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What makes a route safer for cyclists?

A study on cycling collisions in Lancaster, UK

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ABSTRACT

This study aims to understand the factors that make a route safer for cyclists. We use cycling collision data from the city of Lancaster and focus on the locations where the collision numbers vary. We counted the number of vehicles, pedestrians, and bicycles both on a weekday and on a weekend. The presence of bike lanes, pedestrian crossings, streetlights and signage is analysed, and the cycle lanes are observed to see if there are any obstacles (e.g., parked cars), if they are shared with cars, or if they are well maintained or not (i.e. road surface conditions) during the field survey. We also used space syntax analysis to understand the spatial characteristics of those routes with higher cycling potential and used isovists analysis to evaluate the visibility of the locations where the number of collisions is higher and lower. This study helps us to understand the visual and spatial attributes of urban locations with higher cyclist-collision risk and it also provides information to understand the ways in which cycling routes might be designed and/or existing routes improved.

KEYWORDS

Cycling, Collisions, Safety, Space syntax, UK.

1 INTRODUCTION

Cycling is a travel mode that helps people stay active and healthy. In recent years, infrastructure changes such as the introduction of cycle routes/paths in cities have been common. Hence, more people have preferred cycling recently. In addition, cycling rates have increased as people aim to prevent possible mental or physical health issues such as obesity. However, cycling can be a challenging activity in cities, considering safety issues (Westerdijk, 1990). Hence, to promote cycling, it is important to identify the factors that make cycling routes safer/dangerous for people.

One of the significant factors that affects cycling is the environment. However, the number of studies on the association between the environment and cycling behaviour is more limited and the studies mostly focus on the relationship between the environment and walking (Beenackers *et al.*, 2012). Hence, exploring the environment and understanding its relationship to cycling is important. While exploring the cycling and environment relationship, various studies focused on street level attributes (Pikora *et al.*, 2003; Beenackers *et al.*, 2012; Gullón *et al.*, 2015). For example, Beenackers et al. (2012) focused on objective and subjective environmental attributes to explore this relationship and focused on measures such as connectivity, pedestrian crossings, major barriers or traffic hazards. Pikora et al. (2003) investigated environmental factors that can shape walking and cycling and completed interviews with experts. They discovered that different factors included, but were not limited to, walking/cycling surface (e.g., maintenance, continuity or route directness), streets (e.g., vehicle parking, kerb type), traffic (e.g., traffic volume or speed), permeability (e.g., street /intersection design), safety (e.g., lighting, path obstruction, crossings) can affect cycling. Results of these measures were also discussed in detail. For example, Von Stülpnagel and Lucas (2020) investigated the relation of objective and subjective cycling risks. The researchers discovered a high level of alignment between objective and subjective risks; locations with a higher number of crashes were more likely reported as dangerous.

To understand the volume of traffic, on the other hand, gate counts[1] can be used. A number of studies used gate count methods to determine the number of cyclists at specific locations (Rybarczyk, 2010; Law, Sakr and Martinez, 2014) and these observations were expressed as hourly rates. Moreover, vehicle or pedestrian volumes could also be used to understand the aggregate traffic volume and it can be expected that higher levels of collisions occur at locations where there is high level of traffic. For instance, Frank and Pivo (1994) discovered that increased vehicle transportation is associated with decreased levels of cycling. Hence, exploring this relationship is also important to understand cycling behaviour and collision data.

Other studies used space syntax analysis to understand the cycling and environment relationship. Space syntax is a technique to understand human behaviour and environment interaction (Hillier and Hanson, 1984; Van Nes and Yamu, 2021; Yamu, van Nes and Garau, 2021). As mentioned by Von Stülpnagel and Lucas (2020), traffic volume, or the complexity of traffic infrastructure of a specific point, can be estimated through space syntax. However, as argued by Law et al (2014), there is a lack of studies on the role of spatial configuration on cycling activity. Among these

[1] During gate counts, gates/specific points on streets are selected first. Then, an imaginary line is drawn across each gate where cyclists/pedestrians or vehicles are counted whenever this imaginary line is crossed.

studies, Von Stülpnagel and Lucas (2020) demonstrated a relationship between higher centrality (measured by global integration) and the number of crashes. Raford et al. (2005) compared cyclist counts with configurational measures including axial integration, mean angular depth and the number of intersections. They found a strong relationship between the volume of cycling trips and least mean angular depth. Another project also aimed to understand applicability of space syntax analysis for modelling cyclists' route choice behaviour (Liu *et al.*, 2016): bicycle count data was collected and global and local integration were measured. Findings showed that global integration can only weakly explain the bicycle volumes while local integration is positively associated with bicycle flow rates. Moreover, another research study that highlighted the significance of accessible and direct streets on cyclist volumes was conducted by Raford et al. (2007). Similarly, another study on bicycle facility planning and space syntax (McCahill and Garrick, 2008) stated that a good model for predicting bicycle volumes can be constructed using census data as well as the space syntax measure "choice". In addition, Stülpnagel (2020) investigated gaze behaviour during urban cycling and conducted isovist analyses to analyse vista spaces, since they can be relevant for investigating cyclists' behaviour.

In the light of the discussion above, we aim to explore significant factors that affect cycling (cycling collisions) and the environment relationship, which is currently limited in the literature. As explained previously, by analysing spatial configuration and cycling relationship, we address to another gap in the literature.

2 METHODS

2.1 Study area

To investigate this issue, we focused on Lancaster, UK. Lancaster is on the north-western part of England. It is considered as one of the most bike-friendly cities in the UK (Everett, 2020; True Solicitors, 2020) and was chosen as a cycling demonstration town (Cope, 2017). The government invested money from 2005 to 2011 to promote cycling in Lancaster and in a few other cities as a part of this project. Considering the cycling potential of the city, we chose this city as a case area. Moreover, especially after the Covid-19 pandemic, the UK Government decided to increasingly promote cycling and city councils are developing plans accordingly (Department for Transport, 2020). Lancaster city council also developed projects to promote cycling (Lancashire County Council and Lancaster City Council, 2020). This is another reason for us to choose Lancaster.

2.2 Collision rates

The image below (Figure 1) shows the location of the city centre and its surroundings as well as the collision rates. Lancaster city centre is on the southern part of the River Lune, around the train station and Lancaster Castle.

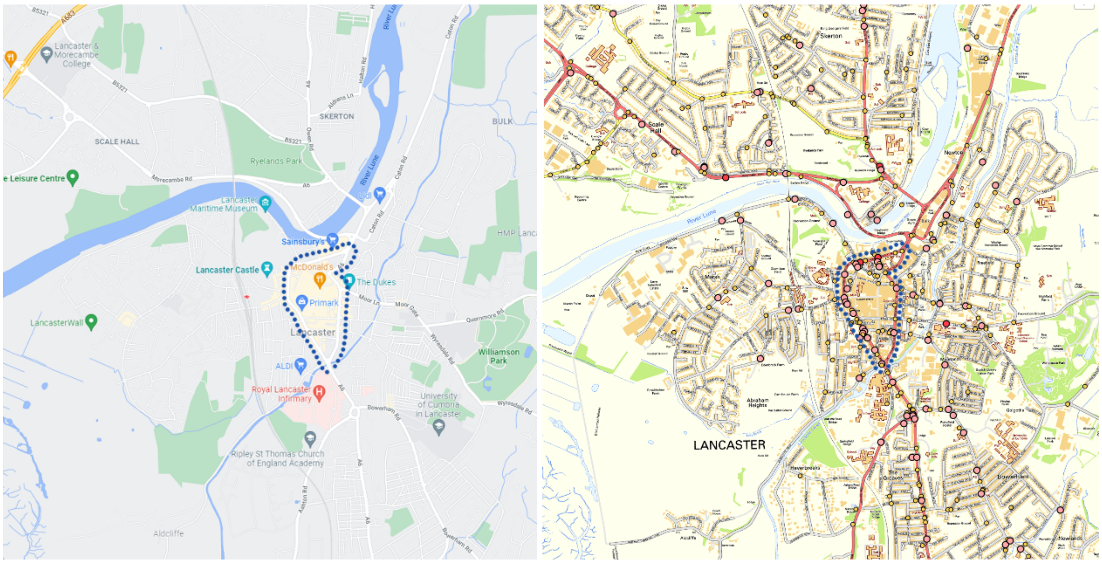

Figure 1. Lancaster city centre and its surroundings (on left) and the collision data received from cyclesreets.net (on right). The border of the study area is shown in blue.

Collision data is collected from an online web page, namely "cyclestreets.net"[2]. Collision data on this web page is collected in the period 1999-2020. It uses STATS19 data from the Department for Transport (DfT). Three categories are defined in this dataset: fatal, serious, and slight collisions. As can be seen in the figure, collision rates are higher in the city centre, especially along one of the main roads, A6 (a circular road in the centre), which is one of the main historic north–south roads in England that runs from Luton in Bedfordshire to Carlisle in Cumbria. Considering the collision data, we focus on southern part of the river and intersections along and around the A6 road, since the collision rates vary there.

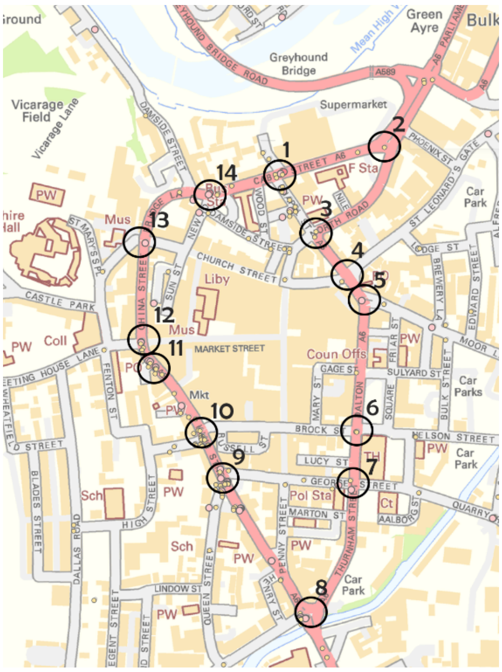

Figure 2. Areas (gates) chosen for the study with high and low number of collisions.

[2] Source: https://www.cyclestreets.net/collisions/ .

Fourteen areas are selected for this study to make more detail analysis: some of these areas have high collision rates and some have low collision rates, but all of them are on the A6 road (Figure 2). Using these areas, we compare the reasons behind the different collision rates. The figure consists of dots with three colours: yellow, pink and red. Yellow shows slight collisions, pink shows serious collisions and red shows fatal collisions.

2.3 Field observations and Space syntax measures

In order to analyse these 14 areas in detail and understand the safety problems and potentials better, field observations were conducted. First, we recorded the number of cyclists, pedestrians and vehicles for five minutes from 6:30 to 9:30 am in the morning and from 4:00 to 7:00 pm in the evening at the intersections. These hours were selected based on the off- peak hours in the UK (Gaudion, 2021). Gate counts were conducted for two time periods: on a weekday (22.11.2021) and a weekend (21.11.2021), and the weather was dry and sunny in both days.

In addition, during the field study, we observed the streetscape attributes, similar to previous studies (Pikora *et al.*, 2003; Gullón *et al.*, 2015). We analysed:

- the existence of the bike lanes (1: there are cycling lanes- 0: no cycling lanes; and the number of roads with the cycling lanes at the intersections),
- existence of bike parking facilities on roads around the intersections (number of bike parking facilities),
- separation of bike lanes from automobile traffic (1: bikes are separated from traffic, 0: bikes are not separated from vehicular traffic),
- existence of street crossings (number of street crossings),
- existence of street lights (1:there are street lights, 0:there are no street lights),
- existence of street trees (1:there are street trees, 0:there are no street trees; and the number of roads with street trees),
- maintenance of the streets (1:streets are well-maintained, 0: streets are not well-maintained),
- path surface of the bike lanes (1:surface is flat, 0: surface is not flat),
- existence of signs for cyclists (1:there is sign for cyclists, 0:no signs for cyclist),
- the intersection design (the number of roads intersected, directions and the road classifications)

and created a table using the information above.

Space syntax analyses are conducted using segment-based analyses and visibility graph analysis (VGA). Street shapefile data is downloaded from Ordnance Survey[3] and revised in ArcMap 10.5.1 using a base map. Segment-based analyses are conducted using a 15km buffer from the centre. Building database is downloaded using Geofabrik[4]. Similar to previous studies (Liu *et al.*,

[3] https://osdatahub.os.uk/downloads/open/OpenRoads

[4] https://download.geofabrik.de/europe.html

2016; Orellana and Guerrero, 2019; Von Stülpnagel and Lucas, 2020), segment analysis are conducted using angular connectivity, integration (radius: n, 2, 3, 5), choice (radius: n, 2, 3, 5 and metric choice-r: 400, 800, 1600, 200, 3000) and normalised metric choice (radius: 400, 800, 1600, 2000, 3000). VGA analysis is also conducted and visual connectivity, visual integration and isovist analyses (VGA analyses are conducted using approximately a 1km buffer from the centre- see Appendix 1) are implemented to understand the relationship between visibility and collisions.

3 ANALYSIS AND RESULTS

3.1 Field observations and collisions

As mentioned before, the number of vehicles, pedestrians (Figure 3), and cyclists (Figure 4) are counted during two time periods (in the morning and in the evening) on a weekday and a weekend. Considering overall numbers, traffic density is higher on gates 2, 6, 8, 12. In all these four gates and in all gates in general (except 3rd gate) overall numbers are higher on weekdays than on weekends. Similar to overall results, the number of vehicles is higher on gates 2, 8, 6 and 12. The number of pedestrians is higher on gates 6, 8, 10 and 12.

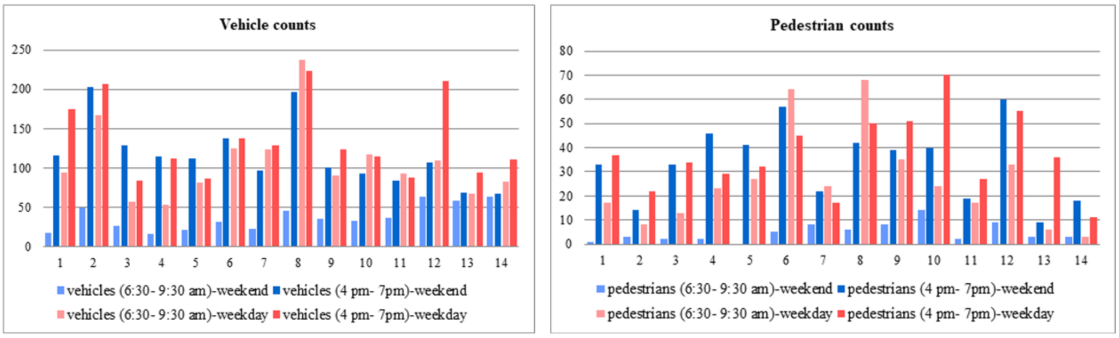

Figure 3. Number of vehicles (on left) and pedestrians (on right) on weekdays and weekends. The X axis represents the gates and the Y axis shows the number of vehicles/pedestrians.

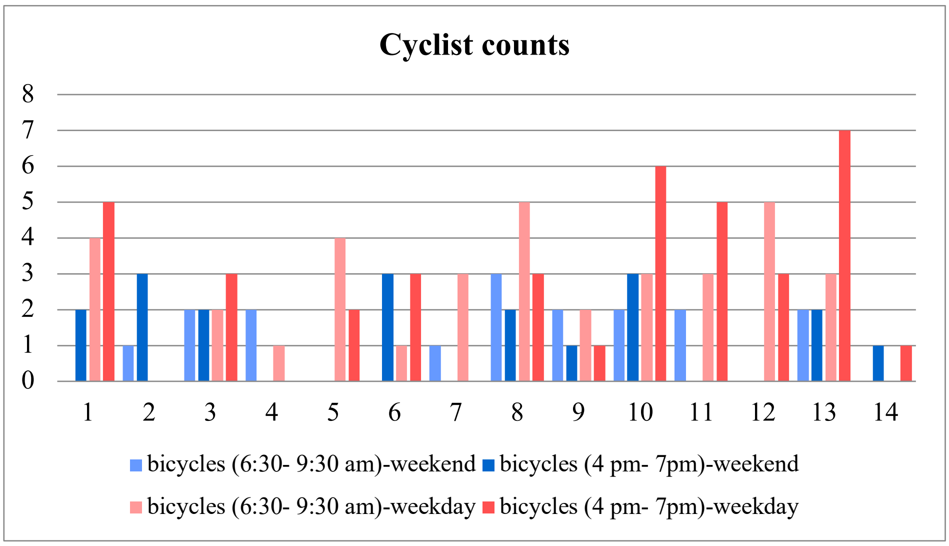

Figure 4. Number of cyclists on weekdays and weekends. The X axis represents the gates and the Y axis shows the number of cyclists.

The number of cyclists, on the other hand, is higher on gates 1, 8, 10 and 13. The number of cyclists is higher on weekdays again; however, gates with higher number of cyclists varies on weekdays and weekends. On weekdays, gates 1, 10 and 13 are busier and on weekends, gates 2, 3, 8, 10 and 13 are busier.

Table 1. Number of collisions at intersections (the red-highlighted cells indicate the highest values)

Intersections	Number of collisions	Fatal accidents	Serious accidents	Slight accidents
1	26	1	3	22
2	14	1	2	11
3	14	0	1	13
4	11	0	2	9
5	9	0	3	6
6	18	0	2	16
7	9	0	2	7
8	36	0	8	28
9	33	1	8	24
10	32	0	5	27
11	16	0	5	11
12	18	0	4	14
13	5	0	1	4
14	7	1	2	4

Considering the number of collisions, another table is prepared (Table 1). This table shows that intersections 1, 8, 9 and 10 have higher number of collisions data. This has similarities with the volume of cyclists. Slight accidents also occurred mostly at intersections 1, 8, 9 and 10. Serious accidents, however, mostly took place at intersections 8, 9, 10 and 11. The correlation between these values, space syntax values and the street level attributes will be analysed in the next section.

3.2 Space syntax analysis and collisions

We conducted a correlation analysis in SPSS using collision data, streets level attributes, pedestrian, cyclists, vehicular counts and space syntax measures. The results showed that only weekday traffic (total number of pedestrians, cyclists and vehicles on a weekday; Pearson correlation= .655, correlation is significant at the 0.05 level) is significantly associated with the total number of collisions. In addition, serious and slight accidents also have correlation with weekday traffic. Pearson correlation is .554 for serious accidents and it is about .650 for slight accidents and the correlation is significant at the 0.05 level in both situations. No significant relationship was observed between the total number of collisions and space syntax measures.

When we consider fatal accidents, on the other hand, we see the impact of other measures (Table 2). Highly correlated variables (Pearson correlation above .7) excluded from the correlation analysis and results showed that existence of street trees can cause fatal accidents more often. In addition, normalised metric choice (r: 800 m) and integration 800 meters have negative correlation with fatal accidents. Therefore, even though we could not see the impact of environmental attributes on serious and slight accidents, we could observe that fatal accidents are related with the environmental attributes.

Table 2. Correlation between fatal accidents and environmental measures

		Fatal accident	Trees	Metric_Choi_Norm_800	T1024_In_800m
Fatal accident	Pearson Correlation	1	.849**	-.703**	-.716**
	Sig. (2-tailed)		0.000	0.005	0.004
	N	14	14	14	14
Trees	Pearson Correlation	.849**	1	-.541*	-0.462
	Sig. (2-tailed)	0.000		0.046	0.096
	N	14	14	14	14
Metric_Choi_Norm_800	Pearson Correlation	-.703**	-.541*	1	.647*
	Sig. (2-tailed)	0.005	0.046		0.012
	N	14	14	14	14
T1024_In_800m	Pearson Correlation	-.716**	-0.462	.647*	1
	Sig. (2-tailed)	0.004	0.096	0.012	
	N	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Finally, we analysed the relationship between the weekday and weekend traffic and environmental attributes (see Appendix 2 and Appendix 3). Results suggested that intersection design (number of directions people can choose, Pearson correlation=.533, at the 0.05 level) and visual connectivity (correlation=.671, 0.01) have positive correlations with weekend traffic. Moreover, street lights (correlation= .583), intersection design (correlation=.590), local choice (correlation=.561) and visual connectivity (correlation=.573) have positive correlations at the 0.05 level with the weekday traffic.

4 DISCUSSION AND CONCLUSIONS

This paper aimed to understand the factors that make routes safer for cyclists. We counted the number of pedestrians, vehicles and cyclists, observed street level attributes and analysed the characteristics of the intersections to understand their relationship with cyclist collision data. The results highlighted that the total collision numbers are correlated with the traffic density, which includes pedestrians, cyclists and vehicles. This result is not surprising since higher traffic density should mean higher number of collision rates (if accidents were to occur randomly to a certain proportion of cyclists then areas that simply had more cyclists passing through them would expect to have more accidents occur there).

Previous studies stated that cyclists can be observed on the most direct and continuous routes (Law, Sakr and Martinez, 2014). Our results showed that traffic density is related with the environmental attributes: visual connectivity and intersection design are correlated with weekend traffic whereas street lights, intersection design, local choice and visual connectivity are correlated with weekday traffic. Hence, on weekdays and weekends, we could observe the impact of visual connectivity and intersection design on traffic density. Therefore, when the intersections provide many alternative directions and when they have higher visual connectivity (when they can be seen from many directions), they have higher traffic volumes. Local choice (r:2) and existence of street lights were also correlated with the weekday traffic, which suggests that when intersections include street lights or when they connect roads that can be used by more people as the shortest route, they have higher volumes of traffic.

Considering the total number of collisions and the various attributes, however, we could only observe a significant relationship between weekday traffic and the collisions. In addition, serious and slight accidents had correlations with weekday traffic. This meant that higher number of collisions occurred at areas where the traffic volume was also high. Fatal accidents, on the other hand, positively correlated with the existence of street trees, and negatively correlated with normalised metric choice (r: 800 m) and integration 800 meters. These results suggested that when the environment involves street trees, the possibility of having fatal accidents increases. Even though this result could not be supported with the correlation between VGA analysis and fatal accidents, future research can focus on the impacts on street trees on collision rates in more detail. In addition, we discovered that when the environment provides more accessible and direct routes, the number of fatal accidents reduces. This finding is surprising as we could expect to have more traffic and therefore more accidents when the roads are well connected (Raford, Chiaradia and Gil, 2007).

This study also has some limitations. Our findings might be affected from the low number of intersections we analysed (n=14). If we were to increase our sample size and use more intersections, we may be able to produce similar results. Future studies should therefore be conducted using higher number of intersections. Similarly, previous studies argued that local values such as local integration can be more useful than global integration in understanding bicycle traffic volume, so bicycle collision as cycling is suitable for short-range trips (Liu *et al.*, 2016). We also expected to see high but positive correlations between integration and choice and collision results, as there could be more traffic (and collisions) at points with higher integration and choice values. However, we could not prove this idea in our analysis. As we mentioned previously, we focused only on the A6 road and the city centre zone. If we focus on more secondary roads or more primary roads but outside the immediate city centre, we would expect the results to differ by being more nuanced. In addition, we expected to see a high correlation between the visibility analysis and the number of collisions (higher collisions occur at points where isovist view or visual connectivity is lower). However, this also could not be proven in this study. We only could see a higher traffic volume at areas with higher visual connectivity. One additional explanation to sample size can be about the way we conducted visibility graph analysis. While conducting the analysis, we use the building data; however, many other additional elements that might affect people's visibility are not taken into consideration such as trees, traffic lights or signs (Von Stülpnagel, 2020). This might affect the results of the study and cause low correlations. Future studies can focus on additional elements and the VGA analysis can be repeated. This can also support our findings and show the significance of street trees on collision data.

In this study we focused on Lancaster city and analysed the city centre. Currently, there are plans to redesign the traffic strategy for Lancaster's city centre and the A6 road. According to these proposals (Lancashire County Council and Lancaster City Council, 2020), the road around the centre (A6) may be partially converted to sustainable travel modes. Eight alternatives have been developed based on this idea and different parts of the road are designed to be used by sustainable travel modes, cycling being a major component of this strategy. Considering the number of collisions, we suggest that it might be more appropriate to convert the road on the western part of the centre to this sustainable travel corridor.

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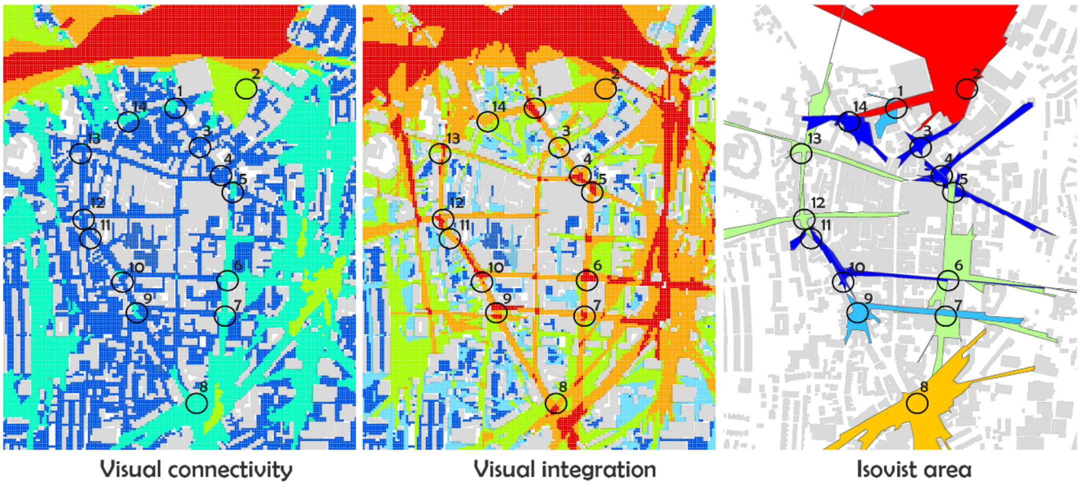

Appendix 1. Visual connectivity, integration and isovist area analysis

Correlations

		Weekend traffic	Street lights	Intersection design (# of directions)	T1024_Ch_R2	Visual Connectivity
Weekend traffic	Pearson Correlation	1	0.358	.533*	0.364	.671**
	Sig. (2-tailed)		0.209	0.050	0.201	0.009
Street lights	Pearson Correlation	0.358	1	0.290	0.469	0.386
	Sig. (2-tailed)	0.209		0.315	0.091	0.173
Intersection design (# of directions)	Pearson Correlation	.533*	0.290	1	.685**	0.333
	Sig. (2-tailed)	0.050	0.315		0.007	0.245
T1024_Ch_R2	Pearson Correlation	0.364	0.469	.685**	1	0.238
	Sig. (2-tailed)	0.201	0.091	0.007		0.412
Visual Connectivity	Pearson Correlation	.671**	0.386	0.333	0.238	1
	Sig. (2-tailed)	0.009	0.173	0.245	0.412	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 2. Correlation between weekend traffic and some of the environmental measures

Correlations

		Weekday traffic	Street lights	Intersection design (# of directions)	T1024_Ch_R2	Visual Connectivity
Weekday traffic	Pearson Correlation	1	.583*	.590*	.561*	.573*
	Sig. (2-tailed)		0.029	0.026	0.037	0.032
Street lights	Pearson Correlation	.583*	1	0.290	0.469	0.386
	Sig. (2-tailed)	0.029		0.315	0.091	0.173
Intersection design (# of directions)	Pearson Correlation	.590*	0.290	1	.685**	0.333
	Sig. (2-tailed)	0.026	0.315		0.007	0.245
T1024_Ch_R2	Pearson Correlation	.561*	0.469	.685**	1	0.238
	Sig. (2-tailed)	0.037	0.091	0.007		0.412
Visual Connectivity	Pearson Correlation	.573*	0.386	0.333	0.238	1
	Sig. (2-tailed)	0.032	0.173	0.245	0.412	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 3. Correlation between weekday traffic and some of the environmental measures