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Pedestrian Safety Engineering and Intelligent Transportation System-Based Countermeasures Program For Reducing Pedestrian Fatalities, Injuries, Conflicts, and Other Surrogate Measures

Cooperative Agreement Number DTFH61-01-1X-00134
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Phase 2 Final Technical Report

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EXECUTIVE SUMMARY

This report documents efforts on and findings from Phase 2 of a cooperative agreement between the Federal Highway Administration (FHWA) and the University of Nevada, Las Vegas (UNLV) Transportation Research Center (TRC), titled “Pedestrian Safety Engineering and Intelligent Transportation System-Based Countermeasures Program For Reducing Pedestrian Fatalities, Injuries, Conflicts, and Other Surrogate Measures” (Cooperative Agreement Number DTFH61-01-X-00018, UNLV Account Numbers: 2360-254-49BX, 2330-254-49CA and 2330-254-49CD UNLV/TRC/RR-02-03). Five state and local agencies in Nevada co-sponsored the program: City of Las Vegas, Clark County Department of Public Works, Nevada Department of Transportation, Nevada Office of Traffic Safety, and the Regional Transportation Commission of Southern Nevada. Several other local agencies and private sector organizations were cooperating partners: City of North Las Vegas, City of Henderson, Orth Rodgers Inc. etc.

The goals of the program are to deploy and evaluate countermeasures (that were identified and developed in Phase 1) to help improve pedestrian safety and walkability (and reduce/minimize risk). The intent of this program is to serve as an example of what would lead to the implementation of successful pedestrian safety countermeasures across the nation. Some of the countermeasures deployed in Phase 2 have been selected in consultation with Florida (Miami-Dade County) team and San Francisco team. This is to permit a comparative evaluation of countermeasures at three different locations in the country.

A Geographic Information Systems (GIS) based methodology was used to identify high pedestrian risk zones and areas in the study area. Initially 16 high risk zones comprising of 47 pedestrian high crash sites were identified in the Phase 1. However, due to limited financial resources to improve pedestrian safety at all the identified locations, eighteen (18) pedestrian high crash sites were identified in the Las Vegas metropolitan area. Of these 18 locations, countermeasures were deployed at 14 locations with the remaining 4 sites as control sites, where none of the countermeasures were deployed. Seventeen countermeasures were initially selected to evaluate in this program Based on the risk associated at each site, multiple countermeasures were deployed at several sites. The deployment of these multiple countermeasures was done in phases to evaluate effectiveness of each individual countermeasure. Data were collected before and after each countermeasure deployment at sites. Statistical analyses were performed on the collected data to determine the significance of the changes in measures of effectiveness before and after deploying the countermeasure.

Although seventeen countermeasures were initially selected to evaluate in this program, it later reduced to fifteen, due to the unavailability of vendors to supply two of the countermeasures, “Enlarged Pedestrian Signal Heads” and “Advanced Warning Roving Eyes for Motorists.” However, a new countermeasure is added to the list and it would be installed at locations where “Enhancer LED Pedestrian Signals” were supposed to have been installed. This report documents the results of analyzes based on fifteen countermeasures excluding the pedestrian enhancer. The summary of the effectiveness of these countermeasures are as follows:

1) “Turning Vehicles Yield to Pedestrians” signs: Significant improvement in motorists’ yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street.
2) Advance yield markings for Motorists: Significant improvement in motorists’ yielding behavior.
3) In roadway knockdown signs: Significant improvement in motorists’ yielding behavior, reduction in percent of pedestrians trapped in the middle of the street.
4) ITS “No-Turn on Red” signs: Significant improvement in pedestrians’ compliance.
5) Pedestrian call button that light up: Significant improvement in pedestrians’ compliance, significant reduction in percent of pedestrians trapped in the middle of the street.
6) Warning signs for motorists: No significant improvement in either motorist or pedestrian MOEs.

7) High visibility crosswalk treatment: Significant increase in motorists' yielding distance, significant improvement in pedestrians' yielding behavior.

8) Median refuge: Significant improvement in motorists' yielding behavior, significant increase in motorists' yielding distance, significant improvement in pedestrians' yielding behavior.

9) Smart lighting: Significant improvement in motorists' yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of "diverted" pedestrians.

10) ITS automatic pedestrian detection devices: Significant improvement in motorists' yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of "diverted" pedestrians.

11) Portable speed trailer: Significant increase in motorists' yielding distance.

12) Pedestrian activated flashing yellow: Significant increase in motorists' yielding distance, significant reduction in percent of drivers blocking crosswalk, significant improvement in pedestrian yielding behavior.

13) Pedestrian countdown signals with animated eyes: Significant improvement in pedestrians' looking for turning vehicles.

14) Danish offset: Significant improvement in motorists' yielding behavior, significant increase in motorists' yielding distance, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of "diverted" pedestrians.

15) Pedestrian channelization: No significant improvement in either motorists' or pedestrians' MOEs.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

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The Study Area

Several cities lie within the boundaries of Clark County, Nevada, but most of the population resides in the City of Las Vegas or in the unincorporated Clark County area. The physical boundaries between the jurisdictions are invisible, creating a unified metropolitan area. The study area includes all of this urban and suburban area. Figure 1 provides an illustration of the Las Vegas metropolitan area or "valley". This is the general extent of the study area.

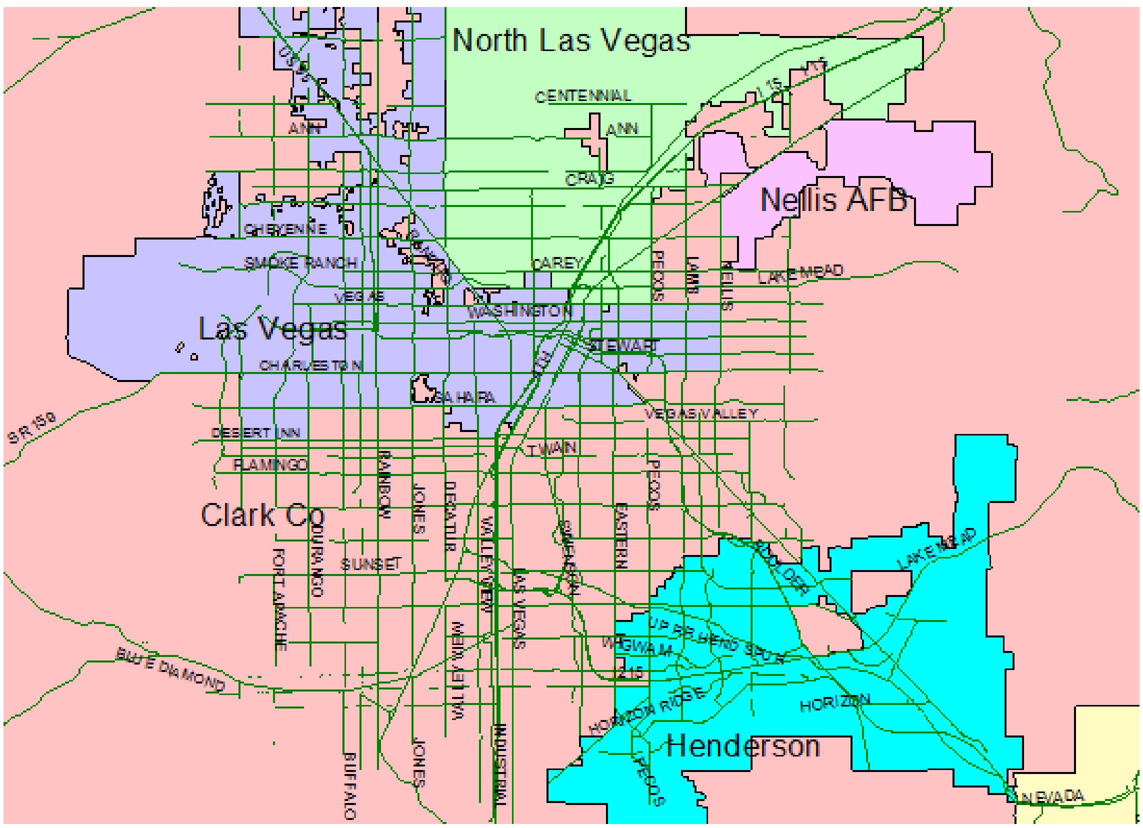

Figure 1: Cities in the Las Vegas Metropolitan Area

Conditions within the study area are consistent with those to be found in many southwestern states and in communities with a wide, fast street system. A history of high incidence of pedestrian crashes has generated awareness in the multiple agencies that govern the area. The roadways in the study area are under the jurisdiction of City of Henderson, City of Las Vegas, City of North Las Vegas, Clark County, or the Nevada Department of Transportation (NDOT). The Regional Transportation Commission of Southern Nevada (RTC) and the Nevada Office of Traffic Safety (OTS) are other entities who have administrative responsibilities for the transportation system and transportation safety in the study area.

Development Patterns

The original downtown core of Las Vegas has been revitalized and transformed to a large casino pedestrian mall with two cross streets. With the partial exception of government and law, the gaming industry dominates the commercial activity in this urban core area. Other economic and civic activities are located away from the urban core. Streets entering this downtown area were reconstructed around the year 2000 to include curb extensions, some wide sidewalks, and landscaping, but the scale favors the motorized vehicle. Near the new mall, the homeless and the unemployed congregate near the day labor office and social services building.

Commerce sprawls out from the center and along Las Vegas Boulevard, known as the Strip. The Strip has evolved into one of the most recognizable and heavily traveled streets in the world. Designed as a Day and Night Scenic Byway, 14 of the 15 largest hotel complexes in the world are located along this roadway. An estimated 90,000 people stroll along the resort corridor every day of the peak season. The strip consists of a minimum of six lanes of through traffic. The sidewalks are often crowded with tourists and visitors with attractions such as mock facades of famous cities from around the world, fountains set to music, and an erupting volcano compete for driver attention.

Old and new residential neighborhoods were built as suburbs, disconnected from any city center, commerce, or services. Many peripheral suburbs, such as Summerlin and Green Valley, are exclusive areas connected only by high-speed arterial streets. Some cater to senior citizens, while others attract young white-collar workers. New development continued to proliferate until recently with the wide, fast streets that are the indicative of auto-oriented urbanity and the concern to pedestrian mobility and safety.

Neighborhood advisory boards and homeowner associations offer some sense of identity to some residential communities. But there is a less obvious, unique identity of place for residents in the City of Las Vegas and County areas than in other cities in the study area, such as Henderson, or North Las Vegas. These areas have better defined central areas and some geographical distinction at their boundaries.

The assets within the neighborhoods of the study area include the various boards and associations representing the interests of the community. They also include a myriad of organizations such as churches, youth groups, school district, health care providers, law enforcement agencies, emergency responders, and committed businesses that are eager to improve quality of life for those who live, work, and shop within the area. These assets are tapped and cultivated in an effort to combine neighborhood resources with local and regional resources to improve pedestrian accessibility, mobility, and safety.

Population

Clark County, Nevada, which includes Las Vegas, has been the fastest growing metropolitan area in the country, with more than 70 percent increase in population during the last decade. The County is home to 75 percent of Nevada’s 2.495 million residents. About 40 million people from across the world visit the Las Vegas valley each year, creating a tourism industry and economic base for support businesses that lures an average of 5,000 new residents to the area each month. Entry level hotel/casino employment positions have been abundant, but most start at minimum wage.

The Hispanic population in Clark County has grown from 11.2 percent of the total in 1990 to 26 percent of the total in 2005, with an estimated 1,200-1,500 Hispanics immigrating to the area each month. Seventy five percent of the Las Vegas Hispanic population was born outside of the United States, suggesting a potential language barrier and related limitations on transportation opportunities. According to The Latin Chamber of Commerce, Hispanics represented 55 percent of the workforce in construction industry in Clark County. Non-white residents, including African Americans and Asians, represent an additional 17.8 percent of the total population.

About 11 percent of the population is over 65 years of age, and 25 percent of the overall population is under the age of 18 years. The number of children under 18 years of age in Hispanic families is significantly higher, representing 36.6 percent of the Hispanic population. These numbers reflect issues that need to be studied when developing treatment programs, particularly education and outreach campaigns. The culture of the Hispanic community and the needs of senior citizens set them apart from the majority of the population who often has easier access to motorized transportation.

Transportation

Las Vegas is a new urban area by most standards. Its development originated during the first half of the twentieth century in a vast desert with ample land for urban sprawl. A majority of the growth in population and the economy growth in this area has occurred over the last 20 years. The low-density template used to develop the desert city provided a traditional street grid pattern with major surface arterial streets at every mile, and rights-of-way adequate to provide for six or eight lanes of traffic that generally travels at or above the posted speed limit of 45 miles per hour (mph). Intersections are wider, often with striped dual or triple left turn pockets, and single or double right turn pockets. A few streets have raised medians, but those with adequate width are more likely to have two-way-left-turn lanes in their center. Sidewalks, when present, are generally a maximum of five feet wide and built at the back of curb, with no buffer between the sidewalk and the travel lanes for vehicles. In the 10 years between 1990 and 2000, the number of lane miles in Clark County more than doubled, for a total of 5,849 miles of lanes. Principal arterial streets and minor arterial streets account for 47 percent of urban vehicle miles of travel in the Las Vegas valley. Expansion of the roadway network continues as the area struggles to serve the growing number of vehicles, but the length of time spent commuting gradually creeps up as congestion overtakes the new roads. The Las Vegas valley is a non-attainment area for national clean air standards.

Citizens Area Transit, the local bus system, began serving the citizens of Clark County in December 1992. In just under 10 years, ridership has grown from 15 million riders in 1993 to 61 million riders in 2006. Special bus service is available for qualified senior citizens and the disabled. The entire system consists of 46 routes served by 336 vehicles, carrying around 180,000 passengers each weekday in the greater Las Vegas Valley. Incidents such as transit system users crossing such “high speed,” “high volume” and “high risk” streets to use the transit system is not uncommon in the study area.

The Clark County School District (CCSD) is the fifth largest in the nation - with an enrollment of about 308,783 students in year 2005. CCSD’s policy is that students who live within two miles of a school are not provided bus transportation by CCSD - i.e., they have to walk, bicycle, get dropped off by a parent/guardian or take public transit. In spite of this policy, many school children ride buses to school, and it is not uncommon to see buses stop on seven lane, arterial streets to allow children to board and depart. Many of the older suburban schools in the Las Vegas valley are adjacent to multi-lane arterial streets. As in many areas of the United States, schools are frequently placed in locations that require motorized transportation. Elementary aged children who cross major streets at intersections proximate to the schools that are not signalized are typically assisted by a crossing guard during school hours, but middle schools generally do not provide crossing guards. School speed zones are aggressively enforced at speeds of 15 mph for elementary and middle schools, and 25 mph for high schools. But officer resources limit the number of school zones that can be policed each day.

Law Enforcement

The City of Las Vegas and Clark County are served by the Las Vegas Metropolitan Police Department (LVMPD), a consolidated agency funded by both entities. There are approximately 1,800 officers in the department, about 130 of who are dedicated to traffic administration, patrol, and crash investigation. The agency investigates approximately 51 percent of the crashes that occur in Nevada. An inter-local agreement with the Nevada Highway Patrol assigns traffic on and near the freeway system to the state troopers.

LVMPD conducts a variety of specialized enforcement programs, including active efforts to increase motorist compliance at marked crosswalks. They conduct regular Selective Traffic Enforcement Programs (STEPs) under traffic safety grants awarded through the Nevada Office of Traffic Safety (OTS). Pedestrian safety has become an issue for the agency and they are committed to helping with this project. One commanding officer shared his viewpoint that motorists are simply unaware of the dangers a pedestrian confronts in the street environment.

Pedestrian Crash Problem in Las Vegas Metro Area and the Safety Program

The pedestrian fatality rate in the State of Nevada had been among the worst in the nation over the past decade. Based on pedestrian fatality rates, Nevada has been among the 10 worst states for pedestrian safety since the early 1990s (NHTSA, 2004). Pedestrian fatalities per 100,000 population in the State of Nevada and the U.S. from 1994 to 2003 are shown in Table 1. Nevada has been ranked first on two occasions during the last 10 years, in 1996 and 1999, as having the worst pedestrian safety in the United States. Thus, the pedestrian safety problem (as quantified by fatal and injury crashes) in Clark County warrants immediate attention.

Table 1: Pedestrian Fatalities in Nevada and US from 1994 to 2003

Year	Pedestrian Fatality Rate per (100,000 Population)		Nevada's Ranking	Pedestrian Fatalities in Nevada
	US	Nevada		
1994	2.11	3.71	4	54
1995	2.12	3.93	5	60
1996	2.05	4.26	1	68
1997	1.99	3.52	4	59
1998	1.93	2.64	6	46
1999	1.81	3.70	1	67
2000	1.69	2.13	10	43
2001	1.72	2.15	7	45
2002	1.68	2.40	6	52
2003	1.63	2.90	3	65

Source: Fatality Analysis Reporting System, National Highway Traffic Safety Administration (2004)

A Geographic Information Systems (GIS) based-analysis of crash data in the Las Vegas metropolitan area was used to identify locations with high pedestrian crash rates. Altogether, 19 sites were identified as pedestrian high crash locations. Based on conditions and crash characteristics, various intelligent transportation systems (ITS) and other engineering pedestrian safety countermeasures were identified for deployment at these locations.

Study Objectives

Various strategies to enhance pedestrian safety have been implemented and evaluated around the world. Such strategies have seen limited deployment and evaluation in the United States. Such countermeasures were deployed and evaluated at high crash locations identified within the Las Vegas valley. A before-and-after evaluation strategy was used to assess the effectiveness of these countermeasures. The successful countermeasures can be considered for similar kinds of traffic volume and site conditions throughout the United States. Some deployed novel strategies and their effects on pedestrians' and drivers' behavior can also be used in different parts of the world. In this research, nine countermeasures were installed and evaluated. Out of these nine, seven of the countermeasures were installed at high-risk locations. The remaining two countermeasures, an in-pavement flashing light system and pedestrian countdown signals, are installed at other locations. The effectiveness of the implemented countermeasures was evaluated under prevailing weather conditions and in the geographic location of the Las Vegas valley.

Goals

The goals of the Federal Highway Administration (FHWA) Pedestrian Safety Program are to identify, develop, deploy, and evaluate pedestrian safety countermeasures to help improve pedestrian safety (minimize risk) and walk-ability. The intent of this program is to serve as an example of what would lead to the implementation of successful pedestrian safety countermeasures across the nation. The Las Vegas metropolitan area is the region targeted for deploying and identifying countermeasures. The focus of Phase 2 of the FHWA Pedestrian Safety Program is to implement engineering and Intelligent Transportation System (ITS) based countermeasures, to evaluate the effectiveness of these pedestrian safety countermeasures for various target groups and causal (risk) factors.

Objectives

The objectives of Phase 2 of the program are to follow up on the findings and recommendations of Phase 1. Specifically, these objectives are to deploy the selected countermeasures at the sites identified in Phase 1, and to evaluate their effectiveness. Some of the countermeasures deployed in Phase 2 were selected in consultation with the Florida, Miami-Dade county team. This was to permit a comparative evaluation of countermeasures at two different locations in the country.

Tasks

As presented in the proposal for Phase 2: Implementation (Volume 1), the work plan to meet Phase 2 objectives and the Government’s requirements consist of the following tasks.

1. Finalize the implementation plan.

2. Coordinate design and implementation of countermeasures with local partners and agencies.
3. Collect data and analyze existing conditions.
4. Collect data after deployment of countermeasures.
5. Conduct statistical analysis and evaluate countermeasures.

Disseminate the outcomes, findings, and experiences from the program through topical avenues.

CHAPTER 2

COUNTERMEASURE DESCRIPTIONS

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COUNTERMEASURE DESCRIPTIONS

A Geographic Information Systems (GIS) based methodology was used to identify high pedestrian risk zones and areas in the study area. Initially 16 high risk zones comprising of 47 pedestrian high crash sites were identified in the Phase 1. However, due to limited financial resources to improve pedestrian safety at all the identified locations, eighteen (18) pedestrian high crash sites were identified in the Las Vegas metropolitan area. Figure 2 shows the map of Las Vegas metropolitan area with the selected 18 locations. Of these 18 locations, countermeasures were deployed at 14 locations with the remaining 4 sites as control sites, where none of the countermeasures were deployed. Seventeen countermeasures were selected to evaluate in this program. These countermeasures are summarized in Table 2 and in Appendix A, DWG No 123.01-123.13.

Table 2: Summary of Countermeasures Proposed and Deployed

Proposed and Deployed Countermeasures
Turning Vehicles Yield to Pedestrian Sign
Advance Yield Markings
In-Roadway Knockdown Signs
ITS No-RTOT Signs
Pedestrian Call Buttons that Light Up
Warning Sign for Motorist
High Visibility Crosswalk Treatment
Median Refuge
Smart Lighting
Advance Warning for Motorists (Roving Eyes)
ITS Automatic Pedestrian Detection Devices
Portable Speed Trailer
Pedestrian Activated Flashing Yellow
Pedestrian Countdown Signals (Animated Eyes)
Enlarged Pedestrian Signal Heads
Danish Offset
Pedestrian Channelization

Some countermeasures that were proposed in the cross cutting treatment report were changed to match the standard required by the MUTCD 2003. These countermeasures are: Turning Vehicle to Pedestrian Sign, Regulatory Sign for Advance Yield Markings, In-Roadway Knockdown Signs, and Warning Sign for Motorists. Further, the countermeasures that need the request for permission to experiment to the FHWA are Smart Lighting, Enhancer LED Flashing Pedestrian Signal, ITS Automatic Pedestrian Detection Devices, Pedestrian Countdown Signal (animated eyes), and In-Roadway Knockdown Signs.

Table 3 shows the summary of each countermeasure that were installed and evaluated in the Phase 2 of FHWA Pedestrian Safety Project. Summary of the countermeasure includes countermeasure code, countermeasure name, countermeasure drawing details and a short description of the countermeasure. Table 4 presents the details of the installed countermeasures for evaluation at each study location. Table 5 addresses problems accomplished by the installed countermeasures at each study location. Appendix A presents pictures and drawings of these countermeasures.

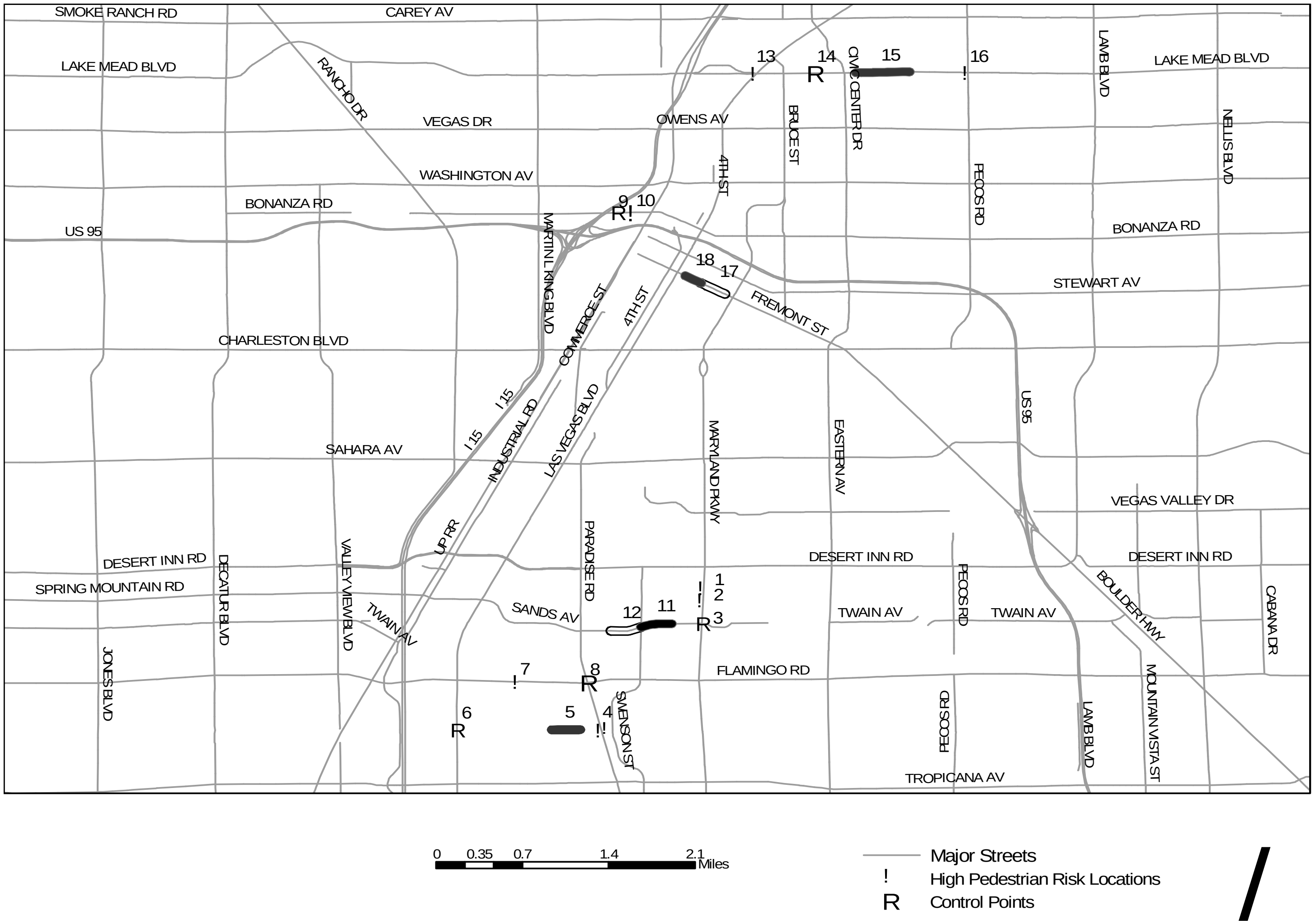

Figure 2: Selected high crash sites

Table 3: Summary of the Potential Countermeasures

COUNTERMEASURE	DWG No.	NOTE
Turning vehicles yield to ped sign	A1 (Appendix A)	1. Electronic Blank-out sign shall be integrated into existing traffic management systems. 2. Housing body and inside framework permanently attached to form a single unit designed to withstand 80 pound per square foot as specified in AASHTO publication entitled standard specification for structural support for highway signs, luminaires 3. Flat aluminum sign face with fiber optics or LED assembly mouted on it 4. Housings constructed of extruded aluminum with a flat aluminum back welded into the housing 5. The sign shall be completely blank out when not energized. No phantom words or leged seen under any ambient light conditions
Advance yield markings + Sign yield to pedestians	A2.1 (Appendix A) A2.2 (Appendix A)	1. See MUTCD Sect.3B.16, Page 3B-33 and 3B-34 1. All components shall be square post, perforated on all four sides 2. Attach anchor and sleeve together prior to driving into ground. Leave at least one hole, but no more than two, above ground or above sidewalk 3. For sidewalk installation, drill sidewalk a 3" hole, the center to be 6" from back of sidewalk 4. Attach post to anchoring system by using at least two 3/8" diameter. drive rivets. 5. Provide 4" minimum lap between post and the anchor/sleeve assembly. One hole, but no more than two, above ground or above sidewalk
In-roadway knockdown signs	A3.1 and A3.2 (Appendix A)	1. 123.05 is YIELD for pedestrian at crosswalk sign 2. 123.05A is WATCH for pedestrian sign (mid-block or no crosswalk locations)
ITS no RTOR signs	A4	1. Electronic blank-out sign shall be integrated into existing traffic management systems. 2. Housing body and inside framework permanently attached to form a single unit designed to withstand 80 pound per square foot as specified in AASHTO publication entitled standard specification for structural support for highway signs, luminaires 3. Flat aluminum sign face with fiber optics or LED assembly mouted on it 4. Housings constructed of extruded aluminum with a flat aluminum back welded into the housing 5. The sign shall be completely blank out when not energized. No phantom words seen under any ambient light conditions
Ped call buttons that light up, other ADA related Technologies	A5 (Appendix A)	1. Pedestrian push button shall not be located more than 24" from the back of walk. If distance from back of walk to push button is 20" to 24", the button shall be located at a maximum hight of 44" from the surface of the walk; otherwise, the 2. The force required to activate control shall be no greater than 5 lb. 3. Post shall be HOT-DIP galvanized by manufacturer or prime painted by manufacturer and finish painted by contractor per specifications and as required by the entity
Regulatory sign for motorist	A6 (Appendix A)	1. All components shall be square post, perforated on all four sides 2. Attach anchor and sleeve together prior to driving into ground. Leave at least one hole, but no more than two, above ground or above sidewalk 3. For sidewalk installation, drill sidewalk a 3" hole, the center to be 6" from back of sidewalk 4. Attach post to anchoring sstem by using at least two 3/8" diameter. drive rivets. 5. Provide 4" minimum lap between post and the anchor/sleeve assembly.

Table 3: Summary of the Potential Countermeasures (Continued)

COUNTERMEASURE	DWG No.	NOTE
High visibility crosswalk treatment	A7 (Appendix A)	1. Types of crosswalks are selected based on the requirement in each jurisdiction
Median refuge	A8 (Appendix A)	-
Smart lighting	A9 (Appendix A)	1. Metal halide fixtures with reflective floodlights to light the walkways of the pedestrian detection. 2. When activated, it gives a brilliant white light that significantly contrast with the golden color of the high pressure sodium bulbs.
ITS automatic pedestrian detection devices	A11 (Appendix A)	-
Portable speed trailers	-	-
Pedestrian activated flashing yellow	A13 (Appendix A)	1. All poles to be HOT-DIP galvanized by manufacturer or prime painted by manufacturer and finish painted by contractor per specifications and as required by the entity. 2. Low bidder must supply shop drawing for design approval before contract can be awarded.
Pedestrian countdown signals (animated eyes)	A14 (Appendix A)	1. The hand symbol (DON'T WALK) is portland orange and human symbol (WALK) is lunar white.
Danish offset	A16 (Appendix A)	-
Pedestrian channelization	A17 (Appendix A)	-

Table 4: Countermeasures Installed for Evaluation at Selected Sites

Site #	Location	Zone #	Jurisdiction	Potential Countermeasures																
				D	E	H	J	K	M	N	O	Q	R	S	T	U	W	X	Y	Z
Maryland Parkway (Flamingo Wash - Sierra Vista Drive)		1																		
1	Maryland Parkway / Sierra Vista Drive		CC							X								X		
2	Maryland Parkway / Dumont Street		CC		X	X				X						X			X	
3	Maryland Parkway / Twain Avenue		CC																	
Harmon (Paradise Road - Las Vegas Boulevard)		2																		
4	Harmon Avenue / Paradise Road		CC	X					X											
5	Harmon Avenue : Paradise Road to Tropicana Wash		CC		X	X				X	X									
Flamingo Road (Paradise Road - Las Vegas Boulevard)		3																		
7	Flamingo Road / Koval Lane		NDOT / CC				X			X							X			
8	Flamingo Road / Paradise Road		NDOT / CC																	
Bonanza Road (D Street - H Street)		4																		
9	Bonanza Road / D Street		NDOT / CLV						X	X										X
10	Bonanza Road / F Street		NDOT / CLV			X				X										
Twain Avenue (Cambridge Street - Palos Verde Street)		5																		
11	Twain Avenue: Cambridge Street to Swenson Street		CC			X									X					
12	Twain Avenue: Swenson Street to Palos Verde Street		CC			X														
Lake Mead Boulevard (Pecos Road - Las Vegas Boulevard)		6																		
13	Lake Mead Boulevard / Las Vegas Boulevard		NDOT / NLV							X								X		
14	Lake Mead Boulevard / McDaniel Street		NDOT / NLV																	
15	Lake Mead Boulevard: Belmont Street to McCarran Street		NDOT / NLV		X					X	X	X	X	X		X			X	
16	Lake Mead Boulevard / Pecos Road		NDOT / NLV	X					X											
Fremont Street (15th Street - 6th Street)		7																		
17	Fremont Street: 11th Street to 8th Street		NDOT / CLV																	
18	Fremont Streer: 8th Street to 6th Street		NDOT / CLV			X		X							X					
Charleston Boulevard (Maryland Parkway - Eastern Avenue)		8																		
19	Charleston Boulevard/ Spencer Street*		CLV		X				X	X		X	X	X						

* New study location
** Excluded from further consideration

CC Clark County
NDOT Nevada DOT
CLV City of Las Vegas
NLV City of North Las Vegas

COUNTERMEASURES

D Turning vehicles yield to Ped Sign
E Advance Yield Markings
H In-Roadway Knockdown Signs
J ITS No RTOR Signs
K Ped Call Buttons that Light Up, other ADA related Technologies
M Regulatory Sign for Motorist
N High Visibility Crosswalk Treatment
O Median Refuge
Q Smart Lighting
R Advance Warning for Motorists (roving eyes)
S ITS Automatic Pedestrian Detection Devices
T Portable Speed Trailers
U Pedestrian Activated Flashing Yellow
W Pedestrian Countdown Signals (animated eyes)
X Enlarged Pedestrian Signal Heads
Y Danish Offset
Z Pedestrian Channelization

Table 5: Relationships between Existing Problems and Installed Countermeasures

Site #	Location	Problems / Concerns											Countermeasure	A
		1	2	3	4	5	6	7	8	9	10	11		
1	Maryland Parkway / Sierra Vista Drive			X	X	X							Enlarged pedestrian countdown signal (animated eyes) (X)	X
		X	X										High visibility crosswalk treatment (N)	X
2	Maryland Parkway / Dumont Street						X	X	X				Advance yield markings + sign yield to pedestrian (E)	X
			X				X						High visibility crosswalk treatment (N)	X
				X			X	X	X				In-roadway knockdown signs (H)	X
				X			X						Danish Offset (Y)	X
													Pedestrian activated flashing yellow (U)	X
3	Maryland Parkway / Twain Avenue	**Control Site**												
4	Harmon Avenue / Paradise Road									X	X		Regulatory sign for motorists (M)	X
										X	X		Turning vehicles yield to pedestrian sign (D)	X
5	Harmon Avenue: Paradise Road to Tropicana Wash						X		X				Advance yield markings + sign yield to pedestrian (E)	X
		X	X										High visibility crosswalk treatment (N)	X
		X		X			X		X				In-roadway knockdown signs (H)	X
				X			X						Median Refuge (O)	X
7	Flamingo Road / Koval Lane		X				X						High visibility crosswalk treatment (N)	X
							X				X		ITS No RTOR signs (J)	X
					X					X			Pedestrian countdown signals (animated eyes) (W)	X
8	Flamingo Road / Paradise Road	**Control Site**												
9	Bonanza Road / D Street						X	X					Warning Sign for Motorists (M)	X
		X		X				X		X			Pedestrain channelization (Z)	X
		X	X				X	X					High visibility crosswalk treatment (N)	X
10	Bonanza Road / F Street	X	X				X	X					High visibility crosswalk treatment (N)	X
		X					X	X		X			In-roadway knockdown signs (H)	X
11	Twain Avenue: Cambridge Street to Swenson Street	X					X		X	X			In-roadway knockdown signs (H)	X
		X					X		X				Portable speed trailers with fine info (T)	

Note:

A Countermeasures in the final implementation stage

* New Location

Problem Description:

1 Pedestrians do NOT use the crosswalks
2 Inconspicuous crosswalks
3 Pedestrians trapped in the middle of street
4 High percent of elderly pedestrian involved in crashes
5 Inconspicuous pedestrian signals due to wide streets
7 Pedestrian failure to yield
8 High speed / high traffic volume
9 Pedestrians do NOT wait for signals/ acceptable gaps
10 High pedestrian / Right turning vehicle conflicts
11 High percentage of night time crashes

Table 5: Relationships between Existing Problems and Installed Countermeasures (Continued)

Site #	Location	Problems / Concerns											Countermeasure	A
		1	2	3	4	5	6	7	8	9	10	11		
12	Twain Avenue: Swenson Streeet to Palos Verde Street	X		X			X	X		X			In-roadway knockdown signs (H)	X
13	Lake Mead Boulevard / Las Vegas Boulevard				X	X							Enlarged pedestrian signal heads (X)	X
		X	X										High visibility crosswalk treatment (N)	X
14	Lake Mead Boulevard / McDaniel Street	**Control Site**												
15	Lake Mead Boulevard / Belmont Street to McCarran Street						X						Advance warning for motorists (Roving Eyes) (R)	
									X				Advance yield markings + sign yield to pedestrian (E)	X
		X					X						High visibility crosswalk treatment (N)	X
										X		X	ITS automatic pedestrain detection devices (S)	X
							X						Pedestrian activated flashing yellow (U)	X
					X		X					X	Smart lighting (Q)	
				X			X						Median Refuge (O)	X
				X			X						Danish Offset (Y)	X
16	Lake Mead Boulevard / Pecos Road						X	X		X	X		Regulatory sign for motorists (M)	X
								X		X	X		Turning vehicles yield to pedestrian sign (D)	X
17	Fremont Street: 11th Street to 8th Street	**Control Site**												
18	Fremont Street: 8th Street to 6th Street	X						X	X				In-roadway knockdown signs (H)	
					X								Pedestrian call buttons that light up (ADA related technologies) (K)	X
		X						X	X				Portable speed trailer with fine info (T)	
19	Charleston Boulevard/ Spencer Street*	X					X						High visibility crosswalk treatment (N)	X
		X								X			Regulatory sign for motorists (M)	X
									X				Advance yield markings + sign yield to pedestrian (E)	X
					X		X					X	Smart lighting (Q)	X
							X						Advance warning for motorists (Roving Eyes) (R)	
										X		X	ITS automatic pedestrain detection devices (S)	X

Note:

A Countermeasures in the final implementation stage

* New Location

Problem Description:

1 Pedestrians do NOT use the crosswalks
2 Inconspicuous crosswalks
3 Pedestrians trapped in the middle of street
4 High percent of elderly pedestrian involved in crashes
5 Inconspicuous pedestrian signals due to wide streets
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7 Pedestrian failure to yield
8 High speed / high traffic volume
9 Pedestrians do NOT wait for signals/ acceptable gaps
10 High pedestrian / Right turning vehicle conflicts
11 High percentage of night time crashes

SUMMARY OF THE COUNTERMEASURES INSTALLED

Brief discussions for each countermeasure are discussed next.

Turning vehicles yield to pedestrian sign

This countermeasure is a symbol sign that reminds turning motorists that they must yield to pedestrians at traffic signals. This sign was tested at two different positions at each high crash location; position 1 placed next to the traffic signal (on the far side of the intersection) and position 2 placed on a sign pole 50 feet ahead of the intersection. Turning vehicles yield to pedestrian sign is as recommended in MUTCD 2003, Section 2B.45 (R10-15) (drawing 123.04 of Appendix A).

Problems addressed

- Pedestrian do NOT wait for signals/acceptable gaps
- High pedestrian/right turning vehicle conflicts

Advance yield markings + Yield here to pedestrian sign

Installation of this countermeasure 30 to 50 feet in advance of crosswalks at uncontrolled locations enhances pedestrian safety. These markings produce a clear zone for pedestrians to reduce conflicts and crashes caused by the screening effect of vehicles on multilane roadways. Advance yield markings are as recommended in MUTCD 2003, Section 3B.16. Additionally, sign yield to pedestrians is following the stand in MUTCD 2003, Section 2B.11 (R1-5a) (drawing 123.02 of Appendix A).

Problems addressed

- Motorist failure to yield
- Pedestrian failure to yield
- High speed/high traffic volume

In-roadway knockdown signs

Pedestrian in-roadway knockdown sign or the in-street pedestrian crossing sign are used to remind motorists for pedestrians' right of way at a crossing or to warn motorists about pedestrian traffic at a mid-block. For the sign at crosswalks, the legend STATE LAW is shown at the top of the sign if applicable. The legends YIELD TO may be used in conjunction with the appropriate symbol (MUTCD 2003, Section 2B.12). This sign is referred to the sign R1-6 in the MUTCD 2003. For the sign at mid-block, the legend WATCH FOR with pedestrian pictogram is proposed for this study. These signs are expected to be effective in increasing the number of motorists stopping for pedestrians and reducing the number of pedestrians, who had to run, hesitate, or abort their crossing (drawing 123.05 and 123.05A of Appendix A).

<u>Problems addressed</u>

- Pedestrian do NOT use the crosswalks
- Pedestrian trapped in the middle of street
- Motorist failure to yield
- Pedestrian failure to yield
- High speed/high traffic volume

ITS No RTOR Signs

This countermeasure is a symbol sign to remind motorists that turning vehicles must come to a full stop and yield to cross-street traffic and pedestrians prior to turning right on red. Many motorists do not fully comply with the regulations, especially at intersections with wide turning radii. Motorists are so intent on looking for traffic approaching on their left that they may not be alert to pedestrians approaching on their right. In addition, motorists usually pull up into the crosswalk to wait for a gap in traffic, blocking pedestrian crossing movements. In some instances, motorists simply do not come to a full stop (Pedestrian and Bicycle Information Center). This sign is placed next to the traffic signal. It remains completely blank when not energized. No phantom words were seen under any ambient light conditions. Electronic blank-out sign are integrated into existing traffic management system. ITS No RTOR sign is following the standard in MUTCD 2003, Section 2B.45 (R10-11) (drawing 123.06 of Appendix A).

Problems addressed

- Motorist failure to yield
- High pedestrian/Right turning vehicle conflicts

Pedestrian call buttons that light up/confirm press, other ADA related technologies

This countermeasure is one of the accessible pedestrian signals (APS). APS is a device that communicates information about pedestrian timing in non-visual format such as audible tones, verbal messages, and/or vibrating surfaces (MUTCD 2003, Section 4A.01). The LED light up button which is installed with this countermeasure also gives information to pedestrians that the sign is activated after they push the button (drawing 123.07 of Appendix A).

Problems addressed

- High percent of elderly pedestrian involved in crashes

Warning sign for motorist

The objective of this countermeasure is to enhance visibility and minimize inappropriate perceptions between pedestrians and the motorists. The MUTCD recommends the use of an advance pedestrian crossing sign in advance of locations where pedestrians may cross but may not be expected by the motorist. Warning sign for motorist is based on the standards set in MUTCD 2003, Section 2C.41 (W11-2) (drawing 123.03 of Appendix A).

Problems addressed

- Motorist failure to yield
- Pedestrian failure to yield
- Pedestrian do NOT wait for signals/acceptable gaps
- High pedestrian/right turning vehicle conflicts

High visibility crosswalk treatment

Currently, existing crosswalks at the selected locations have inconspicuous conditions. The objective of this countermeasure is to enhance visibility and minimize inappropriate perceptions between the pedestrians and the motorists. This countermeasure is also expected to encourage greater number of pedestrians to use cross crosswalks.

Problems addressed

- Pedestrians do NOT use the crosswalks
- Inconspicuous crosswalks
- Motorist failure to yield
- Pedestrian failure to yield

Median refuge

Median refuges are raised barriers in the center portion of the street or roadway that serve as a place of refuge for pedestrians who cross a street at mid-block or at an intersection location. These median, in turn, also helps to reduce the speed of vehicles. They also have benefits for motorist safety when they replace center turn lanes. Desired turning movements need to be carefully provided so that motorists are not forced to travel on inappropriate routes, such as residential streets, or make unsafe U-turns (Pedestrian and Bicycle Information Center).

Problems addressed

- Pedestrian trapped in the middle of street
- Motorist failure to yield

Smart lighting

The objective of the smart lighting strategy is to increase the intensity of illumination at the crosswalk when a pedestrian is detected in the crosswalk. The sudden increase in lighting intensity alerts motorists that pedestrians are in crosswalk more so than when continuous intensity light is used in the crosswalk. Note that high intensity lighting will remain only when pedestrians are present in the crosswalk (drawing 123.12 of Appendix A).

Problems addressed

- High percent of elderly pedestrian involved in crashes
- Motorist failure to yield
- High percentage of night time crashes

ITS automatic pedestrian detection devices

This countermeasure is a device that is installed with advance warning for motorists (roving eyes) or smart lighting. The detection devices use ultrasonic or microwave radar to detect pedestrians at crossing areas. This countermeasure is aimed at reducing overall pedestrian/vehicle conflicts and inappropriate crossings (drawing 123.11 of Appendix A).

Problems addressed

- Pedestrians do NOT wait for signals/acceptable gaps

Portable speed trailers

This mounted radar display trailer is accurate, at about five miles per hour, and easily read at a glance. Additionally, differences from the use of a traditional portable speed trailer which only provides feedback on vehicle speed, this speed trailer also informs the driver of the size of the fine associated with their speed (if they exceed the speed limit). These fine related information was collected from the local police departments.

Problems addressed

- Pedestrian failure to yield
- High speed/high traffic volume

Pedestrian activated flashing yellow

Pedestrian activated flashing yellow is pedestrian-activated overhead flashing yellow lights and downward lighting installed above the crosswalk. The flashing yellow lights could be either activated by a pedestrian pushing a button at the curb or activated by “ITS automatic pedestrian detection devices." These flashing lights are timed to stay on long enough to allow pedestrians to cross the street. This countermeasure has the objective of drawing the attention of drivers to the presence of a crosswalk ahead, and encouraging pedestrians in crossing the street (drawing 123.13 of Appendix A).

<u>Problems addressed</u>

- Motorist failure to yield

Pedestrian countdown signals (animated eyes)

The animated eyes ITS warning sign is installed together with pedestrian countdown signal and walk man pictogram. The main purpose of the "animated eyes" is to remind pedestrian to look left and right for the vehicles before crossing the street. The sign could be activated by a pedestrian call button or using pedestrian detection devices (drawing 123.10 of Appendix A).

<u>Problems addressed</u>

- Pedestrian trapped in the middle of street
- High percent of elderly pedestrian involved in crashes
- Pedestrian do NOT wait for signals/acceptable gaps

Danish offset

Danish Offset is the use of an offset at the middle of a multilane crossing to ensure pedestrians are facing the next half of traffic being crossed. In addition, it also provides a median refuge to pedestrians.

<u>Problems addressed</u>

- Pedestrian trapped in the middle of street
- Pedestrian failure to yield
- Pedestrian do NOT wait for acceptable gaps

Pedestrian Channelization

Pedestrian Channelization is commonly used where the safe direction of pedestrian traffic is required. It is also seen on construction sites and roadway works. This countermeasure can also be used as a safety barrier to separate vehicles and people (drawing 123.08 of Appendix A).

Problems addressed

- Pedestrian do NOT use the crosswalks
- Pedestrian trapped in the middle of street
- Pedestrian failure to yield

Pedestrian do NOT wait for signals/acceptable gaps

CHAPTER 3

DATA COLLECTION PARAMETERS AND MEASURES OF EFFECTIVENESS

CHAPTER 3

DATA COLLECTION PARAMETERS AND MEASURES OF EFFECTIVENESS

Field observations are conducted before and after deployment of countermeasures at site to obtain required data to derive the Measures of Effectiveness (MOEs). Data are collected to identify the effectiveness of the selected countermeasures at each site. Collected data include information pertaining to pedestrians and motorists. Different data collection strategies are used for intersections and mid-block locations. The observed pedestrian crossing behaviors at intersections are: crossing direction, crosswalk usage, pedestrians trapped in the middle of the street while crossing, crossing distance from the crosswalk (if not using crosswalk), waiting time before crossing, purpose of the trip, and yielding behavior. Similarly, the observed pedestrian crossing behaviors at mid-block locations are: crossing direction, trapped in the middle of the street while crossing, distance of crossing from the nearest intersection, waiting time for an acceptable gap, and yielding behavior. In general, the pedestrians' activities approximately 200 feet on either side of the intersections are observed. At mid-block locations, pedestrians' activities between intersections are observed. Data collected on motorists included traffic volume, vehicle approaching speed, yielding distance, etc. Data collection at a site depends on the countermeasures evaluated. Different types of data for evaluation of different countermeasures are listed in the following section.

1. *Crash Frequency (Pedestrian Crashes/Year)*

Crash data are collected from 1996 to 2000 within the Las Vegas metropolitan area. Based on this primary data, high crash locations in the Las Vegas metropolitan area are identified. Countermeasures are also selected based on the high crash locations as well as the type of crashes. The crash database includes pedestrian and vehicle crashes, excluding crashes in parking lots.

2. *Crash Severity (Distribution of Crashes by Injury Type/Year)*

The severity of crash data and their distribution within the Las Vegas metropolitan area are collected. In general, pedestrian crashes are divided into two categories: fatal and injury. Likewise, vehicle crashes are categorized as follows: fatal, injury, and property damage only (PDO). Specifically, crash severities are categorized on a 1 to 5 scale, where 1 is a crash with no injury and 5 is a fatal crash. Alternatively, the severity of crashes is divided into five categories as follows: fatal injury (K), incapacitating injury (A), non-incapacitating injury (B), no visible injury but complaint of pain (C), and no injury, property damage only (O), which is also referred as the KABCO injury scale.

3. Pedestrian and Vehicle Conflicts

A conflict involves an evasive action by a motorist or a pedestrian, where the vehicle and pedestrian are on a collision course. Evasive action is evidenced by a motorist stopping abruptly, slamming on the brakes, or swerving or by a pedestrian suddenly stepping back, lunging back, or running forward to avoid being struck by a vehicle. For a conflict to be scored, evasive action by either a motorist or a pedestrian need to be observed. At signalized intersections, only the pedestrians crossing between the stop bar and the intersection (including within the crosswalk) are considered for evaluating evasive action. Any conflicts occurring in a crosswalk at an intersection where countermeasures have been installed are recorded. At mid-block locations, all conflicts occurring within 300 feet upstream and downstream of the proposed crosswalk/countermeasure locations are recorded for both before and after deployment of the countermeasures. The pedestrian and vehicle conflict is expressed in terms of vehicle or pedestrian volume.

4. Percentage of Pedestrians who look for Vehicles before beginning to Cross

This MOE is scored if the pedestrians look in the direction of a potential threat before stepping off the curb onto the roadway. The data are reported as a percentage of the total pedestrians observed during the study period.

5. Percentage of Pedestrians who look for Vehicles before Crossing Second Half of the Street

This MOE is evaluated for the pedestrians who are at the centerline/center of roadway and visibly scan for vehicles before continuing to cross the second half of the street. The observed data are reported as a percentage of the total pedestrians observed during the study period.

6. Percentage of Captured Pedestrians

The percentage of captured pedestrians is the percentage of pedestrians who modified their paths to use a safety countermeasure, but who do not go out of their way to do so.

7. Percentage of Diverted Pedestrians

The percentage of diverted pedestrians is the percentage of pedestrians who modified their paths to use a safety countermeasure, and who went out of their way to do so. In this case, unlike “captured” pedestrians, these pedestrians would have to divert from their shortest path and walk some additional distance to use the safety countermeasure. This was determined based on observations of “back-tracking” movements by pedestrians.

8. Percentage of Pedestrians Who Pushed the Call Button

To record this MOE, every signal cycle for a given data collection period in which a pedestrian is present is observed as to whether or not the call button is pushed (cycles where no pedestrians are present are ignored in the percentage calculation). This MOE is recorded separately for each treated crosswalk at the intersection. Pedestrians are scored if they push the call button and the recorded data are converted to the percent of the total pedestrians crossing at a signalized intersection. Also, the percent of cycles where the call button is pushed is considered.

9. Pedestrian Not Completing Roadway Crossings

The data pertaining to pedestrians on the roadway or crosswalk can be divided into following categories:

9.1. Pedestrians in the Crosswalk during the Flashing DON’T WALK Phase

When crossing at a signalized intersection, pedestrians in the crosswalk at the end of the flashing DON’T WALK phase are those who are still in the roadway when the solid hand appears on the pedestrian signal. The corresponding percentage of total pedestrians crossing during the observation period is calculated. Data are collected from field observations.

9.2. Percentage of Pedestrians in the Crosswalk at the End of All-Red

The number of pedestrians in or near the crosswalk, who initiate their crossing before the solid DON'T WALK pedestrian signal who are still in a traffic lane after the cross street traffic receive the green signal, is counted. These data are reported in terms of the percentage of total observed pedestrians.

9.3. Percentage of Pedestrians Trapped in the Middle of Crossing

The number of pedestrians who are trapped in the middle of uncontrolled locations for at least 5 seconds is counted. This is generally the result of a pedestrian selecting a gap that is too small for them to completely cross the road before encountering approaching traffic. Pedestrians are scored as trapped in the middle at the centerline or between lanes if they have to wait to finish crossing. These pedestrians are converted into the percentage of total observed pedestrians.

10. Percentage of Pedestrians who begin their Crossing during WALK phase

This MOE is scored if a pedestrian steps from the curb into the crosswalk when the WALK signal is displayed on the pedestrian signal head. These data are converted into the percentage of total observed pedestrians.

11. Pedestrian Signal Violations (Crossing during the DON'T WALK Phase)

A pedestrian is considered to be a signal violator if the pedestrian steps in or near the crosswalk from the curb when the solid DON'T WALK sign is displayed on the pedestrian signal head. Such violators are reported as a percentage of the total pedestrians observed during the study period.

12. *Percentage of Drivers who Yielded to Pedestrians*

Drivers' yielding behavior to pedestrians is recorded. In particular, the yielding behavior of a motorist at a crosswalk, right-turning on red (RTOR), and yielding distance from the crosswalk is recorded. At *signalized intersections,* the percent of drivers who stop or slow to allow pedestrians to cross in front of them before proceeding is observed. Motorists' yielding behavior is only scored when pedestrians have the right of way (i.e., during the WALK phase or during the flashing DON'T WALK phase if pedestrians started crossing when the WALK signal is displayed). *At mid-block locations,* it is the percentage of through vehicles that yields. Drivers' yielding behavior is presented in terms of the percentage of the total observations. The collected data pertaining to motorists' yielding behavior will be discussed next.

12.1. Distance Vehicle Yields before the Crosswalk

The distance a driver stops before a crosswalk at an intersection is the distance between the front bumper of the stopped vehicle and the marked crosswalk. The distance a turning driver (making a RTOR or a permissive left turn) stops/yields to pedestrians in the far crosswalks of an intersection (after initiating the turn and crossing the first crosswalk) is the distance between the front bumper of the vehicle and the marked crosswalk. The distance a driver yields at a mid-block crosswalk is the distance between the vehicle and the crosswalk when the driver first begins to brake in advance of the mid-block crossing. To score the distance the motorist yield to a pedestrian, both a vehicle and a crossing pedestrian need to be present at the same time. The yielding distance of the vehicles are recorded in three categories, less than 10 feet (<10 ft), between 10 to 20 feet (10-20 ft), and greater than 20 feet (>20 ft). To help with field observations, reference marks are identified on the curb at these intervals in advance of the crosswalk.

12.2. Percentage of Vehicles Blocking Crosswalk

The data for the frequency of vehicles blocking the crosswalk at the intersections and mid-block locations are collected. A vehicle is scored as "blocking the crosswalk" when it encroaches the crosswalk. These data on the vehicles that block the crosswalk are converted into the percentage of total observed vehicles during the study period.

12.3. <u>Percentage of Drivers Turning Right on Red coming to a Complete Stop</u>

Drivers are scored as coming to a complete stop if their wheels stopped turning before they enter the crosswalk. Drivers are scored as RTOR coming to rolling stop if the vehicles slow considerably, but the wheels do not stop turning before entering the crosswalk. If drivers turn without appreciably slowing, they are scored as RTOR without slowing. This MOE is reported in terms of the percentage of total observed vehicles during the study period.

At uncontrolled locations, a motorist is scored as yielding if he/she stops or slows, allowing the pedestrian to cross. A motorist is scored as unyielding if he or she passes in front of a pedestrian but would have been able to stop when the pedestrian arrive at the crosswalk. The problem requires calculating the distance that a motorist driving within the posted speed limit can stop for a traffic signal that changes to red using the signal-timing formula. This formula takes into account driver reaction time, safe deceleration rate, posted speed limit, and the grade of the road. The required distance for motorists to stop their vehicles safely within perception and break reaction time is called stopping sight distance (SSD). The SSD is the sum of the distance traveled during the brake reaction time and the distance to brake the vehicle to stop. According to American Association of State Highway and Transportation Officials (AASHTO), the SSD in meters is given as follows:

$$d = 0.278Vt + 0.039\,V^2/a \qquad \text{meters} \qquad \textbf{\textit{(Equation 1)}}$$

Where,

t = brake reaction time, 2.5 sec;

V = design speed, km/h;

a = deceleration rate, 3.4 m/s^2

Equation 1 is used to measure the distance beyond which a driver can safely stop for a pedestrian, and a mark can be placed at this distance on each side of the sidewalk. Motorists downstream of this marking after a pedestrian has entered the roadway can be scored as yielding to pedestrians, but not for failing to yield. Motorists upstream of the landmark when a pedestrian enter the crosswalk can be scored as yielding or not yielding because they have sufficient distance to safely stop. When a pedestrian first starts to cross, only drivers in the first half of the roadway are scored for yielding. Once the pedestrian approaches within half a lane of the marked median, the yielding behavior of motorists in the remaining lanes can be scored.

13. <u>Pedestrian Delay</u>

Pedestrian delay is the time a pedestrian has to wait before crossing the street at a marked or unmarked crosswalk. The duration starts when a pedestrian is first oriented to make the crossing and ends when they begin to cross. Pedestrian delays are measured using a stopwatch. At a signalized intersection, the stopwatch is started at the beginning of the flashing DON'T WALK phase. Each time a pedestrian arrives at a crossing area and prepares to cross the street, the time on the stopwatch is recorded for that pedestrian. When the WALK signal is displayed, the time appear on the stopwatch is recorded. The difference in time between the WALK signal display and the time each pedestrian spent waiting to cross the street is the individual pedestrian delay. The delay is averaged and reported based on the total observations. Pedestrian signal violators are not scored (i.e., pedestrians crossing during the flashing DON'T WALK or during the solid DON'T WALK phase).

When pedestrian crosses at a mid-block location, he/she may continue walking along the road/sidewalk (glancing over his/her shoulder) up until the time that a gap in traffic is detected and the crossing maneuver is initiated. In this case, a zero delay is recorded for the pedestrian, as the pedestrian continues to move up until the time of crossing. Pedestrian delay begins only when the pedestrian turns to initiate the crossing maneuver and stops walking to wait for a gap in traffic. If a pedestrian becomes delayed or trapped in the roadway after starting the crossing maneuver, this additional in-roadway delay is added to the delay the pedestrian experience before crossing to get the pedestrian's total delay.

14. Vehicle Speed

Average vehicle speeds are measured using the space mean speed technique. A length of segment on the upstream of an intersection is measured and a corresponding time taken by a vehicle to travel this segment is recorded. The same strategy is used at mid-block locations. The mean and 85^{th} percentile speed and standard deviation of speed are reported.

15. Vehicle Delay at Intersections/Mid-block Crossings

Vehicle delay is defined as an average amount of time a vehicle is stopped waiting at a traffic signal and/or yielding to a crossing pedestrian. The average vehicle stopped delay is measured using a delay study. Standard methodologies for conducting stopped delay studies at signalized intersections are used. The average vehicle stopped delay for an approach is reported.

16. Other Required Data

In order to quantify the MOEs, data pertaining to traffic volume, pedestrian volume, and crossing locations are collected. The required information and data collected are discussed next.

16.1. Vehicle Volume/Counts

The number of vehicles or vehicle counts is done during peak periods along the sites where countermeasures are deployed. Data are collected during morning and evening peak hours, 7:00 to 9:00 AM and 4:00 to 7:00 PM, respectively. Vehicle counts are obtained from video recording.

16.2. Pedestrian Volume/Counts

Pedestrian movements and pedestrian volume are obtained during peak hours for all the selected sites. Data are collected during morning and evening peak periods, 7:00 to 9:00 AM and 4:00 to 7:00 PM, respectively. At some of the locations, where the pedestrians' peak volume need not be during the vehicle peak period, data was collected from 7:00 AM to 7:00 PM Pedestrian volume and movement information are obtained from real time field observations.

CHAPTER 4

DATA COLLECTION AT SITES BEFORE AND AFTER COUNTERMEASURE INSTALLATION

CHAPTER 4
DATA COLLECTION AT SITES BEFORE AND AFTER COUNTERMEASURE INSTALLATION

Data on the number of pedestrians crossing the street were collected at each of the 19 locations. Data were collected for five hours on each day. Of the five hours, two hours were during the morning and three hours of evening peak hours for vehicle traffic. At some locations, where the pedestrian sample is low due to the non-similarity of the vehicle and pedestrian peak volume times, data was collected for eight to twelve hours. The data collection days were primarily weekdays and data collection over the weekends was minimal. Weekend data collection was mainly intended for locations where pedestrian activities proximate to recreational and shopping areas are expected to be greater during the weekends. At other locations, such as the residential and small commercial locations, more pedestrian activities are expected during weekdays.

The pedestrians’ crossing behaviors were observed at a crosswalk and approximately within 200 feet from a crosswalk at all approaches of an intersection. All pedestrians were observed at mid-block locations, where distance from a crosswalk was not a deciding factor. The yielding behavior and whether a pedestrian was trapped or not trapped in the middle of the street while crossing were recorded. All observed pedestrian data were analyzed based on crossing locations. Both of the crossing behaviors consist of two options for each observation. The yielding behavior consists of two options, either “yielding” or “not yielding.” Likewise, the observation on pedestrians trapped in the middle of the street has two options either “trapped” or “not trapped” while crossing.

After the collection of various elements of the data, data was analyzed to determine the effectiveness of the countermeasure deployed. There are multiple countermeasures deployed at various sites to address multiple problems. Analysis of each site includes site description, aerial photo of the site showing injury and fatal crash locations, problems identified at that particular location, countermeasure proposed to improve the pedestrian safety at that location, countermeasures implementation details, data collection dates and analysis of the data collection at the respective locations. Data was also analyzed based on the type of countermeasure installed. Most of the proposed countermeasures were installed at more than one location. Therefore for each countermeasure, data from different sites was collected and analyzed to determine the overall effectiveness of the countermeasure. Analysis of individual sites and individual countermeasures follows.

Evaluation of Countermeasures

Several statistical tools are used to evaluate the effectiveness of the deployed countermeasures in enhancing pedestrian safety. The types of statistical tools are based on the considered measures of effectiveness (MOEs) for evaluation. The evaluation strategy and the statistical tools used for some of the countermeasures are discussed next:

A before and after study strategy was conducted to evaluate the effectiveness of most of the countermeasures. Data were collected in the morning and afternoon peak periods. This was done both prior and after the deployment of the above mentioned countermeasures ("before and after" condition). Data are stratified and analyzed for morning and evening peak hours based on total observations. The percentage of motorists yielding is obtained for both before and after study evaluation periods.

Z-Test

The z-test for two proportions, a statistical tool, is used to determine if the proportions obtained during the two study periods are significantly different.

Let P_B = proportion of vehicles yielding during the "before" period

P_A = proportion of vehicles yielding during the "after" period

The null hypothesis (H_0) is that the percentage of motorists yielding during "before" period (P_B) and "after" period (P_A) is the same. The alternative hypothesis (H_a) is the percentage of motorists yielding during "after" (P_A) period is greater than the percentage of motorists yielding during "before" period (P_B). They are expressed as follows:

H_0: $P_B = P_A$

H_a: $P_B < P_A$

The one-tail test for proportions is used to test these hypotheses at a 95 percent confidence level.

Let X_B = number of vehicles yielding in the "before" period, out of a total of n_B vehicles

X_A = number of vehicles yielding in the "after" period, out of a total of n_A vehicles

The population proportions $\hat{P}_A$ and $\hat{P}_B$ are estimated by the sample proportions:

$$\hat{P}_A = X_A / n_A \text{ and } \hat{P}_B = X_B / n_B$$

For large sample sizes, the two sample proportions are approximately and normally distributed, and the z-test for testing the equality of the two proportions vs. the 1-sided alternative can be used. The test statistic used is Z_0, and is defined as follows:

$$Z_0 = \frac{\hat{P}_B - \hat{P}_A}{\sqrt{\hat{P}(1-\hat{P})\left(\frac{1}{n_B} + \frac{1}{n_A}\right)}}$$

Where, $$\hat{P} = \frac{X_B + X_A}{n_B + n_A}$$

Z_0 is distributed approximately N (0, 1) when H_0 is true.

The significant probability or P-value for equality of proportions vs. the 1-sided alternative is calculated by:

P-value = $P(Z < Z_0)$

The null hypothesis is rejected if the P-value < 0.05 (for 95% confidence level).

T-Test

A paired t-test and Welch-Satterthwaite t-test are used to compare if speeds are statistically different at two evaluation periods at the 95 percent confidence level. The Welch-Satterthwaite t-test is used when the assumption that the two populations have equal variances seems unreasonable. It is used to identify the difference between means of independent samples.

Let μ_B = population mean during before evaluation period,

n_B = number of observations during before evaluation period,

$\overline{x}_B$ = sample mean of n_B observations,

S_B^2 = sample variance of observations during before study.

Similarly, μ_A, n_A, $\overline{x}_A$, and S_B^2 are the population mean, number of observations, sample mean, and sample variance of after evaluation period, respectively.

The null hypothesis of equal means for "before" and "after" periods vs. the 1-sided alternative is expressed as:

H_0: $\mu_B - \mu_A = 0$

H_a: $\mu_B - \mu_A > 0$

The test statistic computed from the sample is:

$$t_0 = \frac{\overline{x}_B - \overline{x}_A}{\sqrt{\left(\frac{S_B^2}{n_B} + \frac{S_A^2}{n_A}\right)}}$$

The distribution of the test statistic when H_0 is true is a t-distribution with approximate degree of freedom given by:

$$df = \frac{\left(\frac{S_B^2}{n_B} + \frac{S_A^2}{n_A}\right)^2}{\frac{\left(\frac{S_B^2}{n_B}\right)^2}{n_B - 1} + \frac{\left(\frac{S_A^2}{n_A}\right)^2}{n_A - 1}}$$

The significance probability or P-value for equality of means vs. the 1-sided alternative is calculated by:

P-value = $P(t_{df} > t_0)$

If the obtained P-value is greater than the critical α-value, i.e., 0.05 at the 95 percent confidence level, then H_0 is accepted. Similarly, if the P-value is less than the α-value, then H_0 is rejected at the 95 percent confidence level.

CHAPTER 5

ANALYSIS OF INDIVIDUAL SITES

SITE 1: MARYLAND PARKWAY / SIERRA VISTA DRIVE

1.1 Site description

This is an intersection of a six lane minor arterial (Maryland Parkway) with a speed limit 30 mph, and a two land local street (Sierra Vista Drive) with speed limit of 25 mph. At this location, the principle comments relate to the need to connect crosswalks to sidewalk ramps. Initially, these crosswalks are not connected to the ramps at the crossings and end up at the pork chop island. This location has a mixed land use of residential and shopping. Figure 3 presents the aerial photograph of this site. Site 1 in Appendix B presents implementation plan and the conceptual design of this location. Figure 3 shows an aerial photograph of the site with pedestrian crashes super imposed on it for site 1. This figure shows that the pedestrian crashes are distributed along Maryland Parkway.

Figure 3: Aerial Photograph of Maryland Parkway and Sierra Vista Drive

1.2 Problems Identified

A field observation is conducted to identify problems associated with pedestrian safety at this site. Field observation and crash analysis recognize several contributing factors associated with pedestrian safety at this site. The major problems identified for this site are: pedestrians not using the crosswalks, inconspicuous crosswalks, pedestrians trapped in the middle of street, high percent of elderly pedestrian involved in crashes, and inconspicuous pedestrian signals due to wide streets.

1.3 Countermeasures Proposed

A "High visibility crosswalk" treatment was proposed at this location in Stage 1 countermeasure deployment, to help reduce the problem of inconspicuous crosswalks at the location. Stage 1 countermeasure deployment also included relocating the existing pedestrian sign; and install Reflective Pavement Marking (RPM) standard line 100 feet long at the upstream crosswalk. Enlarged Pedestrian Signal Heads are also proposed as Stage 2 countermeasure deployment. The implementation plan for the proposed countermeasures at this location is shown in Table 6.

Table 6: Implementation Plan for Maryland Parkway and Sierra Vista Drive

Treatments	Stage 1	Stage 2	Stage 3
Relocate existing pedestrian sign	**O**	**O**	**O**
Install RPM standard line 100 feet long at the upstream crosswalk	**O**	**O**	**O**
Redesign of East approach to permit only right turns	**O**	**O**	**O**
High visibility crosswalk	**O**	**O**	**O**
High visibility crosswalk from island to sidewalk	**O**	**O**	**O**
Enlarged Pedestrian Signal Heads		**X**	**O**

O - Installed

X – Cannot be installed due to non-availability

1.4 Countermeasures Installed

As indicated before, various countermeasures at each of the sites are deployed in different stages. The descriptions of these deployments are explained as follows:

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are "high visibility crosswalk treatment, relocating existing pedestrian sign; and install RPM standard line 100 feet long at the upstream crosswalk." These countermeasures were installed on October 4-7, 2006. The after condition data for Stage 1 countermeasure deployment was collected on October 31, 2006. Figure 4 and Figure 5 shows the countermeasures deployed at this location.

Figure 4. Reflective Pavement Marking (RPM) standard line at Site 1

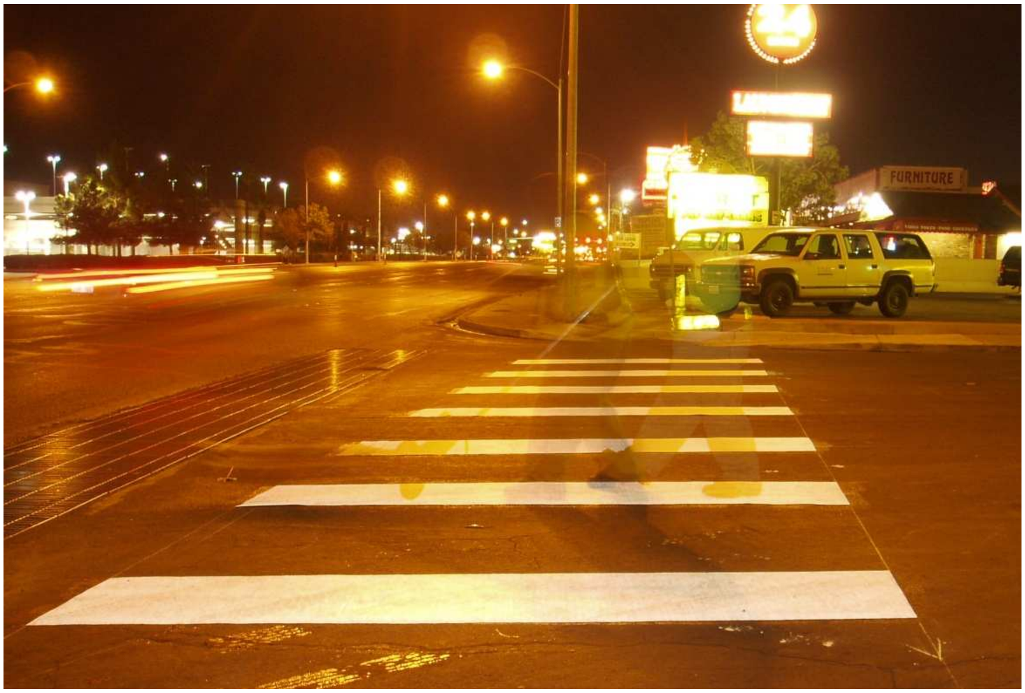

Figure 5: High Visibility Crosswalk Treatment at Site 1

Stage 2 Countermeasure Deployment

Stage 2 countermeasure was stopped due to the non-availability of the vendor to fabricate and manufacture “Enlarged Pedestrians Signal Head” countermeasure.

1.5 Safety MOEs

The results of the safety MOEs are summarized in Tables 7 and 8. Table 7 shows the pedestrian MOEs that are percent of the pedestrians who look for vehicles before beginning to cross, percent signal cycles in which call button has been pushed, frequency of pedestrian signal violation, percent of pedestrians in crosswalk at DON’T WALK, and percent of pedestrians trapped in the roadway. The motorist MOES are summarized in Table 8. These motorist MOEs are percent of drivers yielding to pedestrians, yielding distance, drivers blocking the crosswalk, and drivers making a complete stop.

1.5.1 Pedestrian MOEs

Table 7 summarizes the data collected for pedestrian MOEs at Maryland Parkway and Sierra Vista Drive. It is seen that the “percent of the pedestrians who look for vehicles before beginning to cross" and "percent of pedestrians trapped in the roadway" remained the same (62% and 92% respectively) even after the installation of the high visibility crosswalk treatment countermeasure. There is a decrease (from 85% in Baseline to 65% in Stage 1) in the percent of signal cycles in which call button has been pushed after the installation of the high visibility crosswalk treatment. However, frequency of pedestrian signal violation was decreased to almost half (from 13% in Baseline to 7.3% in Stage 1) after the installation of the countermeasure. The "percent of pedestrians in crosswalk at DON'T WALK was decreased to zero after the installation when compared to 40% during the baseline conditions.

Table 7: Results of pedestrian MOEs at Maryland Parkway and Sierra Vista Drive

Measures of Effectiveness (Safety)	Baseline			Stage 1		
	Sample	N_B	Percent	Sample	N_1	Percent
Percent pedestrians who look for vehicles before beginning to cross	198	122	62	461	285	62
Percent signal cycles in which call button has been pushed	169	144	85	461	302	65
Frequency of pedestrian signal violation	303	40	13	461	34	7.3
Percent of pedestrians in crosswalk at DON'T WALK	8	3	38	461	0	0
Percent of pedestrians trapped in the roadway	217	2	0.92	461	4	0.93

1.5.2 Motorist MOEs

Table 8 summarizes the data collected for motorist MOEs. The collected data for site 1 include percent of drivers yielding to pedestrians, yielding distance, percent of drivers blocking crosswalk, and percent of drivers making a complete stop. It is evident from Table 8, that the motorists are not influenced by the installation of the high visibility crosswalk treatment. All the MOEs collected before and after installation of the high visibility crosswalk treatment show negative impact.

Table 8: Results of motorist MOEs at Maryland Parkway and Sierra Vista Drive

Measures of Effectiveness (Safety)		Baseline			Stage 1		
		Sample	N_B	Percent	Sample	N_1	Percent
Percent of drivers yielding to pedestrians		30	19	63	158	60	38
Distance driver stops/yields before crosswalk	< 5 ft	16	14	88	60	37	62
	5-10 ft	16	2	12	60	22	37
	>10 ft	16	0	0	60	1	1
Percent of drivers blocking crosswalk		89	1	1	158	96	61
Percent of drivers making a complete stop		89	84	94	158	98	62

1.6 Mobility MOEs

Table 9 summarizes mobility MOEs for site 1. The major MOEs collected are pedestrian delay and vehicle delays. From Table 9, it is seen that average pedestrian delay decreases from 60 seconds to 45 seconds per pedestrian after the installation of the high visibility crosswalk treatment. However, on the contrary, average vehicle delay increases from 7.5 seconds to 21.8 seconds after the stage 1 countermeasure installation.

Table 9: Delay at Maryland Parkway and Sierra Vista Drive

Measures of Effectiveness (Mobility)	Baseline		Stage 1	
	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	303	60.09	461	45.26
Average vehicle delay (sec/veh)	1954	7.48	1868	21.81

1.7 Statistical Results

Results from previous tables show that there are notable changes in MOEs associated with installation of countermeasures. Although these results could be used to interpret the effectiveness of these countermeasures, it is important to perform statistical tests to validate the results. The results from the statistical test are explained as follows.

1.7.1 Safety MOEs

The statistical results of the safety MOEs for Maryland Parkway and Sierra Vista Drive are shown in Table 10. As discussed earlier in the analysis, even though there was a decrease in the "percent signal cycles in which call button was pushed," statistically it is not considered significant. Similar is the case with "percent of pedestrians who look for vehicles before beginning to cross" before and after the installation of the high visibility crosswalk treatment. Even though there is a decrease in the "percent of the drivers yielding to pedestrians," the decrease is not statistically significant. However on the flipside, it can be stated that the change in the "percent of the pedestrian signal violations" and "percent of pedestrians in crosswalk at DON'T WALK" in the before and after scenario, is statistically significant in after conditions when compared to the before conditions.

Table 10: Statistical test results of safety MOEs at Maryland Parkway and Sierra Vista Drive

Measures of Effectiveness (Safety)		Baseline vs. Stage 1		
		$P_B - P_1$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$				
Percent pedestrians who look for vehicles before beginning to cross		-0.002	>0.05	Do not Reject
Percent signal cycles in which call button has been pushed		0.19	>0.05	Do not Reject
Percent of drivers yielding to pedestrians		0.25	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	<5 ft	0.25	<0.05	Reject
	5-10 ft	-0.24	<0.05	Reject
	>10 ft	-0.016	>0.05	Do not Reject
Percent of drivers making a complete stop		0.32	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$				
Percent of pedestrians trapped in the roadway		0.0005	>0.05	Do not Reject
Frequency of pedestrian signal violation		0.058	<0.05	Reject
Percent of pedestrians in crosswalk at DON'T WALK		0.375	<0.05	Reject
Percent of drivers blocking crosswalk		-0.59	>0.05	Do not Reject

1.8 Summary

The data collected before and after the installation of the High Visibility Crosswalk Treatment at this location indicates that there is a statistically significant improvement observed in the "percent of the pedestrian signal violations" and "percent of pedestrians in crosswalk at DON'T WALK" MOEs. However, the countermeasure deployment didn't impact the motorist behavior to a notable extent. As per the initial problems identified, it can be stated that the countermeasure addressed the problems of pedestrians not using the crosswalks and inconspicuous crosswalks. The other problems identified at this location such as “high percent of elderly pedestrian involved in crashes,” and “inconspicuous pedestrian signals due to wide streets” would have been addressed by installation of Enlarge Pedestrians Signal Heads. Vendor non-availability hampered the process of installation of this countermeasure.

SITE 2: MARYLAND PARKWAY / DUMONT STREET

2.1 Site description

The intersection of Maryland Parkway/Dumont Street comes under the jurisdiction of Clark County. Land use around this site is primarily commercial with shopping complexes and a shopping mall (Boulevard mall). Maryland Parkway is classified as a major arterial in the north-south direction. It has a posted speed limit of 30 mph. Dumont Street is a minor arterial with a posted speed limit of 25 mph. The average daily traffic (ADT) on Maryland Parkway near the intersection of Maryland Parkway/Dumont Street is 43,000 in the year 2006. The traffic on the eastbound direction of the Dumont Street leads to the Boulevard mall. Figure 6 presents the aerial photograph of the site. Implementation plan and conceptual designs of this site are presented in Site 2A, Site 2B and Site 2C in Appendix B.

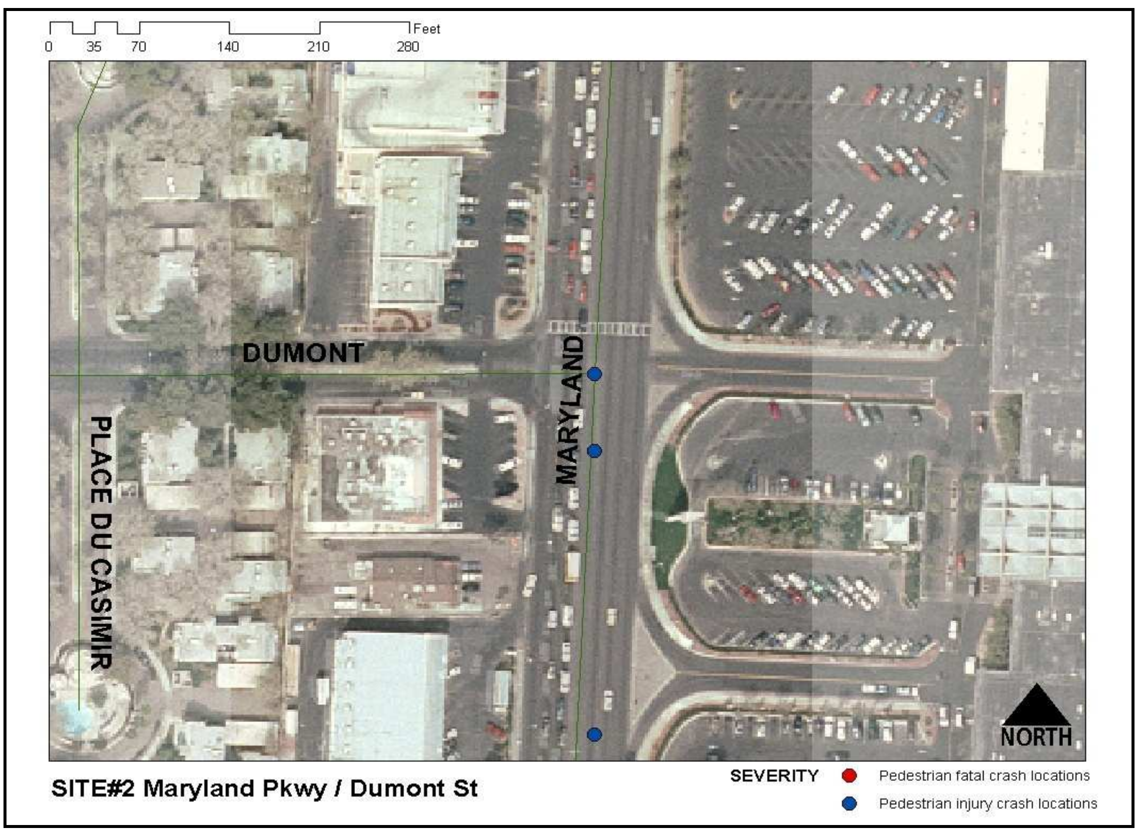

Figure 6: Aerial Photograph of Maryland Parkway and Dumont Street

2.2 Problems Identified

The problems identified at Maryland Parkway/Dumont Street from field observation and from crash data include pedestrians not waiting for acceptable gaps before crossing the streets, drivers failing to yield, pedestrians trapped in the middle of the roadway, and conflicts between vehicles and pedestrians. Since the safety issues are result of both pedestrian and driver behaviors, the selected countermeasures are aimed at altering those.

2.3 Countermeasures Proposed

The proposed countermeasures to address these problems are "Danish offset," "Median refuge," "High visibility crosswalk," "Advance yield markings," and "Pedestrian activated flashing yellow." The implementation plan for the proposed countermeasures at this location is shown in Table 11.

Table 11: Implementation Plan for Maryland Parkway / Dumont Street

Treatments	Stage 1	Stage 2	Stage 3
Install RPM standard line 100 feet long at the upstream crosswalk	**O**	**O**	**O**
Redesign of East approach to permit only right turns	**O**	**O**	**O**
Danish Offset	**O**	**O**	**O**
Median Refuge on East approach	**O**	**O**	**O**
High visibility crosswalk	**O**	**O**	**O**
Advance yield markings + warning sign for motorists		**O**	**O**
Pedestrian actuated flashing beacons			**O**

O - Installed

2.4 Countermeasures Installed

As table 11 indicates, the countermeasures are installed in three different stages. Their description is as follows.

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are "Danish offset, Median refuge, and High visibility crosswalk treatment." These countermeasures are installed on October 12, 2006. The after condition data for stage 1 countermeasure deployment are collected between

October 26 and November 2, 2006. Figure 7 shows the countermeasures deployed in stage 1 at this location.

Figure 7: High Visibility Crosswalk Treatment, Median Refuge and Danish Offset

Stage 2 Countermeasure Deployment

Countermeasure deployed during this stage is "Advanced Yield Markings." This countermeasure is installed on November 06, 2006. The after condition data for stage 2 countermeasure deployment is collected between November 30 and December 1, 2006. Figure 8 shows the countermeasures deployed in stage 2.

Figure 8: Advance Yield Markings and "Yield Here to Pedestrians" Sign

Stage 3 Countermeasure Deployment

Countermeasures deployed during this stage are "Pedestrian Activated Flashing Yellow." This countermeasure was installed on March 7, 2007. The after condition data for Stage 3 countermeasure deployment was collected on March 22 – April 6, 2007. Figure 9 shows the countermeasure deployed in Stage 3 at this location.

Figure 9: Pedestrian Activated Flashing Yellow

The MOEs presented in Tables 12 and 13 represents the safety MOEs for pedestrians and motorists respectively. Table 14 presents the mobility MOEs for both pedestrians and motorists. The statistical test results obtained after the comparison are shown in Tables 15 and 16.

2.5 Safety MOEs

2.5.1 Pedestrian MOEs

Table 12 summarizes the data collected for pedestrian MOEs at the Maryland Parkway and Dumont Street site. It is observed that all the observed pedestrians look for vehicles before beginning to cross and before crossing the second half of street. Pedestrians who divert their path to utilize the facility are not found during baseline period. Data shows that a small proportion of the observed (0.12) pedestrians are trapped in the roadway. Data obtained for stage 1, stage 2 and stage 3 are shown in Table 12.

The implementation of stage 1 and stage 2 countermeasures show decrease in the proportion of pedestrians who look for vehicles before beginning to cross and before crossing the second half of street when compared to baseline. However, in stage 3, there is a notable improvement in pedestrian behavior compared to stages 1 and 2. The proportion of diverted pedestrian has shown a continuous increase at all stages. On the other hand, the proportion of trapped pedestrians at each stage, as well as proportion of diverted pedestrians shows a decreasing trend.

2.5.2 Motorist MOEs

Table 13 summarizes the data collected for motorist MOEs at site 2. The data indicates that the percent of drivers yielding to pedestrians increases in stages 1 and 2, but decreases in stage 3. As anticipated, the proportion of drivers yielding to pedestrians at a distance less than 10 ft decreases, whereas the proportions of drivers yielding at a higher distance increases at all three stages. Note that since the crossing is absent during baseline data collection period, baseline data for drivers yielding distance is not collected. Proportion of drivers blocking the crosswalk also shows decreasing values in various stages.

Table 12: Results for pedestrian MOEs at Maryland Parkway and Dumont Street

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample = 631		Sample = 266		Sample = 198		Sample = 452	
	N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent pedestrians who look for vehicles before beginning to cross	631	100	255	96	185	93	452	100
Percent pedestrians who look for vehicles before crossing 2nd half of street	631	100	251	94	180	91	452	100
Percent of captured pedestrians	631	100	241	91	177	89	381	84
Percent of diverted pedestrians	0	0	25	9	21	11	71	16
Percent of pedestrians trapped in the roadway	73	12	17	6	7	4	9	2

Table 13: Results for motorist MOEs at Maryland Parkway and Dumont Street

Measures of Effectiveness (Safety)		Baseline		Stage 1		Stage 2		Stage 3	
		Sample = 432		Sample = 370		Sample = 246		Sample = 1633	
		N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent of drivers yielding to pedestrians		138	32	170	46	188	76	227	14
		Sample = 138		Sample = 170		Sample = 188		Sample = 227	
Distance driver stops/yields before crosswalk	< 10 ft	-	-	109	64	85	45	34	15
	10-20 ft	-	-	36	21	87	46	154	68
	>20 ft	-	-	25	15	16	9	39	17
		Sample = 432		Sample = 370		Sample = 246		Sample = 1633	
Percent of drivers blocking crosswalk		-	-	12	3	8	3	6	0.4

2.6 Mobility MOEs

2.6.1 Pedestrian Delay

The average pedestrian and vehicle delay measured at this location for different stages is shown in Table 14. The average pedestrian delay at baseline conditions is 3.8 sec/ped. The installation of the countermeasures shows different effects on the average pedestrian delay. The deployment of advance yield markings and “yield here to pedestrians” signs in stage 2 and pedestrian activated flashing yellow in stage 3 shows a higher average pedestrian delay than that experienced during baseline period.

2.6.2 Vehicle Delay

Table 14 shows that the average vehicle delay continuously reduced after the deployment of countermeasures in all three stages. Since no data were collected for the baseline period, similar comparison could not be done.

Table 14: Delays at Maryland Parkway and Dumont Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample	Delay	Sample	Delay	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	631	3.82	266	21.03	198	7.46	452	13.57
Average vehicle delay (sec/veh)	-	-	370	5.78	246	3.81	1633	0.84

2.7 Statistical Results

2.7.1 Safety MOEs

The statistical results of the safety MOEs for the Maryland Parkway and Dumont Street are shown in Tables 15 and 16. Table 15 shows the statistical results when the data for baseline are compared with other stages. These results indicate that no significant increase is seen in the proportion of pedestrians who look for vehicles before beginning to cross, before crossing second half of street, and the proportion of captured pedestrians ($P>0.05$). A significant increase in the proportion of diverted pedestrian is found ($P<0.001$) in later stages compared to the baseline data. The decrease in proportion of pedestrians trapped in roadway is found to be statistically significant. Table 16 shows statistical results obtained when stages 1 and 2, and stage 2 and 3 are compared. A comparison of stage 1 and stage 2 shows no significant increase in the proportion of pedestrians who look for vehicles before beginning to cross, before crossing second half of street, and, percent of captured and diverted pedestrians ($P>0.05$). However, the proportion of pedestrians who look for vehicles before beginning to cross, before crossing second half of street, and the proportion of diverted pedestrians in stages 2 and 3 shows a significant increase ($P<0.05$).

A significant increase in the proportion of drivers yielding to pedestrians is found when stages 1 and 2 are compared with baseline data ($P<0.001$), however no significant increase is found in stage 3. The significant increase in the proportion of drivers yielding to pedestrians at a distance greater than 10 ft is found when stages 1, 2, and 3 are compared.

2.7.2 Mobility MOEs

Tables 17 and 18, show the results of the statistical analyses of the mobility MOEs for the Maryland Parkway and Dumont Street site. The statistical analyses show no significant change in the pedestrian delay when baseline data are compared with stages 1, 2 and 3 ($P>0.05$). A significant decrease in stage 2 is found when compared to stage 1.

The reduction in average vehicle delay from stage 1 to stage 2 is not significant ($P>0.05$), but the reduction from stage 2 to stage 3 is statistically significant ($P<0.001$).

Table 15: Statistical test results of safety MOEs at Maryland Parkway and Dumont Street

Measures of Effectiveness (Safety)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$									
Percent pedestrians who look for vehicles before beginning to cross	0.04	>0.05	Do not reject	0.07	>0.05	Do not reject	0.00	-	-
Percent pedestrians who look for vehicles before crossing 2nd half of street	0.06	>0.05	Do not reject	0.09	>0.05	Do not reject	0.00	-	-
Percent of captured pedestrians	0.09	>0.05	Do not reject	0.11	>0.05	Do not reject	0.16	>0.05	Do not reject
Percent of diverted pedestrians	-0.09	<0.001	Reject	-0.11	<0.001	Reject	-0.16	<0.001	Reject
Percent of drivers yielding to pedestrians	-0.14	<0.001	Reject	-0.44	<0.001	Reject	0.18	>0.05	Do not reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Percent of pedestrians trapped in the roadway	0.05	<0.05	Reject	0.08	<0.001	Reject	0.10	<0.001	Reject

Table 16: Statistical test results of safety MOEs between stages at Maryland Parkway and Dumont Street

Measures of Effectiveness (Safety)		Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
		$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$							
Percent pedestrians who look for vehicles before beginning to cross		0.02	>0.05	Do not reject	-0.07	<0.001	Reject
Percent pedestrians who look for vehicles before crossing 2nd half of street		0.03	>0.05	Do not reject	-0.09	<0.001	Reject
Percent of captured pedestrians		0.01	>0.05	Do not reject	0.05	>0.05	Do not reject
Percent of diverted pedestrians		-0.01	>0.05	Do not reject	-0.05	<0.05	Reject
Percent of drivers yielding to pedestrians		-0.30	<0.001	Reject	0.63	>0.05	Do not reject
Distance driver stops/yields before crosswalk	10-20 ft	-0.25	<0.001	Reject	-0.22	<0.001	Reject
	>20 ft	0.06	<0.05	Reject	-0.09	<0.05	Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$							
Distance driver stops/yields before crosswalk	<10 ft	0.19	<0.001	Reject	0.30	<0.001	Reject
Percent of drivers blocking crosswalk		0.00	>0.05	Do not reject	0.03	<0.05	Reject
Percent of pedestrians trapped in the roadway		0.03	>0.05	Do not reject	0.02	>0.05	Do not reject

Table 17: Statistical test results of mobility MOE at Maryland Parkway and Dumont Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Average pedestrian delay (sec/ped)	-17.21	>0.05	Do not reject	-3.64	>0.05	Do not reject	-9.75	>0.05	Do not reject

Table 18: Statistical test results of mobility MOEs between stages at Maryland Parkway and Dumont Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average pedestrian delay (sec/ped)	13.57	<0.001	Reject	-6.11	>0.05	Do not reject
Average vehicle delay (sec/veh)	1.97	>0.05	Do not reject	2.97	<0.001	Reject

2.8 Summary

The results indicate that the installation of the countermeasures has a positive effect in reducing the number of pedestrians trapped in the roadway and increasing the proportion of drivers yielding to pedestrians, thereby increasing the safety of the pedestrians. The countermeasures also results in an increase in the number of pedestrians using the crosswalk (increase in number of diverted pedestrians). The countermeasures have a positive effect in reducing the vehicle delay at the location of Maryland Parkway and Dumont Street.

SITE 3: MARYLAND PARKWAY / TWAIN AVENUE

Figure 10: Aerial Photograph of Maryland Parkway / Twain Avenue (Control Site)

SITE 4: HARMON AVENUE / PARADISE ROAD

4.1 Site description

A mixed land use pattern is observed around the intersection of Harmon Avenue/Paradise Road. This site is within the jurisdiction of Clark County. The land use includes residential, commercial, and recreational (hotels and casinos). Harmon Avenue spans east-west and is classified as a minor arterial with a posted speed limit of 35 mph. The intersection of Harmon Avenue and Paradise Road has had a total of 12 crashes during the period January 1996 to December 2000. Fifty eight percent of the crashes occurred during daytime. The ADT along this segment of Harmon Avenue for the year 2006 is 17,100. Figure 11 presents the aerial photograph of the site. Implementation plans and conceptual designs of this site are illustrated in Site 4 in Appendix B.

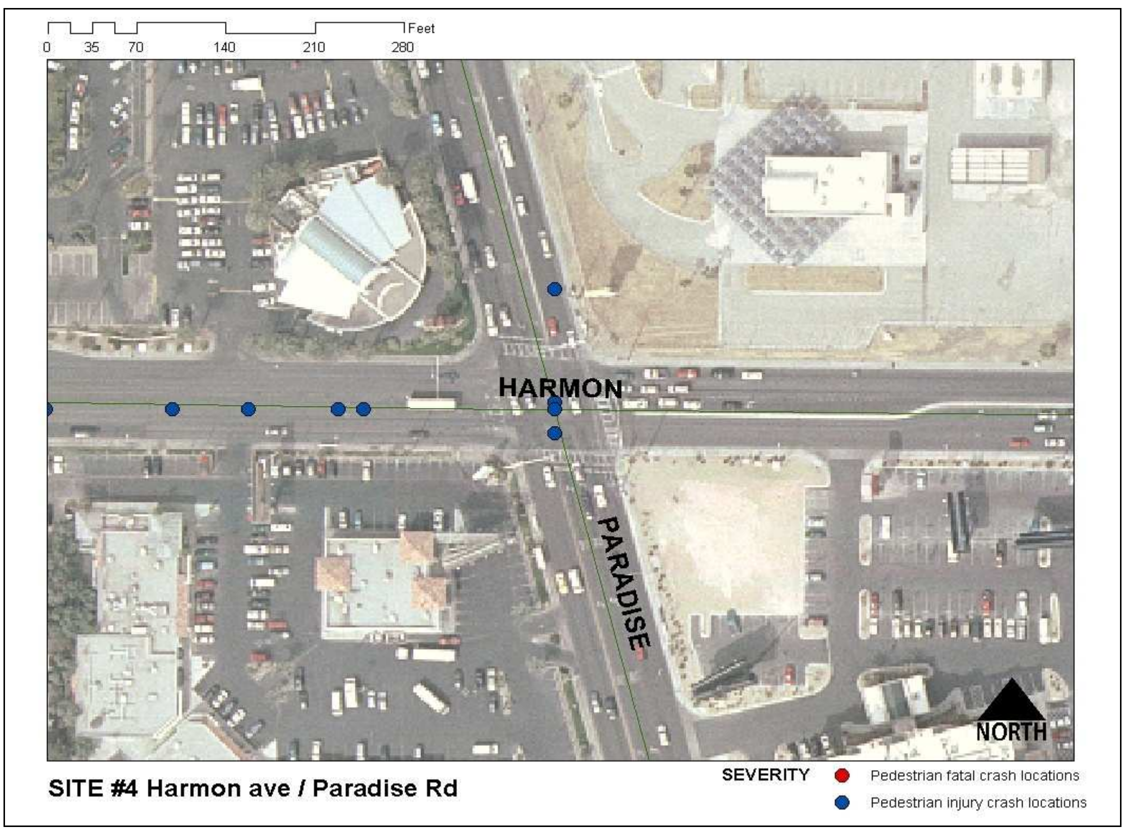

Figure 11: Aerial Photograph of Harmon Avenue and Paradise Road

4.2 Problems Identified

Analyzing crash data and by performing a field evaluation, the problems identified at this location are pedestrians do NOT wait for signals/acceptable gaps and high pedestrian/right turning vehicle conflicts.

4.3 Countermeasures Proposed

The countermeasures suggested for this location are "turning vehicles yield to pedestrian sign." Installing this sign would alert the right turning traffic to yield for the pedestrian. As the right turn vehicle volumes are high at this location, Clark County Public Works-Traffic Division requested the study team not to install "No-Turn on Red" since this would hamper the volume of right turn vehicles. Also in addition to the "turning vehicles yield to pedestrian sign" countermeasure, "warning sign for motorists" are also installed at the location to caution the drivers about/or the presence of pedestrians. The implementation plan for the proposed countermeasures at this location is shown in Table 19.

Table 19: Implementation Plan for Harmon Road and Paradise Road

Treatments	Stage 1
Warning Sign for Motorist	**O**
Turning Vehicles Yield to Pedestrians	**O**

O **-** Installed

4.4 Countermeasures Installed

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are "Warning Signs for Motorists" and "Turning Vehicles Yield to Pedestrians." These countermeasures are installed between June 13 and 17, 2005. The after condition data for stage 1 countermeasure deployment are collected on July 14, 2005. Figure 7 shows the countermeasure deployed in stage 1 at this location.

Figure 12: Turning Vehicles Yield to Pedestrians Sign

4.5 Safety MOEs

Analysis of collected data shows that the average vehicle delay increases from 66.8 seconds/vehicle before the installation to 75.6 seconds/vehicle after the installation of the sign. The proportion of motorists yielding also increased so that more vehicles in the queue yield for pedestrians. Consequently, the vehicle delay also increases. Pedestrian delay increases from 44 seconds/pedestrian before the installation to 61 seconds/pedestrian after the installation of the sign. The motorists' yielding is increased after the sign is installed. This could be because of more turning motorists yielded to pedestrians either on red or green phase of the signal. Even though the pedestrians' arrival is considered as random, some pedestrians might have to wait longer and others might have to wait less. Some pedestrians arrive at the beginning of the WALK signal, (i.e., no waiting time), others arrive during the flashing DON'T WALK phase, and they have to wait for a cycle length typically 120 to 140 seconds. The weighted average of all pedestrians in that range might be a very rough estimate of delay. The field observations show that a vehicle interacts with pedestrians while turning either on red or on green. Motorists' yielding percentage increased indicating that pedestrians do not have to wait longer for turning traffic. Therefore, pedestrian delay should have been reduced. It is unclear why pedestrian delay has increased after the installation of the sign, "Turning traffic must yield to pedestrians."

4.6 Statistical Results

The before-and-after study results show that the installation of the "Turning traffic must yield to pedestrians" sign has increased the proportion of motorists yielding at RTOR from 0.61 to 0.73 percent (P=0.156). Similarly, the proportion of motorists yielding at right turn on green increases from 0.74 to 0.77 (P=0.615) during the after-study period. The installation of the sign, "Turning traffic must yield to pedestrians," shows an increase in motorists yielding while turning either on red or green even though these differences are not statistically significant at 95 percent confidence level.

Before the installation of the sign, "Turning traffic must yield to pedestrians," a notable proportion of (0.11) of vehicles blocks the crosswalk before turning; after the sign is installed, the proportion of motorists blocking the crosswalk is reduced to zero (P<0.001). The observed stopping behavior of motorists before RTOR was installed; this proportional value increases to about 0.97 (P<0.001) after the sign is installed. The values of MOEs during before and after study periods, their difference, and statistical significance are shown in Table 20.

The sign, "Turning traffic must yield to pedestrians," is intended for motorists. However, the before-and-after study result indicates some positive influence on pedestrians' crossing behavior. The proportion of pedestrians looking for turning vehicles at the beginning of the WALK signal increased from 0.54 to 0.93 (P<0.001) before and after the installation of the sign respectively. As the motorists' yielding increases, motorists might stop upstream of the crosswalk. Therefore, more pedestrians watch for turning vehicles before crossing. Marginal differences are observed in the proportion of pedestrians who are in the crosswalk during the flashing DON'T WALK phase and during the all red phase before and after the installation of the sign. The proportion values of pedestrians who are in the crosswalk during the flashing DON'T WALK phase and at the all-red time are decreased by small proportion after the installation of the sign.

Table 20: Statistical test results of MOEs at Harmon Avenue and Paradise Road

S. No.	Measures of Effectiveness	Before		After		(Before - After)	P-value	Null hypothesis
		Sample size	Value	Sample size	Value			
1	Motorists' yielding at right turn on red (in the presence of pedestrian at turn or approach), %	31	61.29	30	73.33	-12.04	0.156	Do not reject
2	Motorists' yielding at right turn on green (in the presence of pedestrians), %	102	73.53	90	76.67	-3.14	0.615	Do not reject
3	Percentage vehicles blocking crosswalk	129	10.85	235	0.00	10.85	0.000	Reject
4	Percentage of drivers executing right turn on red coming to complete stop	129	74.42	235	97.45	-23.03	0.000	Reject
5	Pedestrian delay (sec/ped)	556	44.37	355	61.09	-16.73	0.000	Reject
6	Vehicle delay at intersection (sec/veh)	1,356	66.83	1,275	75.64	-8.81	N/A	N/A
7	Percentage of pedestrians who looked at start of the WALK phase for turning vehicles	542	53.69	370	93.24	-39.55	0.000	Reject
8	Percentage of pedestrians who were in the crosswalk during the flashing DON'T WALK phase	639	45.07	390	43.33	1.74	0.586	Do not reject
9	Percentage of pedestrians who were in the crosswalk at the end of all-red	639	2.66	390	2.05	0.61	0.525	Do not reject
10	Percentage of pedestrians who were trapped in the middle of crossing	618	5.50	373	3.75	1.75	0.194	Do not reject
11	Percentage of pedestrian/vehicle evasive actions, change course/slow to avoid motorists	609	0.82	349	7.74	-6.92	1.000	Do not reject

Note: $\alpha = 0.05$

The proportion of pedestrians who were trapped in the middle of the road while crossing decreases during the after-study from 0.06 to 0.04 (P=0.194). Pedestrians do not have to wait in the middle of the road if they have an acceptable gap for crossing. The motorists' yielding behavior while turning improved. Therefore, motorists turning on permitted left-turn also yielded to pedestrians. As a result, the proportion of pedestrians trapped in the middle is reduced after installation of the sign.

The proportions of evasive actions are 0.008 and 0.077 before and after condition data collection period, respectively. The difference of the proportion of evasive action between before and after period is significantly different (P<0.001) at 95 percent confidence level, which is unexpected.

4.7 Summary

Statistical analysis of the data collected at this location before and after the installation of the “Yield to Pedestrian in Crosswalk” shows benefits that improved overall pedestrian safety at this location. The parameters that are improved after the installation of the countermeasure are reduction in the percent of the vehicles blocking the crosswalk, improvement in percent of drivers coming to complete stop those are turning right turn on red, and decrease of pedestrian delay.

SITE 5: HARMON AVENUE: PARADISE ROAD TO TROPICANA WASH

5.1 Site description

A mixed land use pattern is observed around the intersection of Harmon Avenue/Paradise Road. This site is within the jurisdiction of Clark County. The land use includes residential, commercial, and recreational (hotels and casinos). Harmon Avenue spans east-west and is classified as a minor arterial with a posted speed limit of 35 mph. The intersection of Harmon Avenue and Paradise Road had a total of 12 crashes during the period January 1996 to December 2000. About 58 percent of the crashes occurred at non-intersection location. Fifty eight percent of the crashes occurred during daytime. The ADT along this segment of Harmon Avenue for the year 2006 is 17,100. Figure 13 presents the aerial photograph of the site. Implementation plans and conceptual designs of this site are illustrated in Site 5A, Site 5B, and Site 5C in Appendix B.

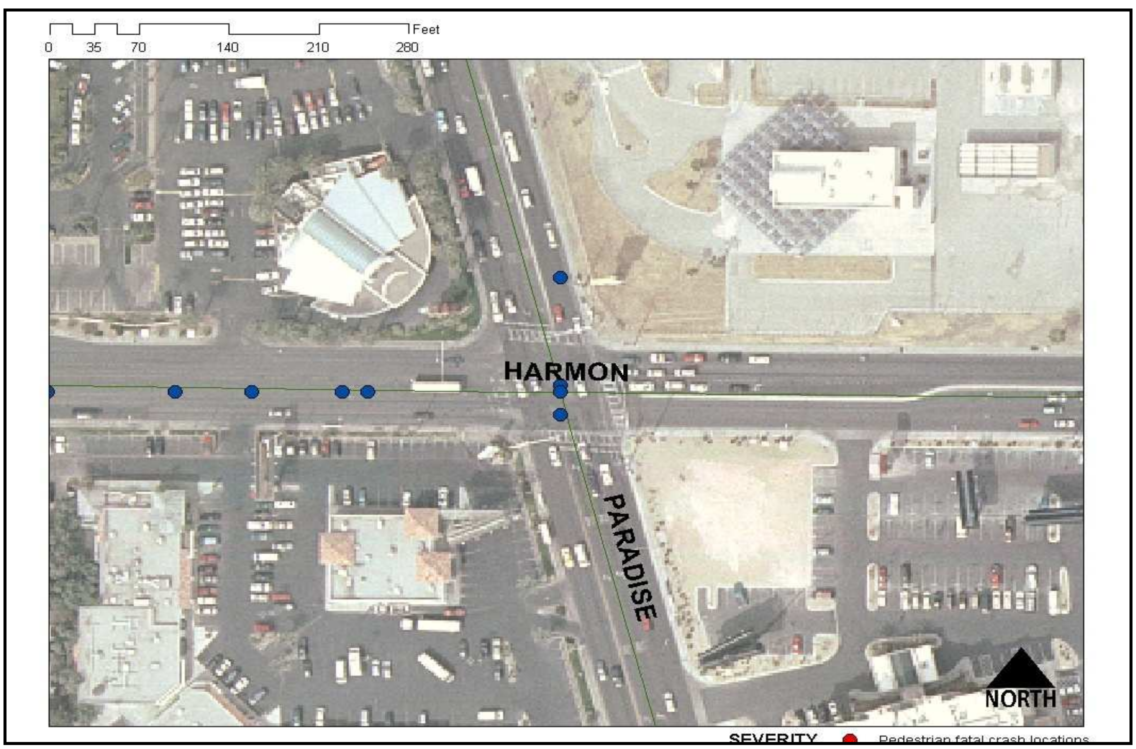

Figure 13: Aerial Photograph of Harmon Avenue: Paradise Road to Tropicana Wash

5.2 Problems Identified

The problems identified at this site include pedestrians not waiting for signals or acceptable gaps before crossing the street, drivers failing to yield, and conflicts between vehicles and pedestrians. Being a mid-block location and since most pedestrian related safety issues are results of motorist driving behavior, the countermeasures are selected primarily to focus on motorists.

5.3 Countermeasures Proposed

The proposed countermeasures are "Median refuge," "High visibility crosswalk," "Advance yield markings," and "In-roadway knockdown signs." The proposed countermeasures are expected to alert motorists of the presence of pedestrians at the site, and to provide pedestrians a refuge in the middle of the street. The implementation plan for the proposed countermeasures at this location is shown in Table 21.

Table 21: Implementation Plan for Harmon Avenue: Paradise Road to Tropicana Wash

Treatments	Stage 1	Stage 2	Stage 3
Median Refuge	**O**	**O**	**O**
High visibility crosswalk	**O**	**O**	**O**
Advance yield markings + warning sign for motorists		**O**	**O**
In-roadway knockdown sign			**O**
Install RPM standard line 100 feet long at the upstream crosswalk			**O**

O - Installed

5.4 Countermeasures Installed

The location of Harmon Avenue from Paradise Road to Tropicana Wash is a mid-block location. The countermeasures are installed in three stages at this location. The countermeasures deployments in various stages are as follows:

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are "Median refuge" and "High visibility crosswalk treatment." These countermeasures are installed on February 21, 2007. After condition data for stage 1 countermeasure deployment are collected on March 8 and 9, 2007. Figure 14 shows the countermeasures deployed in stage 1 at this location.

Figure 14: High Visibility Crosswalk and Median Refuge installed at Site 5

Stage 2 Countermeasure Deployment

Countermeasures deployed during this stage are “Advanced Yield Markings.” These countermeasures are installed on March 9 to 11, 2007. The after condition data for stage 2 countermeasure deployment were collected on March 30, 2007. Figure 15 shows the countermeasures deployed in stage 2.

Figure 15: Yield Here to Pedestrians Sign installed at Site 5

Stage 3 Countermeasure Deployment

Countermeasure deployed during this stage is “In-Roadway Knockdown Signs.” This countermeasure is installed on March 31, 2007. The after condition data for stage 3 countermeasure deployment are collected on April 13, 2007. Figure 16 shows the countermeasure deployed in stage 3 at this location.

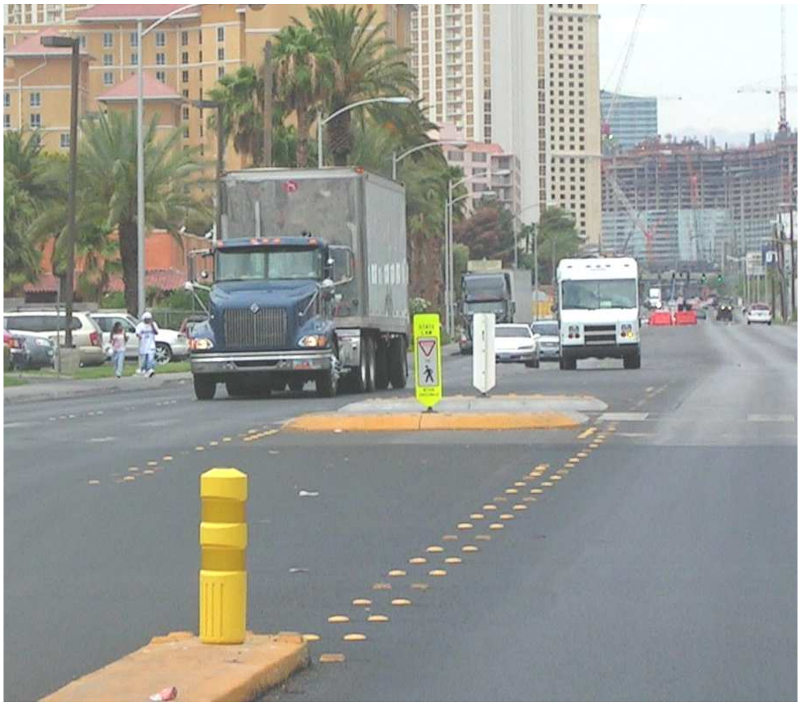

Figure 16: In-roadway Knockdown Signs installed at Site 5

Tables 22 through 24 represent the various pedestrian and motorist MOEs for safety and mobility. The results of the statistical tests for the safety MOEs comparing the baseline conditions with each stage, and between the stages are shown in Tables 25 and Table 26, respectively. Tables 27 and Table 28 show the analyses of statistical results for the mobility MOEs for pedestrians and motorists. These results and the effectiveness of the various countermeasures implemented are discussed next.

5.5 Safety MOEs

5.5.1 Pedestrian MOEs

From Table 22, for baseline, the proportion of pedestrians who look for vehicles before beginning to cross and before crossing second half of the roadway are 0.77 and 0.86 respectively. About 0.18 proportion of the pedestrians are diverted and 0.03 proportion of pedestrians are trapped in the roadway for the baseline period. The installation of countermeasures in stage 1 increases the proportion of pedestrians who look for vehicles before beginning to cross and before crossing second half of the street to 1.00. The proportion of diverted pedestrians increases to 0.20 after stage 1. The proportion of pedestrians trapped in the roadway increases to 0.09. The proportion of pedestrians looking for vehicles before beginning to cross and before crossing second half of the street remains at 1.00 percent at stages 2 and 3. There are no pedestrians trapped in the roadway after the installation of countermeasures in stages 2 and 3.

5.5.2 Motorist MOEs

In Table 23, the baseline data indicate that of all observed drivers, about 0.22 of drivers yield to pedestrians. Since, it is a mid-block location, there are no baseline data available for the distance the driver stop/yield before crosswalk and proportion of drivers blocking crosswalk. After stage 1, the proportion of drivers yielding to pedestrians increases to 0.46. Half of the drivers observed yield at a distance less than 10 feet, 0.45 proportion yield between 10 feet to 20 feet, and the remaining 0.05 proportion at distance greater than 20 feet. About 2 percent of the drivers blocked the crosswalk after stage 1. The installation of advance yield markings and yield here to pedestrians increases the proportion of drivers yielding to pedestrians to 0.53. The proportion of drivers stopping at a distance greater than 10 feet increased to 0.71. Stage 3 data indicate that the proportion of drivers yielding to pedestrians is 0.22, compared to 0.53 in stage 2. The proportion of driver stops/yields before the crosswalk at a distance of 10 to 20 feet is 0.69 in stage 3. The proportion of drivers blocking the crosswalk remains relatively the same throughout all stages.

5.6 Mobility MOEs

5.6.1 Pedestrian Delay

Table 24 shows the average pedestrian and vehicle delay at the various stages. For the baseline conditions, the average pedestrian delay is 19.3 sec/ped. After the installation of the countermeasures in stage 1, the average pedestrian delay decreases to approximately 7.0 sec/ped. The deployment of advance yield markings and “Yield here to pedestrians” signs reduce the delay to 6.1 sec/ped. The implementation of in-roadway knockdown signs decreases the delay to 8.7 sec/ped. This is a decreasing delay from baseline data, but comparing with stages 1 and 2, there is an increase in delay.

5.6.2 Vehicle Delay

The baseline data are not available for this location. The vehicle delay at stage 1 is 2.5 sec/veh, stage 2 is 2.5 sec/veh and stage 3 is 1.3 sec/veh. As the numbers suggest, there is no change in vehicle delay at stage 2 when compared to stage 1. At stage 3, the vehicle delay is reduced compared to stages 1 and 2. The results are presented in Table 24.

Table 22: Results of pedestrian MOEs at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample = 1951		Sample = 388		Sample = 293		Sample = 297	
	N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent pedestrians who look for vehicles before beginning to cross	1510	77	388	100	293	100	297	100
Percent pedestrians who look for vehicles before crossing 2nd half of street	1680	86	388	100	293	100	297	100
Percent of captured pedestrians	1592	82	309	79	247	84	268	90
Percent of diverted pedestrians	359	18	79	20	46	16	29	10
Percent of pedestrians trapped in the roadway	62	3	37	9	0	0	0	0

Table 23: Results of motorist MOEs at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Safety)		Baseline		Stage 1		Stage 2		Stage 3	
		Sample = 77		Sample = 284		Sample = 158		Sample = 400	
		N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent of drivers yielding to pedestrians		17	22	132	46	84	53	89	22
		Sample = 17		Sample = 132		Sample = 84		Sample = 89	
Distance driver stops/yields before crosswalk	< 10 ft	N/A		66	50	19	23	25	28
	10-20 ft	N/A		59	45	60	71	61	69
	>20 ft	N/A		7	5	5	6	3	3
		Sample = 77		Sample = 284		Sample = 158		Sample = 400	
Percent of drivers blocking crosswalk		N/A		6	2	5	3	11	3

Table 24: Delays at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample	Delay	Sample	Delay	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	1951	19.27	388	6.98	293	6.05	297	8.71
Average vehicle delay (sec/veh)	-	-	284	2.45	158	2.48	400	1.3

5.7 Statistical Results

5.7.1 Safety MOEs

Table 25 and Table 26 show the results of statistical tests for the safety MOEs. Table 25 shows that the increase in the percent of pedestrians looking for vehicles before beginning to cross and before crossing second half of the street is statistically significant ($P<0.001$). There is no statistical validation for increase in captured and diverted pedestrians for stage 1 ($P<0.05$). However, the increase in percent of diverted pedestrians in stage 2 and captured pedestrians in stage 3 are significant compared to baseline conditions ($P<0.001$). The installation of countermeasures in stage 1 does not reduce significantly the percent of pedestrians trapped in the roadway compared to baseline ($P>0.05$). However, stages 2 and 3 show a positive effect in reducing the percent of pedestrians trapped in the roadway compared to the baseline ($P<0.001$). The installation of in-roadway knockdown signs significantly reduces the percent of pedestrians trapped in the roadway ($P<0.001$).

Analyzing driver behavior, there is a significant increase in the proportion of drivers yielding to pedestrians in stages 1 and 2 compared to the baseline ($P<0.001$). Not enough statistical evidence exists to support the increase in percent of drivers yielding to pedestrians in stage 2 compared to stage 1. Table 26 shows that there is no significant decrease in the percent of drivers who block the crosswalk compared between any stages ($P>0.05$).

5.7.2 Mobility MOEs

Significant decreases in the average pedestrian delay are observed in stages 1, 2 and 3, compared with the baseline period as shown in Table 27 ($P<0.001$). There is no sufficient evidence to prove that there is a significant decrease in the pedestrian delay between the stages (Table 28). The average decrease in vehicle delay in stage 2 compared to stage 1 is statistically significant ($P<0.001$).

Table 25: Statistical test results of safety MOEs at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Safety)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$									
Percent pedestrians who look for vehicles before beginning to cross	-0.22	<0.001	Reject	-0.22	<0.001	Reject	-0.22	<0.001	Reject
Percent pedestrians who look for vehicles before crossing 2nd half of street	-0.13	<0.001	Reject	-0.13	<0.001	Reject	-0.13	<0.001	Reject
Percent of captured pedestrians	0.019	>0.05	Do not reject	-0.027	>0.05	Do not reject	-0.08	<0.001	Reject
Percent of diverted pedestrians	-0.019	>0.05	Do not reject	-0.08	0.001	Reject	0.08	>0.05	Do not reject
Percent of drivers yielding to pedestrians	-0.24	<0.001	Reject	-0.31	<0.001	Reject	-0.001	>0.05	Do not reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Percent of pedestrians trapped in the roadway	-0.06	>0.05	Do not reject	0.03	<0.001	Reject	0.03	<0.001	Reject

Table 26: Statistical test results of safety MOEs between stages at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Safety)		Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
		$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$							
Percent pedestrians who look for vehicles before beginning to cross		0.00			0.00		
Percent pedestrians who look for vehicles before crossing 2nd half of street		0.00			0.00		
Percent of captured pedestrians		-0.04	0.057	Do not Reject	-0.05	<0.05	Reject
Percent of diverted pedestrians		0.04	>0.05	Do not Reject	0.05	<0.05	Reject
Percent of drivers yielding to pedestrians		-0.06	>0.05	Do not Reject	0.30	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	<10 ft	0.27	>0.05	Do not Reject	-0.05	>0.05	Do not Reject
	10-20 ft	-0.26	<0.001	Reject	0.02	>0.05	Do not Reject
	>20 ft	-0.006	>0.05	Do not Reject	0.02	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$							
Percent of drivers blocking crosswalk		-0.01	>0.05	Do not Reject	0.004	>0.05	Do not Reject
Percent of pedestrians trapped in the roadway		0.09	<0.001	Reject	0.00		

Table 27: Statistical test results of mobility MOE at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Average pedestrian delay (sec/ped)	12.29	<0.001	Reject	13.22	<0.001	Reject	10.56	<0.001	Reject

Table 28: Statistical test results of mobility MOEs between stages at Harmon Avenue: Paradise Road to Tropicana Wash

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average pedestrian delay (sec/ped)	0.93	>0.05	Do not reject	-2.66	>0.05	Do not reject
Average vehicle delay (sec/veh)	-0.03	>0.05	Do not reject	1.18	<0.001	Reject

5.8 Summary

The installation of Median refuge, high visibility crosswalk, advance yield markings, "Yield here to pedestrians" signs, and in-roadway knockdown signs have significant impact in increasing the percent of pedestrians who look for vehicles before beginning to cross, before crossing second half of the street, and diverted pedestrians. This indicates that the countermeasures create awareness in pedestrians to look for potential threats before they step on to the road. Reducing the number of pedestrians trapped in the roadway makes the roadway much safer, and for increased usage of the crosswalk instead of jaywalking.

Decreasing the pedestrian delay is a key component of enhancing pedestrian safety. By doing so, the pedestrian do not get frustrated waiting for an acceptable gap to cross the street. The increase in the proportion of drivers yielding to pedestrians, and yielding at a distance greater than 10 feet improves the safety (comfort zone) for pedestrians.

SITE 7: FLAMINGO ROAD / KOVAL LANE

7.1 Site description

This site is within the jurisdiction of Clark County. The land use pattern is a mixed type with shopping complexes and apartments. Flamingo Road is classified as a major arterial and Koval Lane as a minor arterial. Crash data show a total of 29 crashes from January 1996 to December 2000 with 76 percent of them occurring at the intersection. Forty one percent of the total crashes are due to the motorists' failure to yield. The 2006 traffic count show the estimated ADT on Flamingo Road near Koval Lane to be 40,500. Figure 17 presents the aerial photograph of the site. Implementation plans and conceptual designs of this site are illustrated in Site 7 in Appendix B.

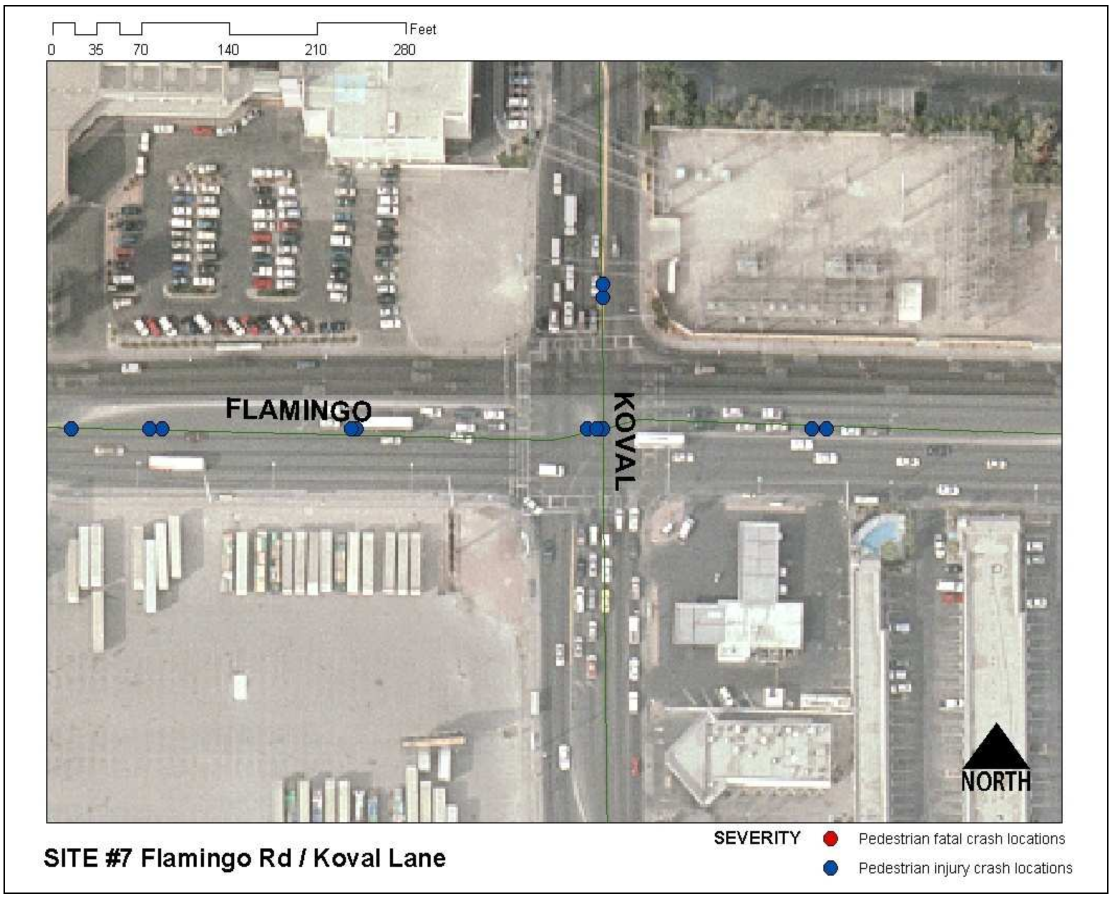

Figure 17: Aerial Photograph of Flamingo Road and Koval Lane

7.2 Problems Identified

Some of the observed problems at this site are motorists' failure to yield and a significant number of nighttime crashes inconspicuous crosswalks, high percent of elderly pedestrian involved in crashes, motorist failure to yield, pedestrians do NOT wait for signals/acceptable gaps and high pedestrian/right turning vehicle conflicts.

7.3 Countermeasures Proposed

Based on the field observation and analysis of crash data, the following countermeasures are selected. These countermeasures aim at addressing both pedestrians and drivers behavior to improve safety. By implementing "High visibility crosswalk," a driver's attention could be attracted towards pedestrians. Installation of "Pedestrian countdown signal" would help pedestrians to judge if they have enough time to cross the street. Similarly, "Pedestrian Countdown Timer with Animated Eyes" would alert the pedestrians to look for the oncoming traffic or turning traffic before they start crossing the road. Installing ITS No RTOR Signs would mitigate the pedestrian and right turning vehicles conflicts. The implementation plan for the proposed countermeasures at this location is shown in Table 29.

Table 29: Implementation Plan for Flamingo Road and Koval Lane

Treatments	Stage 1	Stage 2	Stage 3
High visibility crosswalk	**O**	**O**	**O**
Pedestrian countdown signal (animated eyes)		**O**	**O**
ITS No-RTOR signs			**O**

O - Installed

7.4 Countermeasures Installed

The various countermeasures proposed are installed in two stages at this signalized intersection location are as follows:

Stage 1 Countermeasure Deployment

Countermeasure deployed during this stage is "High visibility crosswalk treatment." This countermeasure is installed on December 19 to 23, 2005. The after condition data for

Stage 1 countermeasure deployment are collected on February 14, 2006. Figure 18 shows the countermeasures deployed in stage 1 at this location.

Figure 18: High Visibility Crosswalk Treatment installed at Site 7

Stage 2 Countermeasure Deployment

Countermeasure deployed during this stage is "Pedestrian countdown signs with animated eyes." This countermeasure is installed on June 9 to 11, 2007. The after condition data for stage 2 countermeasure deployment is collected on July 12 and 13, 2007. Figure 19 shows the countermeasures deployed in stage 2.

Figure 19: Pedestrian Countdown Timers with Animated Eyes

Stage 3 Countermeasure Deployment

Countermeasure deployed during this stage is "ITS No-Turn on Red Signs." This countermeasure is installed on November 26, 2007. The after condition data for stage 3 countermeasure deployment is collected on December 17 and 19, 2007. Figure 20 shows the countermeasure deployed in stage 3 at this location.

Figure 20: ITS No-Turn On Red – Activated

For the intersection of Flamingo Road and Koval Lane, data collected for the pedestrian and motorist MOEs are summarized in Tables 30 and 31. Statistical tests were performed for the safety MOEs for both pedestrians and motorists comparing the baseline conditions with each stage and comparing the individual stages at a 95 percent confidence level. The results are shown in Tables 32 and 33. The effectiveness of the installed countermeasures is discussed below.

7.5 Safety MOEs

7.5.1 Pedestrian MOEs

From Table 30, the percent of captured and diverted pedestrians is 100 and 0, respectively for both baseline condition and stage 1. The installation of high visibility crosswalk in stage 1 does not show any effect in increasing the percent signal cycles in which the call button was pushed, and the percent of pedestrians beginning their crossing during WALK phase. On the other hand, it resulted in decreasing the frequency of pedestrian signal violation, percent of pedestrians in crosswalk at the end of flashing DON'T WALK phase. However, the percent of pedestrians who look for vehicles before beginning to cross, and percent of pedestrians in the crosswalk at the end of all-red phase shows an increase after installation of stage 1 countermeasures. The deployment of pedestrian countdown with animated eyes in stage 2 shows an increase in the percent signal cycles in which the call button has been pushed, pedestrians who look for vehicles before beginning to cross, pedestrians beginning their crossing during the WALK phase, and a decrease in the percent of pedestrians in the crosswalk at the end of all-red phase. Stage 3 results show further increase in the percent signal cycles in which the call button has been pushed. After installation of stage 3 countermeasures, the percent of pedestrians who look for vehicles before beginning cross was 96 percent, which is significant increase from the 86 percent observed after stage 2 countermeasure deployment. The above results suggest that the high visibility crosswalk and pedestrian countdown signal with animated eyes together have produced a positive effect in increasing the pedestrian safety at the intersection of Flamingo Road and Koval Lane. Also installing ITS No-Turn On Red also improved the overall pedestrian safety by increasing the awareness among pedestrians.

7.5.2. Motorist MOEs

According to the results of field observations, (Table 31), installation of a high visibility crosswalk does not help increasing percent of drivers yielding to pedestrians, and percent of drivers making a right turn on red (RTOR) who come to a complete stop. On the other hand, the percent of drivers blocking the crosswalk is reduced by 18 percent in stage 1 from baseline condition. However, after the installation of ITS No Turn On Red Sign, there is a slight increase in the percent value (stage 3 - 48 percent from stage 2 - 36 percent) of the drivers making RTOR who come to complete stop before making their turn.

Table 30: Results of safety MOEs for pedestrians at Flamingo Road and Koval Lane

Measures of Effectiveness (Safety)	Baseline			Stage 1			Stage 2			Stage 3		
	Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent
Percent of captured pedestrians	442	442	100	455	455	100	-			-		
Percent of diverted pedestrians	442	0	0	455	0	0	-			-		
Percent signal cycles in which call button has been pushed	438	207	47	307	145	47	235	188	80	202	172	85
Percent pedestrians who look for vehicles before beginning to cross	419	222	53	380	240	63	235	203	86	202	194	96
Frequency of pedestrian signal violation	442	22	5	303	17	5	235	11	5	202	22	10
Percent of pedestrians beginning their crossings during the WALK phase	439	232	52	455	234	51	544	436	80	-		
Percent of pedestrians in crosswalk at the end of flashing DON'T WALK	430	127	30	455	140	31	544	269	50	-		
Percent of pedestrians in crosswalk at the end of All-Red	430	39	9	455	14	3	544	29	5	-		

Table 31: Results of safety MOEs for motorists at Flamingo Road and Koval Lane

Measures of Effectiveness (Safety)		Baseline			Stage 1			Stage 2	Stage 3		
		Sample	N_B	Percent	Sample	N_B	Percent		Sample	N_B	Percent
Percent of drivers yielding to pedestrians		164	146	89	278	19	7	-	-		
Distance driver stops/yields before crosswalk	< 5 ft	139	112	80	19	18	95	-	-		
	5-10 ft	139	27	20	19	1	5	-	-		
	>10 ft	139	0	0	19	0	0	-	-		
Percent of drivers blocking crosswalk		105	22	21	88	3	3	-	-		
Percent of drivers making RTOR who come to a complete stop		104	87	83	88	32	36		276	132	48
Percent of drivers violating the no RTOR (when pedestrian present)									276	88	32
Percent of drivers violating the no RTOR (when pedestrian not present)									276	188	68

7.6 Statistical Results

7.6.1 Safety MOEs

The statistical tests show that the installation of high visibility crosswalk does not improve significantly the proportion of signal cycles in which a call button is pushed. However, the installation of pedestrian countdown signs with animated eyes shows significant effect in increasing the proportion of signal cycles in which the call button is pushed, both when compared with the baseline as well as with stage 1. A similar effect is seen in the percent of pedestrians beginning their crossing during the WALK phase. A significant increase in the percent of pedestrians who look for vehicles before beginning to cross is found in stage 1 as well as in stages 2 and 3, when compared to the baseline data (Table 32). Also when Stage 1 data are compared with stage 2 and stage 2 compared to stage 3 (Table 33). When compared to the baseline data, the data collected after installations of stages 1 and 3 do not show significant improvement in percent of drivers yielding to pedestrians, and in percent of drivers making RTOR who come to a complete stop when compared to baseline. No significant change in the proportion of drivers stopping at distances greater than 10 ft is observed in stage 1 in comparison to the baseline data. A comparison of stages 1 and 2 shows no significant difference in the frequency of pedestrian signal violation and percent of pedestrians in crosswalk at the end of flashing DON'T WALK and the percent of pedestrians in crosswalk at the end of All-Red.

Table 32: Statistical test results of safety MOEs at Flamingo Road and Koval Lane (Baseline vs. Stages)

Measures of Effectiveness (Safety)		Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
		$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$										
Percent of captured pedestrians			No Change			-			-	
Percent of diverted pedestrians			No Change			-			-	
Percent signal cycles in which call button has been pushed		0.0003	>0.05	Do not Reject	-0.32	<0.001	Reject	-0.37	<0.001	Reject
Percent pedestrians who look for vehicles before beginning to cross		-0.10	<0.05	Reject	-0.33	<0.001	Reject	-0.43	<0.001	Reject
Percent of pedestrians beginning their crossings during the WALK phase		0.01	>0.05	Do not Reject	-0.27	<0.001	Reject		-	
Percent of drivers yielding to pedestrians		0.82	>0.05	Do not Reject		-			-	
Distance driver stops/yields before crosswalk	< 5 ft	-0.14	<0.05	Reject		-			-	
	5-10 ft	0.14	>0.05	Do not Reject		-			-	
	>10 ft		No Change			-			-	
Percent of drivers making RTOR who come to a complete stop		0.47	>0.05	Do not reject		-		0.35	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$										
Frequency of pedestrian signal violation		-0.006	>0.05	Do not Reject	0.002	>0.05	Do not Reject	-0.05	>0.05	Do not Reject
Percent of pedestrians in crosswalk at the end of flashing DON'T WALK		-0.01	>0.05	Do not Reject	-0.19	>0.05	Do not reject		-	
Percent of pedestrians in crosswalk at the end of All-Red		0.06	<0.001	Reject	0.03	<0.05	Reject		-	
Percent of drivers blocking crosswalk		0.17	<0.001	Reject		-			-	

Table 33: Statistical test results of safety MOEs for pedestrians between stages at Flamingo Road and Koval Lane

Measures of Effectiveness (Safety)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$						
Percent signal cycles in which call button has been pushed	-0.32	<0.001	Reject	-0.05	>0.05	Do not Reject
Percent pedestrians who look for vehicles before beginning to cross	-0.23	<0.001	Reject	-0.09	<0.001	Reject
Percent of pedestrians beginning their crossings during the WALK phase	-0.28	<0.001	Reject	-		
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Frequency of pedestrian signal violation	0.009	>0.05	Do not Reject	-0.06	>0.05	Do not Reject
Percent of pedestrians in crosswalk at the end of flashing DON'T WALK	-0.18	>0.05	Do not Reject	-		
Percent of pedestrians in crosswalk at the end of All-Red	-0.02	>0.05	Do not Reject	-		

7.7 Summary

The increment in percent of pedestrians who pushed the call button, percent of pedestrians who look for vehicles before beginning to cross the roadway, percent of pedestrians beginning their crossing during the WALK phase during after the study shows an indication of improving crossing behavior. The decrease in the percent of pedestrians in the crosswalk at the end of all-red is an indication of increased safety for pedestrians. The decrease in the percent of drivers blocking crosswalk indicates that motorists are stopping/yielding far away from the pedestrians, thus increasing safety for pedestrians. There is a significant increase in the percent of drivers coming to complete stop before making a right turn on red (RTOR) after the installation of the ITS No-Turn On Red Sign.

SITE 8: FLAMINGO ROAD / PARADISE ROAD

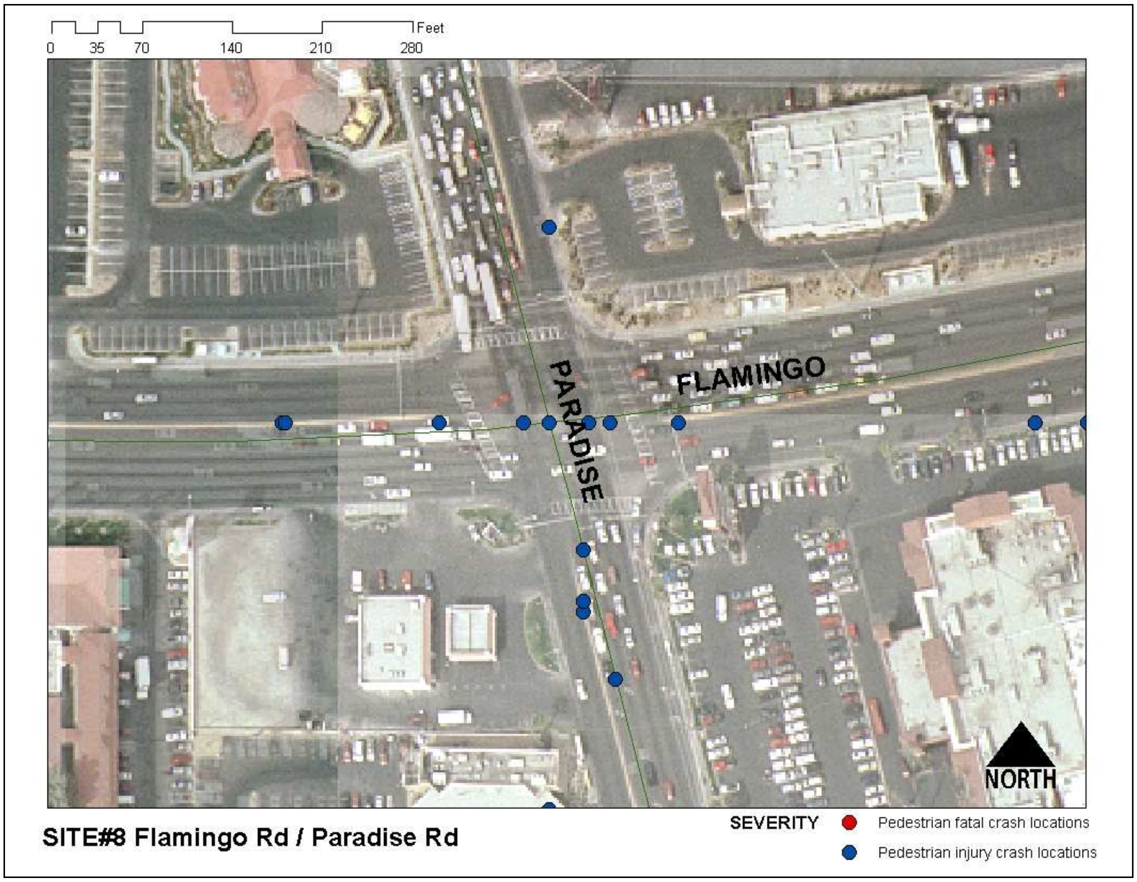

Figure 21: Aerial Photograph of Flamingo Road and Paradise Road (Control Site)

SITE 9 AND 10: BONANZA ROAD: D STREET AND F STREET

9.1 Site description

The land use pattern along Bonanza Road between D Street and F Street site is classified as commercial. The location is within the jurisdiction of the City of Las Vegas and the Nevada Department of Transportation (NDOT). Bonanza Road, D Street, and F Street are classified as minor arterials. The posted speed limit along Bonanza Road is 35 mph. D Street and F Street have a posted speed limits of 25 mph. Bonanza Road/D Street is a three-legged (T intersection), and Bonanza Road/F Street is a four-legged signalized intersections. D Street has only the southbound approach at the intersection. Bonanza Road/D Street had 6 crashes between January 1996 and December 2000. All the crashes had occurred at non-intersection location. Bonanza Road/F Street had a total of 12 crashes in the same period with about 60 percent of the crashes occurring at non-intersections. As per the 2006 traffic count statistics, the estimated ADT along Bonanza Road at this site is 20,100. Figures 22 and 23 present the aerial photographs of the Site 9 and Site 10 respectively. Implementation plans and conceptual designs of this site are illustrated in Site 9 and Site 10 in Appendix B.

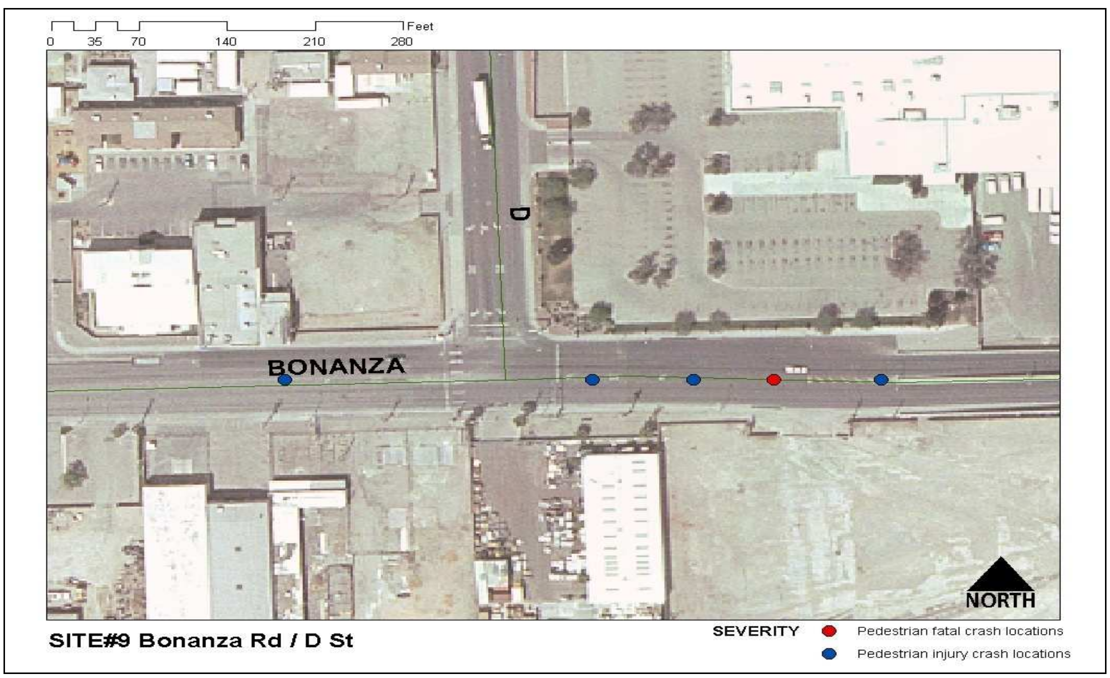

Figure 22: Aerial Photograph of Bonanza Road and D Street

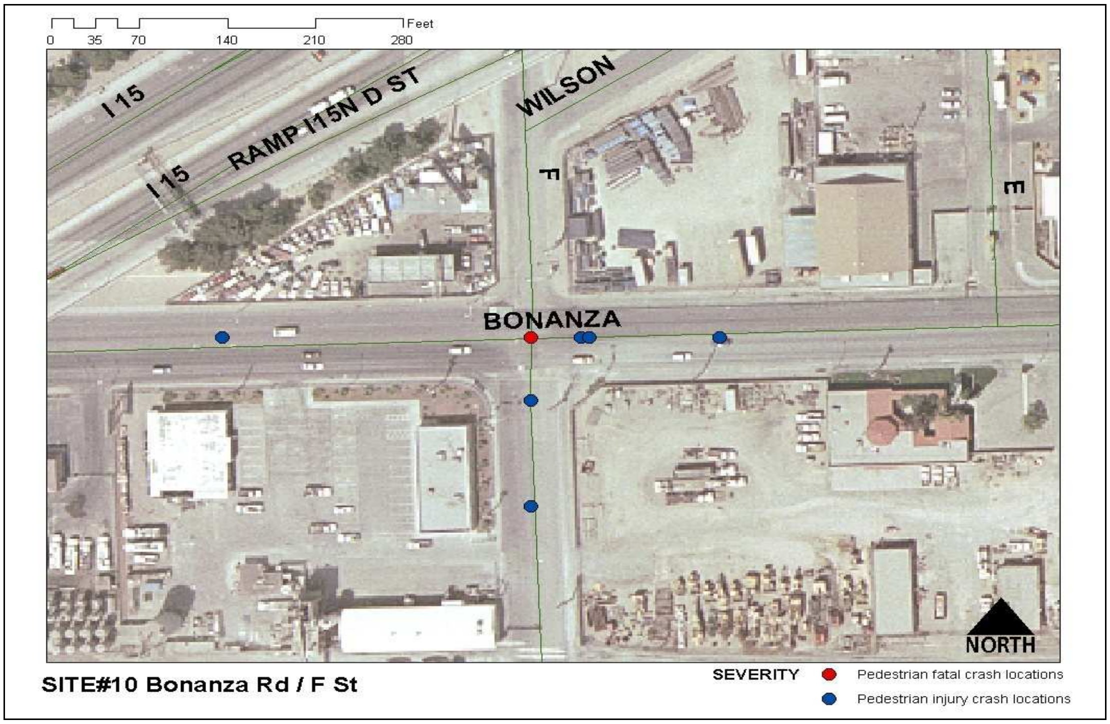

Figure 23: Aerial Photograph of Bonanza Road and F Street

9.2 Problems Identified

Some of the problems observed at Bonanza Road D Street and F Street are pedestrians not using the crosswalks, inconspicuous crosswalks, pedestrians trapped in the middle of the street while crossing, motorists failing to yield, pedestrians failing to yield, and pedestrians not waiting for signals or acceptable gaps.

9.3 Countermeasures Proposed

The installation of "In-roadway knockdown signs" would inform motorists about pedestrian activities in the vicinity, and it would also remind them of the State law that motorists must yield to pedestrians in the crosswalk. Deployment of "High visibility crosswalk" and "In-roadway knockdown signs" is expected to increase motorists' yielding behavior to pedestrians, and more crosswalk users. The implementation plan for the proposed countermeasures at this location is shown in Table 34.

Table 34: Implementation Plan for Bonanza Rd: D St to F St

Treatments	Stage 1	Stage 2	Stage 3
In-roadway knockdown sign	**O**	**O**	**O**
High visibility crosswalk		**O**	**O**
Pedestrian channelization			**O**
Warning sign for motorists			

O - Installed

9.4 Countermeasures Installed

Stage 1 Countermeasure Deployment

Countermeasure deployed during this stage is “In Roadway Knockdown Signs.” This countermeasure is installed between August 22 and 26, 2005. The after condition data for stage 1 countermeasure deployment are collected between September 12 and 16, 2005. Figure 24 shows the countermeasures deployed in Stage 1 at this location.

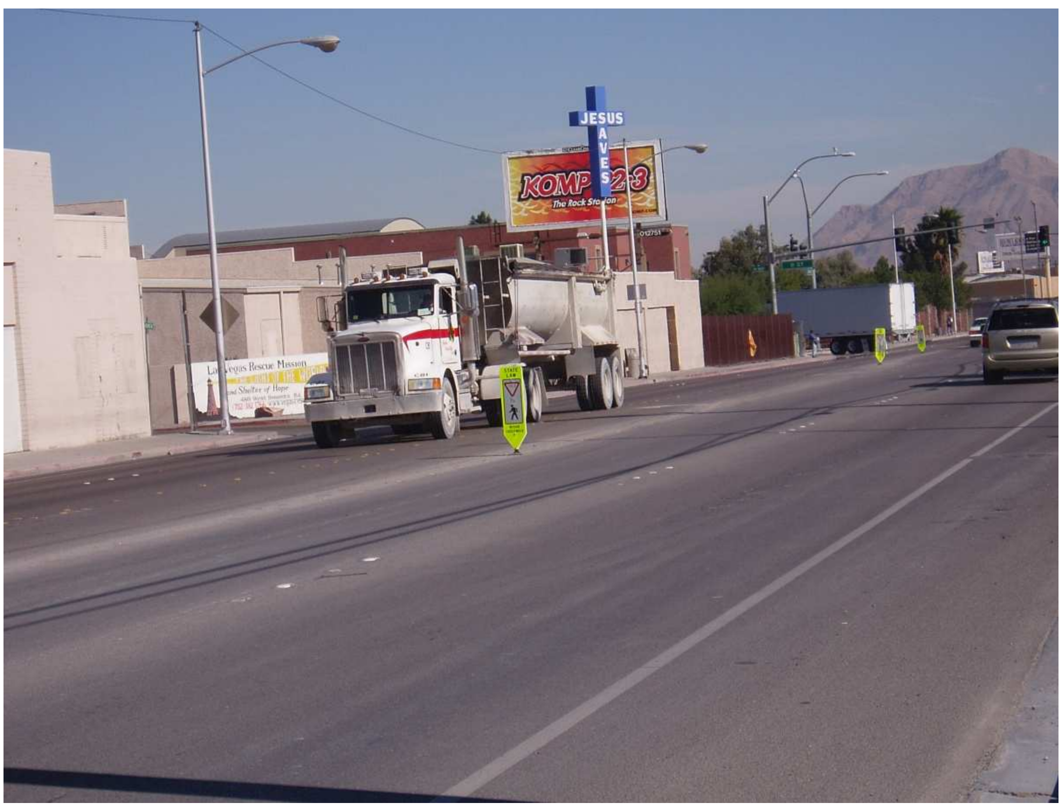

Figure 24: In-roadway Knockdown Signs installed at Site 9/10

Stage 2 Countermeasure Deployment

Countermeasures deployed during this stage are “High Visibility Crosswalk Treatment” and “Warning Signs for Motorists.” These countermeasures are installed on August 4-7, 2006. The after condition data for Stage 2 countermeasure deployment are collected on August 21 to 24, 2006. Figure 25 shows the high visibility crosswalk treatment installed at Site 9/10. Warning signs for motorists installed at the site are shown in Figure 26.

Figure 25: High Visibility Crosswalk Treatment installed at Site 9/10

Figure 26: Warning Signs for Motorists installed at Site 9/10

Stage 3 Countermeasure Deployment

Countermeasure deployed during this stage was "Pedestrian Channelization." This countermeasure is installed on October 29 to November 2, 2007. The after condition data for Stage 3 countermeasure deployment are collected on December 20 and 21, 2007. Figure 27 shows the countermeasure deployed in Stage 3 at this location.

Figure 27: Pedestrian Channelization installed at Site 9/10

9.5 Safety MOEs

9.5.1 Pedestrian MOEs

The baseline data indicate that 100 percent of the observed pedestrians look for vehicles before beginning to cross the roadway and before crossing the second half of the street. The installation of in-roadway knockdown signs in Stage 1, high visibility crosswalk in Stage 2 and pedestrian Channelization in Stage 3 also maintain the "pedestrians look for vehicles behavior before beginning to cross the roadway and before crossing the second half of the street" MOE at 100 percent as shown in Table 35. An increase in the percent of captured pedestrians is observed after the installation of the in-roadway knockdown signs in the Stage 1. Thus the proportion of diverted pedestrians reduced. Different effects are seen in Stage 2 and Stage 3, with decrease in the percent of captured pedestrians and increase in the percent of diverted pedestrians as shown in Table 35. A slight increase is observed in the proportion of pedestrians trapped in the roadway during stage 1. However, after the installation of the high visibility crosswalk, the proportion of pedestrians trapped in the roadway is reduced to zero and is maintained at a similar percentage even after the installation of pedestrian Channelization in Stage 3.

Table 35: Results of pedestrian MOEs at Bonanza Road: D Street to F Street

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample = 197		Sample = 333		Sample = 18		Sample = 100	
	N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent pedestrians who look for vehicles before beginning to cross	197	100	333	100	18	100	100	100
Percent pedestrians who look for vehicles before crossing 2nd half of street	197	100	333	100	18	100	100	100
Percent of captured pedestrians	146	74	289	87	11	61	78	78
Percent of diverted pedestrians	51	26	44	13	7	39	22	22
Percent of pedestrians trapped in the roadway	9	5	32	9	0	0	9	9

9.5.2 Motorist MOEs

The data collected under the MOEs related to motorists are shown in Table 36. The proportion of drivers yielding to pedestrians shows a continuous reduction of 0.74 in the baseline to 0.47 in Stage 1 to 0.00 in Stage 2 and has maintained at a lower proportion of 0.01 in stage 3. The data indicate that the installation of countermeasure in Stage 1 resulted in a greater proportion of drivers yielding at a distance greater than 10 ft. Also, the percent of drivers blocking the crosswalk shows a reduction in Stage 1 compared to baseline period. Data from stages 2 and 3 countermeasure installation do not show notable effect on the motorist behavior.

Table 36: Results of motorist MOEs at Bonanza Road: D Street to F Street

Measures of Effectiveness (Safety)		Baseline		Stage 1		Stage 2		Stage 3	
		Sample = 89		Sample = 106		Sample = 25		Sample = 170	
		N_B	Percent	N_1	Percent	N_2	Percent	N_3	Percent
Percent of drivers yielding to pedestrians		66	74	50	47	0	0	1	0.6
		Sample = 66		Sample = 50		Sample = 0		Sample = 1	
Distance driver stops/yields before crosswalk	< 10 ft	46	70	20	40	-		-	
	10-20 ft	10	15	15	30	-		1	100
	>20 ft	10	15	15	30	-		-	
		Sample = 77		Sample = 284		Sample = 0		Sample = 0	
Percent of drivers blocking crosswalk		5	7	3	6	-		-	

9.6 Mobility MOEs

9.6.1 Pedestrian Delay

The average pedestrian delay measured at this location is shown in Table 37. An increase in pedestrian delay is observed during stage 1; however, it is reduced in stage 2 and further reduced in stage 3 after the installation of the pedestrian channelization.

Table 37: Delay at Bonanza Road: D Street to F Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample	Delay	Sample	Delay	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	197	8.06	333	12.56	18	6.29	113	0.87

9.7 Statistical Results

9.7.1 Safety MOEs

Since the proportions of pedestrians who look for vehicles before beginning to cross and before crossing 2nd half of the street are 1.00, statistically, the null hypothesis cannot be accepted proving no significant changes in the results. The statistical test indicate a significant increase in the percent of captured pedestrians during stage 1 when compared to the baseline data ($P<0.001$). The increase is not statistically significant when stage 2 results are compared with baseline as well as stage 1 data ($P>0.05$). The percent of pedestrians trapped in the roadway significantly reduced in stage 2 compared to baseline as well as with stage 1 data (P=0.001). The results are shown in Tables 38 and 39.

The results show no significant increase in percent of drivers yielding to pedestrians and no significant decrease in percent of drivers blocking crosswalk (P<0.05). The increase in the proportion of drivers stopping/yielding at a distance greater than 10 ft is statistically significant (P<0.05).

Table 38: Statistical test results of safety MOEs at Bonanza Road: D Street to F Street

Measures of Effectiveness (Safety)		Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
		$P_B – P_1$	P-value	H_0	$P_B – P_2$	P-value	H_0	$P_B – P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$										
Percent pedestrians who look for vehicles before beginning to cross		No Change			No Change			No Change		
Percent pedestrians who look for vehicles before crossing 2nd half of street		No Change			No Change			No Change		
Percent of captured pedestrians		-0.12	<0.001	Reject	0.13	>0.05	Do not Reject	-0.03	>0.05	Do not Reject
Percent of diverted pedestrians		0.12	>0.05	Do not Reject	-0.13	>0.05	Do not Reject	0.03	>0.05	Do not Reject
Percent of drivers yielding to pedestrians		0.26	>0.05	Do not Reject	0.74	>0.05	Do not Reject	0.73	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	<10 ft	0.29	>0.05	Do not Reject	-			-		
	10-20 ft	-0.26	<0.05	Reject	-			-		
	>20 ft	-0.006	<0.05	Reject	-			-		
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$										
Percent of drivers blocking crosswalk		0.01	>0.05	Do not Reject				-		
Percent of pedestrians trapped in the roadway		-0.05	>0.05	Do not Reject	0.04	0.001	Reject	-0.04	>0.05	Do not Reject

Table 39: Statistical test results of safety MOEs between stages at Bonanza Road: D Street to F Street

Measures of Effectiveness (Safety)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$						
Percent pedestrians who look for vehicles before beginning to cross	No change			No change		
Percent pedestrians who look for vehicles before crossing 2nd half of street	No change			No change		
Percent of captured pedestrians	0.25	>0.05	Do not Reject	-0.16	>0.05	Do not Reject
Percent of diverted pedestrians	-0.25	<0.05	Reject	0.16	>0.05	Do not Reject
Percent of drivers yielding to pedestrians	0.47	>0.05	Do not Reject	-0.005	>0.05	Do not Reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Percent of pedestrians trapped in the roadway	0.09	<0.001	Reject	-0.13	>0.05	Do not Reject

9.7.2 Mobility MOEs

There is no significant reduction in the average pedestrian delay in stages 1 and 2 compared to the baseline as shown in Table 40 (P>0.05). But a significant decrease is observed in stage 2 when compared to stage 1 as seen in Table 41 (P<0.05).

Table 40: Statistical test results of mobility MOE at Bonanza Road: D Street to F Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Average pedestrian delay (sec/ped)	-4.50	>0.05	Do not Reject	1.77	>0.05	Do not Reject	7.19	<0.001	Reject

Table 41: Statistical test results of mobility MOE stages 1 and 2 at Bonanza Road: D Street to F Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average pedestrian delay (sec/ped)	6.27	<0.05	Reject	5.22	<0.05	Reject

9.8 Summary

The installation of in-roadway knockdown signs and a high visibility crosswalk is effective for reducing the proportion of pedestrians trapped in the roadway and increasing the proportion of pedestrians using the crosswalk to cross the street. The increase in the proportion of drivers yielding at a greater distance enhances safety to pedestrians crossing the roadway. The decrease in the average pedestrian delay in stage 2 indicates that the high visibility crosswalk provides improved mobility.

SITE 11: TWAIN AVENUE: CAMBRIDGE STREET TO SWENSON STREET AND SITE 12: TWAIN AVENUE: SWENSON STREET TO PALOS VERDE STREET

11.1 Site description

Twain Avenue is classified as a minor arterial with a posted speed limit of 35 mph along the corridor between Cambridge Street and Palos Verde Street. Twain Avenue runs in the east-west direction. The location is within the jurisdiction of Clark County. Land use along the corridor is mixed type with some shopping centers and residential apartments. ADT along the corridor for the year 2006 was approximately 21,400. Figures 28 and 29 present the aerial photographs of the Site 11 and Site 12 respectively. Implementation plans and conceptual designs for these sites are illustrated in Appendix B.

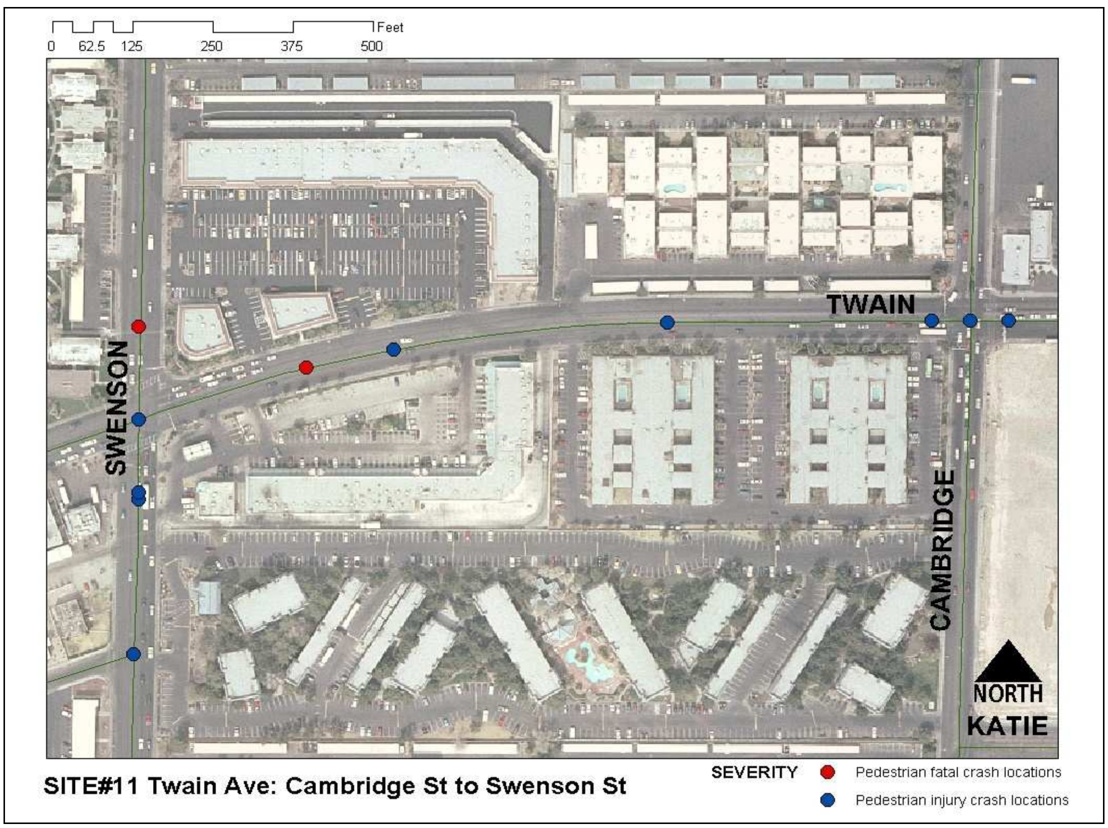

Figure 28: Aerial Photograph of Site 11

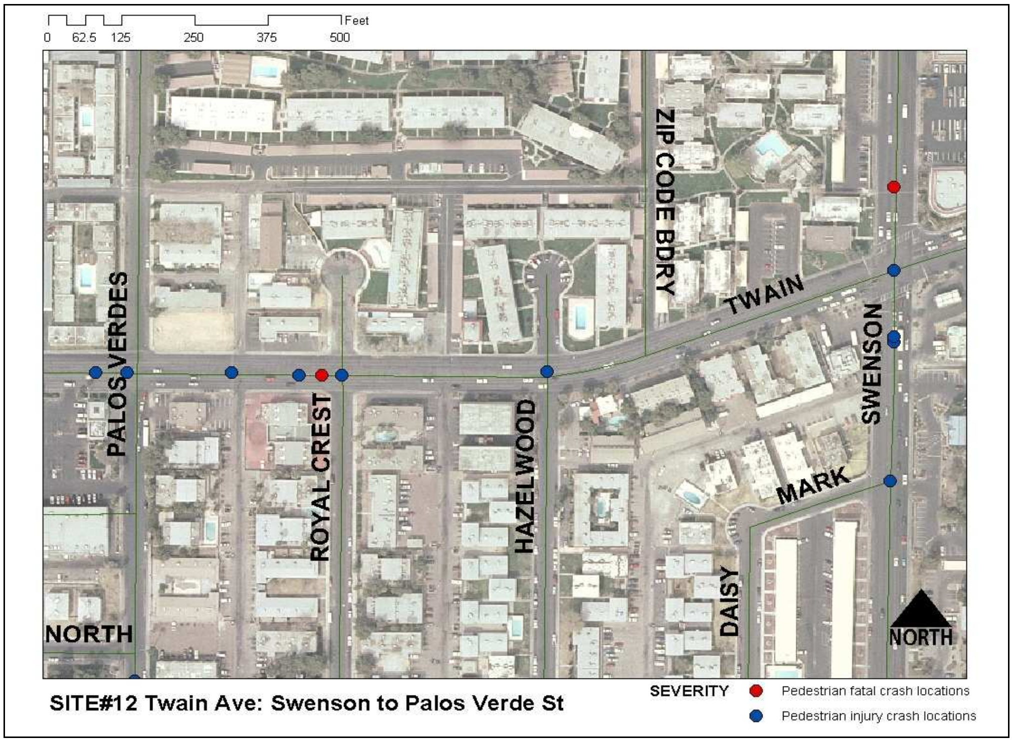

Figure 29: Aerial Photograph of Site 12

11.2 Problems Identified

The problems identified along the corridor include excessive speeding, drivers not yielding to pedestrians, pedestrians trapped in the roadway, and conflicts between vehicles and pedestrians.

11.3 Countermeasures Proposed

The countermeasures deployed at this site include "In-roadway knockdown signs" and "Portable speed trailer." The implementation plans for the proposed countermeasures at the above mentioned locations are shown in Tables 42 and 43.

Table 42: Implementation Plan for Twain Avenue: Cambridge Street to Swenson Street

Treatment	Stage 1
In-roadway knockdown signs	**O**

O - Installed

Table 43: Implementation Plan for Twain Avenue: Swenson Street to Palos Verde Street

Treatments	Stage 1	Stage 2
In-roadway knockdown signs	**O**	**O**
Portable speed trailers		**O**

O - Installed

11.4 Countermeasures Installed

The finalized countermeasures were installed at sites 11 and 12 in 2 stages.

Stage 1 Countermeasure Deployment

The countermeasures deployed during stage 1 are "In Roadway Knockdown Signs." These signs were installed between October 10 and 14, 2005. The after condition data for stage 1 countermeasure deployment were collected between November 1 and 4, 2005. Figure 30 and Figure 31 show the countermeasures deployed in Stage 1 at this location.

Figure 30: In-Roadway Knockdown Signs installed at Sites 11 and 12

Figure 31: Close-up view of "In-Roadway Knockdown Signs" installed at Sites 11 and 12

Stage 2 Countermeasure Deployment

The countermeasure deployed during stage 2 is "Portable Speed Trailer." This countermeasure was installed between August 1 and September 30, 2006. The after condition data for Stage 2 countermeasure deployment were collected on October 18 and 19, 2006. Figure 32 shows the countermeasure deployed in Stage 2 at this location.

Figure 32: Installation location of Speed-trailer on Twain Avenue

Data were collected for various pedestrian and motorist MOEs and the summarized results are shown in Tables 44 to 47.

11.5 Safety MOEs

The safety MOEs identifies includes some related to pedestrians and others related to motorists.

11.5.1 Pedestrian MOEs

Table 44 shows that the proportion of pedestrians who look for vehicles before beginning to cross and before crossing the second half of the roadway increased from 0.80 to 1.00 and from 0.85 to 1.00 respectively. This indicates that the in-roadway knockdown signs have positive impacts with respect to these MOEs. No change in the proportion of captured or diverted pedestrians is observed. The proportion of pedestrians trapped in the roadway reduced from 0.41 in baseline to 0.34 in stage 1, and to 0.37 in stage 2. This also suggests improved safety for pedestrians.

11.5.2 Motorist MOEs

Table 45 shows the percent of drivers yielding to pedestrians in different stages as a measure of motorist MOE. The baseline data indicate only a small proportion (0.07) of drivers yield to pedestrians. After the installation of in-roadway knockdown in the second stage, this proportion increased to 0.35. After the use of speed trailer in stage 2, the proportion of drivers yielding to pedestrian slightly decreased to 0.29. Since the location is a mid-block, the distance of drivers stopping/yielding before crosswalk and the percent of drivers blocking the crosswalk are not applicable.

Table 44: Results of pedestrian MOEs at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2	
	Sample = 165		Sample = 47		Sample = 156	
	N_B	Percent	N_1	Percent	N_2	Percent
Percent pedestrians who look for vehicles before beginning to cross	132	80	47	100	156	100
Percent pedestrians who look for vehicles before crossing 2nd half of the street	141	85	47	100	156	100
Percent of captured pedestrians	165	100	47	100	156	100
Percent of diverted pedestrians	0	0	0	0	0	0
Percent of pedestrians trapped in the roadway	68	41	16	34	58	37

Table 45: Results of motorist safety MOE at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2	
	Sample = 141		Sample = 79		Sample = 119	
	N_B	Percent	N_1	Percent	N_2	Percent
Percent of drivers yielding to pedestrians	10	7	28	35	35	29

11.6 Mobility MOEs

11.6.1 Pedestrian Delay

The average pedestrian and vehicle delay measured at this location are shown in Table 46 for the various deployment stages. The average pedestrian delay increased in stages 1 and 2 compared to the baseline data.

11.6.2 Vehicle Delay

Table 46 shows that compared to the baseline data, average vehicle delays increased in stages 1 and 2.

11.6.3 Vehicle Speed

Table 47 shows the mean vehicle speeds for the various countermeasure deployment stages. The existing condition mean speeds in the eastbound and westbound directions are 40 mph and 35 mph, respectively. The installation of in-roadway knockdown signs reduced the speeds to 34.5 mph and 28.5 mph, in the eastbound and westbound directions, respectively. The difference of the mean speeds between the existing condition and after stage 1 is approximately 6 mph. Similar trends are observed in the westbound direction. The deployment of speed trailer further reduced the speed in the eastbound direction to 31.9 mph. The mean speed in the westbound direction is reduced to 31.3 mph from 35 mph in the baseline period, but this was greater than the mean speed observed after stage 1.

Table 46: Delays at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2	
	Sample	Delay	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	164	0.81	47	12.19	156	14.72
Average vehicle delay (sec/veh)	141	0.18	79	3.23	119	2.49

Table 47: Vehicle speeds at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2	
	Sample	Mean speed (mph)	Sample	Mean speed (mph)	Sample	Mean speed (mph)
Eastbound	150	40.0	100	34.5	250	31.9
Westbound	200	35.0	100	28.5	250	31.3

11.7 Statistical Results

The results of the statistical tests for the safety MOEs for site 12 (Twain Avenue: Swenson Street to Palos Verde Street) comparing the baseline conditions with each stage, and between stages are shown in Tables 48 and 49, respectively. The analyses of statistical results for the mobility MOEs are shown in Tables 50 and 51.

11.7.1 Safety MOEs

The results of the statistical tests for safety MOEs are shown in Tables 48 and 49. The results, when the baseline data and stage 1 data are compared, show that the increase in the percentage of pedestrian who look for vehicles before beginning to cross and before crossing 2^{nd} half of the street are significant at a 95 percent confidence level. These results indicate that the deployment of the countermeasures results in improvements in pedestrian safety. The proportion of diverted pedestrians and captured pedestrians do not change between the various stages. The increase in drivers yielding to pedestrians is found to be significant in both cases as shown in Table 50. The results were not statistically significant at a 95 percent confidence level when the percent of pedestrians trapped in the roadway in stage 1 and stage 2 are compared with the baseline data.

Comparing the data for stage 1 and stage 2, no change in the proportions of pedestrians who look for vehicles before crossing and before crossing the 2nd half of the street, captured and diverted pedestrians is seen. However, Table 51 shows that the percent of drivers yielding to pedestrians and the percent of pedestrians trapped in roadways are not significantly different statistically at a 95 percent confidence level.

Table 48: Statistical test results at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Safety)	Baseline vs. Stage 1			Baseline vs. Stage 2		
	$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Percent pedestrians who look for vehicles before beginning to cross	-0.20	<0.001	Reject		No change	
Percent pedestrians who look for vehicles before crossing 2nd half of street	-0.14	<0.001	Reject		No change	
Percent of captured pedestrians		No change			No change	
Percent of diverted pedestrians		No change			No change	
Percent of drivers yielding to pedestrians	-0.28	<0.001	Reject	-0.22	<0.001	Reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Percent of pedestrians trapped in the roadway	0.07	>0.05	Do not Reject	0.04	>0.05	Do not Reject

Table 49: Statistical test results between stages at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Safety)	Stage 1 vs. Stage 2		
	$P_1 - P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Percent pedestrians who look for vehicles before beginning to cross	0.00	No change	
Percent pedestrians who look for vehicles before crossing 2nd half of street	0.00	No change	
Percent of captured pedestrians	0.00	No change	
Percent of diverted pedestrians	0.00	No change	
Percent of drivers yielding to pedestrians	0.06	>0.05	Do not Reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Percent of pedestrians trapped in the roadway	-0.03	>0.05	Do not Reject

11.7.2 Mobility MOEs

The results of statistical tests for the significance of the mobility MOE is shown in Tables 50 and 51. Statistical tests revealed no significant difference in results obtained for average pedestrian delay and average vehicle delay. The decrease in eastbound mean speed is found to be significant for all three cases as seen in Tables 52 and 53. The decrease in the westbound mean speed, when baseline data is compared with stage 1 and stage 2 is found to be significantly different. However, difference obtained when the westbound mean speed for stage 1 and stage 2 is compared is not statistically significant as seen in Table 53.

Table 50: Statistical test results of mobility MOEs at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average pedestrian delay (sec/ped)	-11.38	>0.05	Do not Reject	-13.91	>0.05	Do not Reject
Average vehicle delay (sec/veh)	-3.05	>0.05	Do not Reject	-2.31	>0.05	Do not Reject

Table 51: Statistical test results of mobility MOEs between stages at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2		
	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Average pedestrian delay (sec/ped)	-2.53	>0.05	Do not Reject
Average vehicle delay (sec/veh)	0.74	>0.05	Do not Reject

Table 52: Statistical test results of speed at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2		
	Difference in Mean Speed	P-value	H_0	Difference in Mean Speed	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Eastbound (mph)	5.50	<0.001	Reject	8.10	<0.001	Reject
Westbound (mph)	6.50	<0.001	Reject	3.70	<0.001	Reject

Table 53: Comparison of speed between stages at Twain Avenue: Palos Verde Street to Swenson Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2		
	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Eastbound (mph)	2.60	<0.001	Reject
Westbound (mph)	-2.80	>0.05	Do not Reject

11.8 Summary

The installation of in-roadway knockdown signs and portable speed trailer has improved the yielding behavior of drivers to pedestrians. This makes roadway safer for the pedestrians crossing the street. The decreases in the vehicle travel speeds at this location suggest that these countermeasures are very effective strategy wherever speeding is an issue.

SITE 13: LAKE MEAD BOULEVARD / LAS VEGAS BOULEVARD

13.1 Site description

The land use at this location is mainly a mixture of commercial and residential. This site is an intersection of a six lane minor arterial (Lake Mead Boulevard) with two left turning lanes and with a speed limit 35 mph, and a four lane minor arterial (Las Vegas Boulevard) with a left turning lane and with speed limit of 35 mph. This site is in the jurisdiction of City of North Las Vegas. It is one of the 4 selected sites along the Lake Mead Boulevard corridor between Las Vegas Boulevard and Pecos Road. There were a total of 8 crashes recorded at the intersection; with all of them reported as injury crashes. Almost 75 percent of the total crashes occurred at the intersection locations. Figure 33 presents the aerial photograph of this site. Site 13 in Appendix B presents implementation plan and the conceptual design of this location.

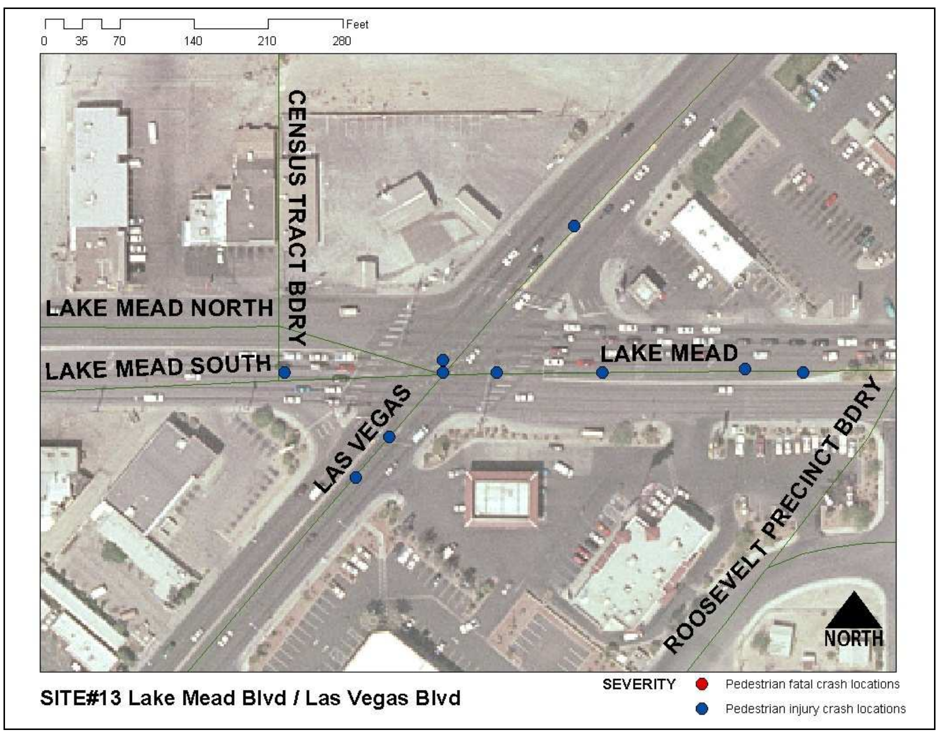

Figure 33: Aerial Photograph of Lake Mead Boulevard and Las Vegas Boulevard

13.2 Problems Identified

Some of the problems identified at this location are pedestrians do NOT use the crosswalks, inconspicuous crosswalks, high percent of elderly pedestrian involved in crashes, and inconspicuous pedestrian signals due to wide streets

13.3 Countermeasures Proposed

A “High visibility crosswalk” treatment is proposed at this location to help reduce the problem of inconspicuous crosswalks at the location. Enlarged Pedestrian Signal Heads are also proposed as a countermeasure deployment. The implementation plan for the proposed countermeasures at this location is shown in Table 54.

Table 54: Implementation Plan for Lake Mead Boulevard and Lake Mead Boulevard

Treatments	Stage 1	Stage 2
High visibility crosswalk	**O**	**O**
High visibility crosswalk from island to sidewalk	**O**	**O**
Enlarged Pedestrian Signal Heads		**X**

O - Installed
X - Not installed due to non-availability

13.4 Countermeasures Installed

Stage 1 Countermeasure Deployment

Countermeasure deployed during this stage is “high visibility crosswalk treatment.” This countermeasure is installed between October 3 and 7, 2005. The after condition data for stage 1 countermeasure deployment are collected on November 7, 2005. Figure 34 shows the countermeasures deployed at this location.

Figure 34: High Visibility Crosswalk Treatment installed at Lake Mead Boulevard and Las Vegas Boulevard

Implementation of stage 2 countermeasure is cancelled due to the non-availability of vendors to fabricate and manufacture “Enlarged Pedestrians Signal Head” countermeasure.

13.5 Safety MOEs

The results of the safety MOEs are summarized in Tables 55 and 56. Table 55 shows the pedestrian MOEs that are percent of the pedestrians who look for vehicles before beginning to cross, percent signal cycles in which call button has been pushed, frequency of pedestrian signal violation, percent of pedestrians in crosswalk at DON’T WALK, and percent of pedestrians trapped in the roadway. The motorist MOES are summarized in Table 56. These motorist MOEs are percent of drivers yielding to pedestrians, yielding distance, drivers blocking the crosswalk, and drivers making a complete stop.

13.5.1 Pedestrian MOEs

Table 55 summarizes the data collected for pedestrian MOEs at Lake Mead Boulevard and Las Vegas Boulevard. It can be seen that the "percent of the pedestrians who look for vehicles before beginning to cross" increased slightly from 38% to 43% after the installation of Stage 1 countermeasure. Percent of signal cycles in which call button has been pushed remained almost the same (58% and 54% respectively) even after the installation of the high visibility crosswalk treatment countermeasure. However, frequency of pedestrian signal violation was increased from 4% in Baseline to 12% in Stage 1 after the installation of the countermeasure. The impact of countermeasure installation on "percent of pedestrians in crosswalk at DON'T WALK" and on "percent of pedestrians trapped in the roadway" remained almost the same in the baseline and the stage 1 conditions.

Table 55: Results of pedestrian MOEs at Lake Mead Boulevard and Las Vegas Boulevard

Measures of Effectiveness (Safety)	Baseline			Stage 1		
	Sample	N_B	Percent	Sample	N_1	Percent
Percent pedestrians who look for vehicles before beginning to cross	411	159	38	377	162	43
Percent signal cycles in which call button has been pushed	411	237	58	377	205	54
Frequency of pedestrian signal violation	411	19	4	377	48	12
Percent of pedestrians in crosswalk at DON'T WALK	411	11	2	377	17	5
Percent of pedestrians trapped in the roadway	411	16	3	377	8	2

13.5.2 Motorist MOEs

It is evident from Table 56, that there is not positive impact on the motorists as a result of the installation of the high visibility crosswalk treatment. All the MOEs collected before and after installation of the high visibility crosswalk treatment showed negative impact.

Table 56: Results of motorist MOEs at Lake Mead Boulevard and Las Vegas Boulevard

Measures of Effectiveness (Safety)		Baseline			Stage 1		
		Sample	N_B	Percent	Sample	N_1	Percent
Percent of drivers yielding to pedestrians		68	24	35	247	67	27
Distance driver stops/yields before crosswalk	< 5 ft	24	11	46	67	20	30
	5-10 ft	24	9	38	67	37	55
	>10 ft	24	4	16	67	10	15
Percent of drivers blocking crosswalk		68	14	21	247	47	19
Percent of drivers making a complete stop		67	50	75	247	82	33

13.6 Mobility MOEs

From Table 57, it is seen that average pedestrian delay increased from 36.6 seconds to 41.3 seconds per pedestrian after the installation of the high visibility crosswalk treatment. However, on the contrary, vehicle delays decreased slightly from 26.7 seconds to 20.8 seconds after the stage 1 countermeasure installation.

Table 57: Delay at Lake Mead Boulevard and Las Vegas Boulevard

Measures of Effectiveness (Mobility)	Baseline		Stage 1	
	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	411	36.64	377	41.31
Average vehicle delay (sec/veh)	774	26.69	864	20.76

13.7 Statistical Results

13.7.1 Safety MOEs

The statistical results of the safety MOEs for Lake Mead Boulevard and Las Vegas Boulevard are shown in Table 58. It is evident from the results table; none of the parameters (either pedestrian related or motorist related) showed statistically significant improvement after the installation of the high visibility crosswalk treatment at Lake Mead Boulevard and Las Vegas Boulevard.

Table 58: Statistical test results of safety MOEs at Lake Mead Boulevard and Las Vegas Boulevard

Measures of Effectiveness (Safety)		Baseline vs. Stage 1		
		$P_B - P_1$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$				
Percent pedestrians who look for vehicles before beginning to cross		-0.04	>0.05	Do not Reject
Percent signal cycles in which call button has been pushed		0.03	>0.05	Do not Reject
Percent of drivers yielding to pedestrians		0.08	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	<5 ft	0.15	>0.05	Do not Reject
	5-10 ft	-0.17	>0.05	Do not Reject
	>10 ft	0.01	>0.05	Do not Reject
Percent of drivers making a complete stop		0.41	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$				
Percent of pedestrians trapped in the roadway		0.017	>0.05	Do not Reject
Frequency of pedestrian signal violation		-0.08	>0.05	Do not Reject
Percent of pedestrians in crosswalk at DON'T WALK		-0.018	>0.05	Do not Reject
Percent of drivers blocking crosswalk		0.01	>0.05	Do not Reject

13.8 Summary

The data collected before and after the installation of the High Visibility Crosswalk Treatment at this location does not show significant improvement in safety for pedestrians as anticipated. The other problems identified at this location such as "high percent of elderly pedestrian involved in crashes," and "inconspicuous pedestrian signals due to wide streets" would have been addressed by installation of Enlarge Pedestrians Signal Heads. However, vendor unavailability hampered the process of installation of this countermeasure.

SITE 14: LAKE MEAD BOULEVARD / MCDANIEL STREET

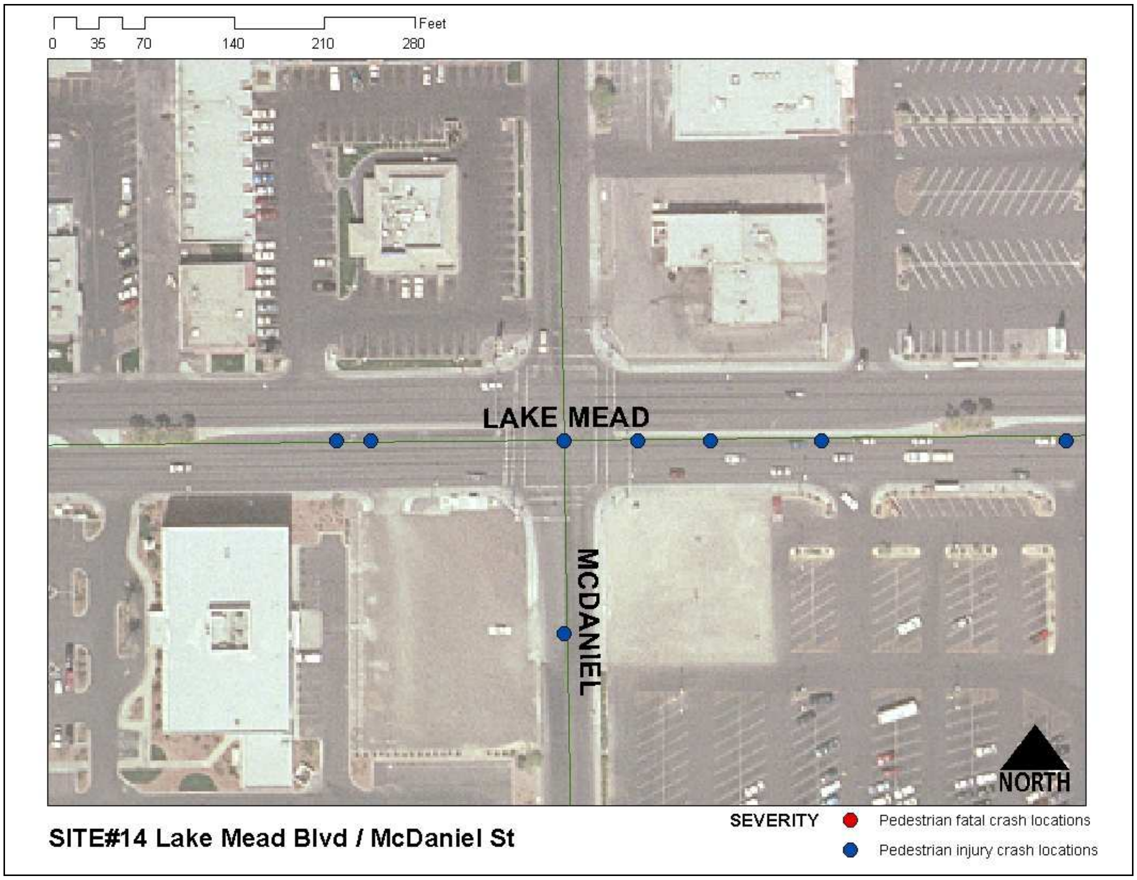

Figure 35: Aerial Photograph of Lake Mead Boulevard and McDaniel Street (Control Site)

SITE 15: LAKE MEAD BOULEVARD: BELMONT STREET TO MCCARRAN STREET

15.1 Site description

The location is within the jurisdiction of the City of North Las Vegas. Land use is primarily residential. Lake Mead Boulevard is a major arterial with a posted speed limit of 45 mph. As per 2006 traffic count statistics, the AADT on Lake Mead Boulevard between Belmont Street and McCarran Street is 44,000. Figure 36 presents the aerial photograph of the site. Implementation plans and conceptual designs of this site are illustrated in Site 15A and Site 15B in Appendix B.

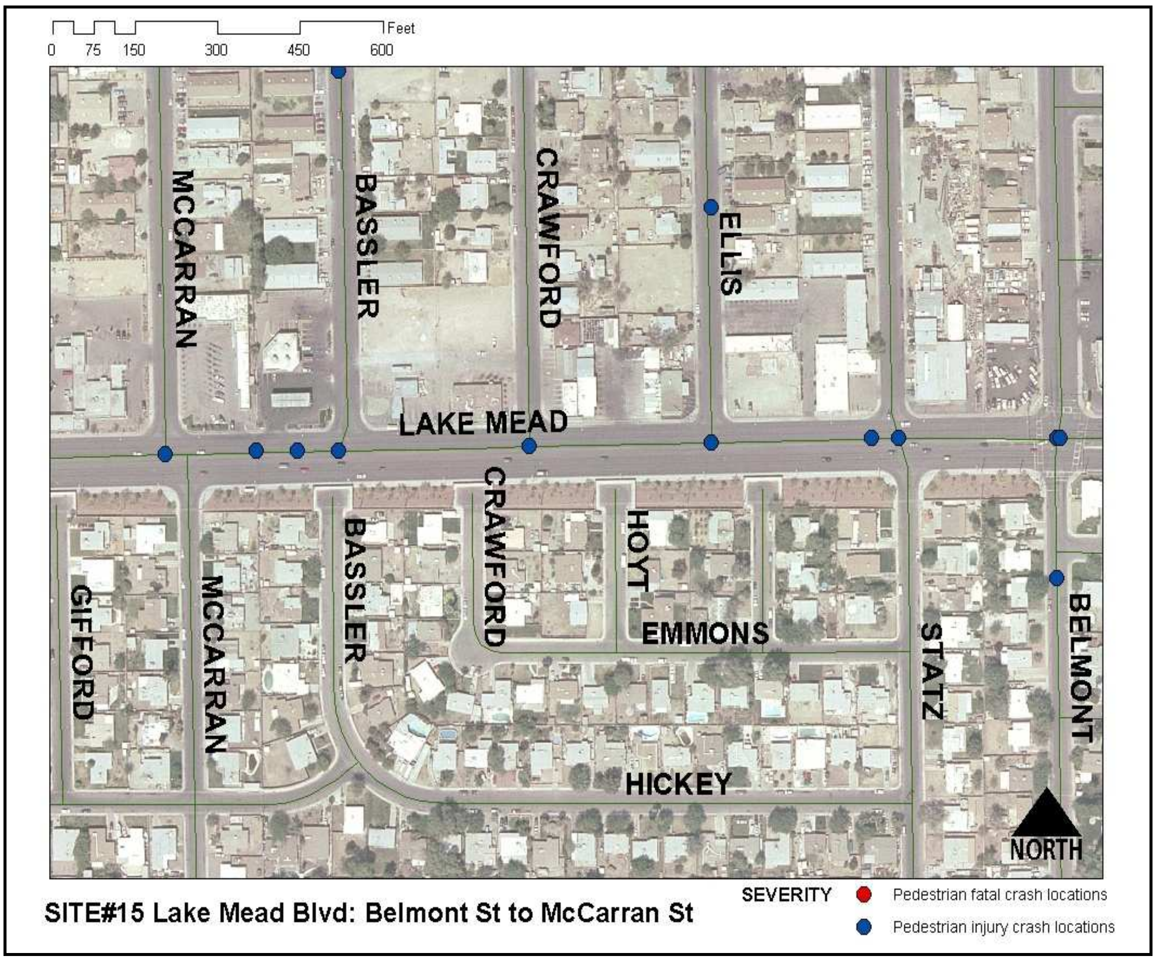

Figure 36: Aerial Photograph of Lake Mead Boulevard: Belmont Street to McCarran Street

15.2 Problems Identified

Some of the identified problems are high percentage of elderly pedestrian crashes, motorists failing to yield, pedestrians not waiting for signals/acceptable gaps, and high proportions of nighttime crashes.

15.3 Countermeasures Proposed

The proposed countermeasures to address these problems are “Danish offset,” “Median refuge,” “High visibility crosswalk,” “Advance yield markings,” “Yield here to pedestrians signs,” “ITS Automatic Detection Devices,” “Smart Lighting” and “Enhancer Pedestrians LED Signal.” The implementation plan for the proposed countermeasures at this location is shown in Table 59.

Table 59: **Implementation Plan for Lake Mead Boulevard: Belmont Street to McCarran Street**

Treatments	Stage 1	Stage 2	Stage 3
Relocated bus stop locations and crosswalks	**O**	**O**	**O**
High visibility crosswalk	**O**	**O**	**O**
Median refuge	**O**	**O**	**O**
Danish offsets	**O**	**O**	**O**
Advance yield markings + sign yield to pedestrians	**O**	**O**	**O**
Smart Lighting		**X**	**X**
ITS automatic pedestrian detection devices		**X**	**X**
Enhancer Pedestrian LED signal			**X**

O - Installed
X - Not Installed

15.4 Countermeasures Installed

The Lake Mead Boulevard site from Belmont Street to McCarran Street is a mid-block location. Multiple countermeasures were installed in a single stage at this location

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are Danish offset, Median refuge, High visibility crosswalk, Advance yield markings and “Yield Here to Pedestrian” signs. These countermeasures are installed between January 29 and February 2, 2007. The after condition data for Stage 1 countermeasure deployment are collected between February 26 and March 2, 2007. Figure 37 and Figure 38 show the countermeasures deployed in stage 1 at this location.

Figure 37: High Visibility Crosswalk Treatment, Danish Offset and Median Refuge

Figure 38: Advanced Yield Markings installed at Lake Mead Boulevard: Belmont Street to McCarran Street

The various pedestrian and motorist MOEs and the summarized results are shown in Tables 60 and 61 respectively. The mobility MOEs are shown in Table 62. The results of the statistical tests for the safety and mobility MOEs comparing the baseline conditions with stage 1 are shown in Table 63 and 64, respectively.

15.5 Safety MOEs

15.5.1 Pedestrian MOEs

From Table 60, it is clear that the percent of pedestrians who look for vehicles before beginning to cross and before crossing second half of the street increased from 0.96 and 0.92 to 1.00, and 1.00, respectively. The percent of captured pedestrians decreased from 100 percent to 84 percent, but the percent of diverted pedestrians increased from zero to 16 percent. There is drastic a decrease in the proportion of pedestrians trapped in the roadway from 0.62 to 0.05 after stage 1.

Table 60: Results of pedestrian MOEs at Lake Mead Boulevard: Belmont Street to McCarran Street

Measures of Effectiveness (Safety)	Baseline		Stage 1	
	Sample = 61		Sample = 123	
	N_B	Percent	N_1	Percent
Percent pedestrians who look for vehicles before beginning to cross	59	96	123	100
Percent pedestrians who look for vehicles before crossing 2nd half of street	56	92	123	100
Percent of captured pedestrians	61	100	103	84
Percent of diverted pedestrians	0	0	20	16
Percent of pedestrians trapped in the roadway	38	62	7	5

15.5.2 Motorist MOEs

Table 61 shows that proportion of drivers yielding to pedestrians from baseline to stage 1 increase from 0.03 to 0.40. There is an increase in the proportion of drivers stopping/yielding at a distance less than 10 feet. A nominal increase is also observed in the percent of drivers blocking the crosswalk in stage 1 compared to baseline period.

Table 61: Results of motorist MOEs at Lake Mead Boulevard: Belmont Street to McCarran Street

Measures of Effectiveness (Safety)		Baseline		Stage 1	
		Sample = 296		Sample = 117	
		N_B	Percent	N_1	Percent
Percent of drivers yielding to pedestrians		8	03	46	40
		Sample = 8		Sample = 46	
Distance driver stops/yields before crosswalk	< 10 ft	2	25	15	39
	10-20 ft	6	75	22	49
	>20 ft	0	0	9	19
		Sample = 296		Sample = 117	
Percent of drivers blocking crosswalk		-		3	6

15.6 Mobility MOEs

15.6.1 Pedestrian Delay

The baseline data indicates that the average pedestrian delay is 21.43 sec/ped. The average pedestrian delay is reduced by 11.90 sec/ped from baseline conditions to stage 1.

15.6.2 Vehicle Delay

The average vehicle delay in the baseline period is 0.24 sec/veh and in stage 1, the delay is 2.16 sec/veh. Table 62 shows the comparison of average vehicle delay at stage 1 and baseline.

Table 62: Delays at Lake Mead Boulevard: Belmont Street to McCarran Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1	
	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	61	21.43	84	9.53
Average vehicle delay (sec/veh)	296	0.24	117	2.16

15.7 Statistical Results

15.7.1 Safety MOEs

There is no significant increase in the percent of pedestrians who look for vehicles before beginning to cross and percent of captured pedestrians in stage 1 compared with baseline data (P>0.05). The MOEs that have significant effect include the following: increase in the percent of pedestrians who look for vehicles before crossing second half of the street, and the percent of diverted pedestrians in stage 1 compared with baseline ($P<0.05$). The reduction in the percent of pedestrians trapped in the roadway in stage 1 is also statistically significant ($P<0.001$).

The results provide evidence that there is a significant increase in the percent of drivers yielding to pedestrians in stage 1 compared to the baseline period ($P<0.001$). There is a significant increase in the number of drivers stopping/yielding at a distance greater than 20 feet after the installation of countermeasures mentioned in stage 1 ($P<0.001$). The complete results of the statistical analyses of safety MOEs for pedestrians and drivers are shown in Table 63.

15.7.2 Mobility MOEs

Table 64 provides the summary of the tests for statistical significance of the results obtained for pedestrian and vehicle delays. This table shows that there is a significant decrease in the average pedestrian delay in stage 1 compared to baseline ($P=0.001$). There is no statistical evidence that the decrease in average vehicle delay is significant ($P>0.05$).

Table 63: Statistical test results of safety MOEs at Lake Mead Boulevard: Belmont Street to McCarran Street

Measures of Effectiveness (Safety)		Baseline vs. Stage 1		
		$P_B - P_1$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$				
Percent pedestrians who look for vehicles before beginning to cross		-0.03	>0.05	Do not Reject
Percent pedestrians who look for vehicles before crossing 2nd half of street		-0.08	<0.05	Reject
Percent of captured pedestrians		0.16	>0.05	Do not Reject
Percent of diverted pedestrians		-0.16	<0.001	Reject
Percent of drivers yielding to pedestrians		-0.36	<0.001	Reject
Distance driver stops/yields before crosswalk	<10 ft	-0.07	>0.05	Do not Reject
	10-20 ft	0.27	>0.05	Do not Reject
	>20 ft	-0.19	<0.001	Reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$				
Percent of pedestrians trapped in the roadway		0.56	<0.001	Reject

Table 64: Statistical test results of mobility MOEs at Lake Mead Boulevard: Belmont Street to McCarran Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1		
	$P_B - P_1$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$			
Average pedestrian delay (sec/ped)	11.90	0.001	Reject
Average vehicle delay (sec/veh)	-1.92	>0.05	Do not Reject

15.8 Summary

The results clearly show the impact of the deployed countermeasures in reducing the waiting time of the pedestrians before beginning to cross and the time spent in the middle of the roadway. Maryland Parkway and Dumont Street is a location with similar countermeasures installed without advance yield markings and "Yield Here to Pedestrian" signs in stage 1. The results at both the sites indicate that the countermeasures are effective in increasing the safety of the pedestrians by decreasing the percent of trapped pedestrians in roadway and increasing the drivers yielding behavior.

SITE 16: LAKE MEAD BOULEVARD / PECOS ROAD

16.1 Site description

The land use at this location is mainly residential. This site is an intersection of a six lane minor arterial (Lake Mead Boulevard) with two left turning lanes and with a speed limit 45 mph, and a six lane minor arterial (Pecos Road) with speed limit of 45 mph. This site is within the jurisdiction of City of North Las Vegas. There are a total of 9 crashes recorded at this intersection from 1996-2000. All the crashes that occurred at this location were injury crashes. The percentage of the motorist's failure to yield (67 percent) is double the percentage of the pedestrian's failure to yield (33 percent). Day time crashes account for 78 percent of the crashes. Figure 39 presents the aerial photograph of the site. Implementation plans and conceptual designs of this site are illustrated in Site 16 in Appendix B.

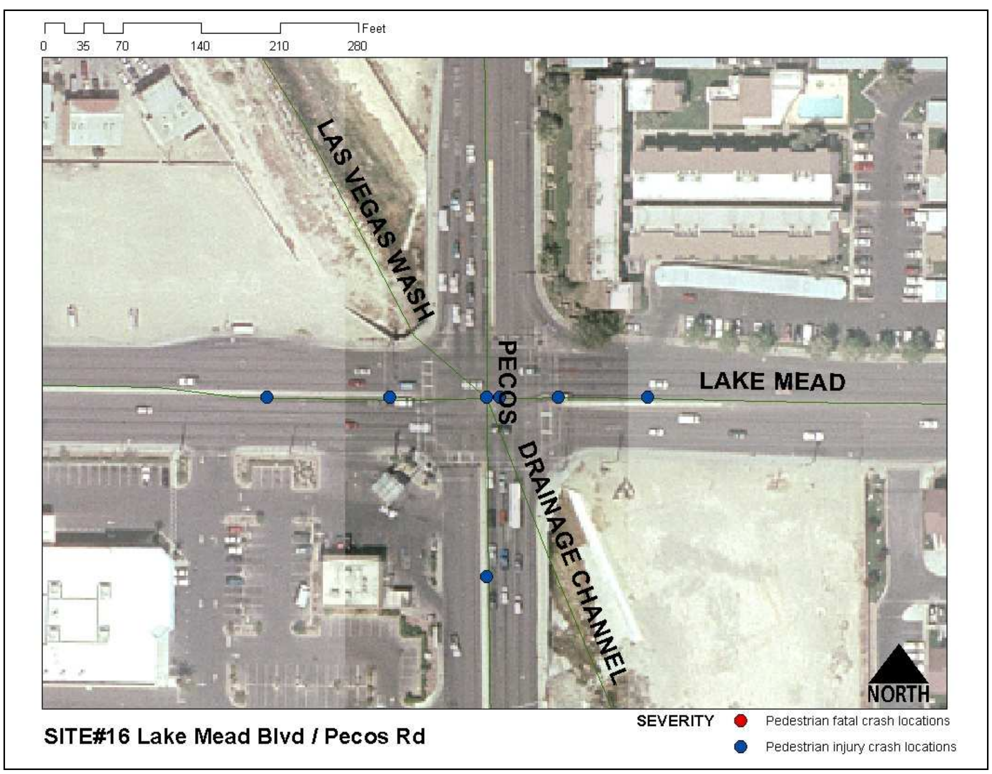

Figure 39: Aerial Photograph of Lake Mead Boulevard and Pecos Road

16.2 Problems Identified

After analyzing crash data and field observation data, some of the problems identified at this location include: motorist failure to yield, pedestrian failure to yield, pedestrians do NOT wait for signals/acceptable gaps, and high pedestrian/right turning vehicle conflicts.

16.3 Countermeasures Proposed

Countermeasures proposed at this location are “turning vehicles yield for pedestrian sign” and “warning sign for motorists.” The implementation plan for the proposed countermeasures at this location is shown in Table 65.

Table 65: Implementation Plan for Lake Mead Boulevard and Pecos Road

Treatment	Stage 1
Warning sign for motorists	**O**
Turning Vehicles Yield to Pedestrians	**O**

O - Installed

16.4 Countermeasures Installed

Stage 1 Countermeasure Deployment:

Countermeasures deployed during this stage are “Warning Signs for Motorists” and “Turning Vehicles Yield to Pedestrians.” These countermeasures were installed between May 16 and 20, 2005. The after condition data for Stage 1 countermeasure deployment was collected from June 6 to 10, 2005. Figure 40 shows the countermeasure deployed in Stage 1 at this location.

Figure 40: "Turning Traffic Must Yield to Pedestrian" signs installed at Lake Mead Boulevard and Pecos Road

16.5 Safety MOEs

The average vehicle delay increased marginally from 25.4 seconds/vehicle to 26.1 seconds/vehicle, before and after the installation of the sign, respectively. Similar trends were observed both morning and evening peak hours during both of the study periods. The percentage of motorists yielding also increases so that more vehicles yielded to pedestrians. Consequently, the vehicle delay also increases. Pedestrian delay increased from 42 seconds/pedestrian to 45 seconds/pedestrian before and after the installation of the sign respectively.

16.6 Statistical Results

The before-and-after study results show that the installation of the "Turning traffic must yield to pedestrians" sign has increased the proportion of motorists yielding at RTOR from 0.51 to 0.92 ($P<0.001$). On the contrary, the proportion of motorists yielding at right turn on green decreased marginally from 0.82 to 0.80 (P=0.566) during the after-study period. However, this difference is not statistically different at the 95 percent confidence level. The installation of the sign "Turning traffic must yield to pedestrians" shows an increase in motorists yielding while turning on red. The values of MOEs during before and after study periods, their difference and statistical significance are shown in Table 66.

Before the installation of the sign, "Turning traffic must yield to pedestrians," proportion of vehicles which block the crosswalk while turning increases from 0.39 before installation to 0.82 after installation (P<0.001). The observed stopping behavior of motorists before RTOR indicates that the proportion of motorists completely stopped before the sign is installed decreases from 0.75 before to 0.58 (P<0.001) after the sign is installed.

The proportion of pedestrians looking for turning vehicles at the beginning of the WALK signal decreases from 0.88 to 0.58 (P<0.001) before and after the installation of the sign respectively. The proportion of pedestrians who are stuck in the crosswalk during the flashing DON'T WALK phase and at the end of all red time decreased from 0.62 to 0.21 (P<0.001) and 0.031 to 0.027 (P=0.393) respectively during after study period.

Table 66: Statistical Test Results at Lake Mead Boulevard/Pecos Road

S. No.	Measures of Effectiveness	Before		After		(Before - After)	P-value	Null hypothesis
		Sample size	Value	Sample size	Value			
1	Motorists' yielding at right turn on red (in the presence of pedestrian at turn or approach), %	76	51.32	55	90.91	-39.59	<0.001	Reject
2	Motorists' yielding at right turn on green (in the presence of pedestrians), %	73	81.94	64	79.69	2.26	0.566	Do not reject
3	Percentage vehicles blocked the crosswalk, %	267	39.33	198	82.32	-43.00	1.000	Do not reject
4	Percentage of drivers executing right turn on red coming to complete stop, %	268	75.37	200	58.00	17.37	1.000	Do not reject
5	Pedestrian delay (sec/ped)	362	42.08	388	45.31	-3.23	0.914	Do not reject
6	Vehicle delay at intersection (sec/veh)							
	AM	812	18.60	1,243	19.82	N/A	N/A	
	PM	1,642	28.77	1,384	31.78	N/A	N/A	
	Total	2,454	25.40	2,627	26.12	N/A	N/A	
7	Percentage of pedestrians who looked at start of the WALK phase for turning vehicles, %	331	87.61	412	58.25	29.36	1.000	Do not reject
8	Percentage of pedestrians who were in the crosswalk during the flashing DON'T WALK phase, %	354	61.86	432	20.60	41.26	<0.001	Reject
9	Percentage of pedestrians who were in the crosswalk at the end of all-red, %	354	3.11	432	2.78	0.33	0.393	Do not reject
10	Percentage of pedestrians who were trapped in the middle of crossing, %	338	5.33	432	2.78	2.55	0.040	Reject
11	Percentage of pedestrian/vehicle evasive actions, change course/slow to avoid motorists, %	345	1.74	432	0.23	1.51	0.021	Reject
12	Vehicle speed (mph)							
	Eastbound	75	33.68	99	36.14	-2.46	0.963	Do not reject
	Westbound	50	40.53	75	29.66	10.87	<0.001	Reject
	Northbound	50	37.72	60	26.96	10.75	<0.001	Reject
	Southbound	50	35.94	60	31.16	4.78	<0.001	Reject

Note: $\alpha = 0.05$

The proportion of pedestrians trapped in the middle of the road while crossing decreases significantly during the after-condition from 0.05 to 0.03 (P=0.040). The motorists' yielding behavior while turning also shows an improvement. As a result, the percentage of pedestrians trapped in the middle decreases after installation of the sign.

The proportion of evasive actions decreases from 0.017 to 0.002 for the before and after study periods respectively. The difference of the proportion of evasive action between before and after period is significantly different (P=0.021) at the 95 percent confidence level. The average vehicle speeds decreases (P<0.001) significantly during the after study period in the northbound, southbound, and westbound directions. On the other hand, the average vehicle speeds shows an increase in the eastbound direction.

16.7 Summary

Statistical analysis of the data collected at this location before and after the installation of the “Yield to Pedestrian in Crosswalk” shows significant benefits that improved overall pedestrian safety at this location. The parameters that were improved after the installation of the countermeasure include, increase in the number of vehicles yielding to pedestrians in crosswalk, reduction in the percent of the vehicles blocking the crosswalk, and decrease of pedestrian delay.

SITE 17: FREMONT STREET: 11^{TH} STREET AND 8^{TH} STREET

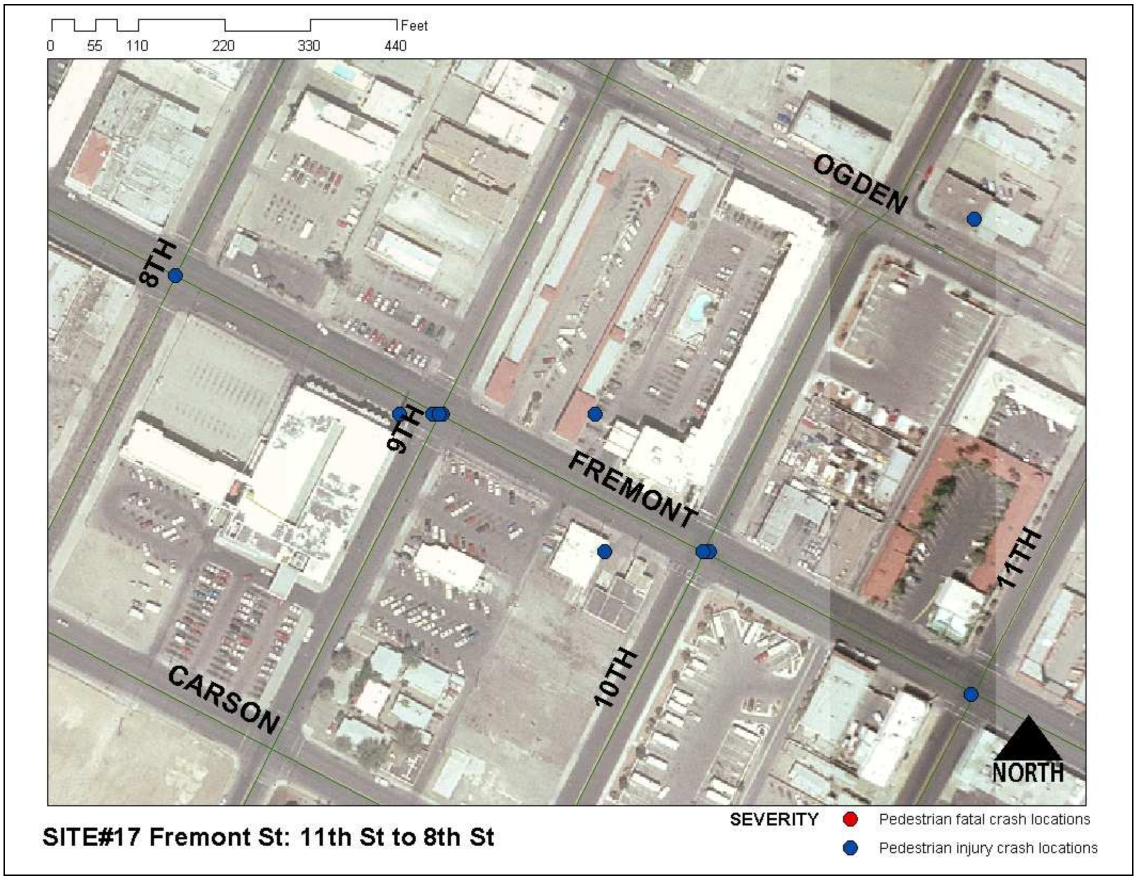

Figure 41: Aerial Photograph of Fremont Street: 11^{th} Street to 8^{th} Street (Control Site)

SITE 18: FREMONT STREET: 6TH STREET AND 8TH STREET

18.1 Site description

Land use adjacent to the corridor includes hotels, casinos and other commercial activities. The location is within the jurisdiction of the City of Las Vegas. Fremont Street is classified as a minor arterial and the posted speed limit is 25 mph. As per 2006 traffic count statistics, the ADT at Fremont Street is 13,800 along this corridor. Figure 42 presents the aerial photograph of the site. Implementation plan and conceptual designs of this site are presented in Site 18 in Appendix B.

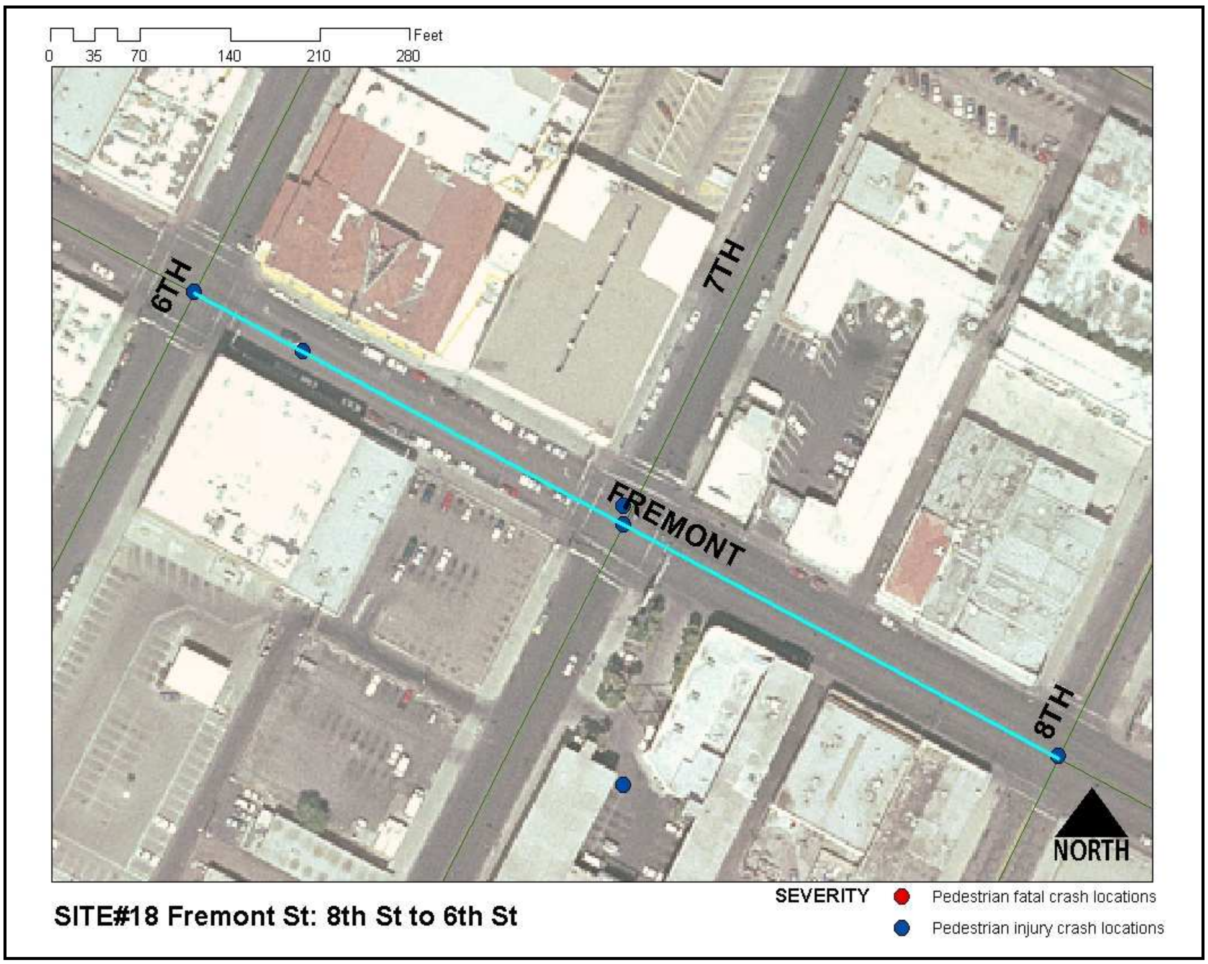

Figure 42: Aerial Photograph of Fremont Street: 8th Street to 6th Street

18.2 Problems Identified

Some of the problems identified at Fremont Street from 8th Street to 6th Street are pedestrians not using the crosswalks, a high percentage of elderly pedestrians involved in crashes, and pedestrians failing to yield. Speeding is a key observed problem at this corridor.

18.3 Countermeasures Proposed

A "Portable speed trailer" is proposed for this location. The installation of portable speed trailers is expected to make motorists aware of the posted speed limit and their current speed. The speed trailers are intended to help motorists to reduce their speed. The other countermeasures at this site include "In-roadway knockdown signs" and "Pedestrian call button that confirm press." The implementation plan for the proposed countermeasures at this location is shown in Table 67.

Table 67: Implementation Plan for Fremont Street: 8th Street to 6th Street

Treatments	Stage 1	Stage 2	Stage 3
Portable speed trailers	**O**	**X**	**X**
In-roadway knockdown signs		**O**	**O**
Pedestrian call buttons that light up			**O**

O - Installed
X - Countermeasure removed

18.4 Countermeasures Installed

Various countermeasures are deployed in three stages and data are collected on weekdays at Fremont Street between 6th Street and 8th Street.

Stage 1 Countermeasure Deployment

Countermeasure deployed during this stage is "Portable speed trailer." This countermeasure is installed between January 1 and 28, 2006. The after condition data for stage 1 countermeasure deployment is collected on February 16, 2006. Figure 43 shows the countermeasures deployed in stage 1 at this location.

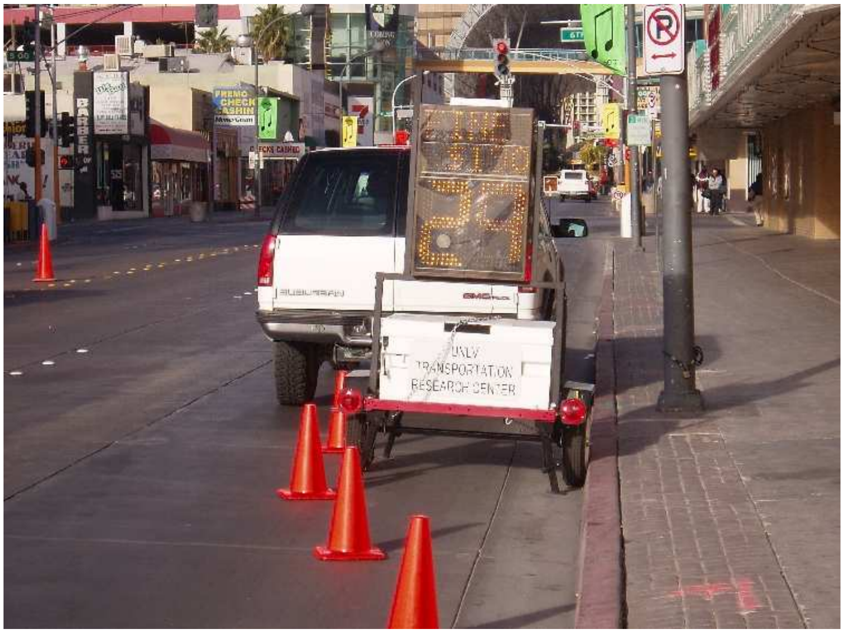

Figure 43: Portable Speed Trailer on Fremont Street

Stage 2 Countermeasure Deployment

Countermeasures deployed during this stage are "In-roadway knockdown signs." This countermeasure is installed on April 25, 2006. The after condition data for stage 2 countermeasure deployment are collected on May 16, 2006. Figure 44 shows the countermeasures deployed in stage 2 at this location.

Figure 44: In-Roadway Knockdown Signs

Stage 3 Countermeasure Deployment

Countermeasures deployed during this stage are “Pedestrian button that confirm press.” This countermeasure is installed between September 25 and 29, 2006. The after condition data for stage 3 countermeasure deployment is collected on December 19, 2006. Figure 45 shows the countermeasures deployed in Stage 3 at this location.

Figure 45: Pedestrian Push Button that Confirm Press

The results of the pedestrian and motorist MOEs are summarized in Tables 68, and 69 respectively. The average pedestrian delay at this site for each stage is shown in Table 70. The statistical significance of the results obtained for all the stages is shown in Tables 71 and 72.

18.5 Safety MOEs

18.5.1 Pedestrian MOEs

Table 68 shows that all of the observed pedestrians look for vehicles before beginning to cross the roadway during all the stages including baseline period. No pedestrians are observed as trapped in the roadway in the baseline period. The proportion of the pedestrians violated the signal in the baseline condition is about 0.17. The proportion of pedestrians who begin their crossing during WALK phase during the baseline period is almost negligible. The deployment of portable speed trailer increases the proportion of pedestrians trapped very slightly. The proportion of pedestrians violating the signal reduced to 0.15 percent in stage 1 compared to the baseline. The installation of in-roadway knockdown signs in stage 2 increases the proportion of pedestrians who begin their crossing during WALK phase to 0.79. However, stage 1 data are not available for this MOE to compare the incremental effect from stage 1 to stage 2. Proportion of signal cycles in which the call button has been pushed is 0.18 in stage 2. The installation of pedestrian push button that confirm press increases the proportion of signal cycles in which call button has been pushed to 0.39 percent. The proportion of pedestrian signal violation decreases to 0.09 in stage 3 compared to other stages. Proportion of pedestrians are trapped in the roadway in stage 3 is negligibly small.

18.5.2 Motorist MOEs

From Table 69, the proportion of drivers yielding to pedestrians is 0.67 during baseline period. About 0.06 proportions of the observed drivers blocks the crosswalk during the same period. Proportion of the drivers stop/yield to pedestrians away from the stop bar is about 0.20. The installation of the speed trailer in stage 1 eliminates all the drivers from blocking the crosswalk. The proportion of drivers yielding to pedestrians decreased to 0.43 in stage 1. In stage 2, almost all of the drivers yield to pedestrians, and only 0. 16 proportions of the drivers block the crosswalk. There are no pedestrians observed to have trapped in the roadway in stage 3.

Table 68: Results of safety MOEs for pedestrians at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)	Baseline			Stage 1			Stage 2			Stage 3		
	Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent
Percent of pedestrians trapped in the roadway	716	0	0	517	5	1	437	9	2	275	1	0.4
Percent of pedestrians who look for vehicles before beginning to cross	716	716	100	517	517	100	437	437	100	275	275	100
Frequency of pedestrian signal violation	716	125	17	517	78	15	437	63	14	275	24	9
Percent of pedestrians who begin their crossing during WALK phase	1013	11	1	-	-	-	202	159	79	248	176	71
Percent signal cycles in which call button has been pushed	-	-	-	-	-	-	202	36	18	174	67	39

Table 69: Results of safety MOEs for motorist at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)		Baseline			Stage 1			Stage 2			Stage 3		
		Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent	Sample	N_B	Percent
Percent of drivers yielding to pedestrians		96	64	67	28	12	43	26	25	96	22	18	82
Distance driver stops/yields before crosswalk	at crosswalk	64	41	64	12	0	0	25	13	52	18	9	50
	between crosswalk and stop bar	64	10	16	12	11	92	25	7	28	18	5	28
	away from stop bar	64	13	20	12	1	8	25	5	20	18	4	22
Percent of drivers blocking crosswalk		161	10	6	12	0	0	25	4	16	22	0	0

18.6 Mobility MOEs

18.6.1 Pedestrian Delay

Table 70 shows the results and a comparison of the average pedestrian delay at this location for various stages. The average pedestrian delay at baseline period is 9.8 sec/ped. There is a reduction in average pedestrian delay in stage 1 compared to baseline data. The installation of in-roadway knockdown signs in stage 2 increased the pedestrian delay to 56.3 sec/ped. A reduction in this MOE is observed in stage 3 compared to stage 2, but increased compared to baseline and stage 1 data.

Table 70: Delay at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2		Stage 3	
	Sample	Delay	Sample	Delay	Sample	Delay	Sample	Delay
Average Pedestrian Delay (sec/ped)	716	9.79	517	7.29	437	56.25	275	11.62

18.7 Statistical Results

18.7.1 Safety MOEs

The results of the statistical analyses are summarized in Table 71. They show that there is no significant change in the proportion of pedestrians who look for vehicles before beginning to cross in stage 1 compared to baseline period. There is no significant decrease in the proportion of pedestrians trapped in the roadway and frequency of pedestrian signal violation in stages 1 and 2 compared to the baseline results ($P>0.05$). The implementation of "pedestrian push button that confirm press" in stage 3 has a significant impact in increasing the percent of pedestrians who begin their crossing during WALK phase ($P<0.001$). This in turn resulted in decreasing the frequency of pedestrian signal violation ($P<0.001$) compared to the baseline data. It is also observed that there is a significant increase in the percent of signal cycles in which the call button has been pushed from stage 2 to stage 3 as shown in Table 73 ($P<0.001$). The percent of signal cycles in which call button has been pushed increased significantly in stage 3 compared to stage 2. There is a significant decrease in the percent of pedestrians trapped in the roadway and pedestrian signal violation in stage 3 compared to stage 2.

From Table 73, it is clear that there is no significant increase in the proportion of drivers yielding to pedestrians in stage 1 compared to baseline ($P>0.05$). However, there is a significant decrease in the proportion of drivers blocking crosswalk ($P=0.001$). Installation of in-roadway knockdown signs in stage 2 significantly increases the yielding behavior of drivers to pedestrians ($P<0.001$). There is not sufficient evidence to suggest the decrease in the percent of drivers stopping/yielding at crosswalk, and between crosswalk and stop bar in stage 2 compared to baseline conditions. However, the decrease in the percent of drivers stopping/yielding between crosswalk and stop bar in stage 2 compared to stage 1 is significant as shown in Table 75 ($P<0.001$).

Table 71: Statistical test results of safety MOEs for pedestrians at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$									
Percent of pedestrians who look for vehicles before beginning to cross		No change			No change			No Change	
Percent of pedestrians who begin their crossing during WALK phase	-	-	-	-0.77	<0.001	Reject	-0.69	<0.001	Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Percent of pedestrians trapped in the roadway	-0.009	>0.05	Do not Reject	-0.02	>0.05	Do not Reject	-0.003	>0.05	Do not Reject
Frequency of pedestrian signal violation	0.02	>0.05	Do not Reject	0.03	>0.05	Do not Reject	0.08	<0.001	Reject

Table 72: Statistical test results of safety MOEs for pedestrian between stages at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$						
Percent of pedestrians who look for vehicles before beginning to cross		No Change			No Change	
Percent of pedestrians who begin their crossing during WALK phase	-	-	-	0.07	>0.05	Do not Reject
Percent signal cycles in which call button has been pushed	-	-	-	-0.20	<0.001	Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Percent of pedestrians trapped in the roadway	-0.01	>0.05	Do not Reject	0.01	<0.05	Reject
Frequency of pedestrian signal violation	0.006	>0.05	Do not Reject	0.05	<0.05	Reject

Table 73: Statistical test results of safety MOEs for motorists at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)		Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
		$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$										
Percent of drivers yielding to pedestrians		0.23	>0.05	Do not Reject	-0.29	<0.001	Reject	-0.15	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	Away from stop bar	0.11	>0.05	Do not Reject	0.003	>0.05	Do not Reject	-0.01	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$										
Distance driver stops/yields before crosswalk	at crosswalk	0.64	<0.001	Reject	0.12	>0.05	Do not Reject	0.14	>0.05	Do not Reject
	Between crosswalk and stop bar	-0.76	>0.05	Do not Reject	-0.12	>0.05	Do not Reject	-0.12	>0.05	Do not Reject
Percent of drivers blocking crosswalk		0.06	0.001	Reject	-0.09	>0.05	Do not Reject	0.06	0.001	Reject

Table 74: Statistical significance of safety MOEs for motorist between stages at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Safety)		Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
		$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$							
Percent of drivers yielding to pedestrians		-0.53	<0.001	Reject	0.14	>0.05	Do not Reject
Distance driver stops/yields before crosswalk	away from stop bar	-0.11	>0.05	Do not Reject	-0.02	>0.05	Do not Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$							
Distance driver stops/yields before crosswalk	at crosswalk	-0.52	>0.05	Do not Reject	0.02	>0.05	Do not Reject
	Between crosswalk and stop bar	0.63	<0.001	Reject	0.002	>0.05	Do not Reject
Percent of drivers blocking crosswalk		-0.16	>0.05	Do not Reject	0.16	<0.05	Reject

18.7.2 Mobility MOEs

Results from Table 75 indicates that there is a significant decrease in the average pedestrian delay in stage 1 compared to baseline data ($P<0.001$). There is no significant reduction in pedestrian delay in any other stages compared with baseline as well as comparison between stages (Tables 75 and 76).

18.8 Summary

Installation of the countermeasures mentioned at this location has significant effect in improving some of the pedestrian safety MOEs. The installation of the portable speed trailer, in-roadway knockdown signs and pedestrian push button that confirm press has significant impacts in increasing drivers' yielding behavior to pedestrians and reducing the drivers blocking the crosswalk in one or the other stages at this location.

Table 75: Statistical test results of mobility MOE at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2			Baseline vs. Stage 3		
	$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0	$P_B - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$									
Average Pedestrian Delay (sec/ped)	2.5	<0.001	Reject	-46.5	>0.05	Do not Reject	-1.83	>0.05	Do not Reject

Table 76: Statistical test results of mobility MOE between stages at Fremont Street: 6th Street to 8th Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2			Stage 2 vs. Stage 3		
	$P_1 - P_2$	P-value	H_0	$P_2 - P_3$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average Pedestrian Delay (sec/ped)	-49.0	>0.05	Do not Reject	44.60	>0.05	Do not Reject

SITE 19: CHARLESTON BOULEVARD: SPENCER STREET TO 17TH STREET

19.1 Site description

Land use classification along Charleston Boulevard corridor includes office complexes, several small commercial activity units, restaurants, and apartments. The location is within the jurisdiction of the City of Las Vegas and the Nevada Department of Transportation (NDOT). Charleston Boulevard between Spencer Street and 17th Street is a mid-block location. The posted speed limit is 35 mph. The ADT along Charleston Boulevard in the study area is estimated to be 37,500 in the year 2006. Figure 46 presents the aerial photograph of the site.

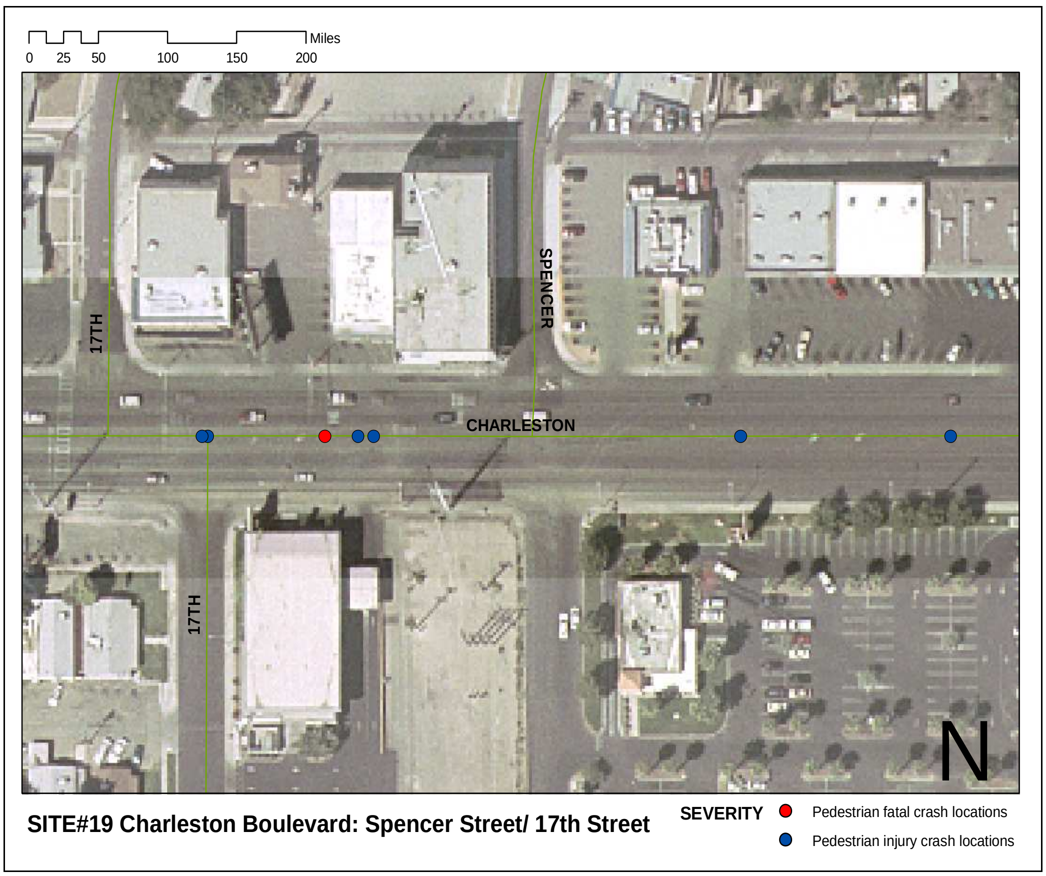

Figure 46: Aerial Photograph of Charleston Boulevard: Spencer Street to 17th Street

19.2 Problems Identified

Some of the problems identified are pedestrians not using the crosswalks, high proportions of elderly pedestrian crashes, motorists failing to yield, pedestrians not waiting for signals/acceptable gaps, and high proportions of nighttime crashes. This mid-block site does not have a crosswalk present. Therefore, pedestrians are expected to use crosswalks located at nearby intersections. However, crash data show several pedestrian crashes occurring away from the intersections.

19.3 Countermeasures Proposed

A "High visibility crosswalk" treatment is proposed at this location to help reduce jaywalking in the vicinity. "Advance yield markings" upstream of the crosswalk alert motorists to yield for pedestrians. "Automatic pedestrian detection devices" and "Smart lighting" help to detect the presence of a pedestrian and brighten up the crosswalk with high intensity lights. These countermeasures are intended to address a significant number of nighttime crashes at this site. Because of the automatic pedestrian detection system, pedestrians are expected to be detected even if they do not press the button to activate smart lighting. The implementation plan for the proposed countermeasures at this location is shown in Table 77.

Table 77: Implementation Plan for Charleston Boulevard/Spencer Street

Treatments	Stage 1	Stage 2
Warning signs for motorists	**O**	**O**
High visibility crosswalk	**O**	**O**
Advance yield markings + sign yield to pedestrians	**O**	**O**
ITS automatic pedestrian detection devices		**O**
Smart Lighting		**O**

O - Installed

19.4 Countermeasures Installed

The study site of Charleston Boulevard from Spencer Street to 17th Street is a mid-block location. Countermeasures are installed in two stages at this location.

Stage 1 Countermeasure Deployment

Countermeasures deployed during this stage are High visibility crosswalk treatment, Advance yield markings and Warning signs for motorists. These countermeasures are installed between August 22 and 26, 2005. The after condition data for stage 1 countermeasures deployment are collected on September 12 and 16, 2005. Figure 47 and Figure 48 show the countermeasures deployed in stage 1 at this location.

Figure 47: High Visibility Crosswalk Treatment at Charleston Boulevard and 17^{th} Street

Figure 48: "Advanced Yield Markings" installed at Site 19

Stage 2 Countermeasure Deployment

Countermeasures deployed during this stage are "ITS Pedestrian detection device, Smart lighting." These countermeasures are installed between January 16 and 19, 2007. The after condition data for Stage 2 countermeasure deployment are collected on February 22 and 26, 2007. Figure 49 and Figure 50 show the countermeasures deployed in stage 2.

Figure 49: Smart Lighting

Figure 50: Automatic Pedestrian Detection

The results of the safety MOEs are summarized in Tables 78 and 79. At this location, innovative ITS pedestrian detection device with smart lighting is installed to address the high proportion of nighttime crashes. Results of the statistical tests for the safety MOEs comparing the baseline conditions with each stage and between stages are shown in Tables 82 and 83 respectively. The overall summary and results of statistical analyses of delays and vehicle speed are shown in Tables 80 and 81, and Tables 84 to 85, respectively.

19.5 Safety MOEs

19.5.1 Pedestrian MOEs

During all the data collection periods, such as, baseline, and stages 1 and 2, all the observed pedestrians look for vehicles before beginning to cross and before crossing second half of the roadway as shown in Table 78. Data show that the countermeasures installed in stage 2 results in increase in the number of diverted pedestrians. In addition, the proportion of pedestrians trapped in the roadway reduces for each stage of the installation of the countermeasures.

19.5.2 Motorist MOEs

Data collected for the evaluation of motorist MOEs are summarized in Table 79. The deployment of countermeasures in stages 1 and 2 increases the proportion of drivers yielding to pedestrians compared to the baseline period. Also, an increase in the proportion of drivers who stop/yield to pedestrians at a distance greater than 20 feet is observed in stage 2. However, a notable proportion of drivers blocked the crosswalk during stage 2 data collection.

Table 78: Results of pedestrian MOEs at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Safety)	Baseline		Stage 1		Stage 2	
	Sample = 24		Sample = 44		Sample = 84	
	N_B	Percent	N_1	Percent	N_2	Percent
Percent pedestrians who look for vehicles before beginning to cross	24	100	44	100	84	100
Percent pedestrians who look for vehicles before crossing 2nd half of street	24	100	44	100	84	100
Percent of captured pedestrians	24	100	44	100	70	83
Percent of diverted pedestrians	0	0	0	0	14	17
Percent of pedestrians trapped in the roadway	9	38	13	30	12	14

Table 79: Results of motorist MOEs at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Safety)		Baseline		Stage 1		Stage 2	
		Sample = 50		Sample = 91		Sample = 116	
		N_B	Percent	N_1	Percent	N_2	Percent
Percent of drivers yielding to pedestrians		3	6	20	22	41	35
		Sample = 3		Sample = 20		Sample = 41	
Distance driver stops/yields before crosswalk	< 10 ft	2	67	8	40	16	39
	10-20 ft	0	0	10	50	16	39
	>20 ft	1	33	2	10	9	22
		Sample = N/A		Sample = 20		Sample = 41	
Percent of drivers blocking crosswalk		N/A	N/A	0	0	5	12

19.6 Mobility MOEs

The average pedestrian and vehicle delay measured at this location is shown in Table 80 for different stages. The average travel speed of the vehicle is shown in Table 81.

19.6.1 Pedestrian Delay

The average pedestrian delay for the baseline conditions is 15.42 sec/ped. After the installation of the countermeasure in stage 1, the average pedestrian delay decreased to 7.52 sec/ped. The average pedestrian delay further decrease to 3.82 sec/ped in stage 2.

19.6.2 Vehicle Delay

Average vehicle delay increased in stage 1 as well as in stage 2. The increase in vehicle delay is greater in stage 2.

19.6.3 Vehicle Speed

The mean of the observed speeds on eastbound and westbound direction, at the baseline conditions is 32.2 mph and 24.9 mph, respectively. An increase in the mean speed is observed in both directions during stage 1 when compared to baseline.

Table 80: Delays at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1		Stage 2	
	Sample	Delay	Sample	Delay	Sample	Delay
Average pedestrian delay (sec/ped)	24	15.42	44	7.52	84	3.82
Average vehicle delay (sec/veh)	50	0.34	91	0.74	116	2.16

Table 81: Speeds at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Mobility)	Baseline		Stage 1	
	Sample	Mean speed	Sample	Mean speed
Eastbound (mph)	266	32.2	172	33.4
Westbound (mph)	250	24.9	223	30.7

19.7 Statistical Results

19.7.1 Safety MOEs

The increase in the percent of captured pedestrian is statistically significant when stage 2 is compared with baseline. The percent of increase in the diverted pedestrians from baseline to stage 2, and stage 1 to stage 2 is statistically significant ($P<0.001$). There is a significant decrease in the proportion of pedestrians trapped in the roadway in stage 2 from baseline condition and 15 percent in stage 2 from stage 1 ($P<0.05$).

From Tables 82 and 83, it can be seen that there is a significant increase in the proportion of drivers yielding to pedestrians from the baseline to stage 1 ($P<0.05$), the baseline to stage 2 ($P<0.001$), and stage 1 to stage 2 ($P<0.05$). Therefore, there is sufficient evidence to reject the null hypothesis at a 95 percent confidence level. The increase in the proportion of drivers yielding distance (10 feet to 20 feet) in stage 1 and stage 2, respectively from the baseline are statistically significant ($P<0.001$). There is no significant increase in the proportion of drivers blocking the crosswalk from stage 1 to stage 2 at this location as shown in Table 83 ($P>0.05$).

Table 82: Statistical test results of safety MOEs at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Safety)		Baseline vs. Stage 1			Baseline vs. Stage 2		
		$P_B - P_1$	P-value	H_0	$P_B - P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$							
Percent pedestrians who look for vehicles before beginning to cross			No Change			No Change	
Percent pedestrians who look for vehicles before crossing 2nd half of street			No Change			No Change	
Percent of captured pedestrians			No Change		0.16	>0.05	Do not Reject
Percent of diverted pedestrians			No Change		-0.16	<0.001	Reject
Percent of drivers yielding to pedestrians		-0.15	<0.05	Reject	-0.29	<0.001	Reject
Distance driver stops/yields before crosswalk	< 10 ft	0.27	>0.05	Do not Reject	0.28	>0.05	Do not Reject
	10-20 ft	-0.50	<0.001	Reject	-0.39	<0.001	Reject
	>20 ft	0.23	>0.05	Do not Reject	0.11	>0.05	Do not Reject
MOE below is tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$							
Percent of pedestrians trapped in the roadway		0.07	>0.05	Do not Reject	0.23	<0.05	Reject

Table 83: Statistical test results of safety MOEs between stages at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Safety)		Stage 1 vs. Stage 2		
		$P_1 - P_2$	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} > P_{before}$				
Percent pedestrians who look for vehicles before beginning to cross			No Change	
Percent pedestrians who look for vehicles before crossing 2nd half of street			No Change	
Percent of captured pedestrians		0.16	>0.05	Do not Reject
Percent of diverted pedestrians		-0.16	<0.001	Reject
Percent of drivers yielding to pedestrians		-0.13	<0.05	Reject
Distance driver stops/yields before crosswalk	< 10 ft	0.01	>0.05	Do not Reject
	10-20 ft	0.11	>0.05	Do not Reject
	>20 ft	-0.12	<0.05	Reject
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$				
Percent of pedestrians trapped in the roadway		0.15	<0.05	Reject
Percent of drivers blocking crosswalk		-0.12	>0.05	Do not Reject

19.7.2 Mobility MOEs

Even though there is a reduction in pedestrian delay from stage 1 to stage 2, it is not statistically significant (P>0.05). There is no significant change in the average vehicle delay in baseline, stage 1 and stage 2 as shown in Tables 84 and 85 (P>0.05). Therefore, the effectiveness of the countermeasures installed at this location has no significant effect in reducing the average vehicle delay. The statistical significance of change in the average speed of the vehicle in stage 1 to baseline is shown in Table 86.

Table 84: Statistical test results of mobility MOEs at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1			Baseline vs. Stage 2		
	Difference in Mean	P-value	H_0	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$						
Average pedestrian delay (sec/ped)	7.90	>0.05	Do not Reject	11.60	<0.05	Reject
Average vehicle delay (sec/veh)	-0.40	>0.05	Do not Reject	-1.82	>0.05	Do not Reject

Table 85: Statistical test results of mobility MOEs between stages at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Mobility)	Stage 1 vs. Stage 2		
	Difference in Mean	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Average pedestrian delay (sec/ped)	3.70	>0.05	Do not Reject
Average vehicle delay (sec/veh)	-1.42	>0.05	Do not Reject

Table 86: Statistical test results of vehicle speed at Charleston Boulevard: Spencer Street to 17th Street

Measures of Effectiveness (Mobility)	Baseline vs. Stage 1		
	Difference in Mean Speed	P-value	H_0
MOEs below are tested for H_0: $P_{before} = P_{after}$ vs. H_a: $P_{after} < P_{before}$			
Eastbound (mph)	-1.20	>0.05	Do not Reject
Westbound (mph)	-5.80	>0.05	Do not Reject

19.8 Summary

It is clear that implementation of ITS pedestrian detection device and smart lighting has a significant effect in increasing the proportion of diverted pedestrians and decreasing the proportion of pedestrians trapped in the roadway, thereby increasing the pedestrian safety. The installation of warning signs for motorists, high visibility crosswalk, and advance yield markings do not show significant effect in reducing the vehicles speed at this location.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

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CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the results of fifteen countermeasures installed at fourteen sites across the Las Vegas metropolitan to evaluate their effectiveness in enhancing pedestrian safety. Some the countermeasures were aimed at changing motorists' behavior whereas the others were aimed at improving pedestrians' crossing behavior. The summary of the effectiveness of various countermeasures are described as follows.

Initially seventeen countermeasures are selected to evaluate in this study. However, due to the unavailability of vendors to manufacture custom make countermeasures, it is later reduced to fifteen. The summary of the effectiveness of these countermeasures are as follows:

1. "Turning Vehicles Yield to Pedestrians" signs: Significant improvement in motorists' yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street.
2. Advance yield markings for Motorists: Significant improvement in motorists' yielding behavior.
3. In roadway knockdown signs: Significant improvement in motorists' yielding behavior, reduction in percent of pedestrians trapped in the middle of the street.
4. ITS "No-Turn on Red" signs: Significant improvement in pedestrians' compliance.
5. Pedestrian call button that light up: Significant improvement in pedestrians' compliance, significant reduction in percent of pedestrians trapped in the middle of the street.
6. Warning signs for motorists: No significant improvement in either motorist or pedestrian MOEs.
7. High visibility crosswalk treatment: Significant increase in yielding distance by motorists, significant improvement in pedestrians' yielding behavior.

8. Median refuge: Significant improvement in motorists’ yielding behavior, significant increase in motorists’ yielding distance, significant improvement in pedestrians’ yielding behavior.
9. Smart lighting: Significant improvement in motorists’ yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of “diverted” pedestrians.
10. ITS automatic pedestrian detection devices: Significant improvement in motorists’ yielding behavior, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of “diverted” pedestrians.
11. Portable speed trailer: Significant increase in motorists’ yielding distance.
12. Pedestrian activated flashing yellow: Significant increase in motorists’ yielding distance, significant reduction in percent of drivers blocking crosswalk, significant improvement in pedestrian yielding behavior.
13. Pedestrian countdown signals with animated eyes: Significant improvement in pedestrians’ looking for turning vehicles.
14. Danish offset: Significant improvement in motorists’ yielding behavior, significant increase in motorists’ yielding distance, significant reduction in percent of pedestrians trapped in the middle of the street, significant increase in percent of “diverted” pedestrians.
15. Pedestrian channelization: No significant improvement in either motorists’ or pedestrians’ MOEs

These results indicate that while most of the countermeasures helped to enhance the safety, some others were not that effective in improving safety. In this study, several countermeasures were implemented together during same stage. Even though they showed significant safety improvements, since they were implemented as a group, the effects of individual countermeasures could not be evaluated. However, several of these countermeasures in the combination are relatively inexpensive. Therefore, if these were to be deployed at any other locations, it would be economically feasible.

CHAPTER 7

APPENDIX LITERATURE REVIEW

CHAPTER 7
APPENDIX: LITERATURE REVIEW

A summarized review of the literature on different pedestrian safety countermeasures is presented in this chapter. It focuses primarily on documentation related to the various and their effectiveness.

Advance Yield Markings, and Yield Here to Pedestrian Signs

Van Houten and Malenfant (1992) evaluated the effectiveness of signs reading "STOP HERE FOR PEDESTRIANS" alone 50 feet upstream of crosswalk and in conjunction with advance stop lines at multilane crosswalks with pedestrian activated amber flashing lights [1]. The type of motor vehicle conflicts, distance the motorists stopped upstream of the crosswalk when yielding to pedestrians, and the percentage of motorists yielding to pedestrians are determined from field observations. Results indicated that signs alone increased the distance that motorists stopped upstream of the crosswalk when yielding to pedestrians and also decreased the percentage of motor vehicle-pedestrian conflicts. The addition of advance stop lines produced a further increase in the distance that motorists stopped upstream of the crosswalk and further reductions in the percentage of motor-vehicle conflicts. These results are observed under conditions when pedestrians activated and did not activate the amber flashing crosswalk light. It is also observed that the percentage of pedestrians activating the light seemed to be a function of the amount of traffic on the street.

Van Houten, Malenfant and McCusker (2001) studied two problems; the difference between the 'yield' and 'stop' situation while using the advance stop lines, and the use of text rather than symbol sign to support the markings [2]. The advance yield markings and signs are placed at different distances in advance of the crosswalks to determine their effectiveness. Motorist and pedestrian behaviors measured included the occurrence of motor vehicle/pedestrian conflicts such as evasive action, the distance motorists stopped before the crosswalk when yielding to pedestrians, and the percentage of motorists yielding to pedestrians. It is found that placing the advance yield markings and signs as close as 10 m upstream the crosswalk and as far back as 15 m or even 25 m in advance of the crosswalk is effective. Although not all vehicles stopped at or near the yield lines, many motorists stopped 9 m or more upstream the crosswalk. It is noted that motorists tended to stop closer to the crosswalk during the treatment condition when traffic is heavy and vehicles are traveling slowly. Much of the improved yielding is likely the result of improved visibility of pedestrians crossing in front of vehicles stopped in advance of the crosswalk.

Van Houten (1998) studied the effect of specific signs and stop line bars designed to influence motorists to stop further upstream from the crosswalk when yielding right of way to pedestrians [3]. Results indicated that such a simple, inexpensive prompting intervention could reduce conflicts between motorists and pedestrians. The introduction of the prompt and stop line reduced motor-vehicle-pedestrian conflicts by almost 80%.

Abdulsattar, Tarawneh, McCoy, and Kachman (1996) evaluated the effectiveness of the “turning traffic must yield to pedestrians” sign. Such signs are installed at 12 marked crosswalks and data are collected before and after the installation of the signs. The measure of effectiveness considered is vehicle-pedestrian conflicts. The results showed that the sign is effective in reducing left-turn conflicts by 20 to 65 percent, and right-turn conflicts by 15 to 30 percent. Both reductions are statistically significant at the 0.05 level [4].

Abdulsattar and McCoy (1999) conducted drivers’ comprehension of a “turning traffic must yield to pedestrians” sign among different age groups during turning maneuvers. For the left-turn situation, younger drivers (under 56 years) paid more attention to the sign than older drivers. During right-turn movements, drivers and pedestrians always are in interaction, unless exclusive right-turn phase is provided. However, this research lacks info on other measures of effectiveness such as motorists’ yielding behaviors, pedestrian and vehicle delay, and vehicle speed [5].

Huybers, Van Houten and Malenfant (2004) studied the effects of a symbolic ‘‘yield here to pedestrians’’ sign and advance yield pavement markings on pedestrian/motor vehicle conflicts, motorists’ yielding behavior, and the distance motorists’ yield in advance of crosswalks at multilane crosswalks at uncontrolled T intersections [6]. When the sign symbolic is used alone, there is a reduction in pedestrian/motor vehicle conflicts and increased motorist yielding distance. The use of fluorescent yellow-green sheeting as the background of the sign did not increase the effectiveness of the sign. Further reductions in pedestrian/motor vehicle conflicts and further increases in yielding distance are associated with the addition of advance yield pavement markings. Advance yield pavement markings, when used alone, are as effective in reducing pedestrian/motor vehicle conflicts and increasing yielding distance as the sign combined with pavement markings.

Retting, Van Houten, Malenfant, Van Houten and Farmer (1996) discussed an experiment in which special signs and pavement markings are used to prompt pedestrians to look for turning vehicles [7]. Three signalized intersections are chosen, two in Nova Scotia, Canada, and one in Clearwater, Florida for the study. All sites are studied before, immediately after, and approximately one year after prompts are introduced. At Nova Scotia, signs which says “Pedestrians: LOOK FOR TURNING VEHICLES” are installed at one site and painted prompts that read “WATCH TURNING VEHICLES” are installed at the second site. After observations are recorded, painted prompts are added to the signs and vice versa. At Clearwater, signs and painted prompts are installed together. The introduction of either sign or painted prompts alone increased the percentage of pedestrians looking for turning vehicles. With the introduction of second prompt, a further improvement in the percentage of pedestrians looking for vehicles is observed. Introduction of both prompts together led to a large increase in the percentage of pedestrians looking for vehicles. It is also noted that the conflicts are nearly eliminated by the prompting interventions.

Van Houten, Malenfant, Van Houten, and Retting (1997) evaluated auditory pedestrian signals and their effect in reducing vehicle and pedestrian conflicts [8]. The percentage of pedestrians not looking for potential threats and conflicts are reduced after the implementation of an auditory signal.

Turner, Fitzpatrick, Brewer and Park (2006) evaluated engineering treatments that can be used to improve the safety of pedestrians crossing in marked crosswalks on busy arterials [9]. They also discussed the analysis of street and traffic characteristics that influenced motorist yielding at un-signalized intersections. The devices that showed red indication to the motorist had a more significant compliance rate than the devices that did not show a red indication. The measured motorist yielding distance for many crossing treatments varied considerably among sites. A statistical analysis did not find any significant differences between many of the crossing treatments even though the difference in average compliance rates appeared to be practically significant. The number of lanes crossed by the pedestrians and the posted speed limit had an effect on the performance of treatments.

Huang, Zegeer, and Nassi (2000) studied a behavioral evaluation of three devices at a eleven locations under different conditions [10]. Pedestrian safety cones in New York and an overhead crosswalk sign in Seattle appeared to be promising tools for enhancing pedestrian safety at mid-block crosswalks on low-speed two-lane roads. The pedestrian-activated signs in Tucson are not as effective in increasing compliance with other devices as they are installed on four and six-lane high speed arterials. None of the treatments had a clear effect on whether people crossed in the crosswalk. The devices by themselves did not ensure that motorists will slow down and yield to pedestrians.

Hakkert, Gitelman, and Ben-Shabat (2002) conducted a study on crosswalk warning systems. Vehicle speeds about 30 m upstream of the crosswalk and near the crosswalk are measured. Drivers' yielding behavior to pedestrians is considered in three situations: when a pedestrian is on the sidewalk; when a pedestrian is on the road at the beginning of crosswalk on crossing maneuver; and when a pedestrian is in the middle of crosswalk on a crossing maneuver. Pedestrians crossing within 5 to 30 m of crosswalk are counted. Conflict rates of vehicles and pedestrians are reduced significantly to less than 1 percent. A reduction to 10 percent in the proportion of pedestrians crossing outside the crosswalk is observed [11].

Nasar (2003) conducted a study to evaluate the effectiveness of written signs with social assistance to increase the proportion of drivers stopping for pedestrians in crosswalks. The written signs with social assistance are "Thank you for stopping" "Please stop next time." If the driver stopped, the pedestrian crosser held up a green "Thank you for stopping" signs to drivers. If the driver did not stop, a confederate held up a pink "Please stop next time." In weeks 1 and 3, baseline data on the proportion of drivers stopping for pedestrians at two sites are obtained. In week 2, the stopping behavior of motorists is observed with social assistance signs. An ABA reversal design is used to evaluate the effectiveness of strategies. The analysis showed a significant increase in stopping behavior of drivers during the treatment condition (50.9 percent) from the baseline conditions (46 percent and 37.3 percent) [12].

Pedestrian Countdown Signals

Eccles, Tao, and Mangum (2004) evaluated the pedestrian countdown signals in Montgomery County, Maryland [13]. A "Before and after" study technique is used to evaluate motorists' and pedestrians' behavior and vehicle speed. The results revealed a significant positive effect on pedestrian behavior and did not have any negative effect on motorist behavior. No effect on vehicle approach speed is observed due to the presence of countdown signals while vehicles entered intersections during clearance intervals [13].

The presence of pedestrian countdown signals caused more pedestrians to enter the crosswalk during the flashing DON'T WALK phase. A larger proportion of pedestrians completed crossing on the flashing DON'T WALK. This, in turn, reduces the chance of more pedestrians completing the crossing maneuver before DON'T WALK [14]. The pre- and post-installation research showed that an addition informational, a numerical descending countdown timer during the flashing DON'T WALK clearance interval, is intuitively understood and used successfully by pedestrians. Pedestrians of over the age of 16 well understood countdown pedestrian indication and used the information appropriately [15].

Van Houten, Retting, Van Houten, Farmer, and Malenfant (1999) evaluated a LED pedestrian signal head with animated eyes that scan from side to side at the start of the WALK indication. The study was conducted at two signalized intersections in downtown Clearwater, Florida, U.S.A. The results demonstrated that the experimental signal decreased the percentage of pedestrians not looking for turning vehicles and vehicle-pedestrian conflicts; similar results were obtained during a follow up study after six months.

Van Houten, Van Houten, Malenfant, and Andrus (1999) conducted a study to evaluate the effectiveness of animated eyes on drivers' behavior. Observers scored data on whether motorist looked right and left before crossing the sidewalk and vehicle-pedestrian conflict. They found a significant reduction in vehicle-pedestrian conflict and an increase in percentage of pedestrians and motorists cautionary for particular threats.

Van Houten and Malenfant (2001) conducted a study on an ITS animated LED signal designed to alert drivers to the presence of pedestrians crossing in front of them at the exit to an indoor parking garage and a mid-block-crosswalk location. Data are collected on each of 25 drivers per daily session at the parking-garage exit and two sets of 20 pedestrians and at least as many drivers during each daily session of the experiment. The study demonstrated that the introduction of the ITS signs are associated with an increase in the percentage of motorists yielding to pedestrians at both the garage exit and mid-block crosswalk locations, and the eyes produced a significantly larger increase than the flashing beacon at the mid-block crossing. Although conflicts are lower when the ITS signal is in place, the number of conflicts occurring during the baseline condition are not significantly high enough to detect an effect. At the mid-block site, both the ITS signal and the yellow beacon are associated with a reduction in the percentage of pedestrians stranded in the center of the road, and the number of conflicts. The ITS 'eyes' display produced a significantly larger increase in the percentage of drivers yielding to pedestrians than the flashing beacon even though both devices only operated when a pedestrian is crossing the street. Specifically, the pedestrian icon showed the direction of the pedestrian who is crossing the street, and the searching 'eyes' display provided a specific request of the drivers to look for the pedestrian. Analysis of the data revealed that the ITS eyes display is inherently understood by drivers and produced a significant increase in yielding behavior and a reduction in conflicts [16].

Van Houten, Malenfant, Van Houten and Andrus (1999) evaluated the effectiveness of animated eyes display as a possible countermeasure at an indoor parking garage exit. The analysis of the study indicated an increase in the number of motorists who look for pedestrians in either direction leaving the garage exit. The increase is maintained three months after the animated eyes are introduced. The use of large electronic displays offered several advantages over incandescent light, including low power requirements and low cost. The use of animated EYES displays directed at drivers might prove a helpful tool in reducing the crashes. The study demonstrated that animated eyes also can increase motorist observing behavior [17].

Carsten, Sherborne, and Rothengatter (1998) evaluated innovative pedestrian signalized crossings as a part of DRIVE II project VRU-TOO (Vulnerable Road User Traffic

Observation and Optimization). Signals are designed to make timings more responsive to pedestrian needs, i.e., to affect signal timings. As a part of innovative signalized pedestrian crossings, microwave detectors are mounted on traffic signals to register the approach of pedestrians. Microwave detection can be applied to replace the normal push-button on signalized pedestrian crossings, provide an earlier activation of the pedestrian phase, provide an extension of the pedestrian phase for late arrivals, and provide longer pedestrian phases when there are large numbers of pedestrians. These signals are installed in three European countries. The site one is in Leeds, England, and flows are up to 6,000 pedestrians an hour. The other two sites, one in Portugal and the other in Greece, had comparatively lower pedestrian flows. Some of the criteria used for evaluation are pedestrian-to-vehicle conflicts, percentage of pedestrians arriving on red who violated the red light (especially the percentage violating red when motorists had green), pedestrian comfort, and the number of encounters between pedestrians and vehicles (an encounter is defined as an interaction between a pedestrian and a vehicle where one needs to change course or speed due to others behavior). They found that pedestrian-to-vehicle conflicts are reduced in the after studies in most of the sites. However, the reduction in conflict in all of the sites is not statistically significant. At site two in Leeds, conflicts are also analyzed in relation to pedestrian flow. The conflict to flow ratio decreased from 1:2,034 in the before study to 1:2,300 in the after study. There is a reduction in the proportion of pedestrians who experienced long waiting times (>30 seconds). Mean queue length decreased at all three sites in Leeds. However, maximum queue lengths went up at two sites [18].

ITS-No Turn on Red Signs

Retting, Nitzburg, Farmer, and Knoblauch (2002) reported finding from a field evaluation of two methods for restricting right turn on red (RTOR) to promote pedestrian safety. The implementation of signs prohibiting RTOR during specified hours yields better results than signs giving drivers discretion to determine whether pedestrians are present [19].

Van Houten and Malenfant (2001) analyzed the effectiveness of an ITS LED at parking garage exit and mid-block locations. The main purpose of the study was to assess the effectiveness of an ITS signal that included animated eyes and pedestrian symbols at a garage exit with limited visibility. The result of the study showed that the introduction of ITS signs increased the percentage of motorists yielding to pedestrians at the garage exit and mid-block crosswalk location. The ITS eyes sign produced a significantly larger increase in driver's yielding behavior than a flashing beacon at the mid-block crossing.

High Visibility Crosswalk Treatment, Refuge Islands and Danish Offsets

Nitzburg and Knoblauch (2001) conducted a study to evaluate high-visibility ladder style crosswalk with illuminated overhead crosswalk sign treatment in low volume and low speed un-signalized intersections in Clearwater, Florida. Traffic volumes, traffic gaps, and drivers' and pedestrians' behavior at control sites and experimental sites are observed. Yielding behavior of drivers in daytime at first half, second half, and both halves of crossing are found is statistically better in experimental sites as compared to comparison sites [20].

Huang and Cynecki (2000) evaluated the effectiveness of various traffic calming treatments on pedestrian and motorist behavior at different locations. The treatments included bulb-outs, raised intersection, and Refuge Island. Before and after data are collected and analyzed for their statistical significance. It is found that the raised intersections and refuge islands are likely to direct more pedestrians to cross within the crosswalk. At most other sites, traffic calming devices did not appear to have significant effects on pedestrians. The bulb-outs in Seattle are associated with increased wait times and a lower percentage of those who crossed in the crosswalk, both undesirable effects from a pedestrian standpoint. These devices by themselves neither ensured that motorists will slow down and yield to pedestrians, nor those pedestrians will cross in the crosswalk. Sometimes these treatments hindered the activities such as street cleaning and snowplowing, impeding emergency vehicle access, and might affect drainage. In addition, the noise of vehicles going over speed humps, raised crosswalks, or raised intersections might disturb nearby residents [21].

Lalani (2001) discussed comprehensive information about the effectiveness of various treatments for pedestrian safety. The information is gathered from different sources including experts, internet surveys and references throughout the world. Based on the information reviewed, it is found that marked crosswalks at uncontrolled locations on higher-volume, multilane facilities using traditional treatments leads to higher pedestrian-related collision rates than at unmarked crosswalks on similar facilities. Installing marked crosswalks, especially at uncontrolled locations, by striping two lines across the roadway and posting a single sign in advance of and at the crossing did not improve pedestrian safety. A variety of low-cost signing and striping techniques are currently being used to improve the safety. A number of higher-cost geometric design features, such as curb extensions and pedestrian refuge islands are used to improve the safety of marked crosswalks. Some studies indicated that removing uncontrolled marked crosswalks from higher-volume, multilane facilities at some locations showed reductions in the rate of pedestrian related collisions. It is also suggested that different intelligent transportation systems based techniques could be employed for improving pedestrian safety [22].

The literature includes documents on the effectiveness of crossing refuge islands as relatively inexpensive devices to protect pedestrians. Pedestrian refuges or crossing islands are raised islands in the center of roadways, allowing pedestrians to cross one half of the street, with a safe place to stop before crossing to the other side of the street. They are typically constructed at marked crosswalks, either at a mid-block location or at an intersection. The crossing islands are best employed when traffic volumes result in few gaps for pedestrians to safely cross the entire street at one shot. Also, they can be deployed when there is little demand to make left turns, and the roadway is particularly wide. A series of studies on the effect of traffic calming measures in six German cities concluded that, “the modification of streets has proven to be more effective than reducing the speed limit. The weaker road users children, pedestrians, and cyclists benefited more from the measures [23].”

Pedestrian refuge islands are particularly suitable for wide two-way streets with four or more lanes of moving traffic traveling at higher speeds. They are particularly useful to persons with mobility disabilities, very old or very young pedestrians who walk at slower speeds, and persons who are in wheelchairs. Wheelchair users need adequate width and level areas for waiting on the refuge. Split Pedestrian Cross-Overs or Danish Offsets are laid out in a staggered configuration at uncontrolled or signalized intersections, requiring pedestrians to walk toward traffic to reach the second half of the crosswalk. These are useful at skewed intersections. It enables pedestrians to focus on crossing each direction

of traffic separately and provides a “refuge” in the middle of the street. By requiring pedestrians to walk facing oncoming traffic, the refuge provides them a better view of oncoming traffic and allows drivers to clearly see pedestrians. Previous studies on pedestrian refuge islands found significance effect of this countermeasure on motorist and pedestrian behavior [21, 22, 24]. The literatures provide evidence that the drivers are more likely to yield at high-visibility crosswalk, and advance yield marking locations.
Bergman, Gray, Moffat, Simpson, and Rivara (2002) conducted a study on inducing city authorities to apply for state funds for creating a model pedestrian refuge in their communities. Ten demonstration sites are funded; seven of them are built or are under construction. There is no guarantee, however, that the presence of the model refuges would lead to community-wide application of these safety enhancements. First, progress in pedestrian safety occurred in small steps. Limited and realistic goals had to be set. The work group is able to meet all the goals established at the outset of the project. Second, the importance of bringing decision makers into the process early and providing them with regular updates is reinforced. Third, media coverage is critical to raising the awareness of public officials. An emotional link is created between the public and the families of trauma victims. Centering kick-off on the events surrounding the death of a child gave the campaign vital energy. The knowledge and energy mobilized by these individuals are needed to continue working with the local engineering staff as the pedestrian safety measures are designed for construction [24].

Speed Trailers

Speeding is attributed to thousands of crashes in work zones each year leading to numerous fatalities and injuries. Sizeable portion of these crashes due to excessive speed emphasizes the need to motivate drivers to comply with speed limits especially in work zones. Studies have shown that most drivers do not slow down in response to the standard regulatory or advisory speed signs that are customarily used to regulate speeds at temporary traffic control zones (work zones) [25]. Research conducted to determine effectiveness of speed trailer to motivate and encourage drivers to observe posted speed limits in work zones indicated that devices with the ability to display drivers' speeds have considerable potential for reducing speeds and improving compliance [25-29]. A study in

Netherlands showed that local automatic speed warning at an urban intersection reduced the mean speed by 5 km/hr [30]. Also, on a two-lane rural road, the percentage of speeders decreased from 40 to 10 percent. The total number of crashes is reduced by 35 percent. This effect is almost the same three years after concluding the experiment [30]. One case study showed that the efficacy of using radar as a speed reduction strategy is a function of congestion and radar detector density, with the strategy being most effective for volumes levels between 200 and 1,400 vehicles per hour per lane [31]. However, one of the researchers found that speed trailer did not influence the speed of the fastest 15 percent of the speeding vehicles. Also, it did not affect the heavy vehicle speeds [32].

Even though it is observed by some of the investigators that increasing the speed limit reduces the crash rate [33-38], the severity of a pedestrian-related-vehicle-crash dramatically increases with the increase in speed [39, 40]. Newton's laws dictate that a doubling in vehicle speed results in a stopping distance four times as long and four times as much kinetic energy absorbed during an impact. Higher driver response times further increase stopping distances. As a result, a small increase in roadway traffic speeds results in a disproportionately large increase in pedestrian fatalities.

According to the studies conducted by two different agencies, the probability of a pedestrian fatality increases at an alarming rate i.e., from 5 percent to 40 percent when the speed at impact with a pedestrian increases from 20 to 30 mph and to about 85 percent for a speed of 40 mph [41, 42]. These data showed that the likelihood of a pedestrian fatality increases in a nonlinear fashion, much faster than the percentage increase in vehicle speed. Hence, speed control plays an important role in the improving pedestrian safety of a region. Traffic calming uses geometric changes to influence travel speed and to perhaps cause drivers to select another route for travel. It is intended to restore local streets to their intended function, thus providing a more livable environment for residents. In most cases, problems on local streets are caused by through traffic, speeding, and/or noise. Speed management goes a step beyond traffic calming by also looking at higher speed facilities, including collectors and arterials. Many of the typical traffic calming techniques used in residential areas to control volume and speed would be difficult to implement on these roadways. However, other techniques need only modifications or a different approach to be effective. The most frequently used techniques on collectors and arterials are:

- Increased enforcement
- Flashing beacons
- Speed limit signing
- Speed trailers, and
- Rumble strips

Speed or radar trailers are mobile roadside devices that use radar to measure the speed of approaching vehicles and display the speed to passing drivers in an effort to decrease speed [43]. The portable units show the posted speed limit of the roadway and display the current speed of the approaching vehicle. Speed trailers have been used as an enforcement tool in some areas when police officers enforce the speeds. However, they are mainly used as a public relations measure to inform motorists of their speeds with the assumption that the speeding motorists would voluntarily reduce their speed. Speed trailers are also used for automated enforcement in a few states, where speeds and license plate numbers are recorded by hidden cameras and citations are issued by the local law enforcement agency. Equipment to collect traffic volumes may also be used within the speed trailer.

A study conducted by Brown (1992) on concentrated police enforcement had shown to positively influence driver behavior, but is difficult to apply to rural contexts. Signs of police enforcement in high crash-risk areas are placed in two rural locations in South Australia. The effects of these signs on vehicle speed are evaluated by conducting radar surveys of mean speeds on the approaches to, and exits from, the sign locations before and after their erection. A minor speed reduction on the exit from one of the signs is observed, but this is not observed in the speeds of the fastest 15 percent of vehicles. This suggested that the highest risk group of speeders is not affected by the signs. The signs did not affect heavy vehicle speeds. It is not considered likely that the signs had a substantial effect on road safety in rural areas [32].

Automated Pedestrian Detection device

In the United Kingdom, Puffin (Pedestrian User-Friendly Intelligent) crossings respond to pedestrian demand and do not delay traffic unnecessarily when no pedestrians are present [44]. Pedestrian presence is sensed either by use of a pressure-sensitive mat or by an infrared detector mounted above the crossing location. Pressure on the mat is used both for initial detection as well as to confirm that the pedestrian has not departed the crossing zone before the Walk signal appears. If the pedestrian departs the crossing zone prior to the appearance of the Walk signal, the call will be canceled.

Puffin crossings may also utilize an additional sensor to detect the continued presence of pedestrians in the crosswalk, thereby allowing the signal phase to be extended for those requiring additional time to cross. The conversion of a standard signal to a Puffin crossing in Victoria, Australia, reduced by 10 percent the number of pedestrians who started to cross before the pedestrian Walk signal is presented [45]. Similar results are reported in Växjö, Sweden [46]. The Swedish results also showed that the number of vehicle-pedestrian conflicts decreased after the microwave detectors are in place.

The Dutch PUSSYCATS (Pedestrian Urban Safety System and Comfort At Traffic Signals) system consists of a pressure-sensitive mat to detect pedestrians waiting to cross, infrared sensors to detect pedestrians within the crossing, and a near-side pedestrian display [47]. Although pedestrians perceived PUSSYCATS to be at least as safe as the old system, many pedestrians reported that they did not understand the function of the mat. As many as half of all pedestrians refuse to use the system. Similar applications are being used in the United Kingdom and France [48].

Summary

Various research efforts have reported on the evaluation of the pedestrian safety countermeasures. Literature related to countermeasures evaluation includes “smart lighting,” “pedestrian countdown signals,” “portable speed trailers,” “turning traffic must yield to pedestrians signs,” “in-roadway knockdown signs,” “high visibility crosswalks,” “warning signs for motorists,” “regulatory signs for motorists,” and “advance yield markings.” However, the literature review identified a need to improve on systematic evaluation of the countermeasures. Identifying potential MOEs for safety countermeasures and evaluating the effectiveness of key countermeasures in a systematic way is the main focus of this research.

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