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IMPLEMENTATION OF THE FIRST PEDESTRIAN SCRAMBLE IN DOWNTOWN SAN DIEGO, CALIFORNIA

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Abstract: In an effort to improve pedestrian movements and provide pedestrian-friendly environment intersection in Downtown San Diego, California, the Center City Development Corporation has proposed an improvement at the intersection of 5th Avenue and Market Street by adding intersection pop outs and exclusive pedestrian signal so called "Pedestrian Scramble". The intersection pop outs are designed to shorten the intersection crossing distance, improve sight distance for pedestrians, and indirectly reduce speed of vehicular traffic approaching the intersection. The scramble signal will allow pedestrians to be serviced exclusively and to cross diagonally or conventionally by stopping vehicular traffic on all approaches. Katz, Okitsu & Associates was asked to conduct a focused and careful traffic operational study and prepare signal modification and design of the first intersection pop outs and pedestrian scramble signal requested by the City of San Diego regarding possible impacts of this improvement to the vehicular traffic conditions at the intersection. This paper describes the traffic operational analysis approach of the proposed pedestrian scramble signal, considering both the existing and future vehicular traffic conditions. This study also includes results from *Synchro* traffic signal analysis models that provide a measure of effectiveness of both the current condition and the future condition with the proposed pedestrian scramble signal. The results from the *Synchro* suggest that the pedestrian scramble signal phase has no significant impact to the current or near-term future vehicular traffic conditions at this intersection. In addition, the paper describes the traffic signal modification and design due to the proposed intersection pop outs and pedestrian scramble signal including handicapped pedestrian access as well. The primary objective of this paper is to evaluate the proposed pedestrian scramble signal to ensure that this proposed pedestrian improvement has no significant impact to the vehicular traffic and to demonstrate the best practice of the signal design and operation being used to implement the first pedestrian scramble signal in San Diego, California.

Keywords: Intersection pop outs, Pedestrian scramble, Signal modification

1. BACKGROUND

Due to the high volume of pedestrians at intersections in Downtown of San Diego, California, the Center City Development Corporation (CCDC) has proposed a pedestrian-friendly intersection improvement project in 2001. The project was to add intersection pop outs and an exclusive pedestrian signal so called "Pedestrian Scramble" at the intersection of 5th Avenue and Market Street. This project was proposed to improve pedestrian movements and provide pedestrian friendly environment in Downtown San Diego, California, USA. The Traffic

Engineering Department, City of San Diego then requested a focused traffic signal operation study and a signal modification design due to the proposed improvement project to ensure that this proposed project has no significant impacts to the current and near-term future traffic conditions at this intersection. Katz, Okitsu & Associates (KOA) was the leading traffic engineering firm of this project conducting the study and the signal design recommendation of the proposed pedestrian scramble signal project at this location.

2. INTRODUCTION

Katz, Okitsu & Associates was asked by the Center City Development Corporation (CCDC) to conduct the focused traffic signal operation study of the proposed intersection pop outs and pedestrian scramble signal at the intersection of 5th Avenue and Market Street. This study was requested by Traffic Engineering Department, City of San Diego regarding the possible operational impacts to the current and near-term future vehicular traffic in terms of traffic congestion throughout the downtown signal coordinated system. Both existing and future traffic conditions were analyzed. Future traffic conditions included 2005 and 2010 projected traffic volume numbers. Since this intersection is currently signalized, a signal modification design is prepared and provided to accommodate the proposed intersection pops-out and pedestrian scramble signal operation.

The proposed project was to improve pedestrian movements and provide pedestrian-friendly environment at the intersection of 5th Avenue and Market Street by reducing the intersection crossing distance and eliminating pedestrian-vehicle conflicts at the intersection. Therefore, the intersection pop outs and the exclusive pedestrian signal phase so called "Pedestrian Scramble" signal is proposed in this project.

The results from the *Synchro* traffic signal analysis suggest that the proposed pedestrian scramble signal has no significant impact to the current vehicular traffic operation at the intersection. The traffic signal modification plans are also prepared due to the proposed pedestrian scramble signal including accessible handicapped pedestrian signal.

3. STUDY LOCATION

3.1 Existing Condition

The intersection of 5th Avenue and Market Street is currently operating as a two-phase signalized intersection. Market Street is a four-lane roadway with 12-ft lanes and 10-ft parking lane on each side. 5th Avenue is a two-lane roadway with 12 ft-lanes. The north leg of 5th Avenue is a one-way northbound street, but the south leg is currently operating for two-way traffic. Figure 1 shows the existing geometries of the intersection of 5th Avenue and Market Street.

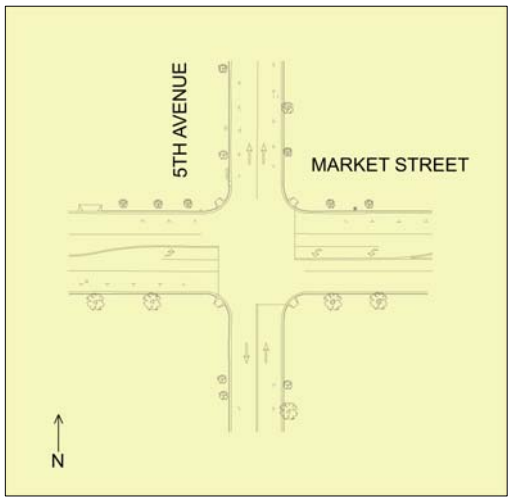

Figure 1. The Existing Geometries of the 5th Avenue and Market Street Intersection

3.2 Proposed Improvements

Due to the high volume of pedestrians at this particular intersection, CCDC has proposed this project to improve pedestrian movements by adding intersection pop outs and a pedestrian scramble signal to the intersection of 5th Avenue and Market Street. The pedestrian scramble signal will allow a pedestrian phase to be serviced exclusively. No vehicular traffic phases will be allowed to receive service during the pedestrian scramble phase. Since the project intersection is interconnected with the downtown signal coordinated system, this analysis also considers the effects that will occur at intersections of:

- Market Street and 2nd Avenue
- Market Street and 4th Avenue
- Market Street and 6th Avenue and
- G Street and 5th Avenue

Figure 2 shows the 5th Avenue and Market Street location including the possible affected locations indicated above. Figure 3 shows the proposed pop outs of the intersection of 5th Avenue and Market Street.

Figure 2. The 5th Avenue and Market Street Intersection Including the Possible Affected Locations

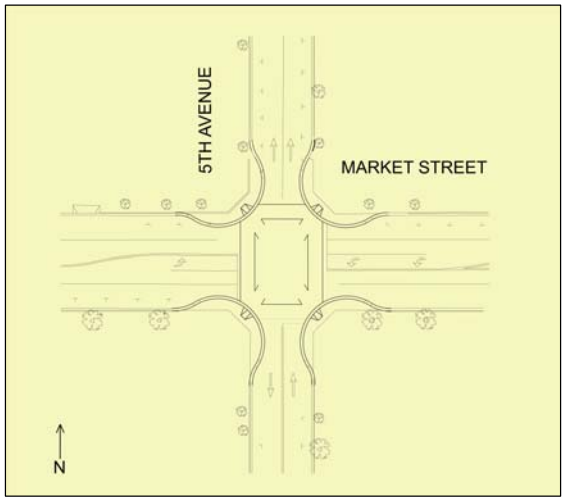

Figure 3. The Proposed Intersection Pop Outs of 5th Avenue and Market Street

4. OPERATIONAL ANALYSIS

4.1 Data Collection and Traffic Volumes Analysis

In this process, traffic volume analysis was conducted. Existing traffic volumes during the morning and afternoon peak hours were obtained from the Traffic Engineering Department, City of San Diego. The study site was also visited and observed during the peak hours on a typical weekday to collect the following information:

- Posted speed limit both on 5th Avenue and Market Street
- Left and right turn lane lengths
- Existing signal timing plans obtained from the City of San Diego
- Percentage of trucks and buses traffic
- Pedestrian traffic volume during peak hours
- Right turn on red traffic
- On-street parking vehicle

This area of downtown in San Diego is continually changing and the future traffic forecasts have not been perfected. Based on future traffic projections that we previously estimated for the Market Street and 2nd Avenue intersection, the same year projection factor had been applied. The existing traffic counts were increased by a factor of 10.5 % per year to 2005 and 2010, and these future numbers were used in our analysis. Using this growth method, the equivalent growth factor for 2005 is 149% and for 2010 is 246%.

4.2 Signalized Intersection Analysis

Peak hour intersection performance is expressed in terms of Level of Service, ranging from Level of Service A (little delay) to Level of Service F (excessive delay). The City of San Diego has determined that for typical intersections, level of service D is the minimum acceptable level of service during peak hours. To conduct the analysis of peak hour operations, the Synchro analysis software was used.

Synchro allows the KOA study team to choose which delay method to be used, i.e. the

Synchro Control Delay or a Highway Capacity Manual (HCM)) Signals Report Delay. The study team decided to choose the Synchro Control delay since Synchro suggests the use of this delay method when detailed modeling of coordination and optimizing offsets are needed. The Synchro Control delay method used in this study is called the Percentile Delay Method shown in Figure 4 below.

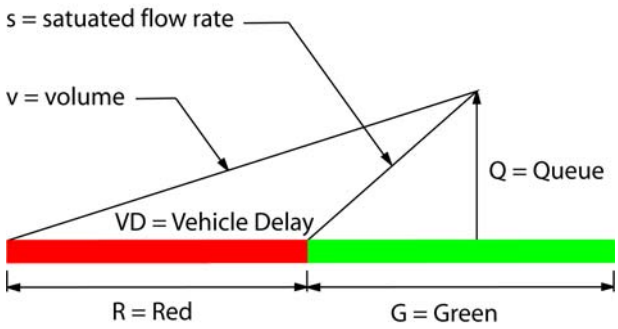

Figure 4. Vehicles Queued at Red Light of Synchro Percentile Delay Method

The average delay for a lane group at a pretimed signal is represented by the area in the triangle in Figure 4. The width of the triangle's base is equal to the effective red time of the phase. The slope of the left side is the arrival rate of vehicles in vehicles per second. The slope of the right side is the departure rate or saturated flow rate in vehicles per second. The height of the triangle is the maximum queue in vehicles. The vehicle delay per cycle is the area of the triangle and the delay per vehicle is the area divided by the vehicles served per cycle.

$$Dp = 0.5 * C * \frac{[\,1-(g/C)\,]^{2}}{[\,1-X*g/C\,]} \qquad (1)$$

Where,

Dp = Uniform Delay per vehicle (second);
C = Cycle Length (second);
g = Effective Green Time (second); and
X = Volume to Capacity Ration (v/c).

This formula is identical to the definition of the Webster's delay model. The only difference between the Percentile and Webster calculations is the determination of green time and the handling of nearly and over-saturated conditions.

For signalized intersection, the Level of Service for the intersection is calculated by taking the Intersection Delay and converting it into letter using this criterion below.

- Level of Service A Delay ≤ 10 seconds per vehicle
- Level of Service B 10 < Delay ≤ 20 seconds per vehicle
- Level of Service C 20 < Delay ≤ 35 seconds per vehicle
- Level of Service D 35 < Delay ≤ 55 seconds per vehicle

- Level of Service E 55 < Delay ≤ 80 seconds per vehicle
- Level of Service F 80 < Delay seconds per vehicle

4.3 Pedestrian Crossing Operational Analysis

The intersection of 5th Avenue and Market Street is currently operating as a signalized intersection with a crosswalk crossing all four legs of the intersection. Existing crosswalk distances are 76 feet and 55 feet crossing Market Street and 5th Avenue respectively. The new crosswalk distances with the proposed intersection pop outs are 63 feet and 42 feet crossing Market Street and 5th Avenue respectively. In addition, the diagonal crossing distances approximately 70 feet in both directions.

Pedestrian timing requirements include the following:

- Walk interval
- Flashing don't walk interval (FDW)

Walk: Under normal conditions, the walk interval is typically 4 to 7 seconds. This will allow an adequate time for pedestrians to leave the curb before the clearance interval starts. In this study, 4 seconds of walk interval is used according to the City use of walk interval in the Downtown area.

Flashing Don't Walk (FDW): The current U.S. Manual on Uniform Traffic Control Devices (MUTCD) indicates that the flashing don't walk time (pedestrian clearance) needs to be of a duration to allow a pedestrian crossing in the crosswalk to leave the curb and travel to the center of the farthest traveled lane before opposing vehicles receive a green indication. The MUTCD requires the FDW time be long enough.

The calculation of the flashing don't walk (pedestrian clearance) is:

$$FDW = W/WS \quad (2)$$

Where,

FDW = Flashing don't walk (pedestrian clearance) time in second;
W = Walk (crossing) distance, as noted above; and
WS = the average walking speed in feet/second (typically 3.5 to 4 feet/sec).

In this study, the FDW for the diagonal crossing is analyzed and calculated based on the diagonal crossing distance of 70 feet and the average walking speed of 4 feet per second, giving the FDW time of 17.5 seconds in the analysis.

5. RESULTS

Katz, Okitsu & Associates utilized the City of San Diego's Synchro file of the downtown signal system. The level of service and the delay of both conditions, existing and future conditions, at these study intersections are shown in Tables 1 to 3, respectively.

Table 1. Intersection Analysis for Existing Condition (2002)

AM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	10.1	B	13.5	B
Market Street/4th Avenue	2.1	A	11	B
Market Street/5th Avenue	5.6	A	20.3	C
Market Street/6th Avenue	2.5	A	4.3	A
G Street/5th Avenue	8.2	A	8.7	A

PM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	7.2	A	7.2	A
Market Street/4th Avenue	10.2	B	9.9	A
Market Street/5th Avenue	9.9	A	17.6	B
Market Street/6th Avenue	4.6	A	3.5	A
G Street/5th Avenue	8.7	A	8.9	A

Table 2. Intersection Analysis for Future Condition (2005)

AM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	11.3	B	8.1	A
Market Street/4th Avenue	4.4	A	3.5	A
Market Street/5th Avenue	6.6	A	29.6	C
Market Street/6th Avenue	5.9	A	5.5	A
G Street/5th Avenue	8.6	A	9.2	A

PM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	10.0	A	8.5	A
Market Street/4th Avenue	10.5	B	12.0	B
Market Street/5th Avenue	11.0	B	20.6	C
Market Street/6th Avenue	6.3	A	8.1	A
G Street/5th Avenue	12.1	B	9.0	A

Table 3. Intersection Analysis for Future Condition (2010)

AM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	>100	F	>100	F
Market Street/4th Avenue	24.2	C	19.5	B
Market Street/5th Avenue	18.5	B	>100	F
Market Street/6th Avenue	10.4	B	10.1	B
G Street/5th Avenue	10.6	B	8.8	A

Table 3. Intersection Analysis for Future Condition (2010)

PM Peak Hour

Intersection	*Without Ped Scramble*		*With Ped Scramble*	
	Delay (sec/veh)	*Level of Service*	*Delay (sec/veh)*	*Level of Service*
Market Street/2nd Avenue	21.7	C	21.7	C
Market Street/4th Avenue	9.1	A	8.6	A
Market Street/5th Avenue	31.6	C	87.9	F
Market Street/6th Avenue	9.1	A	9.0	A
G Street/5th Avenue	23.8	C	21.8	C

Based on our delay and level of service analysis for the existing condition, the impact of the proposed project is not significant with a slight increase in delay and a slight change of level of service. Although there is a slight delay increase for the future condition, there is a more significant change in the 2010 condition. The level of service degraded to Level of Service F in the 2010 condition and KOA hypothesizes that this is partly due to the fact that as the volumes increase on the roadways, the signal cycle lengths still remain constant. In reality, traffic signal cycle lengths will be adjusted according to the future traffic demands and the future level of service will also change accordingly.

6. DESIGN AND IMPLEMENTATION

6.1 Signing, Striping, and Signal Modification

During the design and implementation phase of this project, the signal modification plan was prepared by Katz, Okitsu & Associates. Data collection was done by requesting information from the Record Department, City of San Diego. Field review was then conducted at the project site in order to collect the signing, striping and signal equipment currently used to operate the intersection of 5th Avenue and Market Street.

Figure 5 shows the proposed intersection pop outs and pedestrian scramble signal at the intersection of 5th Avenue and Market Street.

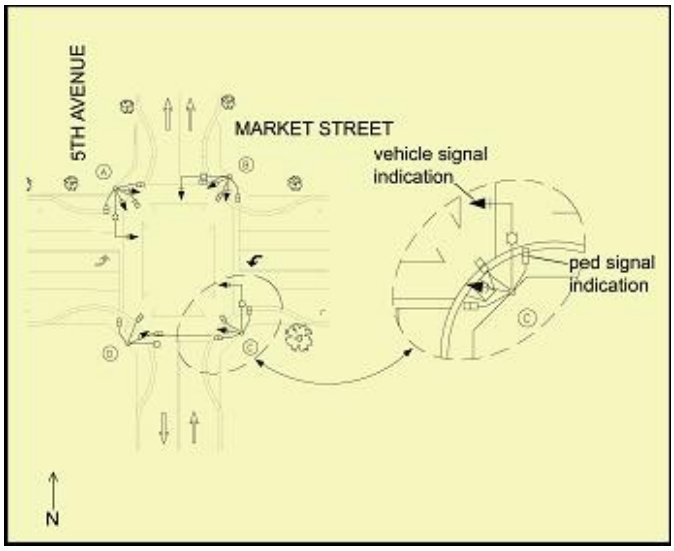

Figure 5. The Proposed Intersection Pop Outs and Pedestrian Scramble Signal at the Intersection of 5th Avenue and Market Street

Existing signal poles at all four corners are proposed to be relocated due to the intersection pop outs design. Pedestrian ramps are also proposed to be installed to provide access for handicapped pedestrians at this intersection. An additional pedestrian signal indication is proposed to be installed and mounted at a signal pole at each corner to accommodate the diagonal pedestrian crossing, resulting in the total of three pedestrian signal indications on each corner of this intersection. An additional pedestrian push button is proposed to be installed and mounted on a signal pole, 45 degrees to conventional crossings, at each corner. Pedestrian Signal consists of housing with a full screen, a message plate, and two light sources. Accessible Pedestrian Signals are also included and installed at the intersection. The Polara Navigator Accessible pedestrian signals are selected to be used for the handicapped pedestrian at this intersection. It provides audible sound during the "Walk" interval of the pedestrian crossing operation. This helps pedestrian who have visual disabilities safely cross streets at a signalized location. "No Turn On Red" sign is required to be posted at the intersection due to the pedestrian scramble operation requirement.

6.2 Pedestrian Scramble Signal Timing and Phasing

The intersection of 5th Avenue and Market Street is currently operating as a two-phase signalized intersection. Currently, phase two of this signal serves pedestrian and vehicular traffic in both directions and phase four serves one-way northbound vehicular traffic and both sides of pedestrian traffic crossing Market Street. The pedestrian scramble signal is proposed to have phases two and four serve eastbound and westbound, and northbound vehicular traffic respectively. In addition, no vehicle is allowed to turn right on red at the intersection. Phase three is now proposed to serve only pedestrian traffic on all directions including diagonal crossing. Figure 6 shows the existing and the proposed pedestrian signal phase diagrams.

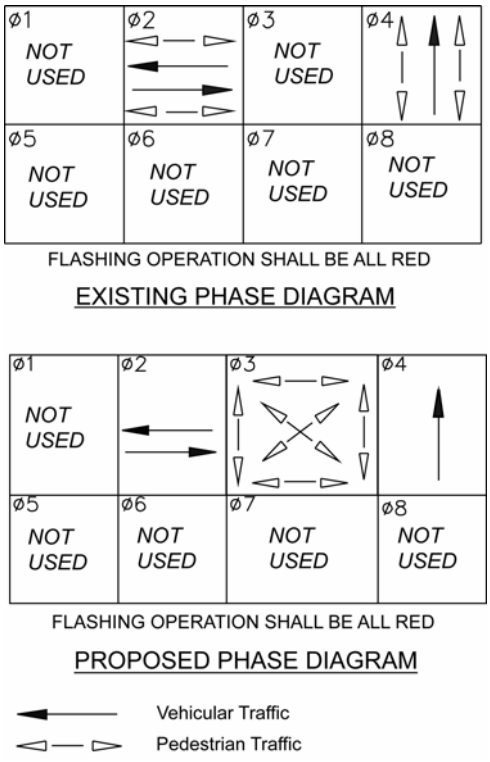

Figure 6. The Existing and the Proposed Traffic Signal Phasing Diagrams

6.3 American Disabilities Act Requirements

American Disabilities Act (ADA) requires pedestrian ramp access at a new or modified signalized intersection for handicapped pedestrians. Therefore, a pedestrian ramp at each intersection corner is proposed to be part of the pedestrian pop out curves at this intersection. The proposed four pedestrian ramps at marked crossing shall be wholly contained within the markings.

Pedestrian scramble signal makes it difficult for pedestrians, who are blind or visually impaired, to recognize the onset of the Walk interval, particularly at locations where pedestrian scramble is implemented and in operation. Therefore, in this project, we proposed to install a new Polara Navigator Accessible Pedestrian signal that provides audible sounds during the "Walk Interval". This audible will automatically be interrupted when the "Flash Don't Walk" comes up, i.e. a flashing light of the "Walk" has ended. This accessible pedestrian signal system also includes voice recorded message, which provides additional information to pedestrian such as direction and street name. All work, materials, and equipment required for installation and operation of the accessible pedestrian system in this project shall comply with the State of California Standard Plans and Specifications. In addition, the machine detection system shall comply with these specifications.

6.4 Implementation

The supplemental traffic study and design prepared by Katz, Okitsu & Associates were finally approved by the City of San Diego in March of 2002. The estimated construction cost was also provided upon a completion of the design work of this project. Later in May, the construction of the proposed improvement had begun. This included the intersection pop outs construction, the signing and striping work, and the additional signal equipments modification and installation for the pedestrian scramble signal. The cost of this improvement was estimated approximately a total of $600,000 (US Dollars), and the entire fee was covered voluntarily by the business owners of the four corners at this intersection. This intersection with the intersection pop outs and pedestrian scramble signal has been opened and operating as the first innovative and pedestrian-friendly intersection in Downtown San Diego, California since November 2002.

7. DISCUSSION

The Center City Development Corporation (CCDC) has proposed this project to improve pedestrian friendly environment due to high volume of pedestrians at the intersection of 5th Avenue and Market Street in Downtown San Diego by adding the intersection pop outs and pedestrian scramble signal. This intersection is located in the Downtown area of San Diego, California, where there is high volume of pedestrians crossing this intersection daily. Katz, Okitsu and Associates was asked to provide the traffic engineering study and design services. Since this project is located in the heart of the downtown area and is going to be the first location implementing the intersection pop outs and pedestrian scramble signal. Many difficulties have arised during the study and design phases. This included a challenge of maintaining current signal coordination system requirement, as well as involving with public opinions in the area. This project also required the City of San Diego's approval before it can be implemented. Therefore, Katz, Okitsu & Associates carefully conducted the traffic engineering study and design due to the unique aspects and requirements of the project. In addition, this included developing signal timing and phasing for the implementation as well.

Pedestrian scramble signal has potential to reduce pedestrian-vehicle conflicts at urban signalized intersections with high volumes of vehicular and pedestrian traffic. The author feels that after the pedestrian scramble is implemented and completely in place, this intersection should be monitored to measure a number of reduced vehicles-pedestrian conflicts associated with the pedestrian scramble, which translate into measurable reductions in pedestrian injuries and fatalities.

Intersection pop outs are designed to shorten pedestrian crosswalk distance and indirectly reduce speed of vehicular traffic approaching the intersection due to high volume of pedestrians at this particular location. Therefore, the speed survey should be conducted and monitored at this intersection. This would potentially help the City of San Diego officials better understand the benefit of the intersection pop outs and the use of this innovative design as part of their traffic calming strategies in San Diego Downtown area.

Since this traffic analysis is based on the static traffic forecasting numbers meaning there is no dynamic traffic assignment approach involved in this analysis. Therefore, the worst case scenario is analyzed and presented in this study and there is a possibility of slightly over estimate the intersection delay and level of service. In addition, the results obtained from the Synchro traffic analysis model are analyzed as the whole network. The total of 5 intersections is only presented in this study.

8. CONCLUSIONS

This study focused on the operational analysis of the intersection at 5th Avenue and Market Street, both with and without the Pedestrian Scramble phase. In addition, since this intersection is part of the downtown traffic signal coordination system, adjacent signalized intersection operations were analyzed as well; all the potentially affected intersections were analyzed for both existing and future conditions.

Based on our delay and level of service analysis for the existing condition, the impact of the proposed project is not significant with a slight increase in delay and a slight change of level of service. Although there is a slight delay increase for the future condition, there is a more significant change in the 2010 condition. The level of service degraded to Level of Service F in the 2010 condition and KOA hypothesizes that this is partly due to the fact that as the volumes increase on the roadways, the signal cycle lengths still remain constant. In reality, traffic signal cycle lengths will be adjusted according to the future traffic demands and the future level of service will also change accordingly.

The pedestrian scramble signal is proposed to have phases two and four that serve eastbound and westbound, and northbound vehicular traffic, respectively. Phase three now serves only pedestrian traffic in all directions including diagonal crossings. In addition, pedestrian scramble signal prohibits vehicle to turn right during red light indication.

Pedestrian scramble signal makes it difficult for pedestrians, who are blind or visually impaired to recognize the onset of the Walk interval. Therefore, accessible pedestrian signal is required to be installed at the intersection as part of the improvement project.

The results from the supplemental traffic study of the proposed intersection pop outs and pedestrian scramble signal at this location suggested that there is no significant impact to the

current and near-term traffic conditions if implemented. After the construction of this project was completed in November of 2002, the intersection pop outs and pedestrian scramble signal have been opened and operating as the first innovative and pedestrian-friendly design intersection in Downtown San Diego, California. Recently, the City of San Diego is planning to propose this type of improvement including intersection pop outs and pedestrian scramble signal at other nearby locations in Downtown San Diego.

9. FUTURE WORK

In addition, the author feels that there is a need to conduct an additional evaluation study after the intersection pop outs and pedestrian scramble signal are completely implemented and in operation. A number of vehicle-pedestrian conflicts should be monitored at this location. A before and after pedestrian-related crash analysis study should also be conducted. Illegal and confused pedestrian crossing should be observed and statistically compared with other recently installed pedestrian scramble intersections in California and in other areas throughout the United States.

ACKNOWLEGDMENT

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