Effects of urban design on road accidents in Hong Kong

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Abstract

In this study, urban design is regarded as land use pattern. This paper reports an investigation on the effects of land use pattern on road accident levels in the 274 Traffic Zones in Hong Kong. Statistical method (correlation and regression analysis) and a mapping technique (Geographic Information System) were employed to analyze the effects of land use factors on fatal and serious injury road accidents. Correlation analysis was carried out to test the interrelationship between the road accident rate and the land use factors. Regression analysis was performed to establish the combination of the significant land use variables that best predicted the road accident level. The Geographic Information System was used to locate the Traffic Zones that had high road accident rates on the digital map. The results indicates that the significant land use variables; such as office and commercial area, residential area, railway station catchment area, number of hotel rooms, and number of cinema seats, are all having an effect on road accidents. While the significant land use variables such as building material storage; greenbelt land area, and villages, produce negative effects. The results of this study can serve as a reference for urban designers considering road safety in their town planning process.

Introduction

Road accidents are caused by many factors, such as human [14], vehicle and environmental factors [17]. The fact is that it is very difficult to change human behavior as a way to reduce road accident. However, improving vehicle and environmental factors are relatively easier to prevent road accident. For example, improving technology can increase the safety level of vehicles and improving
urban design can reduce the risk of road accidents. This paper reports an investigation on the effects of urban design on road accidents in Hong Kong.

Urban design has a wide definition. It governs city design, traffic calming, hard landscaping and architecture [2]. Urban design data in connection to land use pattern [8,11,15,19]; traffic aid [4,8,15]; and road layout [4,15,21] have been considered in various traffic accident studies.

In this study, land use pattern is emphasized in urban design. Land use pattern not only affects population distribution, employment level and traffic pattern [1,9] but may also affect road accident level. Hong Kong has planned to build many new towns as well as to redevelop the urban areas [6]. It is necessary to have a better understanding of the relationships between land use pattern and road accident level in order to develop a safer city.

There are two types of technique to analyze the effects of land use factors on road accident. They are statistical and mapping methods. Statistical method (such as correlation and regression analyses) is used to determine the interrelation between land use factors and road accident level. Many researchers [4,15,16] employed correlation analysis to determine urban design factors that had significant relationships with road accident level. Regression analysis has also been widely used to quantify the interrelationship between the combination of significant factors and road accident level [4,8,15,16]. Petch et al [15] as well as Rivara [16] used mapping method to show the spatial association between land use factors with road accident level. In recent year, Geographic Information System (GIS) [10,15] is often adopted as the mapping tool to perform spatial analysis and make geographical representation of the road accident data.

In this study, both statistical and mapping analyses were applied to investigate the land use effects on road accident level in Hong Kong. Fatal and serious injury road accidents were selected for investigation instead of all types of road accident. It is because fatal and serious injury road accidents costing a substantial loss in human life and economy. Fatal accident is defined as an accident in which at least one person killed immediately, or is injured and subsequently dies of his injury within 30 days of the accident. Serious injury accident is one in which one or more persons injured and detained in hospital for more than 12 hours [7].

**Study area**

This study was undertaken in Hong Kong where including Hong Kong Island, Kowloon and The New Territories (as shown in Figure 1). It has about 6.8 millions population in 2000 and is one of the densest city in the world. The development of Hong Kong is extremely fast in the last few decades. The population size has grown more than double since 1960s. Hong Kong has been undergoing rapid developments in both urban areas and new towns. In order to capture the characteristics of Hong Kong, the territory is sub-divided into 274 Traffic Zones or Traffic Analysis Zones (TAZs) based on the Hong Kong Second Comprehensive Transport Study [6]. The analysis in this paper has been performed using the land use and road accident information in these 274 TAZs.
Figure 1: Map of Hong Kong with territorial and TAZs boundaries.

Sources of data

Road accident data was extracted from the Hong Kong road accident database provided by The Road Safety and Standard Division of The Transport Department. It included the location (the easting and northing grids) and the severity of the road accident. The land use data was extracted from the land use database established by The University of Hong Kong [20]. It contained 25 different land use types in the 274 TAZs. The Hong Kong map with the territorial boundary and the 274 TAZs boundaries (as illustrated in Figure 1) was digitized from the paper map at The Geomatics Computing Laboratory of The Hong Kong Polytechnic University.

Data manipulation

The road accident and land use databases were linked up together and stored into the GIS software, MapInfo [12]. It was completed in 3 steps: (1) Importing the road accident data into the Hong Kong digital map by selecting the same coordinate system; (2) Adopting Structured Query Language (SQL) function to count the amount of road accident in the 274 TAZs; and (3) Merging the road accident data and the land use data of the 274 TAZs together by matching their zone index. The merged database was then used to perform statistical and mapping analysis.
Statistical analysis

Methodology

As this research is aimed to analyze land use effects on road accident level, road accident per area size is considered more appropriate than road accident per population as the dependent variable. Therefore, road accident per area size (i.e. road accident per 1,000,000 km²) was the dependent variable and the 25 different land use factors were the independent variables.

The correlation analysis was performed to test the interrelationship between the dependent variable and the independent variables. The pairwise correlation coefficients between the dependent variable and each of independent variable were computed using the statistical software SPSS [18]. The closer is the absolute value of the pairwise correlation coefficient to 1, the higher is the interrelations between the dependent variable and the independent variables [5]. Those independent variables with high correlation with dependent variable were filtered out and used to perform regression analysis.

The regression analysis, which establishing the relation of the cross-sectional data, was then carried out. It was aimed to establish the combination of the selected land use variables that could best predict the road accident level. Stepwise selection method, a technique that sequentially adding independent variables to the regression model [3], was employed to increase the efficiency of the regression model. More insignificant variables were eliminated out of the final model. The road accident regression model [4,15,16] has the form:

\[ Y = a \prod_{i=0}^{n} X_i^{c_i} \]  

(1)

After the logarithm transformation, eqn (1) becomes

\[ \ln Y = \ln a + \sum_{i=0}^{n} c_i \cdot \ln X_i \]  

(2)

where

- \( Y \) is road accident number per 1,000,000 km²;
- \( X_i \) is land use variables;
- \( a \) and \( c_i \) are coefficients to be calibrated; and
- \( n \) is the number of land use variables remaining in the model after correlation analysis and stepwise selection in regression analysis.

The coefficients of the regression model were calibrated using SPSS [18].

Results

Results of the correlation analysis are shown in Table 1. For comparison purpose, apart from road accident per area size, road accident per number of population was also used as dependent variables to correlate with all the 25 land use variables individually. The results showed that the road accident per area size had a stronger simple correlation with almost all the land use variables than road
accident per population [16]. Therefore, our choice of the dependent variable (road accident per area size) was correct for establishing regression model with those land use variables. After the correlation analysis, 9 out of the 25 land use variables, which had absolute value of the correlation coefficient smaller than 0.1, were eliminated. The 16 remaining variables that met the criteria were selected to perform the regression analysis.

Table 1: Pairwise correlation coefficient between road accident rate and land use variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Road accident Per area size</th>
<th>Road accident per population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building materials storage area</td>
<td>-0.5635</td>
<td>-0.0248</td>
</tr>
<tr>
<td>Village</td>
<td>-0.5477</td>
<td>-0.0280</td>
</tr>
<tr>
<td>Greenbelt land area</td>
<td>-0.5301</td>
<td>-0.0164</td>
</tr>
<tr>
<td>Railway station catchment area</td>
<td>0.4948</td>
<td>0.2806</td>
</tr>
<tr>
<td>Number of cinema seats</td>
<td>0.4554</td>
<td>0.1932</td>
</tr>
<tr>
<td>Commercial and office area</td>
<td>0.4390</td>
<td>0.2998</td>
</tr>
<tr>
<td>Container storage area</td>
<td>-0.3753</td>
<td>0.0949</td>
</tr>
<tr>
<td>Number of hotel rooms</td>
<td>0.3512</td>
<td>0.2629</td>
</tr>
<tr>
<td>Country park</td>
<td>-0.2593</td>
<td>-0.0384</td>
</tr>
<tr>
<td>Market stalls</td>
<td>0.2210</td>
<td>0.1108</td>
</tr>
<tr>
<td>Other specified uses</td>
<td>0.2197</td>
<td>0.0913</td>
</tr>
<tr>
<td>Comprehensive development area</td>
<td>-0.2030</td>
<td>0.0000</td>
</tr>
<tr>
<td>Commercial and residential area</td>
<td>0.1541</td>
<td>-0.0566</td>
</tr>
<tr>
<td>Residential area</td>
<td>0.1466</td>
<td>0.0003</td>
</tr>
<tr>
<td>Secondary school places</td>
<td>0.1170</td>
<td>-0.1040</td>
</tr>
<tr>
<td>Kindergarten places</td>
<td>0.1050</td>
<td>-0.1459</td>
</tr>
<tr>
<td>Number of hospital beds</td>
<td>0.0886</td>
<td>0.0372</td>
</tr>
<tr>
<td>Government, institute, and community area</td>
<td>-0.0832</td>
<td>0.1430</td>
</tr>
<tr>
<td>Flatted factory area</td>
<td>0.0625</td>
<td>0.1275</td>
</tr>
<tr>
<td>Primary school places</td>
<td>0.0619</td>
<td>-0.1409</td>
</tr>
<tr>
<td>Tertiary school place</td>
<td>0.0489</td>
<td>0.0724</td>
</tr>
<tr>
<td>Specialized factory area</td>
<td>-0.0417</td>
<td>0.1188</td>
</tr>
<tr>
<td>Warehousing area</td>
<td>0.0248</td>
<td>0.0501</td>
</tr>
<tr>
<td>Other specified uses</td>
<td>-0.0215</td>
<td>0.0805</td>
</tr>
</tbody>
</table>

The 16 selected land use variables were used as independent variables to establish a regression model with the road accident per area size. After the stepwise regression analysis, 8 more insignificant variables (with t-value smaller than the critical value 1.645) were removed. The coefficients together with the t-values of the significant land use variables are shown in Table 2. The significant
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land use variables were office and commercial area; residential area; railway (Mass Transit Railway and Kowloon Canton Railway) station catchment area; number of hotel rooms; number of cinema seats; building material storage; greenbelt land area; and village. The regression model had the coefficient of determinant equal to 0.685. It implied that model can account for about 68.5% of the variation in road accident rate.

Table 2: Regression model results.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential area</td>
<td>0.71394</td>
<td>0.35429</td>
<td>2.01515</td>
</tr>
<tr>
<td>Railway station catchment area</td>
<td>0.05364</td>
<td>0.01075</td>
<td>4.98832</td>
</tr>
<tr>
<td>Commercial and office area</td>
<td>0.05221</td>
<td>0.01135</td>
<td>4.60139</td>
</tr>
<tr>
<td>Number of cinema seats</td>
<td>0.13431</td>
<td>0.03499</td>
<td>3.83824</td>
</tr>
<tr>
<td>Number of hotel rooms</td>
<td>0.07246</td>
<td>0.02124</td>
<td>3.41221</td>
</tr>
<tr>
<td>Greenbelt land area</td>
<td>-0.08406</td>
<td>0.01086</td>
<td>-7.73877</td>
</tr>
<tr>
<td>Building materials storage floor area</td>
<td>-0.12084</td>
<td>0.02039</td>
<td>-5.92522</td>
</tr>
<tr>
<td>Village</td>
<td>-0.04101</td>
<td>0.01439</td>
<td>-2.84862</td>
</tr>
</tbody>
</table>

In Table 2, it was found that the office and commercial area, railway station catchment area, residential area, cinema and hotel had positive relationships with the road accident level. All of these areas either have high population density, high employment level, high traffic flow, or combination of the previous three characteristics.

The factor of commercial and office areas was found significant by related to the road accident level. Increasing the commercial and office areas seemed to increase the road accident rate. This is contributed to the fact that there are intensive commercial activities in these areas. Consequently, these areas generate huge traffic and pedestrian flows and thus road accidents [13].

The factor of railway station catchment areas was found a significant one in relation to road accident level. It is probably due to extreme high pedestrian density within the railway station catchment area. Railway stations are usually located at the heart of each district with public transport interchanges around them. Therefore, high traffic and pedestrian flows in these areas may give rise to high road accident risk.

The residential area was the most significant factor related to the accident rate in a positive direction according to the t-values shown in Table 2. The higher the t-value, the more significant is the factor in relation to road accident rate. Therefore, larger the residential area, the higher would be road accident rate. Although residential area has lower pedestrian or traffic flow rates than commercial and office area or railway station catchment area, the road accident risk is higher than these two areas. The proportion of children and elder people in residential areas are higher than in other areas. These groups of people have less awareness and less caution to the traffic. It could probably increase the risk of road accident.
The factor of number of cinema seat and hotel room was also significant. Cinemas and hotels are usually located in the urban area. They generate high pedestrian or traffic flow because they provide entertainment and accommodation for local people or tourists.

The factors of building materials storage area, green belt area and village showed a negative relationship with road accident level. It may be due to the fact that these areas are far away from Central Business Districts and have much lower traffic and population densities. As a result, they have much lower road accident rate than other areas such as residential, commercial and office areas.

Mapping Analysis

Methodology

GIS software, MapInfo [12], was used as a mapping tool to illustrate the road accident level in TAZs. The spatial pattern of road accident level could be easily seen on the map. Therefore, the TAZs with high accident rate could be found. Moreover, the employment and population levels were also shown on the map in order to find out the spatial association between these factors and road accident level.

Results

Figure 2 shows the road accident rate (road accident per 1,000,000 km²) in the 274 TAZs in Hong Kong. High road accident level was located in the northern part of Hong Kong Island and Kowloon (as shown in Figure 2). The northern part of Hong Kong Island and Kowloon had high density residential, commercial and office areas together with many railway stations, the road accident risk is much higher as found in the statistical results.

As illustrated in Figure 3, the TAZs in Hong Kong Island and Kowloon with high population or employment levels had high road accident rates. Increasing of residential, commercial and office land uses increase the population and employment levels within the areas. High population and employment levels increase human activities within the areas. It generates many pedestrian and traffic flow. It can increase the road accident rate of the zone.

Discussions

This study illustrates that land use pattern can influence road accident levels in Hong Kong. The land use pattern determines population level, employment level and traffic flow intensity. Higher population level, employment level or traffic flow intensity increase the risk of road accident. Beside, land use pattern also affects the demographic distribution of the people.

In residential area, the proportion of children or elder people is higher than other areas. These people have a higher risk of involving in road accident.
Figure 2: Road accidents per 1,000,000 km² in the 274 TAZs.

Figure 3: Road accident rate, population level and employment level in Hong Kong Island and Kwoloon.
In commercial area, road users, including drivers are usually in hurry, they take less care on road safety or something even ignore road safety. For example, pedestrian walk on the carriageway, or cross the road by ignoring the traffic signal, and lorry drivers illegally park their vehicles on the road side for loading or unloading. These activities contribute to a high risk of road accident.

With the land use planning data, the road accident regression model developed in this study can be used to estimate the road accident level in TAZs. With the GIS, the predicted road accident rates can be shown on the map. Therefore, road accident prevention measures can be easily applied to the high risk TAZs.

Conclusion

This paper investigates the effects of land use factors on road accident level. Statistical and mapping techniques were used to investigate the effects of land use on road accident level. The correlation analysis and stepwise regression analysis, as statistical tools, were adopted to eliminate insignificant independent variables and build up a model to quantify the relationships between road accident level and the land use factors. GIS, as a mapping tool, was also used to locate the TAZ with a high road accident rate. The results indicates that the significant land use variables are the office and commercial area; residential area; railway station catchment area; number of hotel rooms; number of cinema seats; building material storage; greenbelt land area; and village. The results of this study can serve as a reference for urban designers considering road safety in their town planning process.

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References