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Author(s): Mohammed Taleb Obaidat
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Industry Issue Paper

GIS Potential in Management of Pedestrian Accidents in Developing Countries

The main objective of this work was to investigate the potential of utilizing geographic information systems (GISs) in identifying hazardous pedestrian accident-prone locations. The study was performed for roads in Irbid city-Jordan for the years 2002 and 2003. Pedestrian accident data was analyzed by pedestrian characteristics, driver characteristics, accident time and location, environmental conditions, vehicle speed and characteristics, and accident severity. Pedestrian accidents were correlated to operational factors, including traffic volume, vehicle speed, pedestrian volume, street length, and access points. Hazardous locations of vehicle-pedestrian accidents were identified using a GIS query builder. Results showed that there was a high potential for GISs in studying pedestrian accidents.

by Mohammed Taleb Obaidat

INTRODUCTION

One of the important safety issues in developing countries is vehicle-pedestrian accidents. The reasons behind this include serious injuries, fatalities, and economic and social factors. Driving speed is one of the most crucial factors in road safety. Accidents caused by high speed are catastrophic for pedestrians. Pedestrian fatalities are the second leading type of motor vehicle related deaths. For example, Jordan statistics reported by the Jordan Traffic Institute (2000) indicated that about 53,000 traffic accidents occurred during the year 2000, resulting in about 700 deaths and 19,000 injuries. Pedestrians were involved in about 11% of traffic accidents, which resulted in about 43% of the deaths and 31% of the injuries. These numbers and percentages of fatalities and injuries are very high, especially when compared with European Union countries and the United States. For example, pedestrian fatalities as a percentage of total traffic accident fatalities in some of the developed countries were: Belgium 10.4%, Ireland 27.5%, Canada 13.1%, and the United States 12.6% (Latinopoulou et al. 2001). Developed countries have lower percentages of pedestrian fatalities because almost every pedestrian is a driver, which makes them more familiar with the traffic environment (Choueiri et al. 1993). On the other hand, in Jordan and other developing countries, automobile ownership percentages are lower. Therefore, in urban areas most people walk, which increases the likelihood of people being on the streets and facing the risk of being hit by vehicles. Moreover, due to the congested urban area, vehicle owners prefer to park their vehicles in parking lots and walk to their destinations.

In recent years, planners and researchers have focused their attention on pedestrian accidents, primarily in congested urban areas. In the study area, Irbid-Jordan city, pedestrians use the streets rather than sidewalks for walking. Moreover, the access points for pedestrian crossing have been changed frequently. Therefore, pedestrian safety studies should involve data collection, spatial analysis, and integration of a GIS with statistical models. This is due to the GIS's potential in improving accident location evaluation, plotting accident location, identifying high-risk accident locations, and reasons for and analysis of accident occurrence.

In this paper, a GIS was used as a tool to investigate the potential to find hazardous pedestrian accident-prone locations by studying and analyzing accident characteristics.

Literature shows that studies of the usage of GISs for pedestrian safety were focused on developed countries, whereas there is a lack of studies in developing countries. In developing countries, knowledge related to pedestrian safety and GISs is minimal. Moreover, in developing countries the behavior of pedestrians while crossing the road at commercial zones is not easy to predict due to: 1) scattered commercial facilities along arterial roads and no location concentrated commercial centers as in developed countries; 2) lack of pedestrian crossings and well marked facilities, and their incorrect distribution of locations, or spacing along arterials; 3) narrow sidewalks that force pedestrians to cross the road anywhere; and 4) lack of public awareness safety programs for pedestrians.

LITERATURE REVIEW

Safety in urban areas could be improved through development of criteria to identify high pedestrian accident locations. These locations would help planners and decision makers establish pedestrian safety programs (i.e., traffic calming, pedestrian crossing facilities, or vertical separators) and give a better understanding of the causes of pedestrian accidents. A GIS could help in this domain because it has spatial analysis capabilities.

Several studies have cited the potential of GISs in plotting vehicle-pedestrian accident locations and identifying high-risk locations of urban areas (Baltes 1998; Cui 2000; and Schneider et al. 2001). A GIS could be utilized in safety studies because it has the capabilities of performing spatial analysis and mapping analysis, follow-up and updating tasks, and identifying and querying for any contributing factors to reduce accidents. Schneider et al. (2002) utilized GISs in some database operations and a statistical spatial method in order to integrate data of pedestrian accident reports and survey data. They categorize pedestrian accidents according to pedestrian characteristics (gender, age, and ethnicity), types of accidents (involving alcohol, disregarding a traffic signal, and crossing at mid block crosswalk) and event conditions (date, time, location, urban, rural, weather, and surface conditions). Crash data (i.e., annual average number of crashes per million vehicles divided by the average daily traffic volume) was geocoded to the street network in a GIS format to define locations and types of crashes. Location crash rate was compared to the critical crash rate and the location was assigned as a high-crash location if its crash rate is greater than or equal to the critical crash rate (i.e., an optimal value for number of crashes per million vehicles divided by the average daily traffic volume). This optimal value varies by country depending on safety policy, lifestyle level, and traffic infrastructure.

Studies showed that metropolitan transit corridors with large numbers of bus stop users resulted in increased exposure of pedestrians to traffic and more pedestrian-vehicle accidents (Southworth and Owens 1993, and Small et al. 1995). They suggested that streets with high numbers of bus riders need to accommodate people walking safely along and across the roadway. Moreover, bus stop usage was associated with pedestrian accidents near parking facilities.

Al-Masaeid et al. (1997) studied the spatial distribution of pedestrian accidents in Irbid city, Jordan, from 1993 to 1995. They developed a negative binomial regression model in order to predict pedestrian accident frequency at mid-blocks (the distance between two sequential intersections) of arterial roads using the following independent variables: peak traffic flow, mid-block number of public buildings frontage along the arterial, mid-block percentage of commercial area along the arterial, mid-block percentage of green areas along the arterial, sidewalk width, and parking conditions. They found that pedestrian accidents are concentrated along major urban arterials, which accounted for 64% of pedestrian accidents of which 74% occurred within mid-block areas.

Several studies cited GIS benefits and potential for planners and engineers in managing, analyzing, and reporting pedestrian accident locations and high-risk areas (U.S. Department of Transportation, Bureau of Transportation Statistics 2000; and Schneider 2001).

Literature also showed that pedestrians not owning vehicles and pedestrians who parked their vehicles at parking facilities had more vehicle-pedestrian collisions. Therefore, it was important to have a vacant parking space near the pedestrian's destination in order to minimize walking distance. This means that vacant parking spaces located near the pedestrian's destination potentially would decrease vehicle-pedestrian accidents (Small et al. 1995).

Obviously, the literature shows a great impact of vehicle-pedestrian accidents on pedestrian safety and metropolitan area planning. Traffic, geometric, land-use, and pedestrian behavior variables had the greatest impact on pedestrian accidents. Therefore, a GIS was used in this work to study its potential to analyze the pedestrian safety issue in Jordan, a developing country.

GIS DATA COLLECTION

Pedestrian traffic accident data were obtained from original reports of the traffic directorate and public security headquarters in Irbid city for 2002 to 2003. After reviewing the traffic accident reports for the study period, 796 pedestrian accidents reports were separated from about 6,000 traffic accident reports that included all types of accidents with some accidents that occurred outside the borders of Irbid city. Only 395 pedestrian accidents occurred during street crossing.

The following were the major data items that existed in the accident report and helped in analyzing pedestrian accidents, therefore, they were used in the attributes of the GIS themes:

1. Accident related data, including location, severity (slight, medium, severe injury or fatality), time (day, week, month, and year), illumination condition (daylight, night with sufficient light, night with insufficient light, or dark), road surface condition (dry, wet, snowy, icy, flooded, or muddy), and weather condition (clear, fog, rain, snow, strong wind, dust, or other).
2. Pedestrian related data, including age and gender.
3. Driver related data (age and gender), and license type (no license, type 1, 2, 3, 4, 5, 6, 7, or foreign license).
4. Vehicle category (motor cycle, agricultural vehicle, construction vehicle, small passenger car, minibus, bus, truck, dual–purpose vehicle, or special purpose vehicle), and type (foreign, government, private, public, military, or recreation).
5. Speed limit (30-70 kilometers per hour).
6. Pedestrian action (crossing in front of parked vehicle, walking, running, cycling, off road, approaching or leaving vehicle, playing on the road, pushing or towing a carriage, walking on sidewalk, working in the road, or crossing the road).
7. Driver fault (not giving priority to pedestrian, failing to comply with obligatory signs, incorrect reversing, exceeding speed limit, incorrect bending and turning, not giving priority to vehicles, using incorrect lane, driving opposite to traffic direction, incorrect overtaking, driving under the influence of alcohol, incorrect parking, or disregarding a traffic light signal).

It must be noted here that about 30% of the data related to location of accidents were estimated because some of the accident reports did not include the exact location.

GIS LAYERS

Pedestrian accident GIS layers (themes) were developed for the studied period in order to identify entities, attributes, and relationships of variables. The following attributes were used for each layer:

- *Shape*: the type of shape of the specific pedestrian accident location (Point). A vector GIS uses points, arcs, and areas to display location of objects. Point shape was used to represent features (pedestrian accidents) that have a specific location on a horizontal plane. Points could have their size, shape, and color varied to suggest importance.
- *Attributes*: Accident location (street name, mid-block, or at intersection, and roadway classification), speed limit (km/hr), pedestrian crossing action, pedestrian accident time (hour, time of day, date, and month), injury information (number of injuries, gender, age, and severity), driver information (age, gender, and license type), vehicle information (category and type), and environmental conditions (road

surface condition, illumination level, and weather condition).

Tables 1 and 2 show samples of the collected database of pedestrian accidents.

GIS SCHEME AND VEHICLE PEDESTRIAN ACCIDENT LOCATIONS

The Arcview software package was utilized to find hazardous accident locations (ESRI 1997). Using the query option, accident features and records could be selected. Information about accident features, selection of them directly and according to their attributes, one at a time and in groups, is possible. Therefore, pedestrian accident features based on their attributes could be selected using any combination of logical operators (AND, OR, or EQUAL) between variables.

A GIS-based procedure was developed to perform identification, query, and statistical analysis, and to analyze characteristics and spatial distribution of vehicle-pedestrian accidents. Moreover, hazardous vehicle-pedestrian accident locations could be found using the query builder concept. Therefore, digital format and spatial maps could be displayed in real time for the most frequent and high-risk pedestrian accident locations.

The developed GIS-based methodology to find hazardous pedestrian accident locations could be done through the following steps:

1. Build a pedestrian accident database.
2. Define variables and their respective attributes.
3. Build a pedestrian accident spatial features map.
4. Use a GIS to link between a spatial map and associated database.
5. Define selection color.
6. Use GIS query builders to classify pedestrian accidents based on any selected attribute.
7. Identify high-risk pedestrian accident locations.
8. Build spatial maps of most frequent or high-risk pedestrian accident locations based on posted speed, location, pedestrian age and gender, road and weather condition, accident severity, time and date of accident, driver age and gender, license type, and vehicle type and category.
9. Group different query combinations for the studied attributes.
10. Give guidelines and precautions for pedestrian crossing.
11. Construct appropriate pedestrian crossing facilities.

It is worthwhile mentioning here that the high-risk (high severity level) pedestrian accident locations could be queried and manipulated for the following variables:

1. A specified distance of a selected road.
2. Frequency and severity of accidents.
3. Roads of specified speed.
4. Traffic volume.
5. Accident per vehicle km traveled.
6. Spot location, mid-block, or at intersection accident.
7. Number of pedestrian access points.
8. Pedestrian gender, age, and injury severity.
9. Weather and lighting conditions.
10. Any traffic characteristics.
11. Combinations of all of above.

Of course, defining the high severity accident locations would help guide the allocation of funds for safety improvements, assist with planning and pedestrian perception survey studies, provide better understanding of accident causes, and help design operating strategies and programs for pedestrian safety enhancement. It also could help improve pedestrian safety by providing users, pedestrians, drivers, and police with digital map-based computer pedestrian accident data. Pedestrian safety analysis is the final product of the GIS tool.

Practical applications of how the developed GIS scheme would assist planners in improving pedestrian safety include:

1. Helping planners select safer locations of crossing facilities.
2. Minimizing commercial zones, schools, and land use effects that attract pedestrians along arterial roads.
3. Improving crossing facilities of hazardous locations. For example, changing the location and the geometry of crossing facilities or the spacing between them.
4. Minimizing the number of pedestrian crossing facilities along arterials of high traffic volume.

Table 1: Pedestrian Accident Data Sample for the Year 2003

Accident Location	Location Type	Roadway classification	Speed Limit (km/hour)	Pedestrian Action
Abdul Al-Qader Al-Husini St.	Mid-Block	Secondary	40	Crossing the road
Abdul Hamid Sharaf	Intersection	-	50	Crossing the road
Abdul Hamid Sharaf Squire.	Intersection	-	50	Crossing the road
Abdul Hamid Sharaf Squire.	Intersection	-	50	Crossing the road
Abdul Hamid Sharaf St.	Mid-Block	Arterial	50	Crossing the road
Abdul Hamid Sharaf St.	Mid-Block	Arterial	50	Crossing the road
Abdul Hamid Sharaf St.	Mid-Block	Arterial	50	Crossing the road
Abdul Hamid Sharaf St.	Mid-Block	Arterial	50	Crossing in front of parked vehicle
Abdul Qader Al-Tal	Intersection	-	40	Crossing the road
Abdullah Al-Tal St.	Mid-Block	Local	30	Crossing in front of parked vehicle
Abi Al-Nwas St.	Mid-Block	Local	30	Crossing the road
Abi Thar Algafari St.	Mid-Block	Local	30	Crossing the road
Al-Aghwar Terminal	Mid-Block	Local		Crossing the road
Al-Agwar St.	Mid-Block	Arterial	70	Crossing the road
Al-Agwar St.	Mid-Block	Arterial	70	Crossing the road
Al-Agwar St.	Mid-Block	Arterial	70	Crossing the road
Al-Arous St.	Mid-Block	Secondary	40	Crossing the road
Al-Awdeh St.	Mid-Block	Local	30	Crossing the road
Al-Bariha	Intersection	-	40	Crossing the road
Al-Bariha	Intersection	-	40	Crossing the road
Al-Bariha	Intersection	-	40	Crossing the road
Al-Bariha St.	Mid-Block	Secondary	40	Crossing in front of parked vehicle
Al-Bariha St.	Mid-Block	Secondary	40	Crossing in front of parked vehicle
Al-Bariha St.	Mid-Block	Secondary	40	Crossing the road
Al-Bariha St.	Mid-Block	Secondary	40	Crossing the road
Al-Bariha St.	Mid-Block	Secondary	40	Crossing the road
Al-Bariha St.	Mid-Block	Secondary	40	Crossing the road
Al-Bariha St.	Mid-Block	Secondary	40	Crossing the road
Al-Emam Malek St.	Mid-Block	Local	30	Crossing the road
Al-Hamaydeh St.	Mid-Block	Local	30	Crossing the road

Table 2: Sample of Attributes for Pedestrian Accident Layer

Accident Number	Time	Time scale	Date	Month	Injury No.	Injury Age	Injury Gender	Severity	Driver Age	Driver Gender
1	18:15	Evening	1/19	3	1	3	Male	Slight	28	Male
3	16:30	Afternoon	1/1	7	1	4	Female	Slight	32	Male
4	12:30	Noon	1/12	6	1	5	Female	Slight	19	Male
5	19:00	Evening	1/13	1	1	3	Male	Slight	27	Male
6	12:00	Noon	1/19	3	1	3	Male	Slight	39	Male
7	07:30	Mourning	1/20	5	1	3	Male	Slight	51	Male
8	13:30	Noon	1/21	5	1	3	Male	Slight	20	Male
9	20:00	Night	11/22	3	1	45	Male	Slight	34	Male
10	13:30	Noon	1/30	11	1	5	Male	Slight	32	Male
11	20:30	Evening	1/7	9	1	20	Female	Slight	40	Female
12	21:30	Night	1/7	1	1	12	Female	Slight	40	Male
13	16:00	Afternoon	1/10	3	1	24	Female	Medium	36	Male
14	20:30	Night	1/12	6	3	2	Female	Slight	26	Male

Table 2: continued

Accident Number	Driver License type	Vehicle Category	Vehicle type	Road surface condition	Illumination Level	Weather Condition
1	3	Passenger	Private	Dry	Day light	Clear
3	3	Passenger	Private	Dry	Day light	Clear
4	3	Dual purpose	Private	Dry	Day light	Clear
5	4	Passenger	Public	Dry	Day light	Clear
6	4	Passenger	Private	Dry	Day light	Clear
7	6	Truck	Public	Dry	Day light	Clear
8	3	Truck	Private	Dry	Day light	Clear
9	6	Passenger	Public	Dry	Day light	Clear
10	4	Passenger	Public	Dry	Day light	Clear
11	3	Passenger	Private	Dry	Day light	Clear
12	3	Passenger	Private	Wet	Day light	Rain
13	3	Dual purpose	Private	Dry	Day light	Clear
14	4	Truck	Private	Dry	Day light	Clear

INTEGRATION OF GIS AND ANALYTICAL MODELING

Although GISs have sophisticated database operations and data manipulation, their statistical methods are limited to mean and standard deviation of the studied variables. Therefore, for pedestrian safety studies that involve spatial analysis and accident data collection, there is a need to use statistical spatial methods (such as regression analysis) in order to integrate data from different sources.

GIS has the potential to turn accident statistical data, such as number of pedestrian accidents, and geographic data, such as roads and accident locations, into useful information for the purpose of mapping and spatial analysis. Further, GISs can assist in identifying factors contributing to the occurrence of those accidents. Those factors were identified in the developed "GIS Scheme" section.

Numerous decision-making and management tasks could be performed using the integration concept of GIS and analytical modeling:

1. Safe operation of pedestrian crossings.
2. Establishment of pedestrian safety programs.
3. Prediction of the number of pedestrian accidents and their locations.
4. Geometric layout of access points on roads.
5. Fund allocation for pedestrian safety studies.
6. Types of pedestrian crossing facilities.

Using these analyses, management strategies could be developed to reduce pedestrian accidents such as:

1. Construction of formal crossings (pedestrian crossing marking) or vertical separator (underpass or overpass facilities) pedestrian crossing facilities.
2. Construction of wider sidewalks and encouraging pedestrians to use them instead of streets.
3. Use of traffic calming measures (lower speed limit, humps, or bumps).
4. Selection of number and location of pedestrian crossing facilities.

Having a GIS spatial map for the urban street network and using analytical modeling, it is possible to locate the access points and their associated predicted numbers of pedestrian accidents. Therefore, based on high-risk accident locations of GIS queries, the number of access points could be reduced using a selected threshold value. Usually political decisions are made to limit the number of access points to three to five for each arterial road (i.e., a distance of about 50 to 70 meters between every two successive crossing facilities).

DISCUSSION AND ANALYSIS

Defining the spatial maps for hazardous pedestrian crossing locations is very important from the perspective of pedestrian safety, convenience, and traffic jam issues.

The developed GIS-based scheme, for the purpose of finding the severe vehicle-pedestrian accident locations, could give insight to the pedestrian safety problem. The developed maps using this scheme could be updated and be useful for planning purposes. Establishing guidelines for pedestrian safety program effectiveness through educational, engineering, and enforcement treatment could do this. The guidelines are anticipated to report and countermeasure dangerous accidents quickly, make appropriate educational or engineering countermeasures, make safety improvements at severe injuries locations, and design a quick response rescue system for pedestrians and drivers at high-risk accident locations. The guidelines could also be useful for city planners and traffic engineers to identify high-risk access points and advise pedestrians who use them. The results of query maps could also be provided to police, pedestrians, drivers, and citizens in order to inform them about high-risk pedestrian accident locations or locations that have high potential for future pedestrian accidents. In fact, spatial analysis using query options could identify the characteristics of dangerous pedestrian accidents, such as type, pedestrian gender, age, injury severity, time and date, and weather conditions. Combination of different queries would result in a more accurate assessment of high-risk pedestrian accident locations and improvement of pedestrian safety. Moreover, developing a street network characterized by few access points could be a great advantage for city planners and traffic engineers because this would enhance traffic flow and improve the quality of traffic service.

The number of pedestrian accidents depends on number of access points in the roadway; however, vehicle speed, pedestrian volume, and average daily traffic (ADT) are important as well. Congested times of day and streets with higher speed limits had the highest percentage of accidents. Figures 1 and 2 show pedestrian accidents as a function of the time of the day and speed limit. Obviously, the 12 a.m. to 4 p.m. time period and a speed limit of 50 km/hr had the highest percentages of accidents due to traffic congestion and pedestrian movement. Table 3 shows the number of access points and pedestrian accidents of the streets with a high number of severe accidents. The number of access points ranged from 4 to 15 pedestrian crossing locations for every arterial road. The high number of access points increases vehicle-pedestrian conflict and accident potential that makes them locations with a large number of severe pedestrian accidents.

If query builder procedure is used along with statistical modeling, it is anticipated to have numerous advantages such as:

1. Optimization potential of pedestrian crossing behavior.
2. Time saving for pedestrians.
3. Safety potential for pedestrians.
4. Decision making potential for city planners.

Table 3: Characteristics of Most Frequent Vehicle-Pedestrian Accident Streets

Accident Location	Number of Accidents (2002)	Number of Accidents (2003)	Access Points	Speed (km/hour)
King Hussien St.	27	16	12	50
Palestine St.	23	8	10	50
Shafeq Arsheidat St.	18	12	10	50
Abdul Hamid Sharaf	17	7	15	40
Al-Bariha St.	14	10	15	40
Al-Hakmeh St.	7	9	4	60
Al-Quds St.	5	10	6	50
Wasfi Tall St.	9	5	9	40
Balat Al-Shuhada’ St.	5	8	7	40
Omar Al-Mukhtar St.	5	8	5	50
Fo’arah St.	1	9	5	70
Bushra St.	2	7	8	40
King Fysal Athani St.	6	3	7	50
Al-Razi St.	6	2	7	50
Al-Huson St.	4	3	10	40

Figure 1: Pedestrian Accidents as Function of the Time of the Day

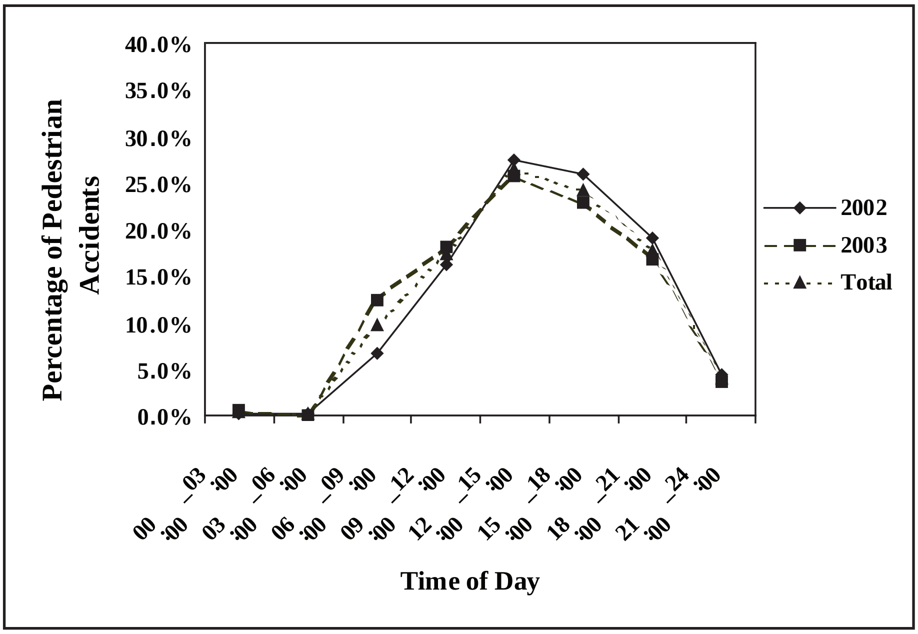
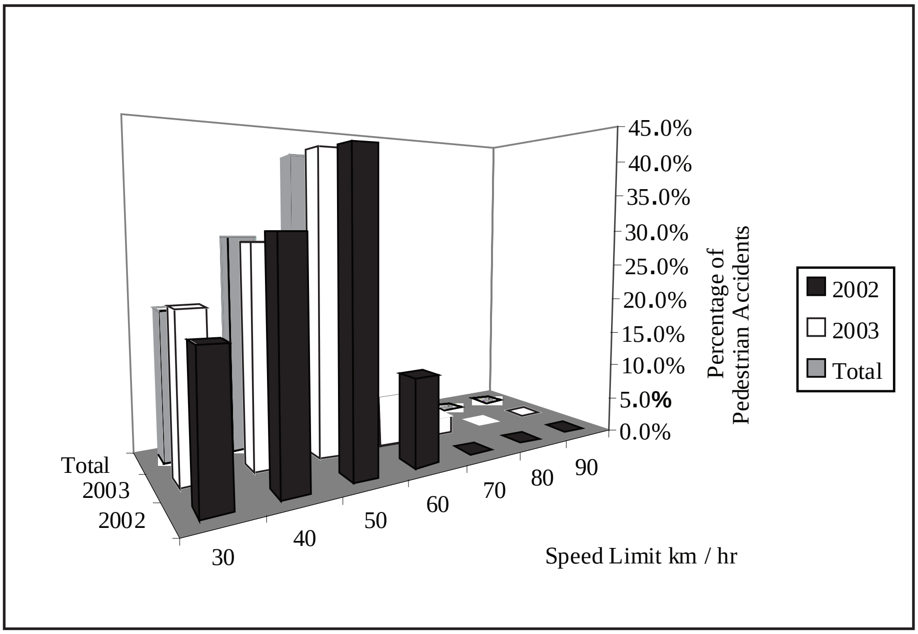


Figure 2: Pedestrian Accidents as Function of the Speed Limit



CONCLUSIONS AND RECOMMENDATIONS

In developing countries, traffic departments do not give pedestrian safety enough attention. They install speed humps wherever severe pedestrian accidents occur, thinking that speed is the only contributing factor in the occurrence of pedestrian accidents. The potential of GISs in the analysis of pedestrian accidents was demonstrated. GIS layers were built for different pedestrian accident attributes, such as accident location, vehicle data, pedestrian data, environmental data, driver's data, and roadway classification.

It was found that GIS query could be used as a viable tool to develop a new scheme in order to find hazardous pedestrian accident locations regardless of the number of constraints and combinations of attributes. Spatial digital maps were demonstrated to show severe pedestrian accident locations. The developed GIS-based scheme has the advantages of flexibility, practicality, time saving, safety potential, and ease-of-use guidelines for city planners and decision makers.

The findings of this work are anticipated to improve pedestrian safety, give guidelines and precautions for pedestrians to control their road crossing, and identify hazardous locations for pedestrian accidents. Moreover, planners and traffic engineers will benefit from this study to construct the appropriate number of pedestrian crossings.

Regardless of the useful findings of this research work that was introduced through GIS technology, many things should be done to enhance pedestrian safety in the Third World countries. These include focusing on educational and enforcement programs for drivers, providing children with road safety skills, avoiding school locations at arterial roads of high ADT, developing appropriate cross walks, increasing refuge islands, utilizing GIS as a training and educational facility, evenly distributing parking lots (especially near public buildings), and providing enough parking space. This will indeed make planners realize that blaming drivers is not the only way to prevent pedestrian accidents or improve pedestrian safety. However, public awareness campaigns, re-engineering of roads, including safer intersection design, educating drivers, defining danger times of high-risk locations, providing parking policies, and monitoring traffic techniques could also be other factors that contribute to pedestrian safety.

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Mohammed Taleb Obaidat *is an associate professor of civil engineering at Jordan University of Science and Technology (J.U.S.T.), Jordan, where he teaches courses in geomatics, photogrammetry, surveying, GIS, remote sensing, transportation engineering, and computer vision. He received a B.Sc. in civil engineering with honors from Yarmouk University, Jordan in 1983; an M.Sc. with honors in transportation engineering from J.U.S.T. in 1988; and both an M.Sc. and Ph.D. with honors in geomatics and computer vision from the University of Illinois at Urbana-Champaign in 1994. Obaidat was awarded the Leica Inc. Fellowship from the American Society for Photogrammetry and Remote Sensing in 1992; the medal of research and academic achievement from his majesty King Husein Ben Talal of Jordan, 1997; and the Scientific Foundation of Hisham Hijjawi for applied science award, 1998.*

Dr. Obaidat has published more than 40 scientific articles in refereed, specialized, and indexed journals and proceedings of international conferences. Obaidat was dean of student affairs at J.U.S.T. (1999-2004). He currently serves as an advisor to the minister of higher education and research for student affairs, Ministry of Higher Education and Research-Jordan.