THE RELATIONSHIP BETWEEN URBAN LAND USE AND PEDESTRIAN AND CYCLIST CASUALTIES

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Abstract: Promoting a modal shift to walking and cycling for shorter journeys as well as making these modes safer has been examined by the UK government, practitioners and academics and researchers. It has been found that urbanisation has the effect of increasing casualties to non-motorised road users. This paper examines the relationship between non-motorised transport casualties (in particular pedestrians and cyclists) and urban land use. The study concentrates on characterising the spatial and temporal variation of non-motorised transport casualties and urban land use. More specifically, this relationship is examined spatially and with respect to day and night, and the weekly variation of working hours. Other associated factors, such as land use proportion, population density and junction density are considered to explain the relationship.

Keywords: pedestrians, cyclists, casualties, urban land use.

HUBUNGAN ANTARA TATA GUNA LAHAN PERKOTAAN DAN KECELAKAAN LALU LINTAS PADA PEJALAN KAKI DAN PENGENDARA SEPEDA

Abstrak: Pemerintah, para praktisi transportasi maupun peneliti di Inggris telah lama mengajak masyarakat untuk lebih banyak berjalan kaki dan memakai sepeda sebagai moda transportasi untuk pergerakan yang berjarak pendek. Berbagai studi mengenai daerah perkotaan menyimpulkan bahwa tingkat urbanisasi yang cepat dan tinggi juga berefek kepada jumlah korban kecelakaan lalu lintas khususnya pejalan kaki dan pengayuh sepeda. Di dalam studi ini diteliti hubungan antara tata guna lahan daerah perkotaan dan korban kecelakaan lalu lintas yang bukan pengendara kendaraan bermotor. Studi ini memfokuskan kepada karakter variasi spasial dan temporal dari tata guna lahan di perkotaan dan korban kecelakaan lalu lintas. Lebih jauh studi ini berfokus kepada malam dan siang hari, variasi jam kerja di dalam satu minggu yang lazim ada di Inggris. Faktor-faktor yang berkaitan lainnya yang juga diperhitungkan adalah proporsi tata guna lahan, kepadatan penduduk dan kepadatan persimpangan di daerah perkotaan.

Kata kunci: pejalan kaki, pengayuh sepeda, korban kecelakaan lalu lintas, tata guna lahan perkotaan.

BACKGROUND

Pedestrians and cyclists are two elements of non-motorised transport, which are environmentally benign modes, cheap and convenient for short distance journeys up to 3.5 km. Less attention has been given in transportation research to these modes of transport since they are low technology, low investment and less congestion, (Rietveld, 2000). In fact, in most countries between 20% and 40 % of road accidents involve pedestrians and cyclists.

According to the theory of urban safety management, land use is one of the policies used to prevent and reduce accidents[2]. Many aspects of road safety analysis are also associated with land uses and its activities [3].

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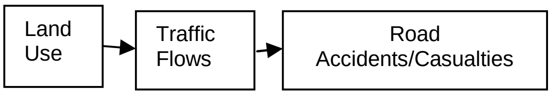
Different types of land use generate different number of trips and traffic, which in turn have the potential to cause road accidents. In other words, each type of land use, indirectly, has the potential to generate road accidents.

Why non-motorised transport?

The House of Commons Transport Committee (1996) examined ways to reduce risk to pedestrians and cyclists. In addition, the Department for Transport (DfT) is promoting a modal shift to walking and cycling for shorter journeys, as well as making these modes safer.



As a matter of fact, pedestrians and cyclists are the most vulnerable road users in road accidents. For example, in the US, pedestrians are the second largest population group to die in motor vehicle related crashes (LaScala, et.al, 2000).

Why urban land use?

The degree of urbanisation is considered to have an impact on non-motorised transport casualties for which demographic factors (e.g. population density), road and traffic environment factors (e.g. road length, junction density, and land use) are strongly associated factors. For instance, the risk of pedestrian accident is up to five (5) times greater for children living in urban areas rather than rural settlements (Petch and Henson, 2000).

In traditional four step traffic models, land use is modelled to estimate the number of trips or the traffic flow. The traffic flow itself, in several accident predictive models, is considered to be an exposure variable for road accidents. Generally speaking, this situation would be described as a sequence or line of analysis.

This study attempts to clarify the relationship between land use patterns in urban areas and pedestrian and cyclist casualties. The main traffic variable such as traffic flow is omitted within the analysis of study.

The main purpose of this study is to identify land-use types, which have high association with number of casualties, and to concentrate on reducing these casualties. As a result, traffic flows are not a substantial issue for non-motorised transport casualties.

To summarise, the relationship between non-motorised transport casualties and their associated factors are carried out in a 'direct manner'. In addition, this study concentrates on the effect of land use factors as a principal determinant of trips on road casualties. To do this, spatial analysis of non-motorised transport casualties within urban land use is carried out.

LITERATURE REVIEW

In relation to land use and road accidents some previous studies have been undertaken:

(a). Population and major sources of employment were concluded to generate a certain level of accidents (Levine, et.al, 1995). This was carried out by investigation of the relationship between activities (number of workers) and motor vehicle accidents.

(b). Land use factors were insignificant in explaining child pedestrian/cyclist casualties (Petch, et.al, 2000). In terms of land use factors, the number of trip attractors or trip generators, percentage of terraced housing, open space (km^2) were used in the analysis. In general, this study investigated the relationship of child casualty distribution (both of pedestrians and cyclists) with traffic, physical, socioeconomic and activity variables.

(c). Giving priority to efforts to prevent pedestrian alcohol impairment, and neighbourhood alcohol availability is suggested (La Scala, et.al, 2000). This conclusion was based on the relationship of spatial location of retail alcohol, demographic factors and road environment with pedestrian injuries. In relation to land use, number of bars, off-premise establishments, and restaurants per km of roadway are connected to pedestrian injuries.

(d). The driveways along the road link were significant in predicting single vehicle crashes as well as multi vehicle crashes (Ivan, et.al, 2000). The effect of land-use on single and multi vehicle crashes was the main objective of this study. It was expressed in terms of the number of driveways on each road segment.

In terms of cyclist safety, little has been found related to land use. Cyclist safety rates were assessed on-road, off-road and on footways (Aultman-Hall and Kaltenecker, 1999). As with pedestrian safety, this study also concluded that urban form (land use characteristics), traffic levels and attitude may affect bicycle safety.

Some previous studies attempted to relate land use characteristics to travel patterns, particularly for walking and cycling (Badoe and Miller, 2000; Cervero and Kockelman, 1997; Rietveld and Brainsma, 1998). Generally speaking, the findings are as follows:

Spatial locations of activities as well as spatial density have a significant role in studying the land use-transport interactions. Those of land use patterns are due to local decisions to respond to market demand such as housing, employment and services. Technically, in land use planning, land use is distributed properly in relation to road safety to minimise conflict between motorised and non-motorised transports.

This can be achieved by reducing the need to travel by vehicles, for example, by locating shops and schools within walking distance of homes. In other words, mixed land use where trip generators and trip attractors are located close to each other could minimise the need to trip by car, thus encouraging walking and cycling.

Urban Land Use

Land use classification in this study is based on the Department for Transport (DfT) on land use classification.

(a). Residential (R), such as houses and flats and road or paths within such area.

(b). Institutional/Communal Accommodation (Q), such as hotels / hostels, old people's homes, children's homes, monasteries and convents.

(c). Highways and road transport (H), such as through routes/distributor roads in housing-estates, bus stations and public car parks.

(d). Non-highway transport routes and places (T), such as railways, airports and dockland.

(e). Utilities (U), such as cemeteries and crematoria, power stations, water works, gas works, refuse disposal places (except those in Landfill Waste Disposal (Y)), TV Masts and electricity sub-stations, gas works or water works.

(f). Industry (I), such as works, refineries, shipbuilding yards, mills and other industrial sites.

(g). Offices (J), such as local and central government offices, banks, building societies and other offices, etc.

(h). Retailing (K), such as shops, garages, public houses, restaurants, post offices, etc.

(i). Storage and Warehousing (S,) such as depots, scrap and timber yards, warehousing built on former dockland.

(j). Community Buildings (C), such as health, educational, community and religious buildings and police stations, prisons, fire stations, etc.

(k). Leisure and Recreational Buildings (L), such as museums, cinemas, theatres, bowling alleys, sport halls, holiday camps, amusement arcades, etc and buildings associated with outdoor recreation.

(l). Vacant Land previously developed (V), includes cleared sites used as temporary car parks or playgrounds.

This classification is then used as a basis for data collection, and for analysing the relationship between land use and road casualties. In this paper, therefore, land use within urban areas refers to these classifications. These are then used to reflect land use diversity, land use density and land use design within the case study area.

In order to cope with multicollinearity of explanatory variables in the model, some land use variables are grouped as follows:

(a). Residential (R) and Institutional/ communal accommodation (Q) are grouped as residential (RQ).

(b). Industry (I) and storage (S) are grouped as industrial (IS)

Some sort of land use is assumed to have relation with temporal variation such as on the weekdays (Monday to Friday) during working hours (7 a.m. to 7 p.m.) and non-working hours (7 p.m. to 7 a.m.). Therefore, non-motorised casualty distribution is analysed according to those temporal variations. For example, schools, offices and commercial premises attract people during working hours, while most pubs, bars and leisure facilities attract people after working hours.

In order to set up the study variables, several criteria have been used:

(a). As the study objective is to examine the effect of land use patterns on non-motorised transport casualties, all of the land use characteristics, including land use density, land use diversity, and land use design, are represented. This is carried out by land use proportion; that is the ratio of each land use in each area to the total Enumeration district area.

(b). Population density reflects possible number of trips generated for several walking and cycling.

(c). Junction density reflects the area where almost pedestrians and cyclists are likely to have accidents. Conflicts between motorised and non-motorised transport are frequent in such areas.

In summary, variables taken as a basis for data.

Data

Data collected are related to the specification of variables of study:

(a). Accident casualties (pedestrian and cyclist): these data describe number and the spatial location of pedestrian and cyclist accidents from 1998 to 2001 throughout the case study area (Newcastle upon Tyne) as shown in Figures 1(a) and 1(b). These data are collected from Traffic Accident and Data Unit of Gateshead M.B.C.

(b). Land use data are collected from digital map supplied by Digimap of Edinburgh University. Land use data as well as road length and number of junction are then processed by ARC/ INFO. The number of junctions divided by road length within an Enumeration District is defined as junction density. Meanwhile, land use data is calculated as the proportion of each type of land use within the study area boundary.

Where: Pwh : Pedestrian casualties during working hours

Pnwh: Pedestrian casualties during non working hours

Cwh : Cyclist casualties during working hours

Cnwh : Cyclist casualties during non working hours.

Collection are described in Table.1

Table 1. Study Variables

Response variables: Pedestrian and cyclist casualties during working hours and non-working hours.
Explanatory variables Population density (residents per km^2) Junction density (number of junctions per km of road). Land-use proportions. Road Length.

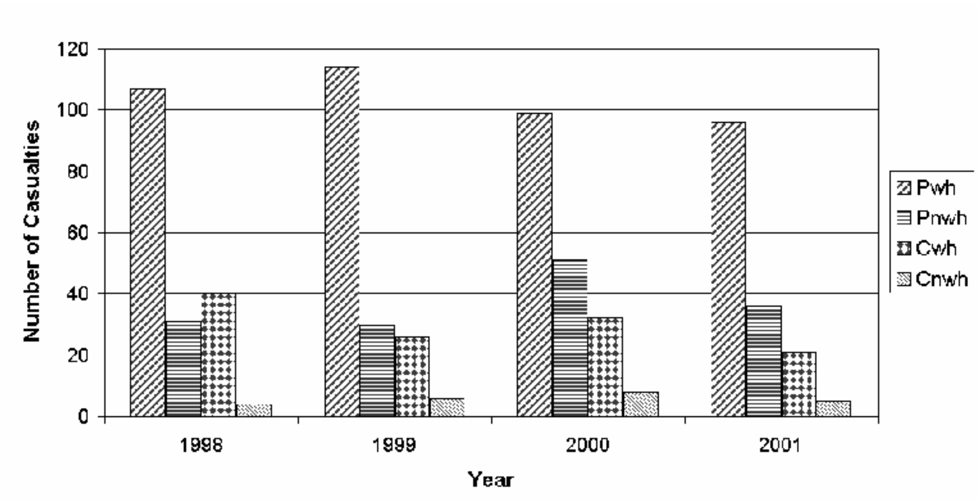


Figure 1(a). Distribution of Non-Motorised Transport Causalities Involved in Road Traffic Accidents (All days)

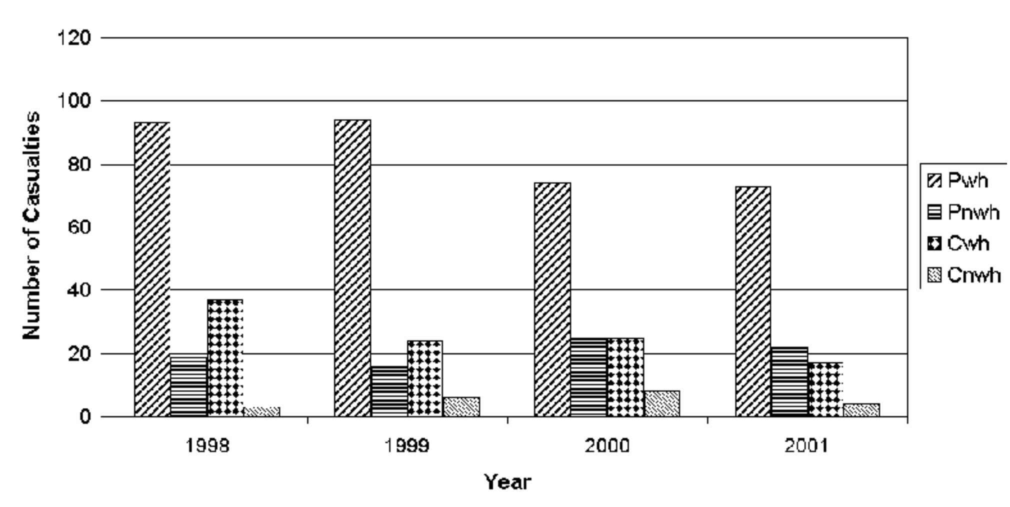


Figure 1(b). Distribution of Non-Motorised Transport Causalities Involved in Road Traffic Accidents (Weekdays)

Land Use Data Collection

In terms of land use data collection, land use can be divided into either activity (functional) or physical characteristics of those places. In urban areas, such a distinction is usually straightforward. This distinction can be made between use of two (2) buildings on the grounds that one was an office while the other was a residential property (Rhind and Hudson, 1980).

The study objective determines land use classification, whether it is based on functional (activity) or physical characteristics.

(a). Functional: services/offices, residential, vacant land, and industry.

(b). Physical: high rise industrial buildings, low-rise non-residential buildings, detached housing, semi-detached housing, open area.

There is common agreement that activity, or more specifically the principal activity, carried on at a site is the main concern of many people in collecting land use data (activity based data). For instance, land-use classification such as predominantly shopping facilities, predominantly housing, predominantly offices services, factory area, play area. In quantifying land use data, the amount of land used for various purposes in an urban area is one of the main parts of the city plan. For example, a high density of services and commercial premises within a single central area attracts a high proportion of trips.

When the land use is recorded based on the predominant land use class as a nominal scale variable, less can be done with such data. Alternatively, other available measurement scales such as ordinal, interval and ratio provide increasing possibilities for sophisticated analysis. Obviously from the study objective of this research, land use is based on its functional and predominant use, which is represented by land use proportion

METHODS

In this study, spatial analysis is used to approach the problem. Basically, spatial analysis uses location (such as casualty locations) as a primary factor in determining casualty distribution and relating casualties with explanatory variables in the model.

Spatially, Enumeration District (ED) is employed as the spatial unit of study. Consequently, all of data as well as analysis are assigned and based on this unit. An Enumeration District is the smallest census boundary in England. In the case study area, 185 Enumeration Districts are used and bounded by [(421,500 Easting; 563,000 Northing) and (426,000 Easting; 569,000 Northing)].

Defining Buffer Zones

Create a buffer zone, which has a radius of 3 km. Each zone is then used as a basis for analysing the relationship the neighbouring land use and the non-motorised transport casualties. The reason for creating such a zone is based on assumption that pedestrians or cyclists move less than 3.5 km (Rietveld, 2000).

In creating the buffer zone, there is one Enumeration District used as a centre of the zone. The criterion for choosing a centre of each buffer is an ED which has proportion of trip attractor (retails, offices and industrial) more than 50%. Logically, when more than 50% are within a short distance it is assumed sufficient to attract the community (generally speaking, potential to generate trips either by walking or cycling).

In this study, two Enumeration Districts have proportion of trip attractors more than 50 %, which are ED with code 06CJNCL and 06CJGSF. These two districts are then chosen as centres around which to create the buffer zones. These two buffer zones are then called zone GSF (vertical line pattern) and zone NCL (dot pattern). Zone GSF consists of 93

Enumeration Districts, while zone NCL consists of 92 Enumeration Districts. The picture of each buffer zone can be seen Figure 2.

Based on land use distribution within each buffer zone (zone GSF and zone NCL) in Table 2, some facts are:

(a). The proportion of trip generators is greater in zone GSF (42 %) than in zone NCL (23%). In addition, population density in zone GSF is greater than in zone NCL. On the other hand, the proportion of trip attractors is lower in zone GSF (19 %) than in zone NCL (28 %).

(b). The proportion of footways and roadways is (relatively) similar between those two zones (GSF and NCL).

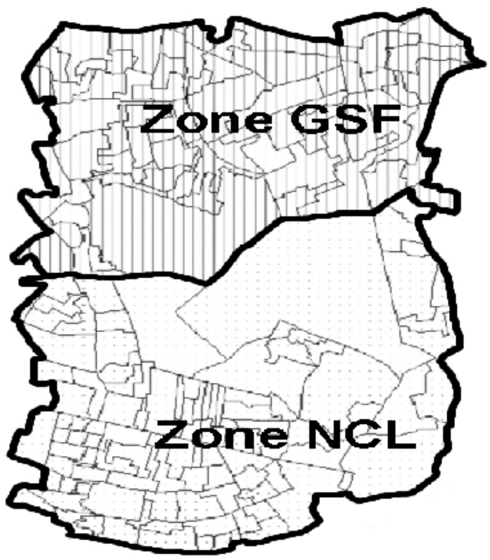


Figure 2. Buffer Zone in the case study area

Table 2. Land-use Proportion

Buffer Zone	Zone GSF	Zone NCL
Population. Density (person/km^2)	3660	3369
Junction density (junction/km)	7	6
R (residential)	0.42	0.21
Q (communal accommodation)	0.00	0.02
H (roadway)	0.10	0.15
T(non-highway places)	0.01	0.01
U (utility)	0.00	0.01
I (industry)	0.02	0.04
J (offices)	0.01	0.03
K (retail)	0.01	0.05
S (storage)	0.00	0.02
C (community building)	0.13	0.10
L (leisure)	0.04	0.04
V (vacant land)	0.17	0.24
W (footway)	0.07	0.07

From the casualty data, it can be seen that most pedestrian and cyclist casualties are more concentrated within zone NCL than in zone GSF. In relation to land use distribution, as a pre-analysis, one would say the greater proportion of trip attractors in a certain area, the more casualties; regardless, either of population density or proportion of trip generators.

Spatially, every casualty and land use factor within a zone is modelled. Casualties are plotted as points, meanwhile land use is plotted as polygons (blocks of land use statistically represented by proportion). In addition, proportion of land use also reflects trip origin and destination of pedestrian and cyclists.

Trip origin and destination of pedestrians and cyclists are assumed within the zone. However, a shortcoming

Multicollinerity Analysis

All of the explanatory variables (population density, junction density and land use factors) are estimated in terms of their correlation. Since there are two buffer zones created, (i.e. GSF and NCL), correlation analysis of those explanatory variables within these two zones is carried out (see Tables 3a and 3b).

Correlation of these variables is used to select the explanatory variables within the initial model. In addition, variable selection is based on the standard error of these explanatory variables. To obtain such, all (initial) models are developed with Poisson regression for which road length is the offset. The results are as follows:

(a). When residential (RQ) is included in the initial model, the standard error of each explanatory is larger than when residential is excluded.

(b). Population density and residential are basically reflecting the same thing, as population resides in residential area. As a result, residential (RQ) is excluded in all models

(c). The models developed either for pedestrian casualties or cyclist casualties are divided to two categories, casualty with essential land use (e) include trip attractors (Popd, Jund, IS, J, K, C, and L) and all land use (except RQ). Such correlation is inevitable in survey work, however, this has less influence on the estimates of coefficient of essential land use rather than all land use.

Working and Non-Working Hours

Land use can be explained by its characteristics in relation to time. In a sense, some sort of land use generates trips during working hours or non-working hours. During non-working hours industry (IS) and offices (J) are not defined, since normally during that time these land use types are closed.

Table 3a. Correlation of Land-Uses in Zone GSF

	Popd	Jund	RQ	IS	J	K	C	L	V	W	H	T	U
Popd	1.00												
Jund	0.04	1.00											
RQ	0.62	0.02	1.00										
IS	-0.22	0.02	-0.34	1.00									
J	-0.07	0.01	-0.25	-0.07	1.00								
K	-0.05	0.05	-0.16	0.01	0.08	1.00							
C	-0.44	-0.03	-0.47	-0.07	0.17	-0.10	1.00						
L	-0.25	-0.08	-0.21	-0.07	-0.08	-0.08	0.04	1.00					
V	-0.33	-0.04	-0.42	-0.07	-0.09	-0.09	-0.14	-0.09	1.00				
W	0.40	0.04	0.22	-0.08	0.12	0.01	-0.26	-0.20	-0.27	1.00			
H	0.60	0.09	0.21	-0.11	0.13	0.08	-0.38	-0.30	-0.16	0.33	1.00		
T	-0.11	0.02	-0.21	0.10	-0.04	-0.04	-0.06	-0.05	0.00	-0.10	0.00	1.00	
U	-0.08	0.05	-0.03	-0.03	-0.05	0.46	-0.07	-0.04	-0.04	-0.05	-0.12	-0.04	1.00

Table 3b. Correlation of Land-Uses in zone NCL

	Popd	Jund	RQ	IS	J	K	C	L	V	W	H	T	U
Popd	1.00												
Jund	-0.01	1.00											
RQ	0.46	0.01	1.00										
IS	-0.27	0.00	-0.32	1.00									
J	-0.26	0.05	-0.39	0.37	1.00								
K	-0.02	0.02	-0.44	0.04	0.32	1.00							
C	-0.27	0.07	-0.38	-0.05	0.00	-0.01	1.00						
L	-0.19	-0.06	-0.22	-0.02	0.00	0.04	0.00	1.00					
V	-0.37	-0.09	-0.45	-0.01	-0.12	-0.16	-0.07	0.00	1.00				
W	0.41	0.00	-0.08	0.09	0.10	0.04	-0.13	-0.16	-0.18	1.00			
H	0.45	0.07	-0.14	0.13	0.24	0.40	-0.27	-0.06	-0.35	0.56	1.00		
T	-0.24	0.04	-0.26	0.10	0.10	0.39	-0.11	-0.04	0.02	0.11	0.23	1.00	
U	-0.20	-0.04	-0.19	-0.02	-0.06	-0.04	0.07	0.00	-0.02	-0.19	-0.19	-0.03	1.00

Table 3c. Temporal Variation of Land Use

Hours	M	T	W	Th	F	Sat	Sun
00.00	Non Working Hours						
07.00-19.00	Working Hours						
24.00	Non Working Hours						

As it can be seen from Table 3c, this study focuses on pedestrian and cyclist casualties in the weekdays from Monday (M) to Friday (F) during working hours and non-working hours. Working hours are defined as 07.00am to 19.00pm., while non-working hours are defined as 19.00 pm up 07.00 am.

Since land use is based on a time division, the casualty data (both pedestrians and cyclists) certainly are distributed prior to the time division. This is carried out using Geographic Information System (Arc/Info and Arc view).

After categorising pedestrian and cyclist casualties per Enumeration District during working hours and non-working hours, these variables (response and explanatory variables) are initially fitted by Poisson regression. Alternatively, these models may also be fitted using Negative Binomial, Zero Inflated Poisson or Zero Inflated Negative Binomial.

With reference to some previous studies in statistical model related accidents (Miaou, 1994; Shankar, et.al, 1997; Lee, et.al, 2002), each of these regression models has its own characteristics.

Poisson regression is used when variance of data is relatively equal to the mean of the data or the ratio of variance to mean is less than 1. When variance is not equal to mean or ratio of variance to mean is greater than 1 (e.g. data is called over dispersed), Negative Binomial, Zero Inflated Poisson Model or Zero Inflated Negative Binomial are explored.

In case of dispersion parameter is statistically significant, Negative Binomial regression is appropriate to perform the model.

Generalised Linear Models

The Generalised Linear Model (GLM) below is used as initial model, which relates casualties to land use factors. Based on such a model the analysis is performed to examine land use factors, which have high association with either pedestrian or cyclist casualties.

$Ln(\mu)=ln(rdlen)+\beta_o+\beta_1.Popd+\beta_2.H+\beta_3.K+\beta_4.C+\beta_5.L+\beta_6.IS+\beta_7.J+\beta_8.V+\beta_9.T+\beta_{10}.W+\beta_{11}.Jund$

Since accidents, which cause casualties, are rare events, the amount of accident data is low. As has been mentioned before, statistically, the data are also known to have excess zero. This may reflect the fact that the area is truly safe, or that there is no land use effect leading to casualties in such an area. This may or may not be true. Even unsafe areas have no accidents during certain observation periods, (Shankar, et.al, 1997).

Furthermore, accidents are defined as two conditions (Shankar, et.al, 1997, Miaou, 1994), first as an accident state where accident frequencies follow some known distribution such as Poisson or Negative Binomial distribution, on the other hand, as zero accident state when zero accident reflect safe area.

In summary, applied to this study, the accident state reflects that land use does have an effect on casualties, on the other hand, zero accident state reflects that land use has no effect on casualties. To model these two conditions, Zero Inflated Poisson or Zero Inflated Negative Binomial is examined.

In Table.4 the ratio of Poisson deviance to degrees of freedom and model distribution selection for typical models in each category are described. Addition of further explanatory variables did not result in any significant decrease in the deviance, and in some cases resulted in non-convergence or unstable estimates (unrealistically large in absolute value with even larger standard errors).

Over dispersion

The model evaluation is carried out to examine those regression models (Poisson, NB, ZIP and ZINB) which are appropriate to represent each type of casualties. Table.4 describes the result of model evaluation.

In order to evaluate those casualties, several criteria taken are described as follows:

(a). When the ratio of deviance to degree of freedom is relatively equal or less than 1 (under dispersion), Poisson regression (with correction for under dispersion) is fitted. When the ratio of deviance to degree of freedom is greater than 1, apart from Poisson regression, alternatively, Negative Binomial (NB), Zero Inflated Poisson (ZIP) or Zero Inflated Negative Binomial (ZINB) are explored.

(b). When the dispersion parameter is statistically significant, Negative Binomial is fitted. Furthermore, in case of many zero data, may imply over dispersion, which are not fitted with NB. In order to overcome with such condition Zero Inflated Poisson or Zero Inflated Negative Binomial are examined.

(c). In order to evaluate whether ZIP or ZINB is more appropriate than Poisson or NB consecutively, Vuong test is performed. In addition, likelihood ratio (LR) test is performed to evaluate whether ZINB or ZIP is more appropriate to fit the model.

Apart from LR, however, when model iteration are not convergence or showing messages such as backed up, not concave, or standard error of individual parameters too large, alternatively, Poisson regression with correction for over dispersion are examined.

Table 4. Model Distribution Selection

Casualties	Explanatory variables fitted	Poisson deviance/ degree of freedom	Statistical test	Model
Cyclist non-working hours GSF	1,Popd,Jund,K,C,H,U ,V,W	41.8/84	Deviance low due to many 0s and 1s	Poisson
Cyclist non-working hours NCL	1,Popd,Jund,K,C,L,H ,U,T,V,W	18.2/81	Deviance low due to many 0s and 1s	Poisson
Cyclist working hours GSF	1,Popd,Jund,IS,JK,C, L	84.6/85		Poisson
Cyclist working hours NCL	1,Popd,Jund,IS,J,K,C ,L	89.8/84		Poisson
Pedestrians non-working hours GSF	1,Popd,Jund,K,C	25.9/88	Deviance low due to many 0s and 1s	Poisson
Pedestrians non-working hours NCL	1,Popd,Jund,K,C,L	68.1/86		Poisson
Pedestrians working hours GSF	1,Popd,Jund,IS,J,K,C ,L	127.8/85	Vuong test of ZIP versus Poisson: Z=1.829 (P=.034)	Zero Inflated Poisson
Pedestrians working hours NCL	1,Popd,Jund,IS,J,K,C ,L	156.2/84	LR test of negative binomial = 0 $□_1^2$=25.5 (P=.000)	Negative Binomial

Where:

Popd = Population density	IS = industry	K = retail	L = leisure building
Jund = Junction density	J = offices	C = community building	H = roadway facilities
U = utilities	W = footway	T = non roadway facilities	V = vacant land

The next step is to identify significant variables (land use variables), which are based on the t statistic value. The model is refitted using those of significant variables, in order to obtain the final model. The final models explain those of land use variables, which have high association with either pedestrian or cyclist casualties during working hours or non-working hours.

Table 5. Significant land-use variables.

	Cyclists	Pedestrians
Non-working hours in zone GSF	All (less T,L) **H**(+)	All (less L) C(+)H(+) Essential Use (less L) **C**(+)
Non-working hours in zone NCL	Essential Use Jund(+)K(+)C(+)L(+)	All **Jund**(+)**K**(+)**T**(+)W(-) Essential use **Jund**(+)**K**(+)
Working hours in zone GSF	All **J**(-)**K**(+)**H**(+)C(+)L(-) Essential use **K**(+)**C**(+)IS(-)J(-)L(-)	All **Popd**(+)**Jund**(+)IS(+)**K**(+)**C**(+)**H**(+)**U**(+)T(+) Essential use **Popd**(+)**Jund**(+)**K**(+)**C**(+)
Working hours in zone NCL	All IS(-)J(+) Essential use **K**(-)IS(-)J(+)	All **Popd**(+)**Jund**(+)**IS**(+)**J**(+)**K**(+)**C**(+)**L**(+)**T**(+)H(-)W(-) Essential use **Popd**(+)**K**(+)**C**(+)IS(+)J(+)L(+)

Where:

Popd = Population density	IS = industry	K = retail	L = leisure building
Jund = Junction density	J = offices	C = community building	H = roadway facilities
U = utilities	W = footway	T = non roadway facilities	V = vacant land

In terms of land use, zone GSF and zone NCL have different patterns. More accidents occurred in zone NCL than in zone GSF. More specifically, within zone NCL, pedestrian casualties are concentrated around the city centre and as well as cyclist casualties which are distributed evenly through the rest of the area. Meanwhile, within zone GSF, both pedestrian and cyclist casualties are distributed evenly across the area. As a result, statistical inference may less be performed in zone GSF.

RESULTS AND DISCUSSION

Since less data are available about either pedestrian or cyclist casualties, in particular during non-working hours, model interpretation may be less reliable in such circumstances. In addition, the model interpretation is then mainly focused on pedestrian casualties and cyclist casualties. Based on models, which are developed for each type of casualty in Table 4, the significant land uses influencing pedestrian or cyclist casualties are listed in Table. 5.

With reference to the buffer zone of casualties, where by the nature, less accident in zone GSF compared to zone NCL, the summary of significant land use influencing casualties is grouped according to its zone.

A bold entry indicates that the absolute value of the associated coefficient was at least twice the standard error and other entries indicate that the absolute value of the coefficient exceeded the standard error. Statistically, the natural logarithm of road length (km) is an offset and the bracketed sign is the sign of the estimated coefficient.

As a matter of fact, as can be seen from Figure.1, there were few casualties in the non-working hour cyclist category. Eleven casualties in 10 out of 93 Enumeration Districts in zone GSF and 10 casualties in 9 out of 92 Enumeration Districts in zone NCL, so there were few statistically significant results. The main exception was the coefficient of H in the model for zone GSF that was 16.49 with a standard error of 7.01. A possible explanation is that, for this zone, a large proportion of highway in an Enumeration District attracts more cyclists, possibly passing through, than accounted for by the logarithm of road length used as an offset. Apparently, NCL is an inner city zone and shops are not well positioned for cyclists.

The essential use models for pedestrian casualties during non-working hours for the two zones are summarised in Table. 6 (b). In Table 6(b) Poisson regressions for pedestrian casualties during non-working hours which the natural logarithm of road length (km) is an offset. The scale parameter is taken as 1, and standard errors are shown in brackets underneath the estimated coefficient. Apparently NCL is a popular area of city during evenings with public houses and bars open from 5.pm until after midnight.

In Table 6(c) Pedestrian casualties in zone GSF and zone NCL during working hours are summarised. The natural logarithm of road length (km) is an offset. Standard errors are shown in brackets underneath the estimated coefficient.

In relation to land use category, which is all land use (except RQ), statistically, this influences the model results. Including other uses leads to a degree of Multicollinerity. Consequently, the coefficient of estimated parameter has large standard errors and therefore, few if any of the coefficients are individually statistically significant. This leads to difficulties in interpretation. Therefore, leaving out non-essential land use is justified.

Table 6a. Poisson regression for cyclist casualties during working hours

Variable	Zone GSF	Zone NCL
1	-0.6935 (0.4388)	-0.1543 (0.3620)
Popd	-0.000092 (0.000072)	-0.00003399 (0.00003513)
Jund	0.009646 (0.01691)	-0.001086 (0.04601)
IS	-12.39 (7.243)	-1.778 (1.141)
J	-6.610 (5.322)	2.400 (2.048)
K	10.17 (1.706)	-3.664 (1.545)
C	1.701 (0.8339)	-0.5058 (1.002)
L	-5.691 (3.489)	0.1033 (1.737)
Deviance/degree of freedom	84.57/85	89.78/84

Table 6b. Poisson regression for pedestrian casualties during non working hours.

Variable	Zone GSF	Zone NCL
1	-4.179 (1.837)	-2.740 (0.4733)
Popd	-0.0003524 (0.0001821)	0.00003001 (0.00002958)
Jund	-0.3004 (0.2555)	0.1348 (0.03848)
K	1.200 (12.80)	7.937 (0.8464)
C	5.958 (2.622)	0.6375 (1.199)
L		-3.412 (4.021)
Deviance/degree of freedom	25.868/88	68.14/86

As a result, land use effects on casualties are concluded to be limited to essential land uses, which are Industry (IS), Offices (J), Retail (K), Community Building (C) and Leisure building (L).

When few accidents occurred in a zone during a certain period of time, those reflect few casualties. As a result, it is difficult to interpret such land use effects on casualties. Consequently, during non-working hours, only pedestrian and cyclist casualties in the city centre (zone NCL) can be interpreted.

Table 6c. ZIP and Negative Binomial models for pedestrian casualties during working hours

Variable	Zone GSF	Zone NCL
1	-1.242777 (0.482765)	-0.900738 (0.397989)
Popd	0.0001554 (0.0000605)	0.0000624 (0.0000252)
Jund	0.0202967 (0.0087867)	0.028294 (0.037158)
IS	-1.6516 (4.8674)	1.409878 (1.40487)
J	2.29978 (2.9239)	2.96708 (1.87716)
K	5.72353 (1.66725)	5.103543 (0.988729)
C	2.24494 (0.808356)	2.157907 (0.790481)
L	-1.638106 (2.06869)	1.844403 (1.511869)
Inflate 1	1.8594 (1.36175)	
Popd	0.0001561 (0.0001486)	
Jund	-0.45933 (0.19572)	
IS	4.9625 (13.1903)	
J	11.96147 (11.12535)	
K	-16.1836 (13.391)	
C	-7.8189 (7.3138)	
L	-4.86879 (7.03875)	

On the other hand, during working hours pedestrian casualties are affected by population density, community building and retail. Meanwhile, for cyclist casualties retail has two effects, which are positive in zone GSF and negative relationship in the city centre (zone NCL). The latter may be affected by pedestrianisation around the shopping area in the city centre. Negative relationship means when number of retail premises increase casualties reduce.

Focusing on retail (K), during non-working hours is more related to land uses such as bars, public houses and restaurants, whereas during working hours this is more related to land uses such as shops and supermarket.

The essential use models for cyclist casualties during working hours for the two zones are summarised in Table. 6(a). In Table 6(a) Poisson regressions for cyclist casualties during working hours which the natural logarithm of road length (km) is an offset. The scale parameter is taken as 1 and the standard errors are shown in brackets underneath the estimated coefficient.

CONCLUSIONS

By comparing previous study findings on land use effects to encourage walking and cycling with the model results, a conclusion may be drawn. With reference to previous studies, the proportion of retail and other uses are considered to reflect mixed land use within the adjacent area. Based on the model results above, retail influences pedestrian casualties during working and non-working hours. Less can be done to interpret pedestrian and cyclist casualties during non-working hours since few accidents occurred. In other words, pedestrian casualties during working hours are more related to land use than during non-working hours and cyclist casualties during working/non working hours.

On the other hand, as shown in Table 2, the proportion of retail in zone GSF (0.01) is 4% less than that in zone NCL (0.05). It may be concluded that the increasing proportion of retail is relatively significant to influence casualties.

Apparently, retail premises may reflect the existence of mixed land use in the adjacent area. This may encourage walking and cyclist, which in turn may influence casualties.

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