et al. 1975a, 1975b, 1975c)

It should be noted, however, that Squires and Parsonson (1989) reported that TWLTLs should be used instead of raised medians when the number of driveways per mile exceeds 45. Harwood and St. John (1985) also reported this finding in an FHWA report.

In summary, Squires, and Parsonson (1989) concluded when high-volume driveways are present, raised medians would be safer, and when a large number of low-volume driveways are present, TWLTLs would be safer. Squires and Parsonson's findings are supported by Parker (1983) and Harwood and St. John (1985). However, this finding is contrary to the finding of Glennon et al. (1975a, 1975b, 1975c) in their FHWA report.

Mid-block Openings: ***Mid-block openings can be considered if the distance constraints are met and the opening would help alleviate strain on nearby intersections when a large generator is present.***

Table A-16, taken from the Missouri Department of Transportation (MoDOT) minimum guidelines (2003), is a general guide for installation of mid-block openings in urban areas.

Table A-16: MoDOT minimum lengths between mid-block openings

Roadway Classification	In Current and Projected Urban Areas
Major Arterial	1320 to 2640 ft (full); 660 to 1320 ft (directional)
Minor Arterial	1320 ft (full); 660 ft (directional)

(Source: MoDOT 2003)

The preferred type of median treatment depends on certain factors as found in NCHRP Report 395 (Bonneson and McCoy 1997) which is shown in Table A-17.

Table A-17: Preferred mid-block left-turn treatment for different factors

Comparison Factor	Raised Median vs TWLTL	Raised Median vs Undivided	TWLTL vs Undivided
Operational Effects			
Major street through movement delay	nd	Raised Median	TWLTL
Major street left-turn movement delay	nd	Raised Median	TWLTL
Minor-street left & through delay	nd	Raised Median	TWLTL
Pedestrian refuge area	Raised Median	Raised Median	nd
Operational Flexibility	TWLTL	Undivided	nd
Other Effects			
Cost of maintaining delineation	nd	Undivided	Undivided
Median reconstruction cost	TWLTL	Undivided	Undivided
Facilitate snow removal	TWLTL	Undivided	nd
Visibility of delineation	Raised Median	Raised Median	nd
Aesthetic potential	Raised Median	Raised Median	nd
Location for signs and signal poles	Raised Median	Raised Median	nd

nd – not determined
(Source: Bonneson and McCoy 1997)

Number of lanes: ***A raised median should be given consideration when the number of through lanes is more than four.***

Research performed in several southwestern states found that the crash rate on a 6-lane road with a TWLTL is as high as 11 crashes per 100 MVM. This crash rate is similar to an undivided road with access points. Crashes occur because of the high number of lanes drivers must maneuver across (CTRE 2003a).

CTRE 2003b compared the pedestrian crash rates of mid-block and intersection by roadway type. Table 18 shows the results. Divided four-lane highways had much smaller crash rates both at mid-block and intersection. Five-lane highways with TWLTL had pedestrian crash rates as high as those of undivided four-lane highways. Four lanes is a reasonable boundary for considering a raised median as a refuge point.

Table 18: Mid-block and intersection pedestrian crash rates by roadway type

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

a = crashes per million vehicle miles,
b = crashes per million entering vehicles
(Source: CTRE 2003b)

A.2 Sample Application of the Procedure – St. George Boulevard, St. George, UT

St. George Boulevard in St. George, Utah is two miles long and runs east-west while intersecting Interstate 15 near the east end and stopping at Bluff Drive, a principal arterial, on the west end as illustrated in Figure A-10. Currently there is no parallel parking permitted, no shoulder available, and the speed limit is 30 miles per hour. The boulevard has five lanes including a center TWLTL. There are 111 driveways and 15 intersections, which equates to 56 driveways and eight intersections per mile. The businesses along the boulevard are mostly auto-oriented, gas stations, lodging, beauty salons, restaurants and real estate agencies. On the north side of the boulevard, from 400 East to 700 East there are high cliffs that cut off parallel streets. Rear-end and intersection crashes are common, site circulation at the businesses is poor, and the road cannot be widened unless businesses are removed. There is a division between those who oppose and those who are for raised medians among the businesses on the corridor.

Figure A-10: St. George Boulevard
(Source: maps.yahoo.com)

The procedure developed in this study is used to evaluate whether St. George Boulevard should receive a raised median. The decision making process is based on the seven factors discussed in Section A.1. These factors include:

1. Crashes,
2. Pedestrians,

3. Volume,
4. Delay,
5. Driveways per mile,
6. Midblock opening, and
7. Number of lanes.

Each of these factors will be discussed in the following subsections.

A.2.1 Crashes

The highest number of crashes on St. George Boulevard take place at the intersection of 1000 East, Bluff Street, River Road, I-15 Northbound on-ramp, and I-15 Southbound off-ramp, as outlined in Table A-17. St. George Boulevard extends from Bluff Road on the west to River Road on the east. 1000 East is the first road west of the interstate, while the interstate is adjacent to River Road.

The two highest crash types between 1992 and 2002 are rear end (60 percent) and right angle (24 percent) collisions. Approximately 39 percent of all rear end crashes occur at an intersection, while approximately 52 percent of all right angle crashes between 1992 and 2002 occur at a traffic signal. This leaves 48 percent that occur at the midblock.

It is theorized that the reason that most crashes occur at 1000 East is because of the short length between the I-15 off-ramp and 1000 East. This creates problems with merging and diverging traffic, as there are two through lanes, a right turn lane, and a left-turn lane. Cars traveling west have to compete with cars getting off of the interstate. It is hypothesized that for this reason the two highest crash segments are 1000 East – SB Off-Ramp and 900 East – 1000 East as outlined in Table A-18. The third, fourth and fifth highest segments are 700 East -800 East, Bluff Street – 400 West and 400 West – 300 West.

It is not really clear why 700 East - 800 East has a relatively high number of crashes except that it is still close to the interstate, and there is a gas station and a McDonald's on opposite sides of the street. Bluff Road is the other major North-South thoroughfare in St. George besides the interstate, and it carries about 40,000 vpd in the study area.

Table A-17: Highest ranking crash intersections on St. George Blvd

Intersection	Number of Crashes 2003	2002	2001	Total	Rank
1000 East	16	31	26	73	1
Bluff Street	7	28	29	64	2
River Road	14	25	24	63	3
I-15 NB On-Ramp	13	12	18	43	4
I-15 SB Off-Ramp	8	17	11	36	5

2003 includes 1/1/03 – 6/30/03 only
(Source: St. George Traffic Engineering Division)

Table A-18: Highest ranking crash segments on St. George Blvd

Segment	Number of Crashes				Rank
	2003	2002	2001	Total	
1000 East - SB Off-Ramp	11	27	9	47	1
900 East - 1000 East	7	13	14	34	2
700 East - 800 East	8	13	5	26	3
Bluff Street - 400 West	4	12	8	24	4
400 West - 300 West	7	7	8	22	5

2003 inlcudes 1/1/03 – 6/30/03 only
(Source: St. George Traffic Engineering Division)

Knowing where the high crash areas are, the question is: Will a raised median help reduce the types of crashes that prevail on this boulevard? Raised medians typically reduce right angle crashes between left-turn (LT) vehicles and on-coming through vehicles as well as the severity of crashes. They also tend to cause crashes to shift to the intersections. In addition, they also tend to increase rear-end, sideswipe, and merging/diverging crashes. Based on the knowledge that there are already high crash rates at the intersections, a raised median may not improve these areas. However, it is expected that conflict points on the midlbock would be reduced.

A.2.2 Pedestrians

St. George Boulevard is not necessarily pedestrian friendly because of high traffic volume, narrow sidewalks, mostly auto-oriented businesses, fast-food chains, and not many attractive locations for pedestrians to stroll, particularly on the east end of the boulevard. Therefore, a raised median would do little benefit for the small amount of pedestrians. On the other hand, there is an antique mall near Main Street that is very attractive and friendly to pedestrians. It has many small shops and attractive restaurants. Given that there are many motels and inns along the boulevard, overnighters might find it enjoyable to walk through the downtown area. In this case, a beautifully landscaped raised median would entice pedestrians to walk along the boulevard. The raised median would make crossing the boulevard more controlled and safer; however, for this to be effective the sidewalks must be upgraded as well.

Another consideration would be a high percentage of the elderly in the city. As older people walk slower, a raised median would make it easier for them to cross the road if they desired. As of now, auto-oriented businesses thrive because pedestrian-friendly shops cannot. Raised medians may be the catalyst to help revive a more pedestrian friendly environment.

A.2.3 Volume

The ADT on St. George Boulevard is approximately 40,000 vpd. This exceeds the recommended volume for a TWLTL. Raised medians are recommended by the FHWA, ITE, and CTRE when ADT is above 24,000 – 28,000 vpd. According to volume, a raised median is recommended. The reason for this is because right angle crashes are not adequately prevented with a TWLTL. A raised median can restrict certain movements that will make right angle crashes in midblock sections less common. This is important because right angle crashes are associated with higher severity. Also, left-turns are controlled. With TWLTLs, motorists can make left-turns anywhere on the road. With a raised median, left-turns are restricted to intersections and midblock openings. Left-turn crashes typically account for almost three-fourths of all crashes as illustrated previously in Figure A-3.

Another important factor with a high volume of traffic is the smooth flow of traffic. St. George Boulevard connects I-15 with Bluff Drive, which serves approximately 40,000 vpd. When a raised median is present, the drivers have much less distractions of drivers making a left-turn from the TWLTL. There are also less opportunities for conflicts because certain movements are restricted. Moreover, vehicle movements are more predictable, which enables motorists to feel safer behind the wheel. If the main purpose of St. George Boulevard is to move traffic east-west, a raised median will help that happen.

A.2.4 Delay

Delay is very difficult to measure, but the main causes of delay are easily recognized. Delay occurs most often when a road is blocked by vehicles that extend out into the through lanes from left-turn or right-turn lanes or by traffic signals that simply lower the capacity of the roadway. A TWLTL is generally adequate when vehicles need to make left-turns because it removes the vehicle from the through lane. A left-turn bay built into a raised median is usually adequate as well. Judging by the types of businesses on the corridor, a large amount of left-turns will not be made except at Smith’s Food and Drug at 400 West. The intersection at 400 West should be adequate for those turns. If a left-turn lane built into a raised median is not long enough to meet the demand it is difficult to change this without extensive reconstruction. For St. George Boulevard, a TWLTL or a raised median would be adequate to keep delay low.

A.2.5 Driveways per Mile

St. George Boulevard has 56 driveways per mile and 8 traffic signals per mile. According to previous studies, crashes per mile increase by 118 percent when there are 40 to 60 driveways per mile (Table A-12). When there are 60 driveways per mile or more, then the increase is 171 percent (Table A-12). When driveways per mile increases, the margin between crash rate on TWLTLs versus raised medians increases. The crash rate on TWLTLs increases at a faster rate than raised medians. In fact, the crash rate actually decreases on raised medians when driveways exceed 60 per mile (Table A-14).

When signalized access points per mile are compared, raised medians have a lower crash rate compared to a TWLTL. When there are six or more signalized access points per mile, raised medians experience a lower crash rate than the raised median. This boulevard has eight access points per mile. Hence, on this account, a raised median is an appropriate option.

A.2.6 Midblock Openings

Each segment on St. George Boulevard is about 550 feet long. The length of 550 feet is not adequate to install midblock openings, according to Table A-15 of the procedure. Therefore, midblock openings would not be permitted as left turn bays at intersections will occupy most of the distance. If left turns need to be made they would have to be done at the intersections. Since many of the businesses can be reached by making a left-turn from the TWLTL right now, adjustments in traffic behavior will have to be made. For instance, to get to a store on the opposite side of the street, a driver would either make a U-turn or take a left at the intersection and use Tabernacle Street or 200 North to return to St. George Boulevard so that a right turn can be made. This could be avoided if better site circulation were available so that motorists could navigate through store parking lots instead of using the adjacent roads. Also, Tabernacle Street may have more traffic which may help the businesses on this street.

A.2.7 Number of Lanes

St. George Boulevard has two lanes in each direction. This road however carries an ADT that adequately fills three lanes in each direction. It is highly recommended by the FHWA, CTRE, and ITE to have a raised median when there are three lanes in each direction. Therefore, as far as the actual number of lanes is concerned a TWLTL is adequate for this road. However, because of the high volume of traffic on this road, a raised median may be recommended. The purpose behind having a raised median with three lanes is because the number of traffic movements increases dramatically with more lanes, not to mention with a TWLTL. A raised median is an appropriate option.

A.2.8 Evaluation of Result

Since most of the crashes that occur on St. George Boulevard are rear-end crashes, a raised median may not help decrease the major type of crash that currently takes place. However, a raised median will eliminate potential for midblock left-turn related crashes. A raised median may help improve pedestrian circulation on St. George Boulevard. Nothing was mentioned about beautifying the area, but a raised median with trees, rocks, and shrubs combined with improvements to the sidewalks would be effective in beautifying the corridor. The volume on the corridor seems to be the strongest point in favor of a raised median. Moving traffic through the area is important and a TWLTL may not be adequate or appropriate with the high traffic volume. A low amount of delay can be reasonably accommodated with either a raised median or TWLTL. There would be no midblock openings which would allow left-turns into businesses. With a raised median, motorists would have to always make right-turns into the businesses which may be a nuisance to some drivers. This can be altered, however, using Tabernacle Street as a frontage road. Also, such movements would bring more traffic to this currently quiet shopping street. The number of lanes on this corridor does not indicate a need for a raised median, however, the number of driveways per mile does. Raised medians are associated with fewer crashes per mile as the number of driveways or signalized access points increase above forty driveways or six signals per mile. The boulevard has about sixty driveways and eight signals per mile indicating a raised median is a legitimate option. Based on this analysis, a raised median is recommended for St. George Boulevard.

APPENDIX B

APPENDIX B: MANAGER SURVEY

Appendix B presents a copy of the manager survey used for this opinion survey.

Store Name:_____________________
Filled in by:_____________________

Brigham Young University
Provo, UT 84602

Economic Impact of Median Design along University Parkway
(Business Impact Survey)

Orem, UT
Purpose of Survey

The Utah Department of Transportation is studying the effect of raised medians. Guidelines are being developed for the installation of raised medians, and as part of this project, economic impact to adjacent businesses is being studied. This is an anonymous survey conducted by BYU students to determine store managers' opinions regarding how raised medians have affected business. Completing this survey is voluntary. Please answer each question honestly. <u>All answers will be held confidential.</u>

Thank you for filling out this important survey!!

1. When did this business begin operations at this location?

   Month Year
   _____ ____

2. What do you believe is the percentage of your customers who are passerby customers and those who intend on stopping at your business? Passerby customers are those customers who are not intending to stop at your particular business (i.e., impulse customers) as opposed to planned stops by customers who had intended on stopping at your business.

   Percent passerby traffic___ Percent planned stop___

3. Do you believe your regular customers have remained about the same, are more likely, or have been less likely to visit your business due to the raised median?

   Less likely___ Stay about the same___ More likely___

4. Please rank the following considerations from "1" to "6" (with "1" being the most important) that consumers use when selecting a business of your type:

Distance To travel	Hours of Operation	Customer Service	Product Quality	Product Price	Accessibility to Store
—	—	—	—	—	—

5. Please indicate below whether you feel the installation of the raised median has made the following items "Better," "Worse," or about "The Same" as before the median was installed.

	Better	Worse	The Same
Traffic Congestion	____	____	____
Traffic Safety	____	____	____
Property Access	____	____	____
Business Opportunities	____	____	____
Customer Satisfaction	____	____	____
Delivery Convenience	____	____	____

6. How many people are employed by your business? Please give the average annual number, including working owner and/or manager to the best of your knowledge. Construction year is shown in bold.

	1997	1998	1999	2000	2001	**2002**	2003
Full-time	____	____	____	____	____	____	____
Part-time	____	____	____	____	____	____	____

For questions 7-9,

- Please give your best estimate of the percentage impact, up or down, on your business.
- If you do not think there was a large change during construction or if there has not been a large change after the installation, then mark an "X" for "No change."
- Please place an "X" for "Not sure" if you are uncertain about what the effect was during the construction or is now after the installation.
- Please take into consideration the current economic slump.

During and after the construction, has there been a change in:

7. Your number of customers per day?

	During Construction (As compared to before construction)	After Installation (As compared to before construction)
Percent increase	____%	____%
No change	____	____
Percent decrease	____%	____%
Not sure	____	____

8. Your number of full-time employees?

	During Construction (As compared to before construction)	After Installation (As compared to before construction)
Percent increase	____%	____%
No change	____	____
Percent decrease	____%	____%
Not sure	____	____

9. Your number of part-time employees (enter as equivalent full-time employees)?

	During Construction (As compared to before construction)	After Installation (As compared to before construction)
Percent increase	____%	____%
No change	____	____
Percent decrease	____%	____%
Not sure	____	____

Please use this space to discuss any additional thoughts you may have about the raised median installation along University Parkway. Please attach an additional page if necessary.

Once again, thank you very much for your time in completing this important survey! If you have questions regarding this survey or the study please contact the research supervisor Dr. Mitsuru (Mike) Saito at (801) 422-6326. If you have questions regarding your rights as a participant in research projects, you may contact Dr. Shane S. Schulthies, Chair of the Institutional Review Board for Human Subjects, 120B RB, Brigham Young University, Provo, UT 84602; phone, (801) 422-5490.

APPENDIX C

APPENDIX C: CUSTOMER SURVEY

Appendix C: presents a copy of the customer survey used for this opinion surveys.

Store Name:___________________________

Brigham Young University is studying the economic impact of the raised median installation along University Parkway in Orem, Utah from 400 W to 200 E for the Utah Department of Transportation. This is an anonymous survey to evaluate how customer's opinions are affected by the recently built raised median. There are 11 questions that take 2-3 minutes to answer. Completing this survey is voluntary. Please answer each question honestly.

1. Are you aware of the project in which a raised median was installed along University Parkway from 400 W to 200E?
   ___Yes ___No

2. Did you patronize this business prior to the construction of the raised median?
   ___Yes ___No

3. When leaving this business will you have to go the opposite way than you would like and make a U-turn (or series of right turns)? If answer is No, skip to 5.
   ___Yes ___No

4. Is this driving maneuver different than before the raised median was installed along the center of University Parkway in front of this business?
   ___Yes ___No

5. If the construction of the raised median prevents you from making a left-turn from the two-way left-turn median lane, do you believe you will be more likely to visit this business, less likely, or about the same?
   ___Less likely ___Stayed about the same ___More likely

6. Did you make a special trip to visit this business or just stop here because it is convenient on the way to your primary destination?
   ___Special trip just to this business (or went out of way to stop here)
   ___Pass-by / convenient

7. If you visited this business prior to the median installation, do you believe you are now more likely or less likely to visit this business or is it about the same?
   ___Less likely ___Stayed about the same ___More likely

8. If less likely in Question 7, why?
   ___Access more difficult
   ___Takes longer to get here
   ___Other stores more convenient
   ___Other, please describe________________

9. If more likely in Question 7, why?
___Access more convenient
___Less time to get here
___Access more safe
___Other, please describe________________

10. Please rank the following considerations from “1” to “6” (with “1” being the most important) that you use when selecting a business of this type:

Distance To travel	Hours of Operation	Customer Service	Product Quality	Product Price	Accessibility to Store
___	___	___	___	___	___

11. Please indicate below whether you feel the installation of the raised median has made the following items “better,” “worse,” or about “the same” as before the median was installed.

	Better	Worse	The Same
Traffic Congestion	____	____	____
Traffic Safety	____	____	____
Property Access	____	____	____
Customer Satisfaction	____	____	____

Do you have any other comments regarding the raised median (Please write them here)?

If you have any questions regarding this survey or the study please contact the research supervisor Dr. Mitsuru (Mike) Saito at (801) 422-6326. If you have questions regarding your rights as a participant in research projects, you may contact Dr. Shane S. Schulthies, Chair of the Institutional Review Board for Human Subjects, 120B RB, Brigham young University, Provo, UT 84602; phone, (801) 422-5490. Thank you very much for your time in filling out this survey!

APPENDIX D

APPENDIX D: CUSTOMER AND MANAGER SURVEY COMMENTS

D.1 Customer Survey Comments

- It looks nice but the money could have gone elsewhere
- I would have felt better if they had planned and done it right the first time instead of realizing they needed to make adjustments after the first phase. Big time waste of tax payers dollars
- I’ve seen some people get really confused about entering the freeway south bound since this change was finished
- It looks good, better than before and somehow makes the traffic a bit safer.
- It is nice looking but does make it harder to get to places. It is frustrating if I miss my turn and have to drive out of my way to turn.
- It can be fairly ANNOYING! When people don’t know it is there – they drive dangerously trying to figure out where to turn in.
- I don’t like it. It makes left turns on this road terrible (both turning left onto the Parkway and from the Parkway to stores
- Good job guys.
- Hates the raised median
- More dangerous
- Infinitely better – saves lives
- Traffic is a nightmare all up and down this street. I usually try to avoid taking this street. I usually go on 1200 S or other supporting streets because this one does not make for easy access.
- I drive through parking lot to a light instead of left on Parkway
- Plants make it look nice. Outside should look good – Appealing
- Lack of customer service here
- Doesn’t come here often
- Doesn’t matter
- All for raised medians because reduces crashes. People would dart across road without them.
- Doesn’t like it.
- It would be more convenient to be able to turn into the [store] parking lot without the hassle of the raised median. I realize that it helps with U turns but really the congestion would be less if it was not there
- Wishes they had a median opening for this business. She has to drive through another store’s lot.
- Grateful it was installed because of fatal crash. It’s too bad it wasn’t installed earlier.
- Can’t say much because he builds the medians
- Kind of annoying to them
- Should have raised medians on all busy streets. They save lives.
- Frustrated that you have to go clear to the median opening to get around. Should be median openings. Doesn’t like raised median that is in front of her business.
- If maintained with landscape then good

- Upset that Granite is moving. Better customer service than RC Willey. Raised medians are annoying.
- Medians suck
- Medians look nice if planted
- I like them
- Only if safety is improved
- Ok here but bad at Wal-Mart
- Looks nice
- I like the trees
- Likes green things
- I don't like them
- Don't put them around me
- Inconvenient
- Likes it, pretty, adds to community
- If I can drive on them, I will
- Driving maneuver: They come straight across from south of University, so they go straight at RC Willey at the light and cut through parking lot-it's just easier
- Looks nice
- Forces too many u-turns
- It's pretty, but makes things difficult
- Likes it very much because it is beautiful. Road is supposed to be a parkway by the name anyways
- If rush hour, they are deterred from coming to store
- Looks nice. They might be a pain, but they make the city look a lot nicer.
- They kind of suck
- Less chance of head-on collisions
- Didn't affect me that much
- More difficult when congested
- Kind of a pain. Don't like traffic. Ask us about roundabouts, we'll fill out a survey on those.
- Makes it difficult. I don't like them. Bad idea.
- Feels safer because she knows the people who were killed in the car crash [on University Parkway a few years ago], which was caused by a head-on collision.

D.2 Manager Survey Comments

- We are an Insurance Claims Office. Our Business is not generated by passerby or planned. This survey would be more appropriate if it was an agent sales office. At the holiday we have 50 to 60 employees
- .They need to put a(n) [turn] arrow [at 400 W] to cut down on people taking chances when crossing the street. The amount of car crashes has not decreased.
- Not able to determine question 8 or 9. He has had continuous growth. My business is probably not impacted as much by the installation because of its nature. However, other businesses in the building may feel the impact. I feel that there is some impact in trying to rent the building to tenant businesses.

- Our business does not rely on drive by business. The best improvement has been the stop light which makes it much safer to turn into our business, it would be better not to have trees in the median for vision reasons.
- Raised median has had little or no effect. The planting of trees on the other hand has had more negative effect.
- We have seen some growth in our business since construction but our growth has been less than our competition in Honda. We are seeing fewer customers but our sales have increased because of our increase in trained employees not because of increase in traffic. Access to our property is very difficult!
- Doubtful that median has had any effect.