The Visualisation of *SiN* in Edinburgh

Suzanne Meade, Dr. Kathryn Stewart, Prof. Mike Maher
TRI, Edinburgh Napier University

1 Abstract

Traffic safety has three primary dimensions: exposure (to risk), risk (of having a crash subject to a certain amount of exposure) and consequences (crash outcome e.g. injury type of a given crash). This paper focuses on two of those elements, exposure and risk.

Many countries, including Scotland, aim to increase the number of kilometres cycled or walked – thus increasing exposure – but the risk element can only change if conflicts between all users and their environment changes and existing safety problems associated with cyclists and pedestrians are reduced or removed.

The popularisation of the Safety in Numbers (SiN) effect in policy has led to a paradigm shift among planners and engineers in their approach to pedestrians and cyclists. The SiN effect proposes that increasing cycling or pedestrian activity leads to reduced accident risk. This is a relatively recent concept that it is increasingly popular in transport policy dialogue and among cycling and walking advocates in particular.

However, the co-existence of SiN and increased risk in low vulnerable road users (VRU) activity areas has also been identified by researchers. Therefore, while an aggregate SiN effect across a city or country may be evident, the effect may be weaker or absent throughout the region under consideration thus leaving high VRU risk areas unchanged. There is also still considerable debate surrounding the link between SiN and its causal effects that hinders evaluation.

This paper discusses the SiN theory in the context of exposure and risk in Scotland. Using a combination of GIS and multi-variate regression analysis to explore the spatial distribution of SiN, the research asks: 'who is safe in numbers?' and 'where?'. The spatial element of this research locates the strength or weakness of SiN across census Data Zone areas and explores the spatial distribution differences of risk and exposure in Edinburgh.

The spatial evaluation of risk and exposure is currently difficult especially for those who must implement current transport polices. This research aims to provide transport planners and policy makers with a visual tool to better understand VRU road safety and the SiN effect at a local level. Poor safety perceptions and outcomes are barriers to encouraging transfer to alternative modes of transport and poorly understood accident risk may limit future government investment in evidence-based safety improvement even if SiN appears to exist, at least at a global level. Considering the third element of road safety – outcomes – the magnitude of VRU injury and subsequent public health burden may continue to increase.

2 Introduction

Government policies seek to increase active travel and at the same time set targets for reduced overall road injury accidents. In Scotland, despite supportive policies and initiatives, long-term trends for active travel throughout Scotland have seen a reduction in walking and a slight increase in cycling to work or education, although some urban centres have pockets of improvement which buck this trend.

Active travel is a determinant of a healthy population[1] but negative perceptions of road safety and higher injury risk limit the potential success of wider active travel policies and directly influence emergency services. According to the 2001 census Edinburgh is one of the Scottish populations reporting one of the highest levels of health and Edinburgh inhabitants walk and cycle more than anywhere else in Scotland.

Road safety global performance has improved in line with government targets. However, there is a performance dichotomy when long term motorised and non-motorised transport users are examined separately, Figure 1 illustrates that overall fatality numbers have fallen, but the number of cyclists and pedestrian fatalities have not changed substantively. In particular, Figure 1 shows that there is an increasing serious cyclist injuries trend. This trend is observed in both police and hospital admission records[2].

Pedestrians and cyclists are involved in 23% of all road casualties in Scotland, 15% and 8% respectively[3]. However, their combined share of travel to work accounts for only 15.6%, 13% and 2.6% respectively[4], and their overall distance travelled is also proportionally less, cycling accounts for just under 1% of the total vehicle kilometres travelled each year on Scottish roads. Therefore, pedestrians and cyclists have a disproportionately high share of casualties relative to their activity within the transport system and their potential to cause injury to another party is low.

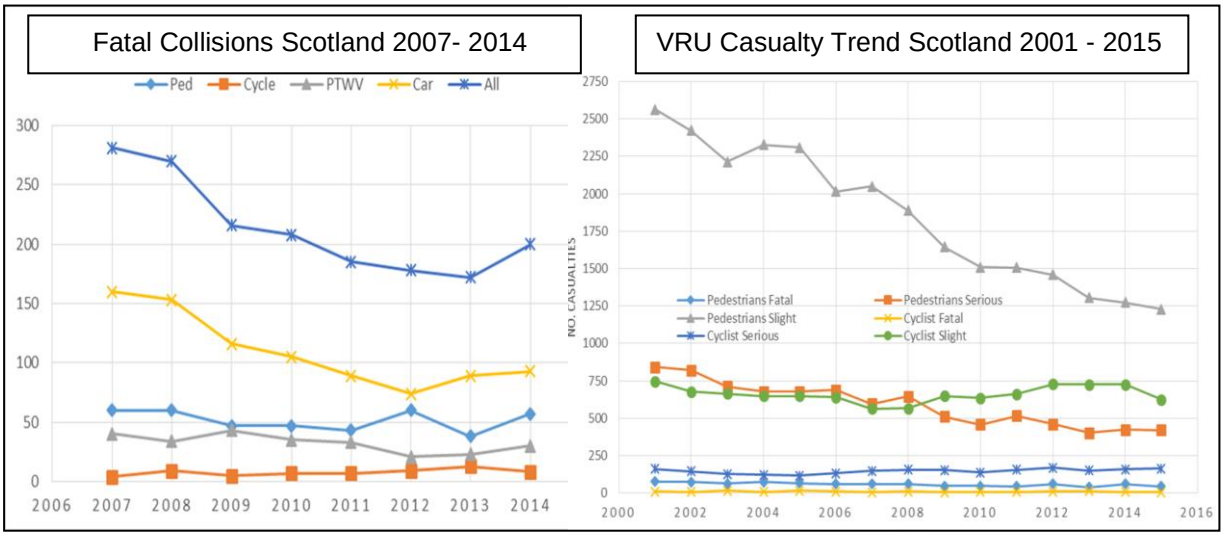

Figure 1: Police Recorded Casualties (Stats19) Scotland

Local governments and advocacy groups in Scotland[5] [6] promote the increasingly popular transport paradigm 'safety in Numbers' (SiN) to encourage active travel through more cycling and walking. One of the reasons behind promoting this paradigm is that perceived risk is a significant barrier to mainstream cycling in Scotland[7]. In contrast to SiN, other research points to the lack of segregation and route continuity[8] and poor safety behavioral mechanisms[9] as the cause of safety problems among cyclists rather than a lack of participation.

Motorised road safety paradigms and policy does not advocate SiN as a safety measure, despite having the same observed non-linear relationship between the number of vehicles and number of collisions. The road safety approach for motorized transport in Scotland, which has been successful, is based on evaluation, data collection and research which informs design standards and policy. According to the OECD[10] most authorities lack the factual basis to assess VRU safety or the impact of their 'safety improving' policies.

Therefore, evidence of the manifestation of SiN and the strength or weakness of the phenomenon is important to understand because it may inadvertently effect perceptions, road safety expectations, and

road performance and finally SiN may not be as effective in Scotland as found elsewhere. As discussed earlier experts[11] [12]urge caution as to the transferability of SiN results across countries or indeed regions. Furthermore, continued negative perceptions of road safety risk and higher injury risks limit potential success of wider active travel policies and directly influence emergency services burden.

It is the increasing trend in cyclist casualties and prominence of the SiN paradigm that's has motivated this research. What one does not wish to see is increased active travel, which improves our population health, associated with an increase in walking or cycling related injuries or fatalities. The following sections discuss SiN in some detail and sets out the research aim and the research questions presented in this paper.

2.1 Safety in Numbers

SiN is a very interesting concept in that the users themselves are the safety measure, if increased, they promote better safety. The other side of that concept would also seem plausible however; what if we have fewer numbers, as would be the case in areas outside urban centres. It is also somewhat counterintuitive, given the fact that walking or cycling involves a much higher per kilometer casualty risk than driving.

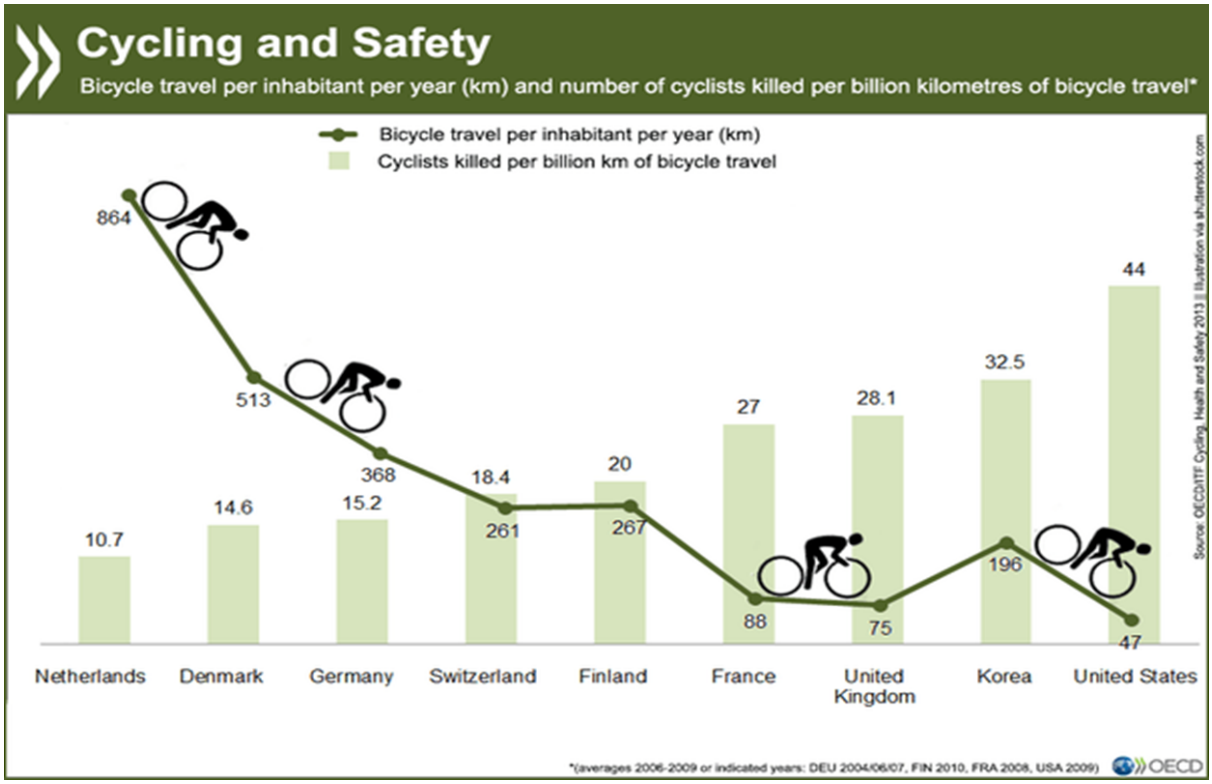

Figure 2: OECD comparison of cyclists travel against cyclist fatalities [Source: OECD/ITF, Cycling, Health and Safety, 2013, Figure 3.14.]

Briefly, SiN is a recent paradigm in transportation research that has emerged as a causal inference for a non-linear relationship between estimates of the numbers of VRU in an area and the rate or number of traffic collisions experienced by VRU. Thus, greater numbers of VRU are believed to modify the behaviours of drivers that create safer streets/roads. The trend is illustrated in Figure 2 above.

The evidence often referred to is the empirical research conducted by Jacobsen[13] that demonstrated a non-linear relationship between the numbers of VRU and the frequency of collisions with motorists.

The main finding was that a doubling of cycling or walking volume would be associated with a 41 % increase in the expected accidents.

The UK has one of the lowest cycling populations in Europe and the long-term trend in Scotland has hovered around 2% since 2001. Many of the countries where SiN has been researched such as the Netherlands and Sweden, have 43% and 19% of their population cycling every day[14] so the context and culture is considerably different in terms of the balance between active travel and dominance of motorisation.

More recent research has however started to examine the mechanisms behind SiN which are far from conclusive[15 16 17 18 19 20]and many questions remain, including risk and the context [21], as to the under lying causes or indeed strength of the phenomena and its transferability. In terms of how transferable SiN research findings are to the UK and indeed, Scottish context remains to be seen. A review of the literature to data has not identified evidence of the phenomenon in a Scottish context.

2.1.1 SiN Scale Micro, Macro and Meso

While there has been considerable research into SiN at a country or city level (macro) and at the individual link or junction level (micro), very little research has focused on the differences within a city or region scale at a meso scale. There is growing recognition among road safety researchers that a meso level safety analysis can be more beneficial than municipal or national level[22 23]. Nationally aggregated road safety figures at a macro level may not reflect local level scenarios because they can't capture local variation and while micro level is useful to design engineers at a link or junction level, it is too location specific to be helpful in planning and policy level analysis.

Planners and policy makers need a policy tool rather than design tool at a local level. Meso level spatial research in the Netherlands[24] and more recently Hong Kong[25] produced results at a local level with the potential to be used as a planning aid to assess cycling risk.

As discussed above researchers have yet to pin down the causal factors associated with SiN generally conducted at a macro scale, country level, in countries with a much more active and user balanced transport system. As such, there are things we could understand better about SiN in a Scottish context to inform our VRU policies and the following should be considered.

- Evidence for SiN and the strength or weakness of the effect in Scotland: it is important to understand because it may effect perceptions and impact injury rates.
- Transferability of SiN research /results across countries or regions is unknown.
- What (if any) is the local (meso) level variation in SiN?

2.2 Research aim and objectives

There is a need for research that evaluates cycling exposure to risk and resultant safety outcomes in Scotland. The strength of a SiN effect and visualisation of relative VRU risk in Scotland has received little attention previously. Very few studies identified in the literature investigate road safety at small meso level.

This paper investigates in part whether there is a VRU *SiN* effect in Scotland due to increased mobility and examines if there are wider spatial, demographic and policy differences affecting VRU. The research question to be answered is, 'At a local level, is there a SiN effect evident among VRU in Scotland?'

Therefore, is SIN happening when increased cycling takes place in Scotland? This theory has been used to justify promotion of increased cycling and walking within our current infrastructure and it is important to assess this approach.

3 Methodology

3.1 Data

Stats19 data from 2001 to 2003 and those from 2010 to 2012 were pooled into two three-year data sets for killed and serious injuries in each geographic zone. The casualty data was pooled over three years to avoid zero entries. All cycling casualties, including weekend and public holidays, were included. The data used is set out in **Table 1** below.

Variable	*Description*	*Data Source*
Dependent		
Bcol	Bicycle casualties	Stats 19 Datasets Department for Transport
Independent		
Bdist	Cyclist, million vehicle kilometres	Census 2001, 2011 / National Travel Surveys
VehDist	Vehicle, million vehicle kilometres	Department for Transport/Transport Scotland

Table 1: Research variables, description and data source.

3.2 Exposure

One of the prevailing challenges in cycling research is ascertaining a representative level of 'exposure' or simple how much cycling happened and where. Unlike research into motorised transport, cyclist exposure is typically difficult to estimate due to lack of data collection. Therefore, it is difficult for researchers to determine if a change in the number of accidents over time is due to increased accident risk, (users or environment becomes more unsafe) or if the increase in accidents is due to a higher proportion of cyclists using the existing roads and routes and therefore that there are more incidents.

At a macro or country level, overall estimates such as those published annual by the Department for Transport (DfT) may be appropriate but at a regional or local level they are less so because cycling varies depending on urban/rural context and other cycling variables. Other researchers have investigated cycling accidents at a micro level using link road or junction count data; however, at this scale data is typically only available at selected locations throughout a city and cannot be used as a reasonable estimate for higher spatial analysis with in a city.

In terms of where people cycle, the best available meso level data is available from the census which provides data on mode of travel to work and study. While this data only captures trips to work or study, research by Goodman[26] found that this data was highly correlated with cycling modal share for all trips and therefore can be used as a proxy for all cycling trips. The Scottish Household Survey Travel Diary indicates that approximately one third of cycling trips are undertaken for the purpose of commuting and it is assumed that 400 one-way trips per year [27].

Therefore, the census 2001 and 2011 method of travel to work or education data was used to estimate distances cycled in each council area and for the City of Edinburgh geographical zones. It was possible therefore to estimate the number of million vehicle kilometres cycled per year in each council area and Edinburgh ward.

The following formula[28] used to estimate cycling exposure, was used to estimate distance cycled in each geographic zone in Scotland:

$$D = n \times f \times d \times p \qquad (1)$$

Where *D* is the total annual distance cycled in each zone, *n* is the number of people who cycled to work or study in each zone, f is the frequency of trips, *d* is the average distance in kilometres of each bicycle trip and *p* is the proportion of commuting bicycle trips assumed discussed above. The metric million-vehicle-kilometres (mvkm) is typically used for comparability.

3.3 Modelling

Accident prediction models (APM), of various function forms, are used to analyse accidents for sample of sites, links or regions, evaluate the factors, design elements or other variables that contribute to the observed accident frequency or safety performance. APM typically use statistical regression analysis techniques to investigate the relationship among variables. Their purpose is twofold, to predict the frequency of accidents or to attempt to explain the association between different accident types or severities and several independent variables.[29] [30]

While meso level modelling of VRU is uncommon, the more usual micro or macro level APM have seldom been developed for VRU such as cyclists [31] but are commonly developed for vehicular models. APM variables comprise the response or dependent variable (accidents), traffic volume or risk factors and other explanatory variables.

In this paper, the research question seeks to examine the SiN phenomenon; hence these models have been developed in a similar manner to previous research using regression analysis. Negative Binomial (NB) regression models similar to models developed by Schepers, Elvik and Yao and Loo of the following general form are used:

$$\text{Number of } Cyclist\ Collisions_i = exp(\alpha).CyDist^{\beta 1}.exp\ (\beta 2 Z_i) \qquad (2)$$

Where $Cyclist\ Collisions_i$ is the number of cyclist killed or serious casualties in each area *i*, *Z* is a set of control variables, $\beta 2$ is the corresponding set of parameters and *CyDist* is cycling exposure measured in million vehicle kilometres travelled. In the equation above, when $0<\beta 1<1$, this suggests that the increase in cyclists casualties and distance travelled is less than linear which describes the SiN phenomenon. By developing models similar to previous research, it is possible to compare Scottish *SiN* results with those found elsewhere. As discussed in the introduction the co-efficient developed by Jacobsen suggest that doubling the amount of cycling (exposure) would result in a 41% increase in casualties. (N.B. where if the $\beta 1$coefficient was 0.5, such that two to the power of 0.5 equals about 1.41 – giving a 41% increase when cycling is doubled.)

4 Results

4.1 Cycling risk comparison for Scottish Council areas

A comparison of cycling mode share across the 32 Scottish council areas between the 2001 and 2011 census, shown in Figure 3 below, reveals that the majority of councils have below 2% of cycle mode share; the only notable increase above this level was in Edinburgh. Outwith areas that have had marked improvement it is difficult to determine if more cycling has improved road safety hence this research focuses on Edinburgh as a case study.

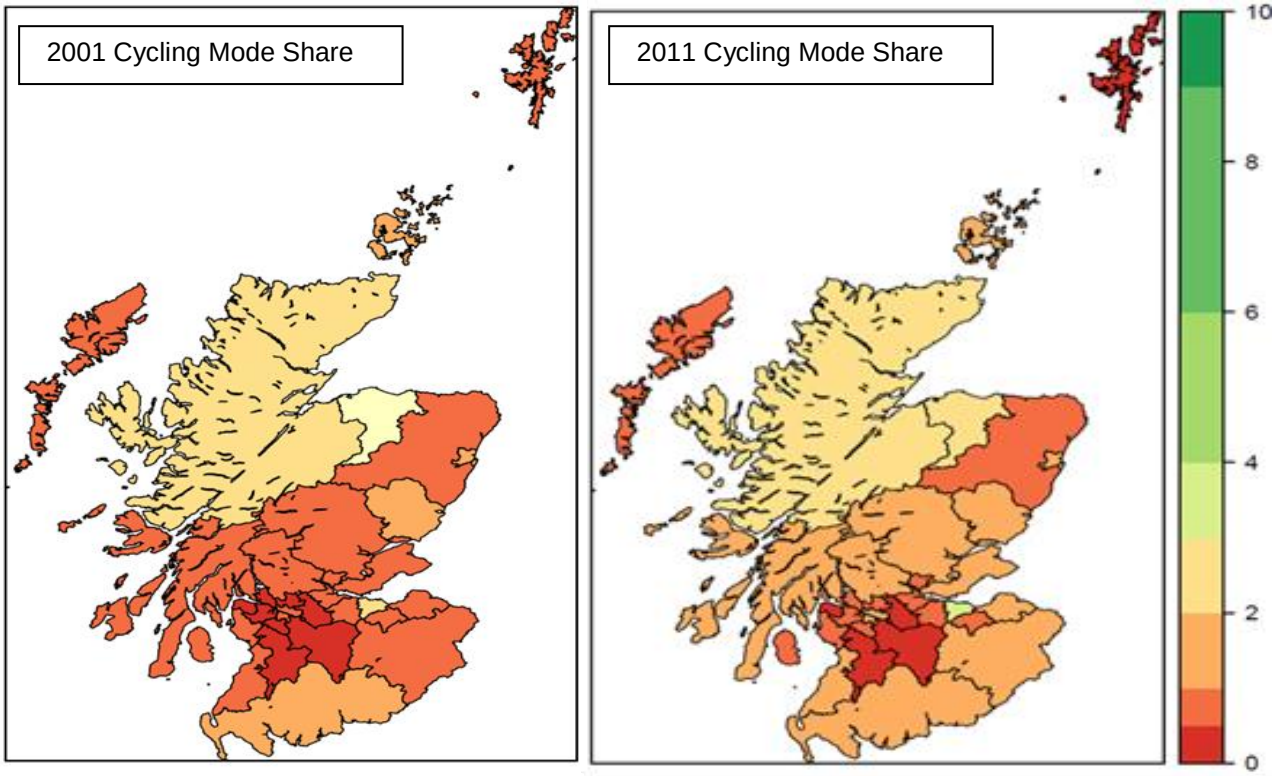

Figure 3: Comparison of cycling mode share (%) across Scottish Council Areas 2001 to 2011.

The overall risk appears to have improved, illustrated in Figure 4 below that compares the KSI against distance travelled between 2001 and 2011.

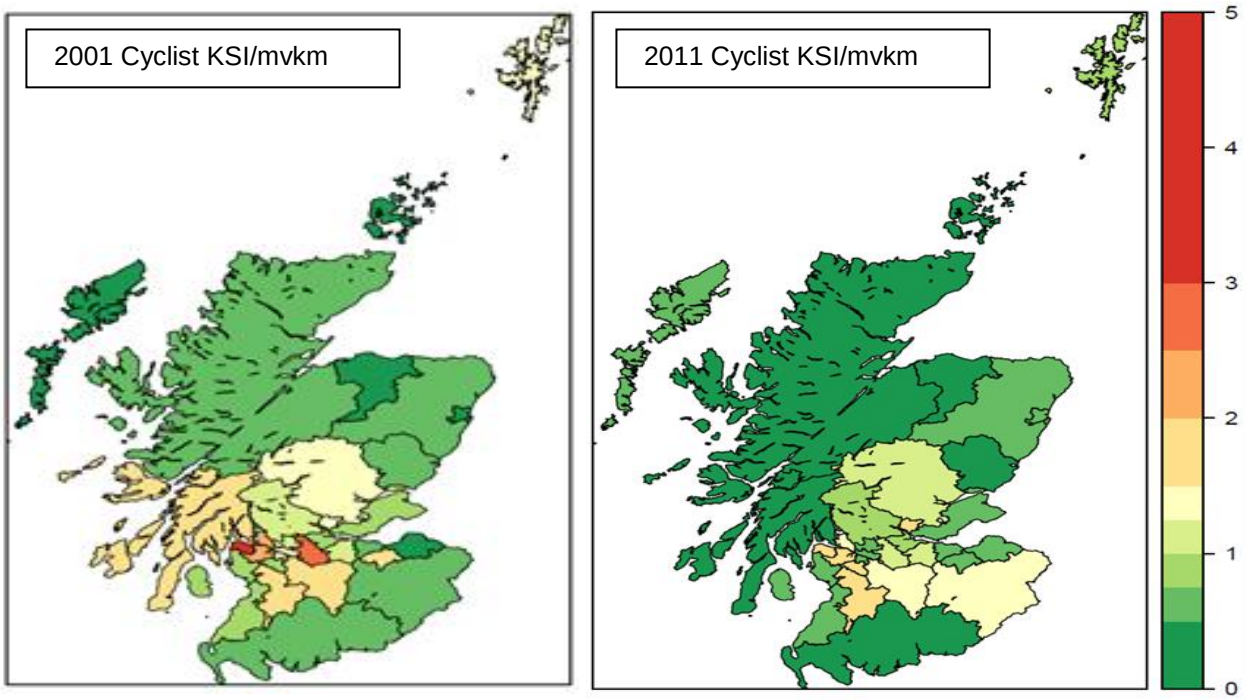

Figure 4: Cyclist risk Comparison (Collision/mvkm) across Scottish Council Areas 2001 to 2011.

To help gain more insight into the number of cyclist collisions in each area and the killed or seriously injured (KSI) metric, percentage cyclist mode share against KSI per distance travelled were examined for the census years 2001 and 2011, shown in Figure 5 and 6 below.

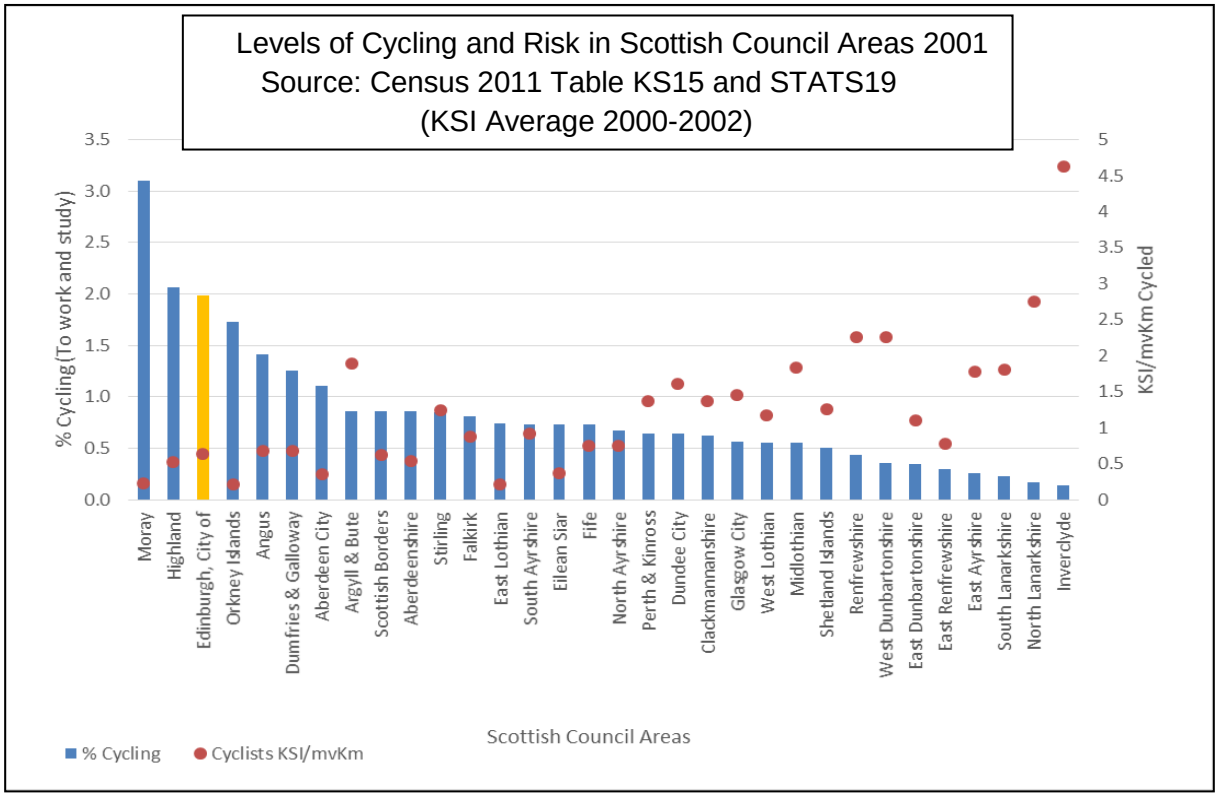

Figure 5: Levels of Cycling Risk in Scottish Council Areas 2001

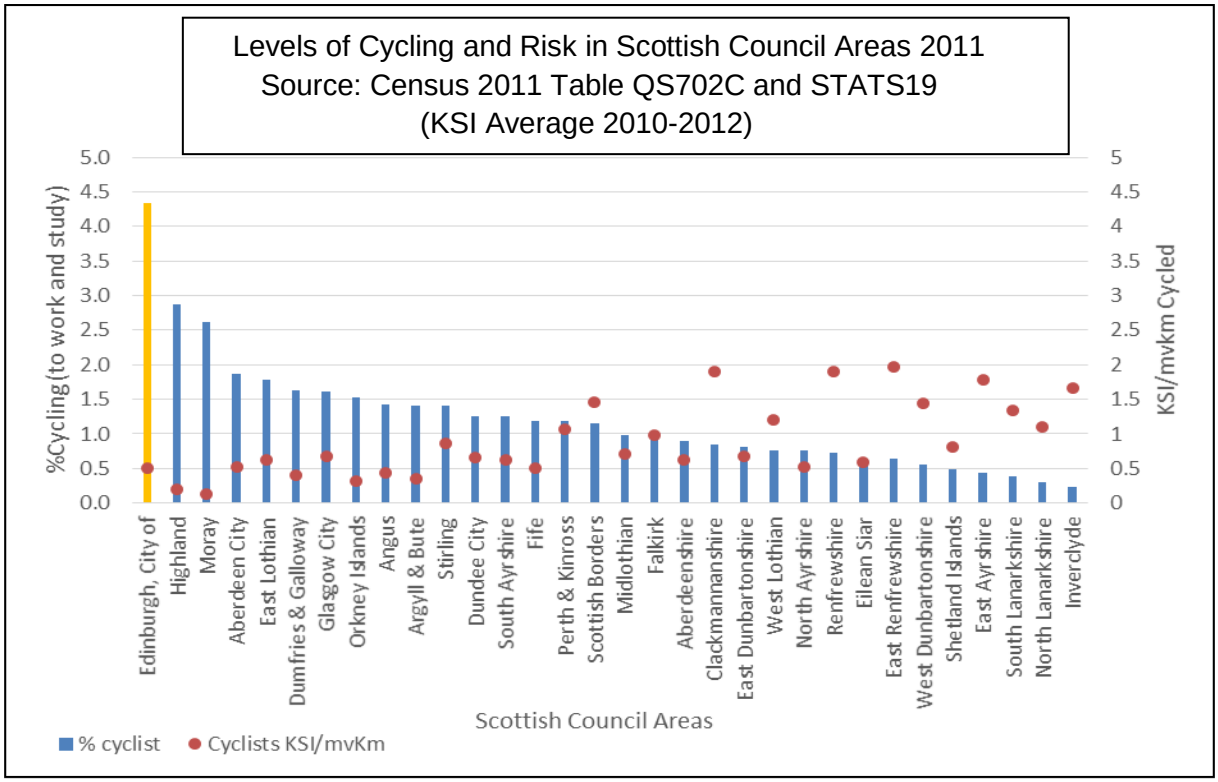

Figure 6: Levels of Cycling Risk in Scottish Council Areas 2011

The comparison suggests that areas with higher levels of cycling have lower risk rates (KSI/mvkm), a similar association as previously illustrated across international comparisons in Figure 2. There is an indication that some council areas have improved road safety between 2001 and 2011 however, Edinburgh (highlighted in yellow), which doubled its cycling mode share in 10 years, appears to have

about the same injury risk (around 0.5 KSI/mvkm) despite the increased mode share and distance travelled by cyclists.

Overall, between 2001 and 2011, there has been little absolute change in cycling at a global level, Edinburgh being the exception.

4.2 Cycling risk regression for Scottish Council areas

The initial models presented here only include the variables listed in Table 1 above. The results for Scotland are shown in Table 2 and in Table 3; the Scottish results are compared with other international studies[32] [33]. The relevant variable co-efficients were always more than zero but less than one, which shows the non-linear relationship between cycling exposure and number of casualties indicative of the SiN effect as found in other research.

Negative Binomial Regression				
(Cyclist Casualties)	Coefficient β	SD	z	P>z
2000-2002				
Cyclist Dist.	0.68	0.103	6.567	<0.001
Cyclist Dist + Veh Dist	0.31, 0. 725	0.129, 0.185	2.382, 3.920	0.017, <0.001
2010-2012				
Cyclist Dist.	0.71	0.086	8.168	<0.001
Cyclist Dist + Veh Dist	0.54, 0.35	0.137, 0.219	4.001, 1.603	<0.001, 0.109

Table 2: Initial Negative Binomial Models

Negative Binomial Regression					
(Cyclist Casualties)	Coefficient β (2000-2002)	Coefficient β (2010-2012)	Jonsson (2005) Sweden	Schepers *et al*. (2011) Netherlands	Turner *et al. (2006) New Zealand*
Cyclist Dist.	*0.68*	*0.71*			
Cyclist Dist + Veh Dist	*0.31, 0. 725*	*0.54, 0.35*	0.35, 0.76	0.48, 0.73	0.09, 0.29

Table 3: International Comparison of Negative Binomial Coefficients

The main findings are summarised:

- There is little difference between the 2001 and 2011 cyclist distance only models.
- The models developed with cycling distance only have higher co-efficients for cyclist distance than in the joint models.
- The addition of vehicle distance into the model reduces the cycling distance co-efficient and the results are broadly comparable with those in previous studies.
- The 2010-2012 model atypically shows a relatively smaller vehicle distance coefficient which warrants further investigation.

4.3 City of Edinburgh – Ward Level Analysis

The city of Edinburgh has experienced a doubling of cycling activity (work and study) between the years 2001 and 2011 from 2% to 4.3%. The most recent estimate of cycling as a main mode of transport to work in Edinburgh is approximately 4.2%, however this is an average and within the city's wards the mode share varies from a high of almost 10% (Meadows/Morningside) to a low of 2% (Sighthill/Gorgie and Liberton/Gilmerton) illustrated in Figure 7 below.

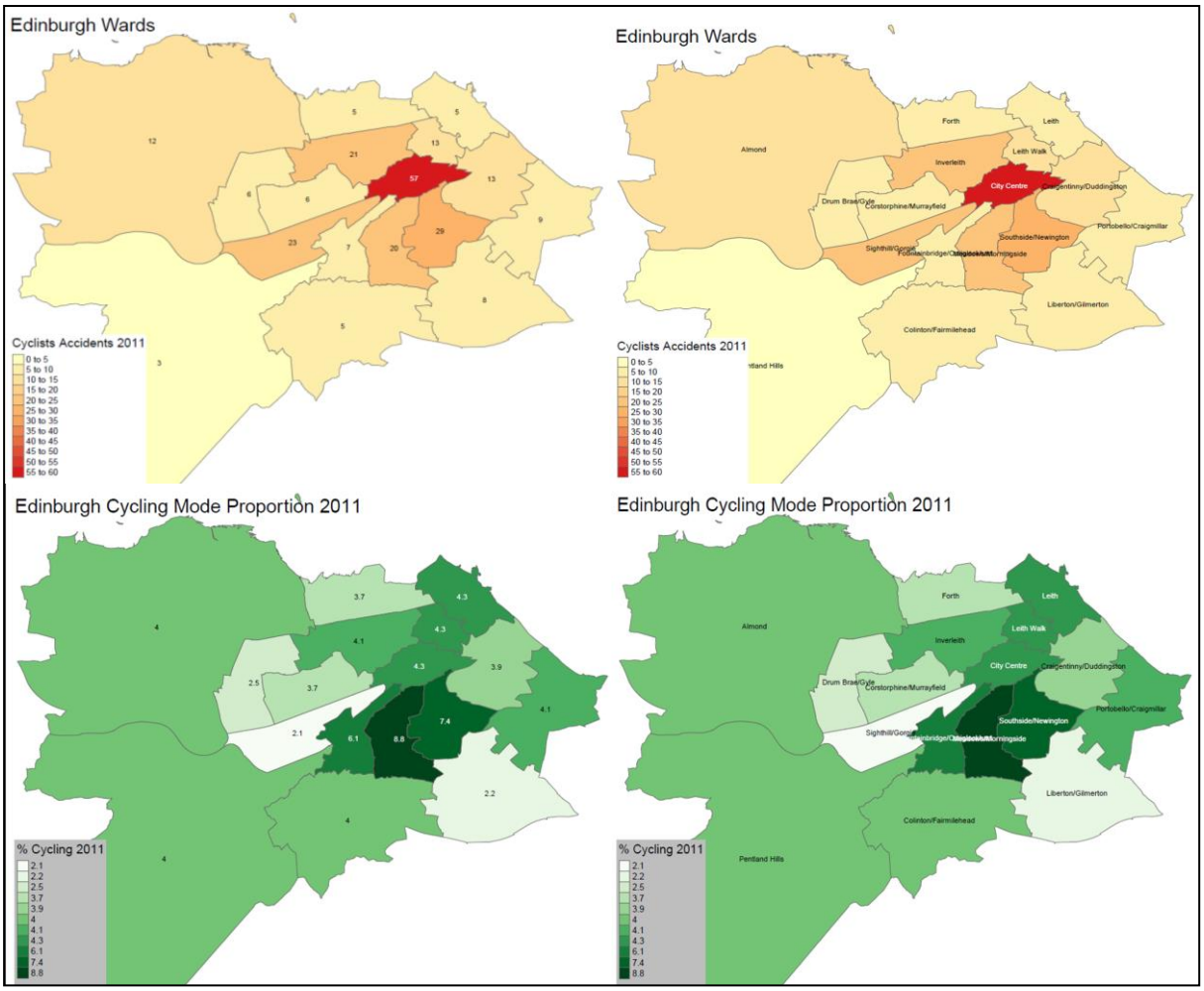

Figure 7: City of Edinburgh Cyclist Accidents and Cyclist Mode Share 2011

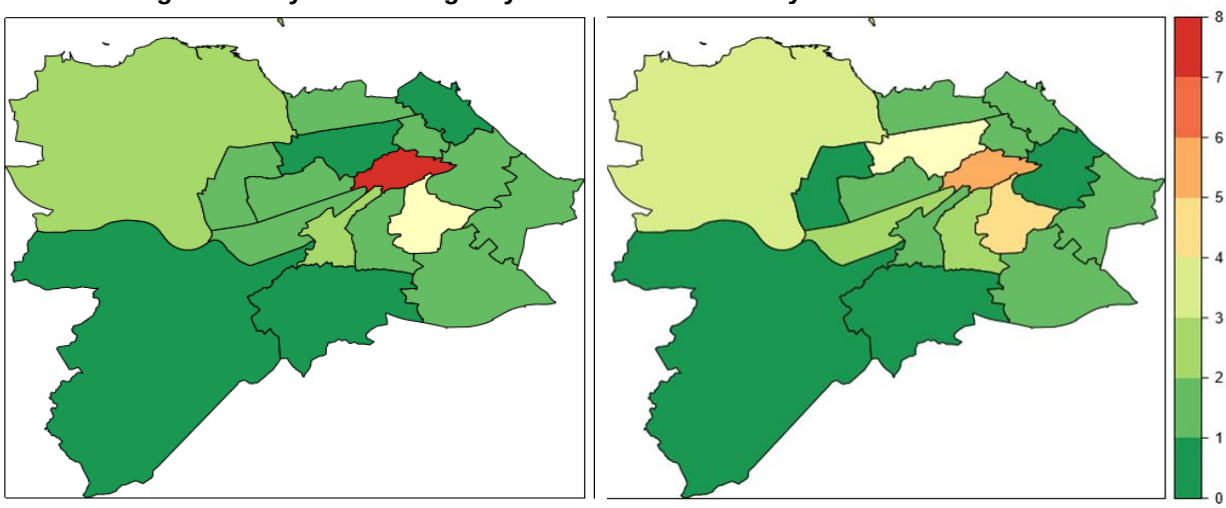

Figure 8: 2001 and 2011 Comparison of Cyclist Accident Risk /mvkm

Figures 7 and 8 highlight the variation in mode share across Edinburgh and demonstrate the risk variability across the city. This does suggest that the SiN effect is somewhat apparent in Edinburgh, and that it appears to have spatial variation. The comparison between 2001 and 2011 indicates that the risk pattern has altered between 2001 and 2011.

5 Discussion

The evidence from this empirical study demonstrates that the SiN phenomenon among cyclists is present across council areas in Scotland; however, the results are weaker when compared to those found in higher cycling populations in previous research. This finding is reasonable because Scotland has a low overall level of cycling compared with The Netherlands and Sweden.

The analysis of the two separate time periods found that the SiN relationship has not changed substantially at a global level over ten years. This too is reasonable given the limited change in cycling between the 2001 and 2011 census.

The finding that vehicle flow was positively associated with cyclists KSI casualties is in accordance with other studies[34] [35]. This is an intuitive finding, given that over 80% of cyclist casualties involve a car in Scotland. The initial models' results confirm that more vehicle and/or cyclists exposure contributes to more vehicle-cyclist collisions and that increasing cyclist's volume alone does not fully explain a SiN effect.

Similar to the research conducted in by Vendenbulckle[36] the SiN effect is weaker or absent in rural areas. Regional differences are important to consider and SiN may not be a feasible reality outside cites due to infrequent user volumes, higher traffic speeds or where cyclist infrastructure is absent and given the rural and urban split in Scotland this is an important policy consideration.

Edinburgh has the highest levels of cycling in Scotland at approximately 4.2% and accounts for approximately 28% of the total distance cycled in Scotland (with only 9% of the Scottish population being in Edinburgh). Between 2001 and 2011 cyclist KSI increased by approximately 40% while cycling approximately doubled. From initial regression analysis, the growth in cycling volume and increase in KSI follow a non-linear relationship. This suggests that there is a slightly stronger SiN effect in Edinburgh than in Scotland as a whole. This 40% increase in risk while cycling doubles is very close to the SiN prediction described by Jacobsen and discussed earlier.

The models developed by Jacobsen did not control for the effects of vehicular volumes or other explanatory factors, found to be significant in subsequent research by Elvik, Schepers and Yao and Loo and indeed Jacobsen in his follow up paper to the original research published in 2003. The factors that have resulted in some areas having lower or higher injury risk for cyclists in Scotland are still not fully understood.

6 Conclusion

These research results add to the body of evidence on SiN and confirms that the phenomenon is evident in Scotland. While SiN indicates that risk declines as the number of cyclists increase it also implies that the absolute number of KSI will still increase.

While the spatial evaluation of risk and exposure is currently difficult due to data limitations this research demonstrates the benefit of using a visual tool to better understand VRU road safety and irrespective of the SiN effect, risk varies spatially with considerable variation within urban areas.

Furthermore, SiN is a global approximation, it does not address rural issues (or where there is low/ no growth in cycling- risk remains). Given the drop in cycling in some council areas, policies promoting SiN would be inappropriate. Rural areas in Scotland that wish to promote cycling tourism should be cognisant of their local requirements and would need alternative approaches.

Cycling advocates argue that putting too much emphasis on safety can undermine efforts to encourage cycling and may deter people. On the other hand, the risks are real and are higher, per kilometre travelled, than motorised travel alternatives (except for motor cyclists), and therefore risk factors should be understood in order to mitigate them. Furthermore, while the SiN phenomenon is

observed in the Scottish data, the number of KSI will continue to rise as cycling increases because SiN does not equate to a reversal or cessation in the absolute number of KSI it only indicates a less than linear proportional increase relative to cycling increase in an area. Consequently, an assumption that greater numbers of cyclists will reduce road injury risk under all circumstances may be an overly simplistic policy to adopt and negative safety perceptions which are known barriers to cycling may persist.

As pointed out in several recent publications it is important to recognise that SiN is a phenomenon that does not necessarily suggest a causal relationship. Yao and Loo argued that once the SiN statistical association is established efforts should be made to discover their cause. Understanding the mechanisms of such a causal association may provide clues about how to reduce cyclists risk and how to enhance the impact of increased numbers of cyclists. Poorly understood accident risk may limit future government investment in evidence-based safety improvement even if SiN appears to exist, at least at a global level. In order to develop polices to improve safety it is crucial to improve the knowledge gap so that successful and sustained policy is fact based[37].

This research is part of a wider project that will seek to examine the underlying explanatory factors that influence the likelihood of vehicle-cyclist accidents.

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