USING GIS TO ASSIST DECISION MAKERS IN IDENTIFYING UNSAFE BUS-STOPS

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ABSTRACT

Enhancing bus transit system performance and increasing its market potential has a significant impact on congestion and air quality in urban areas. Such derived benefits can be maximized by providing safe and improved access to buses at bus-stops. Buses typically stop at locations farther away from an intersection. These locations typically do not have adequate facilities such as crosswalks to cross the streets. Riders or users, thus, tend to cross the streets midblock from either behind or in front of the buses. These unsafe maneuvers result in pedestrian crashes and pedestrian-vehicle conflicts. Identifying high pedestrian crash concentration areas near bus-stops and implementing mitigation strategies using available funds would not only help decision makers and transit system managers increase safety but also attract more number of riders. The focus of this paper is to develop a Geographic Information Systems (GIS) based methodology to assist decision makers in identifying and ranking bus-stops in pedestrian high crash concentration areas. The GIS based methodology involves (1) geocoding pedestrian crash data, (2) identifying pedestrian crash concentrations by generating a crash concentration map, (3) overlaying this on a bus-stop coverage to identify pedestrian high crash locations in the vicinity of bus-stops, (4) extracting the number of crashes in the vicinity of each bus-stop in pedestrian high crash concentration areas, and, (5) ranking the high crash bus-stops. Crash frequency (the number of pedestrian crashes in the vicinity of the bus-stop) is used to rank the bus-stops. The causes of pedestrian crashes at these bus-stops then need to be studied to identify appropriate strategies to enhance safety at unsafe bus-stops. The development and the working of the GIS based methodology is illustrated using 2000 - 2002 pedestrian crash data, bus-stop coverage, and street centerline coverage for the Las Vegas metropolitan area. Potential strategies and countermeasures to enhance safety at unsafe bus-stops are also discussed in the paper.

KEY WORDS

GIS, decision making, bus-stops, safety.

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INTRODUCTION

Increase in traffic congestion and decrease in air quality standards is a major problem in many urban areas. The quest to address these problems has been going for several years. An enhanced bus transit system is one possible solution to solve the growing congestion and air quality problems in urban areas. The success of bus transit systems depend a lot on the generated revenue which, in turn, depends on the ridership. However, the bus transit market potential cannot be explored to its full extent unless issues related to safety of bus passengers (either on board or during their travel to the bus-stop) and accessibility to bus-stops is addressed.

In general, a majority of bus transit trips begin and end with a walk trip. Providing appropriate pedestrian facilities along bus transit corridors make access to transit systems more effective. At a minimum, such facilities include sidewalks, crosswalks, and pedestrian signals. However, facilities such as crosswalks and pedestrian signals do not exist at bus-stops which are farther away from an intersection. Lack of these facilities or having to use long circuitous routes encourage bus transit system users to cross the streets midblock from either behind or in front of the buses to board or alight a bus. These unsafe maneuvers result in pedestrian crashes and pedestrian-vehicle conflicts. The focus of this paper is to identify and rank bus-stops in pedestrian high crash concentration areas. Capabilities available in standard Geographic Information Systems (GIS) software are explored to identify the problem areas. The results obtained can be used by transit system managers to further study the causes of crashes, understand the problems and identify strategies to better plan and operate bus transit systems which have a significant impact on congestion and air quality in urban areas. The study also assists in identifying target locations for education, outreach, and enforcement to enhance safety.

DATA COLLECTION

The data required to conduct this study includes pedestrian crash data, bus-stop coverage, bus ridership data, and street centerline network in a GIS format. For this study, the crash data for years 2000 - 2002 was obtained from the Nevada Department of Transportation. The bus-stop coverage and bus ridership data was obtained from the Regional Transportation Commission of Southern Nevada. The street centerline coverage is obtained from Clark County GIS Manager's Office.

METHODOLOGY

A GIS based methodology was developed to identify and rank bus-stops in pedestrian high crash concentration areas. The GIS based methodology involves the following steps. Each of the above identified steps is discussed in detail below.

1. Geocode pedestrian crash data
2. Create a pedestrian crash concentration map
3. Overlay bus-stop coverage on pedestrian crash concentration map

4. Extract number of crashes for each bus-stop in pedestrian high crash concentration areas
5. Rank high crash bus-stop locations based on pedestrian crash frequency

1) Geocode Pedestrian Crash Data

In this step, the pedestrian crash data collected is geocoded using features in standard GIS software. The street centerline coverage is used to address-match the crash data. As the study area is an urban area, street name / reference street name and address reference systems were used to address match the crash locations.

2) Create a Pedestrian Crash Concentration Map

The geocoded pedestrian crashes obtained in Step 1 may show spatial clustering and dispersion across the study area. However, the presence of a dot on a GIS map does not necessarily equal one crash. Several crashes may have occurred at this point. For example, Figure 1(a) shows the spatial distributions of pedestrian crashes along a study corridor. As an example, 7 pedestrian crashes occurred at the Flamingo Road / Maryland Parkway intersection whereas only 1 pedestrian crash has occurred at the Flamingo Road / Tamarus Street intersection during the study period. However, in the figure, both the locations appear as if they have only one crash each. This is because the symbols for each of the crashes at one location lie on top of each other and cannot be distinguished. In other words, the map does not exactly reflect the crash concentrations of locations having more than one crash. Thus, developing crash concentrations is extremely helpful in identifying high pedestrian crash concentration locations. This can achieved using the density map feature available in GIS software. Figure 1(b) shows the concentration of crashes created using Kernel Density Method for the same location discussed in Figure 1(a). From the figure, it can be clearly seen that the Flamingo Road / Maryland Parkway intersection has a greater number of pedestrian crashes when compared to the Flamingo Road / Tamarus Street intersection, and hence by comparison is a “higher” crash concentration location.

3) Overlay Bus-stop Coverage on Pedestrian Crash Concentration Map

The objective of this study is to identify bus-stops in pedestrian high crash concentration areas. In this step, the bus-stop coverage is overlaid on the crash concentration map developed in Step 2 to identify bus-stops in pedestrian high crash concentration areas.

4) Extract Number of Crashes for Each Bus-stop in Pedestrian High Crash Concentration Area

Pedestrian high crash concentration areas are classified into no, low, medium, and high risk level areas. The focus of this step is to extract the number of pedestrian crashes in the vicinity of each bus-stop in pedestrian high crash concentration areas. Bus-stops that are considered further in analyses could only be those in high risk areas, medium and high risk areas, or low, medium, and high risk areas. Firstly, buffers are generated around the bus-stops in selected risk level areas using features available in standard GIS software to identify pedestrian crashes in the vicinity of each bus-stop. The buffer distance should be selected such that only crashes related to and within the area of bus-stop of interest are identified. Secondly, the buffers are then overlaid over the geocoded pedestrian crash coverage to capture the identified pedestrian crashes in the vicinity of each bus-stop. Clipping, which is performed to cut a portion of one layer using one or more polygons in another layer, is used to capture the pedestrian crashes. The resultant layer from the clipping process is a clipped crash shape file which gives the total number of crashes which fall in all the buffers. This layer does not identify the exact buffer in which a crash falls. In order to link the crashes with their corresponding buffer, the join tool is used. The two databases that are joined are clipped crash database and buffered bus-stop database. With the help of join tool each crash is linked with its corresponding bus-stop buffer.

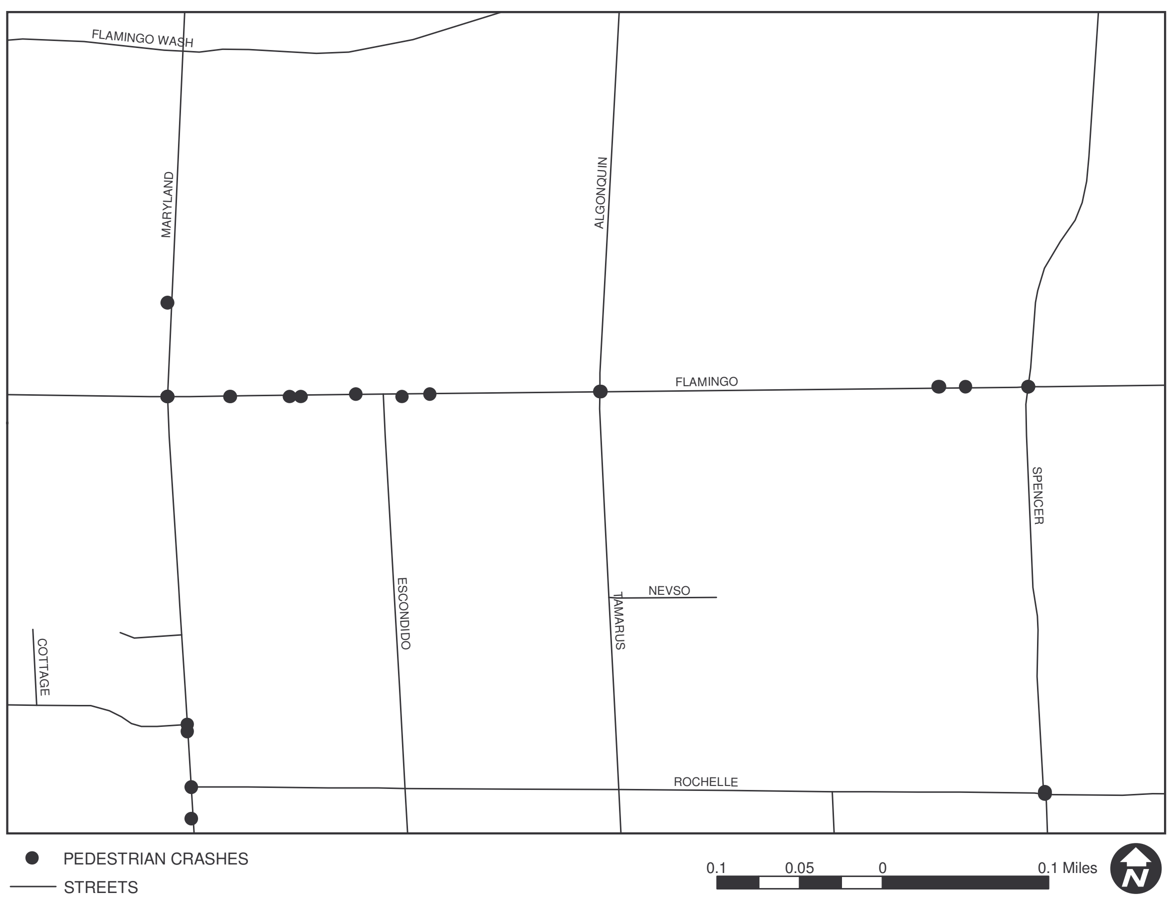

Figure 1(a): Spatial Distribution of Pedestrian Crashes – Points

5) RANK HIGH CRASH BUS-STOP LOCATIONS BASED ON PEDESTRIAN CRASH FREQUENCY

The ranking of high crash bus-stop locations is done using crash frequency method. In this method, the high crash bus-stop locations are ranked based on the number of pedestrian crashes (crash frequency) in the vicinity of the high crash bus-stop location. Methods such as crash rates for each high crash bus-stop computed by dividing the number of pedestrian crashes in the vicinity of a high crash bus-stop by the number passengers (alighting and boarding) using the same high crash bus-stop could not be considered due to unavailability of transit ridership data.

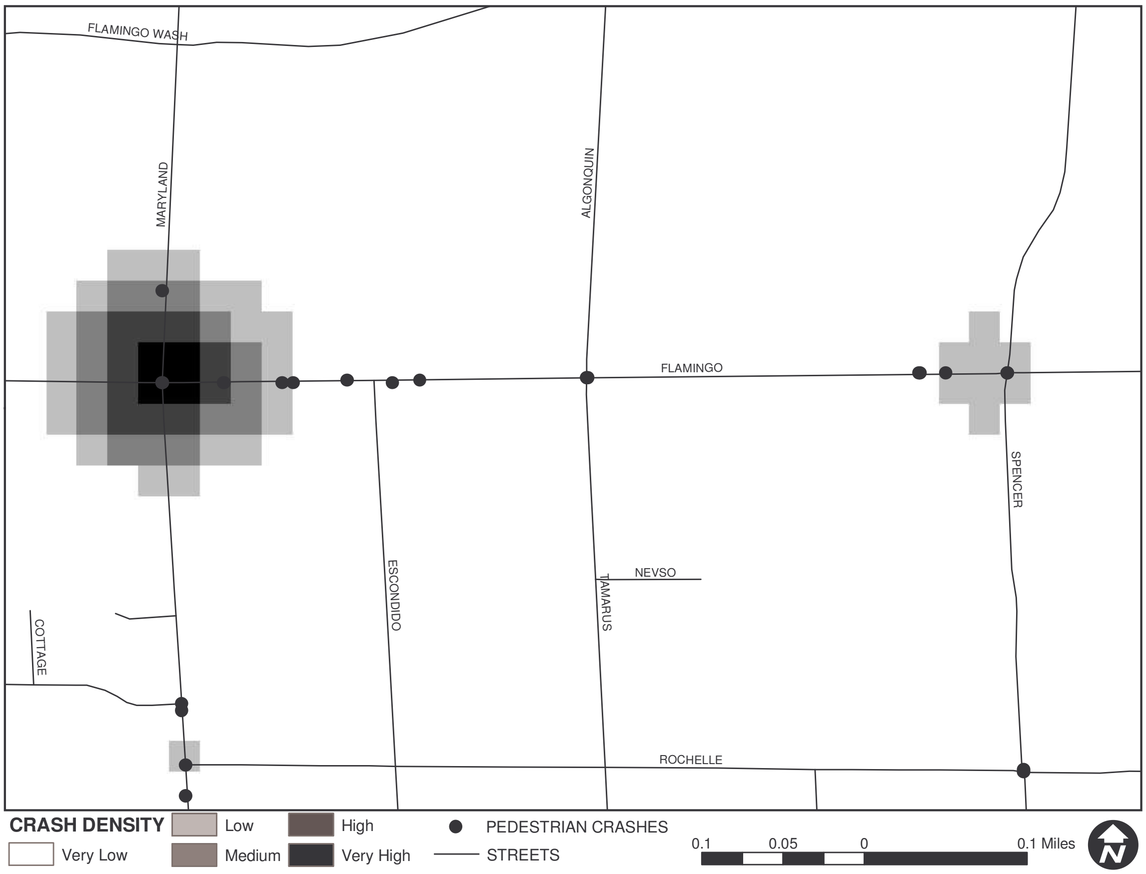

Figure 1(b): Spatial Distributions of Pedestrian Crashes – Concentration

ILLUSTRATION

The Las Vegas metropolitan area in the state of Nevada is considered as the study area for the illustration of the methodology. On an average, the Las Vegas metropolitan area has seen more than 50 fatal pedestrian crashes and 600 injury pedestrian crashes per year over the last 5 years. This history of high incidence of pedestrian crashes in the Las Vegas metropolitan area has generated awareness in the multiple agencies (City of Henderson, City of Las Vegas, City of North Las Vegas, Clark County, and the Nevada Department of Transportation) that govern the area. Crash data indicate that motorist failure to yield is a major contributing factor of pedestrian crashes at an intersection whereas pedestrian failure to yield is a major contributing factor of pedestrian crashes at midblock locations (crashes on a street which are more than 100 feet away from a cross street). Observations also show that a majority of pedestrian crashes are outside the resort corridor and along high speed / high volume arterial streets. Most of these high speed / high volume arterial streets (include both major and minor arterial streets) are part of the large and extensively used local transit system (Citizens Area Transit - CAT).

CAT began serving the citizens of Clark County, Nevada in December 1992. In just under 10 years, ridership has grown from 15 million riders in 1993 to 51 million riders in 2001 – catapulting CAT to the 27th largest bus system in the nation. Special bus service is available for qualified senior citizens and the disabled. At present, the system consists of 52 routes served by 308 buses. Average daily passenger ridership has risen to 150,000 during the last five years, which is a growth rate twice that of the national average (CAT, 2005). The significantly high percent of pedestrian crashes due to pedestrian failure to yield at midblock locations and bus-stops being far away from intersections indicate that transit system users contribute to a notable proportion of the pedestrian crashes at bus-stop locations.

The pedestrian crash data for years 2000 - 2002 was obtained and geocoded using Arc/Info software. A pedestrian crash concentration map is then created using Kernel Density Method. In order to identify high crash bus-stops, the bus-stop coverage is overlaid on the pedestrian crash concentration map. Figure 2 shows the overlaid bus stop coverage on the crash concentration map.

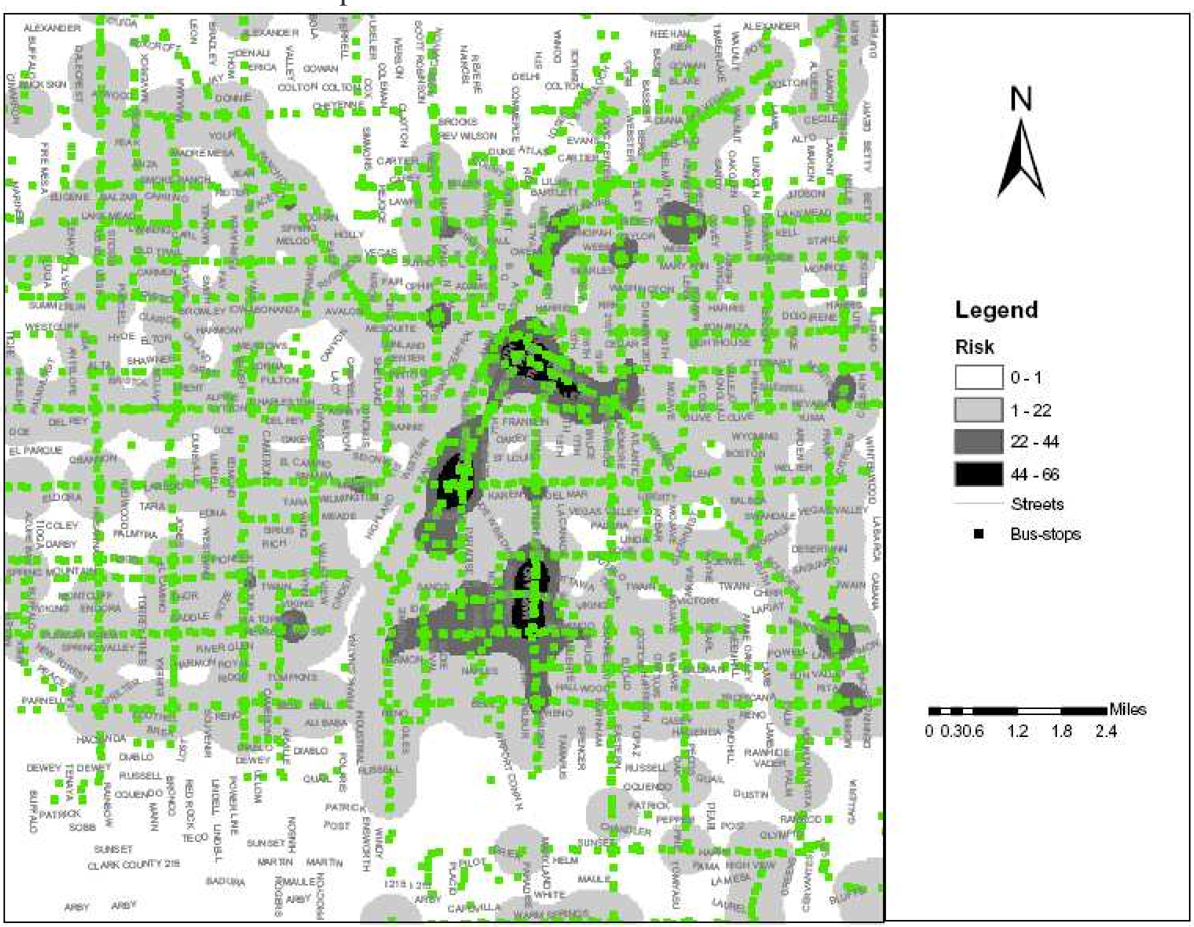

Figure 2: Bus-stop Coverage Overlaid on the Crash Concentration Map

For illustration purposes, all the bus-stops in low (1 to 22 pedestrian crashes per unit area), medium (22 to 44 pedestrian crashes per unit area), and high (44 to 66 pedestrian crashes per unit area) risk areas were considered for further analysis. It has to be noted that area above is a function of circular buffer radius. Buffers, 100 feet and 200 feet in radius, were generated and tested for inconsistency and use. Clipping was done to capture and eventually estimate the number of pedestrian crashes in the vicinity of each bus-stop in pedestrian crash concentration areas. Table 1 and Table 2 show the number of pedestrian crashes, when buffers were generated using 100 feet and 200 feet radius respectively, for the top 10 high pedestrian crash bus-stop locations. In general, it is observed from the tables that the number of pedestrian crashes when 200 feet radius was used is at least twice as the number of crashes when 100 feet radius was used.

Table 1: List of High Crash Bus-Stops – Buffer Radius = 100 feet

Rank	ROUTE #	STOP #	STOPNAME	# Ped. Crashes
1	1062	150	Rancho Dr.-Lake Mead Bl.(S)	5
2	1062	220	Rancho Dr.-Bonanza Rd.(S)	5
3	1071	660	7th St.-Fremont St.(N)	4
4	3021	151	L.V.Bl.S.-Circus Circus/Riviera Hotel(M)	4
5	1081	220	Main St.-L.V.Bl.S.(N)	3
6	1091	160	Maryland Pky.-Sierra Vista Dr.(N)	3
7	1092	290	Maryland Pky.-University Rd.(S)	3
8	2113	290	Carey Ave.-Belmont St.(E)	3
9	3011	280	L.V.Bl.S.-Oakey Bl.(S)	3
10	70021	100	L.V.Bl.S.-Circus Circus/Riviera Hotel(M)	3

Table 2: List of High Crash Bus-Stops – Buffer Radius = 200 feet

Rank	ROUTE #	Stop #	STOPNAME	# Ped. Crashes
1	3012	105	L.V.Bl.S.-Sahara Ave.(N)	11
2	1092	210	Maryland Pky.-Sierra Vista Dr.(S)	8
3	70021	100	L.V.Bl.S.-Circus Circus/Riviera Hotel(M)	8
4	3021	151	L.V.Bl.S.-Circus Circus/Riviera Hotel(M)	8
5	1092	230	Maryland Pky.-Twain Ave.(S)	7
6	2104	250	Lake Mead Bl.-L.V.Bl.N.(W)	7
7	1062	150	Rancho Dr.-Lake Mead Bl.(S)	6
8	1091	130	Maryland Pky.-Twain Ave.(N)	6
9	2033	345	Twain Ave.-Maryland Pky.(E)	6
10	2154	390	Bonanza Rd.-M.L.K. Bl.(W)	6

High crash bus-stop locations identified were different and inconsistency in rankings was observed when different radius was used to extract the number of crashes. The differences in the results obtained indicate that the number of crashes estimated is sensitive to the considered radius. Most near-side and far-side bus-stops are constructed such that they are 75 feet to 100 feet away from the intersection. Considering a buffer radius greater than 100 feet may result in capturing pedestrian crashes which may fall in the vicinity of another bus-stop at the same intersection. Based on the results obtained from the GIS analyses and that the influence area should be as small as possible, 100 feet is recommended for use in this type of studies.

MITIGATION STRATEGIES

Mitigation strategies or countermeasures need to be identified to improve safety at bus-stops and attract more transit riders. In general, bus-stops should provide a safe and pleasant environment for passengers. They should have shelters, landscaping, and adequate lighting. Bus-stop design should minimize conflicts with not only motorized traffic but also other non-motorized users such as bicyclists on bike lanes or pedestrians walking past passengers waiting to board. The alighting passengers from the bus should be guided to cross the road from behind the bus rather than from in front of the bus. This would enable the passengers to see the oncoming traffic. Pedestrians and commuters should also be guided not to walk near the bus or cross the road by walking near the bus. Chances of the bus driver to notice such pedestrians and commuters walking near the bus are less. This may lead to a fatal crash involving the transit bus and the pedestrian or commuter. Some potential mitigation strategies to improve safety and make a bus transit system more attractive are listed below.

- Provide signs on the road, near the bus-stop, and along the street encouraging commuters to cross the road using the crosswalk at the nearest intersection (if a midblock crosswalk does not exist near the bus-stop).
- Provide an audio message (announcement) directing / encouraging alighting passengers to make use of the nearby crosswalk.
- Provide crosswalks near the bus-stop if there are no crosswalks 500 feet downstream or upstream of the location.
- Build bus turnouts wherever feasible so that the alighting passenger has a clear vision of the approaching traffic while looking to cross the road.
- Educate the risk of crossing streets with or without inadequate facilities using television, flyers, and brochures. Information should include high crash bus-stop locations.
- Conduct enforcement at the identified high crash bus-stop locations and study /advertise its effectiveness.
- Channelize pedestrian movement to crosswalks wherever feasible.
- If sidewalks do no exist along bus routes, construct sidewalks to the nearest intersection or section of existing sidewalk.
- Construct overpasses near bus-stops with high pedestrian activity. A benefit-cost study need to be done to look at this option.

CONCLUSIONS

This paper presents a GIS based methodology to identify bus stops in pedestrian high crash concentration areas. The bus-stop coverage was overlaid on the developed crash concentration map to identify the high crash bus-stop locations. Use of 100 feet and 200 feet buffer radiuses were studied to extract pedestrian crashes in the vicinity of high crash bus-stops. High crash bus-stop locations were then ranked using crash frequency and crash rate methods. Inconsistency in rankings was observed when different radius was used to extract the number of crashes. Based on the sensitivity of results obtained and that the influence area should be as small as possible so as to not to capture crashes which are in the vicinity of other bus-stop locations, 100 feet buffer radius is recommended for use. The transit system managers can use the list of high crash bus-stop locations to study the causes of crashes in detail, understand the problems, and identify strategies to better plan and operate bus transit systems which have a significant impact on congestion and air quality in urban areas. The study also assists in identifying target locations for education, outreach, and enforcement to enhance safety.

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