An investigation of the temporal and spatial patterns of pedestrian accidents in commercial and business areas: a case study of Hong Kong

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ABSTRACT

The identification of accident-prone time periods and locations can help to improve pedestrian safety. This paper addresses the issue of pedestrian safety in Hong Kong by examining the temporal and spatial concentrations of pedestrian accidents in two major commercial and business areas – Central, the central business district (CBD), and Causeway Bay, a busy shopping district nearby. Pedestrians in commercial and business areas have particularly high risk of road traffic accidents because of the co-existence of high volumes and flows of pedestrians and automobiles. In this paper, geographic information system (GIS) and a spatial statistical method, namely the nearest neighbour analysis, were used to analyze the road accident data of 2003. Several hourly accident peaks were identifiable. Spatially, the distributions of pedestrian accidents in both study areas were found to be significantly clustered. Moreover, the degree of clustering was more remarkable in the shopping district than in the CBD. The temporal and spatial concentrations were then discussed with reference to the surrounding land uses. The paper concludes by highlighting the importance of incorporating pedestrian safety in the process of transport and land use planning.

Key words: Pedestrian accidents, temporal and spatial patterns, commercial and business areas

1. INTRODUCTION

Recently, pedestrian safety has become increasingly important in the road safety agenda of many countries. According to a recent road safety report issued by the European Conference of Ministers of Transport (an analysis of 25 countries mainly in Europe), pedestrians were the most vulnerable group of road users in traffic accidents -- nearly one-third of the total road traffic deaths were pedestrians. Table 1 shows the pedestrian fatalities of individual countries by the major world regions. In terms of the share of pedestrians killed in road accidents, Hong Kong compared badly with the other high-income economies, such as Japan (28.4%), the United Kingdom (25.1%), the United States of America (16.5%) and Germany (13.2%). In Hong Kong, more than 50% of the road users killed in road traffic accidents were pedestrians. Such alarming statistics urge us to look into the problem of pedestrian safety in Hong Kong by asking the most basic but fundamental questions of "when" and "where". In the international literature, studies on these fundamental questions remain rare. An early study of Wade et al. (1982) attempted to investigate when and where pedestrian accident casualties in Britain tended to occur. They analyzed the differences of adult and child pedestrian casualties by the time (time-of-day, day-of-week and season-of-the-year) and place factors (road classification, degree of urbanization and distance from home). Levine et al. (1995) examined the hourly variations and spatial distributions of motor vehicle crashes in Honolulu. They found that crashes were highly concentrated between 0600 and 0900 and in weekdays. Two spatial patterns of crashes, namely geographically concentrated and dispersed, were also identified. Another study by Schneider and his colleagues (2004) examined the spatial distribution of perceived and actual pedestrian accident locations in a university campus environment. Several clusters of police-reported and perceived pedestrian-vehicle collisions were identified but they were found to be spatially different to each other.

Table 1 Pedestrian fatalities[1] in total road accident fatality by selected countries, 2000

Continent	Country	Code	Share of pedestrians in road accident fatalities (%)
Europe	Austria	A	14.3
	Albania	ALB	36.4
	Belgium	B	9.7
	Bulgaria	BG	31.2
	Switzerland	CH	22.0
	Czech Republic	CZ	24.4
	Germany	D	13.2
	Denmark	DK	19.9
	Spain	E	15.5
	Estonia	EST	38.7
	France	F	10.4
	Finland	FIN	15.7
	Hungary	H	27.7
	Ireland	IRL	20.5
	Iceland	ISL	3.1
	Luxembourg	L	14.5
	Lithuania	LT	36.7
	Latvia	LV	39.6
	Norway	N	13.8
	Netherlands	NL	9.8
	Portugal	P	20.7
	Poland	PL	35.8
	Romania	RO	47.4
	Sweden	S	12.4
	Slovenia	SLO	19.2
	United Kingdom	UK	25.1
	Yugoslavia	YU	30.1
Asia	Japan	JAP	28.4
	Russian Federation	RUS	44.1
	Hong Kong	**HK**	**56.0**
America	Morocco	MA	31.2
	United States^	USA	16.5

^ Data in 2002

Source: European Conference of Ministers of Transport

The purpose of this paper is to understand the current situation of pedestrian safety problems in Hong Kong by examining the temporal and spatial patterns of pedestrian crashes and to identify any concentrations of pedestrian accidents over time and over space. Pedestrian accidents here refer to road traffic accidents which involve pedestrians and at least one vehicle.

2. CHARACTERISTICS OF THE STUDY AREAS

Central, the CBD core and the major hub of employment in Hong Kong, and Causeway Bay, a famous shopping district near the CBD, were selected as the study areas. Both of them are located along the harbour front with the former situated on a fairly hilly slope and the later on a rather flat land. In both districts, road space is very limited and conflicts among different road users, mainly between drivers and pedestrians, are common. Moreover, both districts have highly mixed land use patterns.

[1] The term "fatality" for all European countries was standardized to death within 30 days (number killed x correlation factor). Likewise, in Hong Kong, a fatal accident is defined as death occurring within 30 days from the injury.

2.1 Land use in Central

Map 1 displays the composition of major land uses within the study area of Central. Connaught Road Central, Des Voeux Road Central and Queen's Road Central are the three major roads in Central. From the map, one finds a large concentration of commercial (C) land use in the center of the study area along the three major roads. A large variety of commercial activities, such as financial, accounting, insurance, banking and legal services, high-order retailing, and other personal services (e.g. clinics), can be found on commercial land use. Stretching northwestwards from the core area of C land use is an area of commercial/residential (C/R) land use, which is characterized with retail shops on ground floors and residential flats on the upper floors. In contrast, the south-eastern part of the study area is dominated by government/community/institution (G/IC) land use and open space (O). Both land uses can be seen to be characterized by lower pedestrian and traffic densities. Relatively lower densities of development such as Comprehensive Development Area (CDA), other specialized uses (OU) and open space (O) can be found in the northern reclaimed land. In the western inner part of the study area, there is a noticeable area of high-density residential (R-A) area with middle-density (R-B) and low-density (R-C) residential land uses scattered around. In general, the complexity of land uses increases with increasing distance from the harbour front.

2.2 Temporal patterns of pedestrian accidents in Central

The temporal distributions of pedestrian accidents of an area can reveal the characteristics of the land uses of that area. The temporal patterns of pedestrian accidents in 2003 were analyzed by the time of day, as shown in Figure 1, and the day of the week, as shown in Figure 2. First of all, pedestrian crashes were distributed very unevenly over the 24-hour day with more crashes occurring in the daytime and fewer at night (Figure 1). Also, three accident peaks, namely the morning peak (0800-0900), the afternoon peak (1400-1500) and the evening peak (1700-1900) can be identified. These concentrations reflect the dominance of work trips in an employment center. In the mornings and in the evenings, work trips to and from the commercial and commercial/residential land uses generated huge volumes and flows of pedestrians and traffic nearby and increased the exposure and the risk of pedestrians to road traffic accidents. Therefore, accident peaks appeared in these two rush periods of time. Also, the importance of the morning and evening peaks were nearly the same, each accounting for about 8% of the annual total pedestrian accidents. Furthermore, in the afternoon, a lot of people leave their office for lunch. In Hong Kong, the lunch hour is usually from 1300 to 1400 or 1430. The need to rush back to work at and after 1400 greatly increases the potential danger of being involved in road traffic collisions. During the non-office hours at night after 2000, pedestrians and vehicular traffic largely reduce and thus pedestrian accidents are lower. Interestingly, there were a small night accident peak at 2200 and a small mid-night accident peak at 2400. These two lower peaks may be associated with the bars and cafes near Lan Kwai Fong in Central, which attracted a lot people and traffic at nights. More importantly, the availability of alcohol in that district could also have increased the accident risk of pedestrians as people were less aware of road conditions after consuming alcohol. The weekly variations (Figure 2) of pedestrian accidents in Central also demonstrated clear characteristics of the commercial and business-oriented CBD. It was found that the percentage of pedestrian accidents generally increased from Monday till Friday and started to fall when approaching the weekends. One of the possible reasons to explain this is the weekday-weekend difference of work trips. All in all, the occurrence of pedestrian accidents is very much related to the volumes of pedestrians and traffic generated by the surrounding land uses in different time periods.

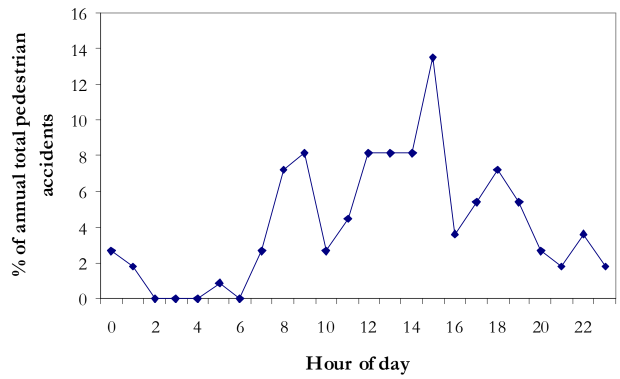

Figure 1 Hourly distribution of pedestrian accidents in Central, 2003

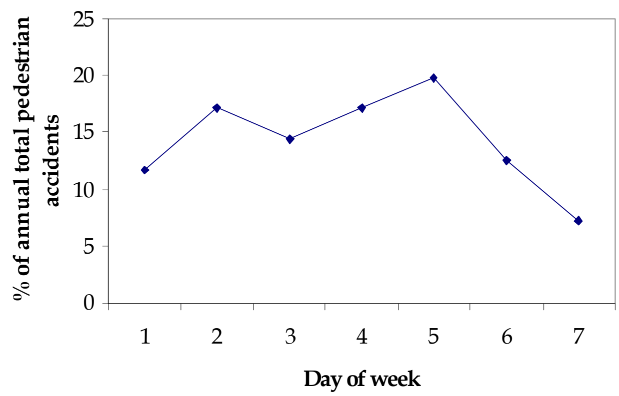

Figure 2 Weekly distribution of pedestrian accidents in Central, 2003

2.3 Land use in Causeway Bay

The spatial distribution of land uses in Causeway Bay is displayed in Map 2. Gloucester Road and Hennessy Road-Yee Wo Street are the key arteries in Causeway Bay. The western side of the study area is dominated by commercial/residential (C/R) land use, where the lower floors are the retail shops while the upper floors are for residential use. There are many famous and popular shopping malls attracting both local shoppers and tourists. Sogo, the World Trade Center and Times Square are some examples. In the central part of Causeway Bay, there is an area with lower density of development consisting of open space (O) (e.g. Victoria Park), government/institution/community (G/IC), other specialized uses (OU) (e.g. horse race course and Hong Kong Stadium) and green belt (GB). The eastern side of the study area is mainly high-density residential (R-A) land use. Some low-density residential (R-C) areas are found along the southern boundary of the study area. Overall, Causeway Bay is a district characterized by shopping and recreational activities.

2.4 Temporal patterns of pedestrian accidents in Causeway Bay

The temporal distributions of pedestrian crashes in Causeway Bay clearly reveal the nature and characteristics of the district. The hourly fluctuations of pedestrian accidents over the day are shown in Figure 3. The great variability reflects that most of the trips generated from the commercial/residential land use were concentrated in the daytime and the major accident peaks occurred also in the daytime.

In addition, it is noteworthy that there were two afternoon peaks at 1300-1400 and 1600 in this shopping district. The percentage of pedestrian accidents occurring between 1300 and 1800 was as high as 48%. Unlike Central, the morning peak was shorter in duration and of less relative important. This is also related to the nature of the underlying land uses. Shopping and recreational activities usually take place in the afternoon in weekdays like after school or after work and also in the afternoon on weekends. Moreover, when compared to the CBD, the night accident peak and the mid-night accident peak were higher and occurred at a later time at 2100 and 0200 respectively. In Causeway Bay, many dining restaurants and leisure shops are open until mid-night or even around the clock. Late at night, people might have a perception that the less crowded roads and streets were safe. Such misconceptions can make people less alert of the road traffic conditions. Speeding at night is also more common. Over the week, pedestrian accidents were more concentrated at weekdays instead of at weekends. From Figure 4, we see that they were clustered in the middle of the week, from Wednesday to Friday. One explanation may be the agglomeration effect and congestion effect suggested by Graham & Glaister (2003). Though a huge amount of people and traffic were attracted to Causeway Bay at weekends, such agglomeration often causes serious congestion and leads to lower speed driving. Thus, it is less likely for pedestrian accidents to occur.

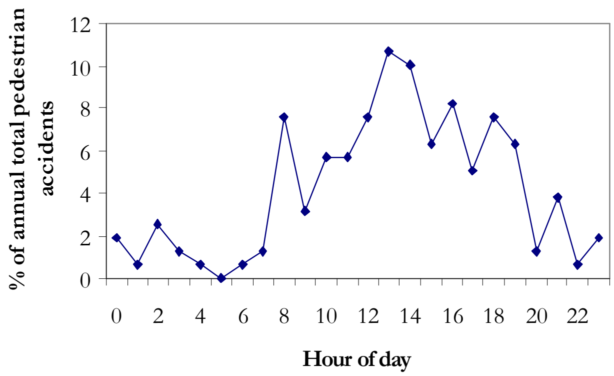

Figure 3 Hourly distribution of pedestrian accidents in Causeway Bay, 2003

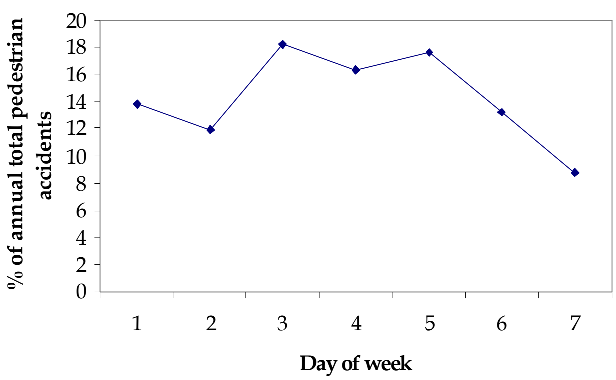

Figure 4 Weekly distribution of pedestrian accidents in Causeway Bay, 2003

3. SPATIAL PATTERNS OF PEDESTRIAN ACCIDENTS

Apart from looking at the temporal concentrations of pedestrian accidents over the day and week, it is also essential to examine accident clusters in the spatial dimension. GIS and the nearest neighbour analysis (NNA) were employed to find out the spatial patterns of pedestrian accidents in the two selected study areas. The former was first utilized to geo-code the pedestrian accident points for calculating the nearest distance of each accident point, whereas the later statistical technique was used to provide a descriptive index of the spacing of each set of points. The summary spatial statistics is known as the standardized nearest neighbour index (*R*), which measures whether the observed average nearest neighbour distance ($\overline{NND}$) is statistically different from its theoretical average nearest neighbour distance ($\overline{NND_R}$) (Eqn. 1).

$$R = \frac{\overline{NND}}{\overline{NND_R}} \tag{1}$$

, where $\overline{NND_R} = \dfrac{1}{2\sqrt{n/area}}$

, *n* is the number of accident points in the study area, *area* is the size of the study area

Then, *R* is compared to the three theoretical patterns with their associated *R* values of a perfectly clustered pattern (*R*=0), random pattern (*R*=1) and perfectly dispersed pattern (*R*=2.149). To test whether the spatial clustering is likely to be due to chance, we used the classical hypothesis testing and the one-sample difference-of-means test (Eqn. 2).

$$Z = \frac{\overline{NND} - \overline{NND_R}}{\sigma_{\overline{NND}}} \tag{2}$$

, where $\sigma_{\overline{NND}} = \dfrac{0.26136}{n\sqrt{1/area}}$

Two sets of null hypotheses and alternative hypotheses were developed as follows.

H_0 (A): The $\overline{NND}$ in Central in 2003 is equal to that of $\overline{NND_R}$.

H_1 (A): The $\overline{NND}$ in Central in 2003 is statistically different from that of $\overline{NND_R}$.

H_0 (B): The $\overline{NND}$ in Causeway Bay in 2003 is equal to that of $\overline{NND_R}$.

H_1 (B): The $\overline{NND}$ in Causeway Bay in 2003 is statistically different from that of $\overline{NND_R}$.

The decision rule was that the null hypotheses could be rejected if the calculated *Z*-values were greater than +1.96 or smaller than -1.96, given $\alpha = 0.05$.

Lastly, the two-sample difference-of-means test was used to compare the spatial patterns of the two study areas. It was first hypothesized that the distribution of pedestrian accidents in Central was more clustered than that in Causeway Bay. This is because of the high concentrations of office buildings and high-order retail shops in the former district and relatively more ubiquitous distribution of recreational and retailing activities in the latter. A one-tail test was applied and that the null hypothesis could be rejected if the *Z*-values were smaller than -1.645, given $\alpha = 0.05$. H_0 (D) tests whether the pedestrian accident pattern in Causeway Bay was more clustered than that in Central.

H_0 (C): The $\overline{NND}$ in Central is equal to the $\overline{NND}$ in Causeway Bay.

H_1 (C): The $\overline{NND}$ in Central is smaller than the $\overline{NND}$ in Causeway Bay.

H_0 (D): The $\overline{NND}$ in Causeway Bay is equal to the $\overline{NND}$ in Central.

H_1 (D): The $\overline{NND}$ in Causeway Bay is smaller than the $\overline{NND}$ in Central.

The results of the one-sample and two-sample difference-of-means tests are shown in Table 2. Firstly, the values of R in the two study areas were found to be smaller than 1, implying that the spatial patterns in the CBD and the shopping district can be described as statistically clustered. Moreover, the clustering of pedestrian accidents in both the CBD and shopping areas in 2003 were found to be statistically significant at 95% confidence level. H_0 (A) and H_0 (B) are rejected. Secondly, the pedestrian accident pattern in Causeway Bay, the shopping district, was found to be significantly more clustered than that in Central, the CBD. H_0 (D) is also rejected at 95% confidence level.

Table 2 Results of one-sample and two-sample difference-of-means tests

Testing	Hypo-thesis	*Area* (m²)	*n*	$\overline{NND}$ (m)	$\overline{NND}_R$ (m)	*R*	*Z*	Results
One-sample	**H (A)**	1419377.06	111	47.87	56.54	0.85	-3.09	Reject H_0(A)
	H (B)	2080880.45	158	37.27	57.38	0.65	-8.43	Reject H_0(B)
Two-sample	**H (C)**						32.42	Cannot reject H_0(C)
	H (D)						-34.42	Reject H_0(D)

Next, it is important to analyze the locations of pedestrian accident clusters so that policy-makers can formulate effective policies to improve pedestrian safety. It is believed that land uses nearby are good indicators not only of the volume but also the types and characteristics of pedestrians and vehicles attracted to an area. Hence, the pedestrian accidents were overlaid on the respective land use maps of the study areas (Map 3 & Map 4).

In Central, it is notable that pedestrian accidents were highly concentrated near the commercial (C) land use in the central part of study area and commercial/residential (C/R) land use in the north-western part along the three major transport routes. Some of them were located in the residential land use in the western part, mainly in the high-density residential (R-A) areas. Rarely were pedestrian crashes found in the Comprehensive Development Area (CDA) in the northern waterfront, and the open space (O) and government/institution/community (G/IC) in the southern part. The low number of pedestrian accidents near CDA is worthy of further study because this land use represents a highly-mixed land use type (often major employment centers as well) but better planning. In Causeway Bay, most of the pedestrian crashes occurred near the commercial/residential (C/R) land use at the western side. There were also some spatial clustering of pedestrian accidents near the high-density residential (R-A) land use in the north-eastern and the eastern side of the study area. In contrast, there were very few pedestrian accidents near the land uses of open space (O), other specialized uses (OU), green belt (GB) and government/institution/community (G/IC). Generally, pedestrian accident clusters were mainly found near the land uses with high pedestrian and traffic densities such as commercial land use and mixed commercial/residential land use. Moreover, areas with lower density of development experienced fewer incidences of pedestrian accidents.

4. CONCLUSION

This paper addresses two fundamental but seldom touch-on questions of "when" and "where" pedestrian accidents took place. The concentrations of pedestrian accidents in commercial and business areas have been examined. It was found that the incidence of pedestrian accidents over time (in a day and in a week) and over space (surrounding land uses) was closely associated with the functions and land use characteristics of an area. Both the temporal and spatial analyses of pedestrian accidents somehow reflected the nature and characteristics of the underlying land use pattern. The results suggest that certain land uses are associated with high potential risk of pedestrians to road traffic accidents. In this way, it is strongly suggested that pedestrian safety should be incorporated into the process of land use planning so that the safety of pedestrians can be better protected. For instance, there is some preliminary evidence to show that the better planned CDA land use may be safer to pedestrians. Moreover, more attention and resources need to be placed on areas of high-density, pedestrian accident-prone commercial (C) and commercial/residential (C/R) uses. They should have higher priorities of pedestrian safety measures (e.g. pedestrianization and traffic calming measures), facility improvements (e.g. guard railings, footbridges and subways) and publicity initiatives (e.g. road safety campaign). In the long run, pedestrian accidents can be minimized if the planning of pedestrian safety can be more carefully considered in the overall transport and land use planning process.

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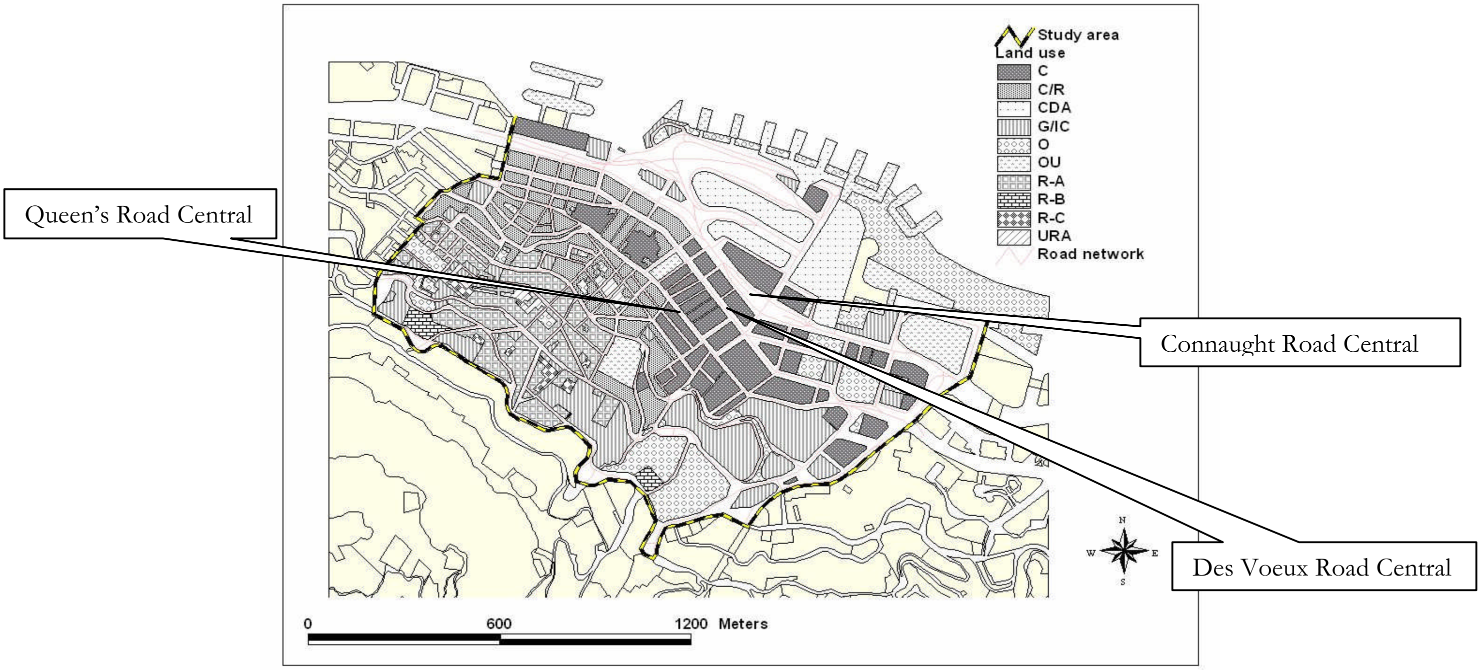
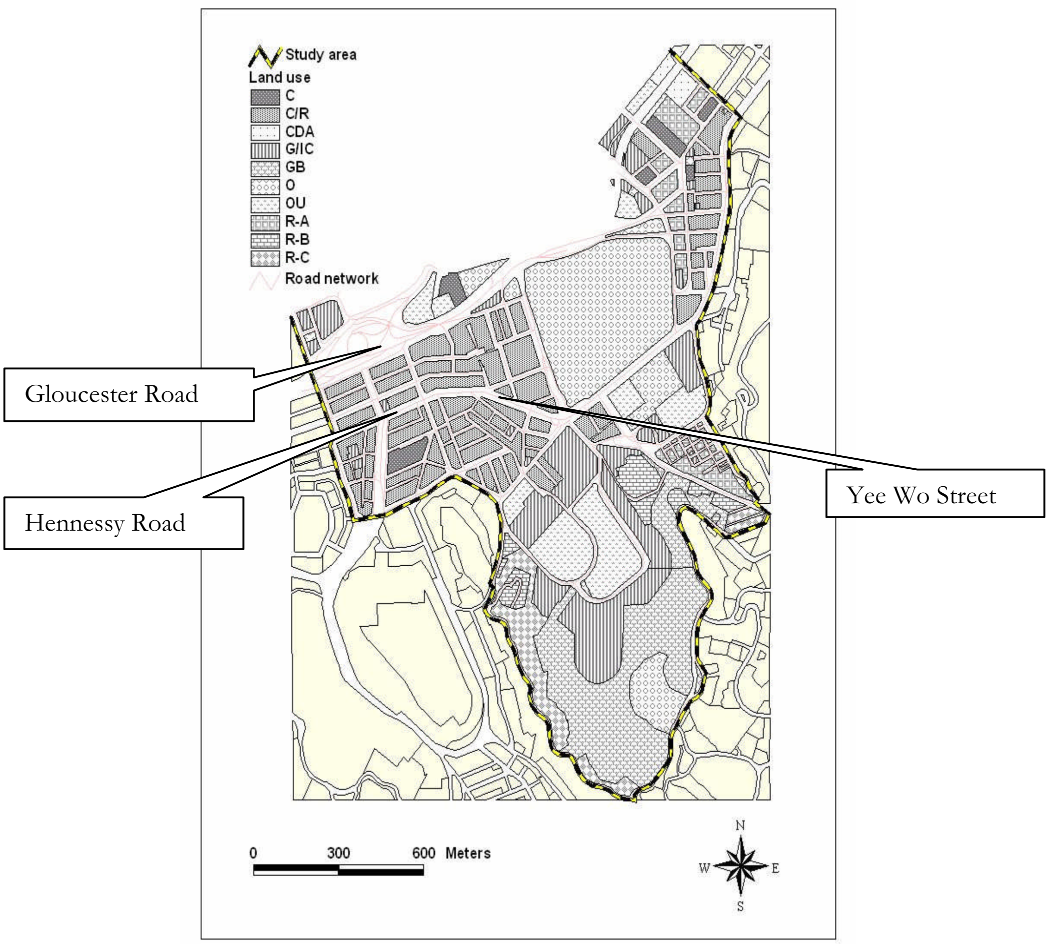
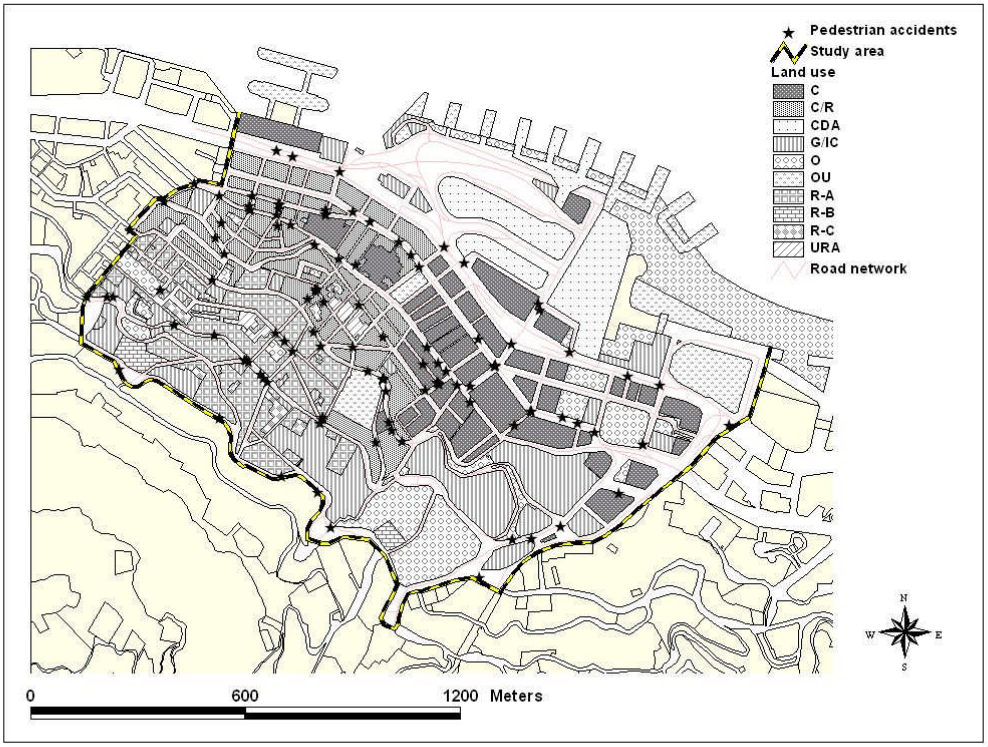


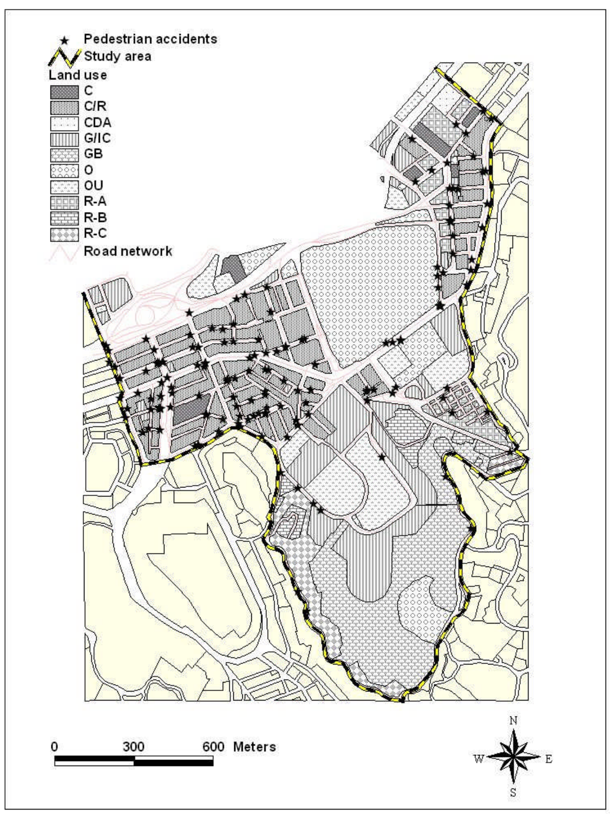
Map 1 Study area and land uses in Central



Map 2 Study area and land uses in Causeway Bay



Map 3 Distribution of 2003 pedestrian accidents in Central



Map 4 Distribution of 2003 pedestrian accidents in Causeway Bay