THE INFLUENCE OF URBAN LAND USE ON PEDESTRIANS CASUALTIES (CASE STUDY AREA: NEWCASTLE UPON TYNE, UK)

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Abstract
Killed and seriously injured (KSI) and slight casualties on pedestrians due to accident occurrences in urban area were analysed in the city of Newcastle upon Tyne focusing on three groups involving children, adult and elderly. In the UK, children include persons below 16 years, adult between 16 and 64 years and elderly over 64 years. The analysis was carried out by focusing on these groups of ages in relation to the existing spatial patterns of urban land use in the city centre. The data source were taken from the local traffic accident data unit during period between 1998 and 2001 involving pedestrians ages, demography data from UK census 2001 and land use data for 2001 from Digimap UK. Ward which is one of the output boundary areas referring to UK Census 2001 has been chosen as the spatial unit of study. Urban land use types included in the analysis are both trip generators and attractors which refer to official land use classification published by Department for Communities and Local Government (formerly the Office of Deputy Prime Minister /ODPM). Poisson regression models were performed using number of pedestrian accidents including these three groups of ages as response variables and census and land use data as explanatory variables. The analysis shows that the increase of retail by 1% in average will increase KSI on adult pedestrians by 30% and 50% during weekdays and weekend non working hours respectively. Meanwhile, the increase of retail by 1% in average will increase slight injury by 40% on adult pedestrians during weekdays working hours and by 30% during weekdays and weekend non working hours.

***Key Words*:** Pedestrian casualties, Group of ages, Urban Land Use.

1. INTRODUCTION

In March 2000 the UK Government announced a new national road safety strategy and casualty reduction targets for 2010. These new targets were introduced to concentrate on achieving a further substantial improvement in road safety over the next ten years, with particular emphasis on child casualties. The new targets, which are stated in the document 'Tomorrow's road-safer for everyone' are based on the annual average casualty levels over the period 1994 to 1998. By 2010 it is hoped that there will be, compared with the average for 1994-1998:

- A 40% reduction in the number of people killed or seriously injured in road accidents.
- A 50% reduction in the number of children killed or seriously injured and
- A 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 million vehicle kilometres.

The government road safety targets are set in terms of persons killed or seriously injured (KSI). Since fatalities run at under 10% of the number of serious injuries, road safety performance is effectively being measured in terms of serious injuries[3]. In order to achieve these targets, factors related to road casualties should be well identified. The Institution of Highways and Transportation (IHT) in 1997 stated that one factor which would be reasonably linked to road safety strategy is land use policies.

Land use is a trip determinant as it has a strong corelation with both trip generations and attractions so that considered to be the main factor to influence some road environment variables such as traffic flow, speed limit and pedestrian activities[8]. It has been accepted that different land uses generate different numbers of trips, which interact with traffic flow, speed limit and pedestrian activity. This interaction, in turn, has the potential to cause road accidents. The accident frequency may therefore be dependent on the interaction level of these three factors. In other words, different land use patterns may generate different accident rates.

Meanwhile, the UK government has encouraged a modal shift from motorised transport to walking and cycling for short journeys as well as making these modes safer. Short journey is suitable for walking less than 2km or cycling less than 5km. In the UK Planning Policy Guidance (PPG) 13[14] stated that mixed land uses in urban area with an excellent walking environment substantially reduces motorised transport trip frequency and encourages non-motorised transport, especially for the short journeys. Consequently, pedestrian friendly environments have been considered to improve the quality of life of urban dwellers by reducing traffic accidents and environmental pollution. However, an increasing degree of urbanisation is associated with an increase in pedestrian accidents through demographic factors (e.g. population density), road and traffic related factors (e.g. road formation, junction density and traffic flows). For instance, the risk of child pedestrian accidents is up to five times greater for those who live in urban areas than in rural settlements[13].

This study will investigate the relationship between urban land use and casualty types including fatal and serious injured (KSI) and slight casualties emphasising on three age groups which are children (under 16), adult (between 16 and 64 years) and elderly (more than 64 years).

In many accident casualty related investigations, the traffic flows are included generally as explanatory variables. Since this study concentrates on pedestrian casualties, which mainly involve short walking and cycling trips and adjacent land use patterns in the city centre, traffic flows are excluded from the analysis. In other words, this study mainly investigates the pedestrian casualties in an urban area with special consideration of pedestrians' group of ages, urban land use patterns, to ascertain and develop a possible relationship between them.

2. A REVIEW: ROAD CASUALTIES AND LAND USE

There is a substantial difference between accident and casualty. Road accident is related to 'the event', while casualty is related to the number of 'victims' due to accident. Consequently, in a road accident there may be more than one casualty.
According to DETR in 2000 three types of road casualties are defined as follows:

a. A fatal injury is one which causes death less than 30 days after the accident; a fatal accident is an accident in which at least one person is fatally injured.
b. A serious injury is one which does not cause death less than 30 days after the accident and which is in one (or more) of the following categories:
   (i). An injury for which a person is detained in hospital as an in patient
   (ii). or any of the following injuries (whether or not the person is detained in hospital): fractures, concussion, internal injuries, crushings, severe cuts and lacerations, severe general shock requiring treatment.
   (iii). Or any injury causing death 30 or more days after the accident.
   A serious accident is one in which at least one person is seriously injured, but no-one suffers a fatal injury.
c. A slight injury is any injury which is neither 'fatal' nor 'serious' – for example, a sprain, bruise or cut which is not judged to be severe, or slight shock requiring roadside attention; a slight accident is one in which at least one person suffers 'slight' injuries, but no-one is seriously injured or fatally injured.

Land use and urban activities in an urban area make a significant involvement in generating land use-transport interactions[17]. The transport and land use interaction can be happened between zones (inter-zonal) or within a zone (intra-zonal). When mixed land use is established within a zone, there is a strong possibility for generating intra-zonal interaction of land use and transport. Similarly, when land use is defined as single zone, for instance a zone with predominantly residential areas, or predominantly shopping or industrial areas, the interaction of land use and transport tends to happen between zones or inter-zones. It is necessary therefore to have an appropriate unit of study which is used as a zone of analysis. In this study, a ward is considered appropriate to be a single zone which also used as a unit of study.

The two main planning policies in the UK which are relevant to walking and urban land use are PPG 6[15] and PPG 13[14]. PPG 6 underlined that mixed land use is encouraged in town centres with emphasis on retail, employment and leisure development. In addition, this focuses on built environment improvement through good urban design, a coherent parking strategy and town centre management. Consequently, this leads to the inclusion of retail, employment and leisure building as land use variables in the study analysis.

Urban form is considered as a secondary factor in both choices of walking and cycling, whereas motivations and limitations are a primary factor[2]. Basically, urban form indicates the physical characteristics of an urban area. 'Urban form' has a broader meaning than the term 'land use'; it includes factors such as transportation systems and urban design. Regardless of scale, there are three basic measures of urban form related to walking and cycling. These are land use design, land use diversity and land use density. Statistically, these measures are significant in reducing motorised trip rates and in encouraging walking and cycling, despite their effect appearing to be fairly marginal[2].

Many researchers identified proximity, orientation and mixed land use which encourages walking and cycling [1,6,9,16]. Proximity is defined as the distance between one and two or more land use type, for instance, the distance between residential areas to workplaces. Meanwhile, orientation is the urban structures of a city, whether all activities are concentrated in the city centre (single centre orientation) or distributed throughout the city (multi-centre orientation). The city of Newcastle upon Tyne follows the first structure that is single centre orientation.

It is obviously important to have a consistent land use classification which includes the common urban land uses such as residential, shopping, education and social and residential. This study uses the UK land use classification current at the time of the study, issued by the relevant government department (Department for Communities and Local Government, formerly Office of the Deputy Prime Minister /ODPM). This is shown in Table 1.

Table 1 The Land Use Classification – According to the Office of the Deputy Prime Minister (Land Use Change in England to 1997: LUCS-14)

	Land Use Classes	**Notation Used**
1	Residential houses and flats, and roads or paths within such areas	R
2	Institutional/Communal Accommodation hotels / hostels, old people's homes, children's homes, monasteries and convents	Q
3	Highways and road transport through routes and distributor roads in housing estates, bus stations and public car parks	H
4	Non-highway transport routes and places railways, airports and dockland	T
5	Utilities facilities for post and telecommunications, gas works, power stations and electricity sub-stations, water and sewage works, cemeteries and crematoria, refuse disposal places (except those in (Y))	U
6	Disposal landfill waste disposal	Y
7	Industry factories, refineries, shipbuilding yards, mills and other industrial sites	I
8	Offices local and central government offices, banks, building societies and other service industries	J
9	Retailing shops, garages, public houses, restaurants and post offices	K
10	Storage and Warehousing depots, scrap and timber yards and warehousing	S
11	Community Buildings health, educational, community and religious buildings and police stations, prisons, fire stations	C
12	Leisure and Recreational Buildings museums, cinemas, theatres, bowling alleys, sport halls, holiday camps, amusement arcades, and buildings associated with outdoor recreation.	L
13	Vacant Land previously developed cleared sites used as temporary car parks or playgrounds.	V

It has been shown that pedestrian injury rates are related to traffic flow, population density, age, composition of the local population, unemployment, gender, education and availability of alcohol through bars, restaurants and off license outlets[7]. Social economics include many factors which are not only applied to certain locations (number of population, average income) but also pertain to individual characteristics (gender, age). In terms of temporal pattern, road accidents occurred frequently during weekdays between 7 a.m. and noon, or between 2 p.m. and 6 p.m. These are recognised as peak hours, during weekdays. It does make sense that peak hours in which traffic flow is high will potentially have more accidents. During the weekend, road accidents occurred mostly after 11 p.m. when bars, pubs or restaurants were closed. In relation to these leisure activities, pedestrian fatalities were positively related to alcohol[5], despite the desirability of people trying not to use the streets on foot when they drunk.

Some land-uses have noticeably different effects on trip attractors during working hours (Monday to Friday – 8 am to 6 pm) and non-working hours (Monday to Friday – 6 pm to 8 am and weekends). For example, schools, offices and commercial premises attract people during working hours, while most pubs, bars and leisure facilities attract people after working hours. So, separate models are essential for investigating accidents during working hours and during non-working hours. At weekends, the travel patterns will be substantially different in relation to the land-use, so separate models would be necessary for the detailed analysis of weekend pedestrian casualty patterns[20].

3. DATA DESCRIPTION AND PRELIMINARY DATA ANALYSIS

3.1 Case Study Area

Newcastle upon Tyne was chosen as the case study area. The city of Newcastle upon Tyne is the major city in the northeast of England. The district of Newcastle has an area of 113km^2 and a population of about 270,000. The case study area consists 11 wards as shown in Figure 1 with the total size is approximately 18 km^2.

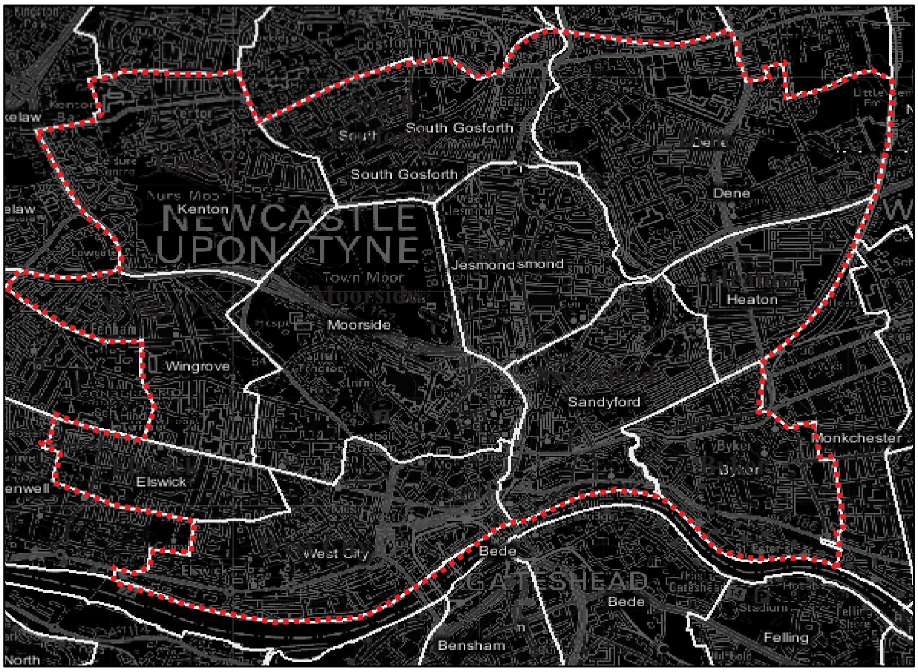

Figure 1 Case study area –The city of Newcastle upon Tyne

3.2 Land Use Information

Land use data for each ward showed that trip generators such as population density and residential areas were less in two wards, Moorside and West City, compared with the rest of the wards in the case study area. This is because these two wards contain most of the city centre and they predominantly comprise offices, industrial areas, retail, community buildings such as universities, schools and colleges and leisure building such as cinema halls and theatres.

Table 2 describes the proportions of land use in all eleven wards in the city of Newcastle upon Tyne using the land use classification presented in Table 1. In addition to the land use classes defined, there is another land use class which has not been set up in this classification, that is, footway and pedestrian precinct for which pedestrians are the only mode of transport on these premises. For the purposes of this study, this land use is defined as footway/pedestrian precinct (W). These land use classification is used as a basis for data collection for the predominant land use within the case study area. In order to reduce the number of variables included in the model, however residential (R) and Institutional/communal accommodation (Q) are collectively grouped as RQ; similarly industry (I) and storage (S) are grouped as IS.

Table 2 Land Use Proportions in eleven wards within the City of Newcastle upon Tyne

Ward	Population density people/km^2 (all ages)	Land use proportions								Junction Density (Junction/km)	Road Length (km)
		RQ	IS	J	K	C	L	W	Other		
Byker	3980	0.28	0.14	0.02	0.05	0.06	0.07	0.08	0.30	7	29
Dene	3613	0.41	0.01	0.01	0.03	0.24	0.11	0.06	0.13	6	35
Elswick	7125	0.60	0.00	0.03	0.03	0.05	0.00	0.09	0.20	7	14
Heaton	7243	0.44	0.04	0.00	0.04	0.07	0.09	0.10	0.22	6	20
Jesmond	5590	0.42	0.00	0.03	0.01	0.08	0.06	0.07	0.33	6	29
Kenton	3190	0.38	0.00	0.01	0.00	0.07	0.00	0.07	0.47	7	27
Moorside	2599	0.14	0.00	0.02	0.04	0.12	0.06	0.05	0.57	5	32
Sandyford	4982	0.23	0.06	0.07	0.03	0.07	0.14	0.10	0.30	7	33
South Gosforth	4522	0.53	0.00	0.01	0.02	0.08	0.01	0.06	0.29	10	31
West City	2037	0.14	0.19	0.06	0.10	0.05	0.03	0.10	0.33	7	42
Wingrove	5232	0.35	0.00	0.00	0.01	0.14	0.01	0.07	0.42	5	19

Notes:

RQ	Residential area	J	Offices	W	Footway/Pedestrian Precinct
IS	Industry	K	Retail	Jund	Junction Density (junctions per km)
C	Community Building	L	Leisure Building	RdLgth	Road Length (km)
Other	includes Open Space, Highways and other transport facilities				

Travel patterns in this case study area were obtained from journey to work data of the UK Census 2001. The travel patterns were actually more relevant for working-ages, however, this gives an overall view on people movements within the area.

West City and Moorside are the most popular wards in the City in relation to journey to work by walking for people over 16 years of age. Apparently, these journeys occurred mostly within the same ward. Most walking trips into the city centre from other wards were generated from the neighbouring wards of Sandyford and Jesmond. In other words, people who travel to work on foot mostly live and work in the same or neighbouring wards.

3.3 Data Description

Spatial data

Land use data were collected using the Digimap service of EDINA (Edinburgh University). The land use data explain the predominant land use within the study area. Two formats of mapping were used, Landline (vector mapping at 1:1, 250 scale), and Meridian map (vector mapping at 1:50,000 scale). Land use proportions, road lengths and junction density were calculated from these maps using the Geographic Information System (ARC/INFO).

The Landline map covers land use blocks in Newcastle in a precise manner such as shops, cinemas, offices and car parks. The map is then used to produce land use proportions. The Meridian map was used to provide data about road lengths and classes. Roads in the UK are classified as Motorway, A road, B road, or unclassified. Road lengths were obtained by data query through the Geographic Information System (GIS) software ArcView and Arc/Info.

Casualty data

The accident casualty data in Newcastle were obtained from the Tyne and Wear Traffic Accident and Data Unit (TADU) (based at Gateshead Metropolitan Borough Council) for the period 1998 and 2001. Accident locations, temporal data (time and day of accidents), pedestrian ages were retrieved from the databases as appropriate.

Population data

Demographic data for each ward were obtained from UK Census 2001. Population data is transformed into population density by dividing the population of a ward by the area (measured in square kilometres).

3.4 Preliminary Data Analysis

In weekdays, working and non-working hours are considered to be 8am to 6pm and from 6pm to 8am respectively. For weekends, working and non-working hours are considered to be 11am to 5pm and from 5pm to 11am.

Tables 3 and 4 represent number of Killed or Seriously Injured (KSI) and slight casualties on pedestrians in each ward in Newcastle city for children, adult and elderly. Total number of KSI and slight casualties for each ward is represented in figure 2. Accordingly, the highest casualties both KSI and slight happened on adult pedestrians. It was also observed that adult pedestrian casualties happened mostly in West City ward in the city centre and were spread unevenly among the other wards.

In relation to land use patterns, industry and retail have the highest proportion in West City compared to the other wards. This is leading to a question whether the industry and retail will influence adult pedestrian casualties. In order to answer such question the analysis will be carried out using statistical methods.

		Byker	Dene	Elswick	Heaton	Jesmond	Kenton	Moorside	Sandyford	South Gosforth	West City	Wingrove
Child	Week Day Working Hours	0	2	1	0	0	0	1	0	0	0	0
	Week Day Non-working Hours	1	0	0	1	0	0	0	0	0	0	0
	Weekend Working Hours	0	1	0	0	0	0	0	0	0	0	0
	Weekend Non-working Hours	0	0	1	1	0	0	0	0	0	0	0
Adult	Week Day Working Hours	2	1	1	1	1	2	8	1	1	7	1
	Week Day Non-working Hours	1	0	0	0	1	0	2	4	1	16	3
	Weekend Working Hours	0	0	0	0	1	0	0	0	0	3	1
	Weekend Non-working Hours	0	1	1	0	2	0	0	1	1	9	1
Elderly	Week Day Working Hours	1	0	0	1	0	0	3	1	2	2	0
	Week Day Non-working Hours	0	0	0	0	0	0	0	0	0	0	0
	Weekend Working Hours	2	0	1	0	0	0	0	0	0	0	1
	Weekend Non-working Hours	0	0	0	0	0	0	0	1	0	0	0

Table 3 Number of KSI during the period of 1998-2001 in Newcastle

		Byker	Dene	Elswick	Heaton	Jesmond	Kenton	Moorside	Sandyford	South Gosforth	West City	Wingrove
Child	Week Day Working Hours	10	12	9	3	3	6	4	6	3	10	6
	Week Day Non-working Hours	3	3	3	2	0	1	1	1	1	3	4
	Weekend Working Hours	1	2	2	0	1	1	1	0	0	4	0
	Weekend Non-working Hours	0	1	1	0	0	0	0	0	0	2	3
Adult	Week Day Working Hours	5	4	8	6	11	5	21	6	10	83	5
	Week Day Non-working Hours	4	3	4	3	4	0	13	14	2	44	2
	Weekend Working Hours	1	1	0	0	1	1	5	0	2	12	1
	Weekend Non-working Hours	2	1	3	0	1	2	6	4	4	50	4
Elderly	Week Day Working Hours	3	1	1	1	0	0	5	1	2	8	0
	Week Day Non-working Hours	1	1	0	0	0	0	1	0	0	1	0
	Weekend Working Hours	0	0	0	1	0	0	3	0	0	1	1
	Weekend Non-working Hours	0	0	0	0	0	0	0	0	0	0	0

Table 4 Number of Slight Casualties during the period of 1998-2001 in Newcastle

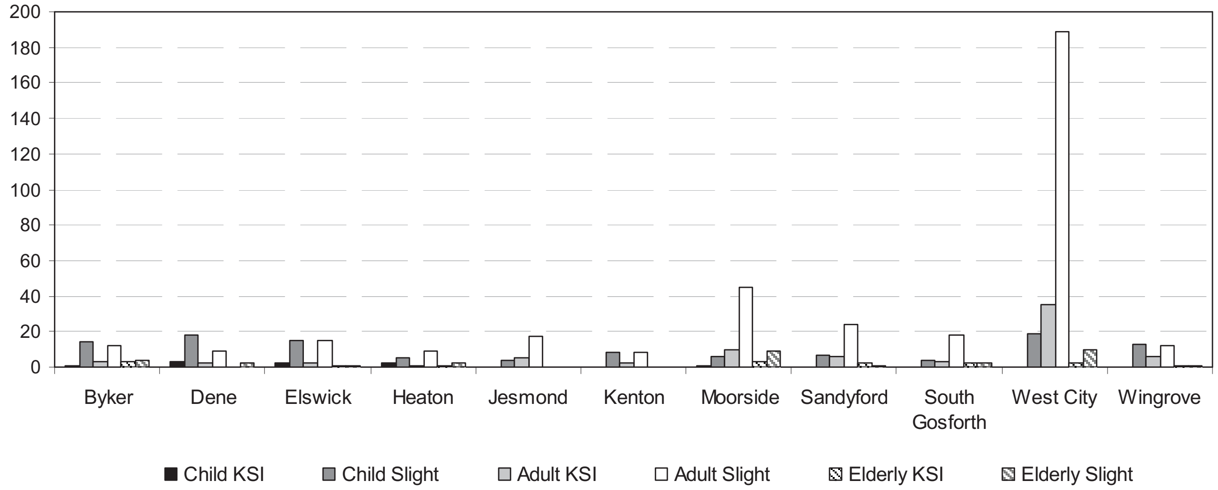

Figure 2 Number of KSI and Slight Casualties during the period of 1998-2001 in Newcastle

4. MODEL DEVELOPMENT AND ANALYSIS

As accidents are rare events, there may be no accidents during the time of observation even though population and roadways are present. As a result, traffic accidents are generally explained to be a discrete variable. Consequently, the same principal applies to casualties. According to Table 1, the West City ward has the highest road length compared to the other wards. This is relevant to the fact that the highest pedestrian involvement in casualties also occurred in that ward (see fig. 2).

In order to establish the relationship between pedestrian casualties and land use, the emphasis in this study is basically placed on locations and time of the casualties. The casualty data used in this study come from actual observations, not from experimental observations. Therefore, the distribution of road casualties at a site with respect of time is non normal, and the Poisson process is the best way to explain the accident related distributions[11]. Under such circumstances the standard least square regression would not fit to model the data. It is necessary, therefore, to examine in detail the alternative statistical distribution of casualties using a statistical technique such as the Generalised Linear Model with a quasi-Poisson preferably Negative Binomial distribution[12]. As with regression analysis, the Generalised Linear Model describes the existence of the relationship among various observable quantities. The Generalised Linear Model extends linear models to accommodate both non-normal response distributions and transformations to linearity[4,10].

Increasing the length of a road means the population has more exposure to the possibility of a casualty. To model such circumstances, Poisson regression, in which road length is offset, is fitted to all models in order to estimate the deviance (*dv*) and degree of freedom (*df*). Offsetting road length means equalising the effect of road length on accidents and subsequently casualties in every unit of analysis. As a result, the population has an equal risk of an accident regardless of the size of the unit of analysis, in this study a ward is considered as a unit. In the initial model, in both equations, (1) and (2) road casualties are assumed proportional to road length, in which Natural Logarithm (*Ln*) of road length (*rdlen*) is used as the offset. In this study, the offset value is fixed to be 1.

All the models had the general form that the logarithm of the hypothetical mean accident rate in a ward (μ) was equal to a linear combination of the explanatory variables with the logarithm of road length (*Ln(rdln)*) as an offset. The explanatory variables included population density and junction density as well as land-use proportions.

$$\mu = rd.len\left(e^{\beta_0+\beta_1 Popd+\beta_2 K+\beta_3 C+\beta_4 L+\beta_5 IS+\beta_6 J+\beta_7 Jund}\right) \tag{1}$$

$$Ln(\mu) = Ln(rd.len)+\beta_0+\beta_1 Popd+\beta_2 K+\beta_3 C+\beta_4 L+\beta_5 IS+\beta_6 J+\beta_7 Jund \tag{2}$$

Note:
Population density (Popd) is applied separately for children, adult and elderly. Therefore, in children casualties models apply children population density, in adult casualties model apply adult population density and in elderly casualties model apply elderly population density .

The proportion of residential land-use (RQ) was not included in any models because it is highly correlated with population density and measures a similar feature within a ward. Industry (IS) and offices (J) were excluded from models for accidents during the weekend and weekdays non-working hours because they are usually closed. Some correlation between explanatory variables is inevitable in survey work, but this has less influence on the estimates of coefficients of essential land-use (trip attractors: IS, J, K, C & L) and their standard errors, if the potential explanatory variables are restricted to essential land-use rather than being selected from all land-use classification. With these exceptions, the models were developed by restricting land-use proportions to trip attractors (IS, J, K, C, and L in weekdays working hours; K, C, and L in weekdays and weekend working and non-working hours).

Generally, using all land-use categories (except RQ) leads to a degree of multi-collinearity. Consequently, the estimated coefficients of land-use proportions can have large standard errors and few are individually statistically significant. This leads to difficulties in interpretation. Restricting the analysis to essential land-use (IS, J, K, C, L during weekdays working hours and K, C, L during weekdays non working hours and the weekend) tends to give more reasonable models and more precise results[21].

Several test trials were conducted in order to find out the best model for each case. Each group that had less than 10 casualties were excluded in the study. As the results, there are four and eight models developed for KSI and slight casualties respectively. The GLIMs were initially fitted with an assumption that the number of accidents in a ward had a Poisson distribution with a mean equal to μ. In Tables 5 and 7 the ratio of Poisson deviance to degrees of freedom and model distribution selection for typical models in each category are described.

Table 5 Test Trails to Find the best distribution for the Detailed Analysis (KSI were equal or more than 10)

Trials	Explanatory variables fitted	deviance (dv)	degree of freedom (df)	Statistical test	Model Fitted
Adult KSI ▪ weekdays ▪ working hrs	1, APopd, Jund, IS, J, K, C, L	3.09	3		Poisson
Adult KSI ▪ weekdays ▪ non-working hrs	1, APopd, Jund, K, C, L	16.64	5	LR Test of Negative Binomial: $\alpha = 0$, $\kappa_1^2 = 0.00$ (p=0.980)	Poisson
Adult KSI ▪ weekend ▪ non-working hrs	1, APopd, Jund, K, C, L	9.33	5	LR Test of Negative Binomial: $\alpha = 0$, $\kappa_1^2 = 0.00$ (p=1.00)	Poisson
Elderly KSI ▪ weekdays ▪ working hrs	1, EPopd, Jund, IS, J, K, C, L	4.14	3		Poisson

Notes:

Popd	Population density	IS	Industry	K	Retail	L	Leisure building
Jund	Junction density	J	Offices	C	Community building		
APopd	Adult Population density			EPopd	Elderly Population density		

However, there was evidence of over dispersion (ratio between deviance and degree of freedom more than 1) for some KSI models. Over dispersion leads to underestimation of standard errors of coefficients, so alternative models were tested and fitted, as described in Table 5. The model results for KSI are summarised in Table 6.

Table 6 Results –KSI Models (casualties were equal or more than 10)

Variables	Elderly KSI during weekdays working hrs		Adult KSI during weekdays working hrs		Adult KSI during weekdays non working hrs		Adult KSI during weekend non working hrs	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
1	**-6.92***	-1.74	0.48	0.15	-2.52	-0.78	**-7.47***	-1.83
Popd	$-53.58e^{-04}$	-0.94	$-1.20e^{-04}$	-0.31	$0.91e^{-04}$	0.29	$5.28e^{-04}$	1.12
Jund	1.01	1.15	-0.37	-1.49	-0.19	-0.69	0.06	0.25
IS	-6.04	-0.24	-11.08	-1.19	--	--	--	--
J	-25.65	-1.04	0.01	0.00	--	--	--	--
K	23.16	0.38	**32.97***	1.86	**27.76*****	2.67	**38.21****	2.34
C	24.21	0.60	-3.46	-0.51	-6.38	-0.84	-4.42	-0.48
L	28.64	1.24	-2.49	-0.20	-2.47	-0.28	-20.08	-1.36
Summary Statistics								
N	10		26		28		16	
Dv	4.14		3.09		16.64		9.33	
df	3		3		5		5	

Notes:

Popd	Population density	IS	Industry	K	Retail
Jund	Junction density	J	Offices	C	Community building
dv	Deviance	*df*	Degrees of freedom	L	Leisure building

-- in Coef. and *t*-stat. indicates parameter not estimated and *t*-stat. not calculated respectively.

Bold figures are significant as follows: * Significant at 80%, ** Significant at 90%, *** Significant at 95%

As with KSI models, there was evidence of over dispersion (ratio between deviance and degree of freedom more than 1) for some slight casualties models. Over dispersion leads to underestimation of standard errors of coefficients, so alternative models were tested and fitted, as described in Table 7. The model results for slight casualties are summarised in Tables 8 and 9.

Table 7 Test Trails to Find the Best Distribution for the Detailed Analysis (slight casualties were equal or more than 10)

Trials	Explanatory variables fitted	deviance (dv)	degree of freedom (df)	Statistical test	Model Fitted
Children · weekdays · working hrs	1, Popd, Jund, IS, J, K, C, L	3.10	3		Poisson
Children · weekdays · non-working hrs	1, Popd, Jund, K, C, L	3.29	5		Poisson
Children · weekend · working hrs	1, Popd, Jund, K, C, L	7.13	5		Poisson
Adult · weekdays · working hrs	1, Popd, Jund, IS, J, K, C, L	4.20	3		Poisson
Adult · weekdays · non working hrs	1, Popd, Jund, K, C, L	15.69	5	LR Test of Negative Binomial: $\alpha = 0$, $\kappa_1^2 = 0.00$ (p=1.00)	Poisson
Adult · weekend · working hrs	1, Popd, Jund, K, C, L	4.97	5		Poisson
Adult · weekend · non working hrs	1, Popd, Jund, K, C, L	11.85	5	LR Test of Negative Binomial: $\alpha = 0$, $\kappa_1^2 = 0.55$ (p=0.46)	Poisson
Elderly · weekdays · working hrs	1, Popd, Jund, IS, J, K, C, L	5.81	3	LR Test of Negative Binomial: $\alpha = 0$, $\kappa_1^2 = 0.00$ (p=1.00)	Poisson

Notes:

Popd	Population	IS	Industry	K	Retail
Jund	Junction density	J	Offices	C	Community
dv	Deviance	*df*	Degrees of	L	Leisure building

Table 8 Results – Adult Slight Casualties Models (casualties were equal or more than 10)

Variables	Adult during weekdays working hrs		Adult during weekdays non working hrs		Adult during weekend working hrs		Adult during weekend non working hrs	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
1	-0.55*	-0.56	-0.02	-0.01	-0.66	-0.78	-1.26*	-0.82
Popd	-0.11e^{-04}	-0.09	-0.83e^{-04}	-0.57	-0.51e^{-04}	-1.38	-1.12e^{-04}	-0.61
Jund	-0.12	-1.29	**-0.30***	-1.84	-0.17	-0.74	-0.09	-0.61
IS	**-9.33***	-2.55	--	--	--	--	--	--
J	10.98	1.47	--	--	--	--	--	--
K	**35.97***	4.21	**23.66***	4.20	**15.99***	1.70	**26.29***	4.17
C	-3.58	-0.89	**-6.95***	-1.82	3.33	0.46	-1.31	-0.26
L	**-8.41****	-2.33	**6.95***	1.90	-13.35	-0.30	**-12.06****	-2.19
Summary Statistics								
N	164		93		24		77	
dv	4.20		15.69		4.97		5.81	
df	3		5		5		3	

Notes:

Popd	Population density	IS	Industry	K	Retail
Jund	Junction density	J	Offices	C	Community building
dv	Deviance	*df*	Degrees of freedom	L	Leisure building

-- in Coef. and *t*-stat. indicates parameter not estimated and *t*-stat. not calculated respectively.
Bold figures are significant as follows: * Significant at 80%, ** Significant at 90%, *** Significant at 95%

Table 9 Results – Children and Elderly Slight Casualties Models (casualties were equal or more than 10)

Variables	Children during weekdays working hrs		Children during weekdays non working hrs		Children during weekend working hrs		Elderly during weekdays working hrs	
	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.	Coef.	*t*-stat.
1	**-2.92*****	-2.70	**-3.78***	-1.97	**-4.18***	-1.56	-3.65	-1.48
Popd	**14.31e^{-04}*****	3.55	**18.33e^{-04}*****	2.78	10.13e^{-04}	1.02	-17.77e^{-04}	-0.72
Jund	-0.07	-0.56	-0.19	-0.84	-0.15	-0.49	0.20	0.72
IS	**6.91***	1.53	--	--	--	--	-10.40	-0.98
J	6.38	0.75	--	--	--	--	-23.33	-1.07
K	-3.46	-0.32	**18.58***	1.78	**25.37***	1.94	**47.28***	1.71
C	**5.01***	1.58	3.32	0.74	5.32	0.75	-8.26	-1.04
L	-0.56	-0.15	-0.41	-0.06	-8.17	-0.78	9.29	0.82
Summary Statistics								
N	72		22		12		22	
dv	3.10		3.29		7.13		11.85	
df	3		5		5		5	

Notes:

Popd	Population density	IS	Industry	K	Retail
Jund	Junction density	J	Offices	C	Community building
dv	Deviance	*df*	Degrees of freedom	L	Leisure building

-- in Coef. and *t*-stat. indicates parameter not estimated and *t*-stat. not calculated respectively.
Bold figures are significant as follows: * Significant at 80%, ** Significant at 90%, *** Significant at 95%

5. RESULTS AND DISCUSSIONS

Discussions are focused on land use types which has 90% or 95% significance pedestrian casualties, based on the model results as shown in Table 10. Briefly, Table 10 shows the statistically significant explanatory variables obtained from the analysis.

Adult pedestrians were more vulnerable than children and elderly pedestrians in relation to casualty types (killed or seriously injured /KSI or slight casualty). Retails use were significantly related to both KSI and slight casualties on adult pedestrians while no land uses were found significantly related to KSI on children and elderly pedestrians. Retails were significantly related to KSI on adult pedestrians during non working hours during both weekdays and weekend. Meanwhile, slight casualties on adult pedestrians were significantly related to retails during weekdays both during working and non working hours and weekend non working hours.During working hours retail is associated with shops, supermarket, stores and during non-working hours related with restaurants, public house, bars. The significant coefficient of retail during non working hours can be accounted for by fact that it is a popular area of the city during evenings with public houses and bars open from 5pm until after midnight during period 1998-2001.

Table 10 Land Use Features that influence KSI and Slight Injured on Pedestrians

Accidents Types	Land Use	Accidents Types	Land Use
Children KSI ▪ weekdays and working hrs	------	***Children Slight*** ▪ weekdays and working hrs	**Children Density(+),** Industry(+), Community Building(+)
Children KSI ▪ weekdays and ▪ non-working hrs	------	***Children Slight*** ▪ weekdays and ▪ non-working hrs	**Children Density(+),** Retail(+),
Children KSI ▪ weekend and working hrs	------	***Children Slight*** ▪ weekend and working hrs	Retail(+),
Children KSI ▪ weekend and ▪ non-working hrs	------	***Children Slight*** ▪ weekend and non-working hrs	------
Adult KSI ▪ weekdays and working hrs	Retail(+)	***Adult Slight*** ▪ weekdays and working hrs	**Retail(+),** Industry(-), **Leisure Building(-)**
Adult KSI ▪ weekdays and ▪ non-working hrs	**Retail(+)**	***Adult Slight*** ▪ weekdays and non-working hrs	**Retail(+),** Leisure Building(+), Junction Density(-), Community Building (-)
Adult KSI ▪ weekend and working hrs	------	***Adult Slight*** ▪ weekend and working hrs	Retail(+)
Adult KSI ▪ weekend and ▪ non-working hrs	**Retail (+)**	***Adult Slight*** ▪ weekend and non-working hrs	**Retail (+), Leisure Building(-)**
Elderly KSI ▪ weekdays and working hrs	------	***Elderly Slight*** ▪ weekdays and working hrs	Retail(+)
Elderly KSI ▪ weekdays and ▪ non working hrs	------	***Elderly Slight*** ▪ weekdays and non working hrs	------
Elderly KSI ▪ weekend and working hrs	------	***Elderly Slight*** ▪ weekend and working hrs	------

Notes:
- A bold entry indicates that the absolute value of the associated coefficient was at 90% or 95% significance and other entries indicate that the absolute value of the coefficient was at above 80% significance.
- The + or - sign in the brackets indicate the propensity of the explanatory variable to the pedestrian accidents.

Leisure building has a significant negative association with slight casualties on adult pedestrian during weekdays working hours and weekend non working hours. This is probably best explained by the definition of land-use; leisure building includes theatres, museums, cinemas were not as attractive as restaurants, pubs and bars for adult pedestrians during weekdays working hours and weekend non working hours.

No land usewere found to influence KSI on children and elderly casualties. Children population density was significantly has a positive association with slight children casualties during weekday working hours and a negative association during weekday non working hours. This may indicate that more children travelling during weekday working hours and very less during weekday non working hours.

Based on the model results, the proportion of retail are associated with both KSI and slight casualties on adult pedestrian casualties. The developed model, therefore, was used to conduct the sensitivity analyses on both KSI and slight casualties on adult pedestrians.

In the city centre during weekdays, an increase of 1% in the proportion of retail land use is estimated to increase the mean number of adult pedestrian casualties (KSI) by a factor of 1.3 in non-working hours. The estimated factor for retail land use during weekend non working hours is 1.5. Similarly, an increase of 1% in the proportion of retail land use during weekdays working and non working hours and weekend non working hours is estimated to increase the mean number of adult pedestrian slight casualties by a factor of about 1.4, 1.3, and 1.3 respectively. Equation 3 shows how the model was used to arrive at these values.

$$Ln(\mu) = \beta_3 K \quad \ldots\ldots\ldots\ldots \qquad (3)$$

where:

Killed or Seriously Injured	Slight Injured	
Weekdays	Weekdays	
Non Working Hours	Working Hours	Non Working Hours
β=27.76; K=0.01; μ= 1.3	β=35.97 ; K=0.01; μ= 1.4	β=23.66 ; K=0.01; μ= 1.3
Weekend	Weekend	
Non Working Hours	Non Working Hours	
β=38.21; K=0.01; μ= 1.5	β=26.29; K=0.01; μ= 1.3	

6. CONCLUSIONS

Based on the data, accident casualties occurred more on adult pedestrians than on children and elderly pedestrians. This may reflect the travel pattern that number of walking trips to/from Newcastle city centre was dominated by adults during both weekdays and weekend. The casualty analyses indicate that retail may influence KSI on adult pedestrians casualties during non working hours on both weekdays and weekend. In addition, retails also influence slight casualties during weekdays working and non working hours and weekend non working hours.

The analyses lead to a conclusion that KSI on adult pedestrians tends to happen during non working hours. Therefore, priority should be given to reducing pedestrian accidents in city centres associated with retail outlets, almost certainly public houses, clubs, and bars. This can be achieved by reviewing opening time regulations that apply to such retail land use. More specifically, more attention and reinforcement should be given to planning permission for the development of retail. This may cover the number, location and opening/closing hours of retail outlets.

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