COMPARISON OF MODE-SPECIFIC PERCEIVED SAFETY AMONG CYCLIST IN MULTI-MODAL URBAN NETWORK

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ABSTRACT

In recent years walking and cycling are being actively promoted as sustainable alternatives to motorized travel. Unlike walking, cycling requires sharing of road space with other modes of travel. To promote cycling in a multimodal urban transport network, it is important to establish the safety and efficiency of the network from a cyclist's perspective. This paper presents a study on understanding the compliance and perceived safety experience of cyclists when compared with driving in a congested urban network. A fixed response questionnaire based survey was conducted on the existing cyclists in Dublin city in Ireland. The survey responses were analyzed in an Ordered Logistic Regression framework to identify the factors which influence the compliance and safety experience of cyclists. Analysis of the survey responses of cyclists in Dublin has revealed several new areas, in which improvement could increase the perceived safety of cyclists. Policy related to use of safety accessories, cyclists' compliance with the rules of the road, educating young cyclists has been discussed in the paper.

Keywords: Cycling, Perceived Safety, Compliance with traffic laws, Car-ownership

INTRODUCTION

With a growth in the dependency on motorized transport in European cities, concerns are being raised as to the problems this causes; increased congestion, traffic emissions and public health problems are issues policy makers wish to address. As a result interest has turned to sustainable modes of transport. Walking and Cycling are being promoted as alternatives to motorized modes. These non-motorized modes prove beneficial in congestion and emission reduction, as well as offering individuals the opportunity to stay fit and healthy. In 2005, the cost of congestion in the Greater Dublin Area in Ireland was €2.5 billion. This poses considerable threat to the Irish economy. As such, policy makers have taken an interest in promoting these sustainable modes. In 2009, Ireland's first National Cycling Policy Framework (NCPF) was published (Department of Transport, 2009). This document aims to increase Irish cycling mode share to 10% of all computer trips by 2020. At the time of publication, this mode share stood at 1.9%. Although Dublin's commuter mode share of cyclists is higher than this average, at 3.2% in 2006 (Central Statistics Office, 2006), it remains far below the targets set out in the NCPF.

Despite cycling fatalities accounting for only 3.5% of all road fatalities on Irish roads between 1998 and 2008 (Road Safety Authority, 2010), cycling remains a largely unpopular mode of travel among the inhabitants of Dublin city. In comparison with cycling friendly countries and cities, this is still extremely low. Cycling mode shares in countries like the Netherlands, Denmark and Germany are on an average between 10%-26% with some cities reaching 35%-40% (Ministerie van Verkeer en Waterstaat, 2009). The mode share for cycling in Amsterdam is 27% while it is as high as 37% for Copenhagen (Pucher and Buehler, 2008). Additionally, it is important to note that through appropriate safety management, Copenhagen has been able to reduce the number of seriously injured cyclists for the last three decades despite a significant upward trend in the number of kilometers cycled. The perception of cycling as an unsafe mode of travel contributes considerably to its lack of popularity. Studies have shown that the risk of an accident while cycling are much higher than that while driving (Aultman-Hall and Kaltenecker, 1999; Zegeer, 1994). A previous study of the attitudes of the transport network users of Dublin found that 21% of drivers do not cycle because they feel it is "too dangerous because of traffic" (Keegan and Galbraith, 2005). Therefore, the factors affecting the perceived safety of cyclists are required to be established, interrupted and investigated to better understand the reasons for these perceptions, in order for the issue to be addressed.

This paper presents a study based on a questionnaire type survey of cyclists in Dublin city, Ireland. The survey was conducted in order to collect information from cyclists on their perceptions of safety while cycling in Dublin, as well as information on their behavior while cycling and how they interact with the network. The initial analysis looks at the determinants effecting cyclist compliance with the rules of the road. A further analysis separates respondents into two groups according to whether or not the option to drive is available to them, to investigate the factors which influence each group. Both analyses where conducted using ordered logistic regression (OLR) based modeling methods.

Existing research has looked at the behavior differences according to location, age and gender. Harris et al. (2006) states that females are more likely than males to perceive a negative outcome in many recreational, social and health related situations. Female cyclists and non-cyclists perceive cycling as a higher risk than males as they are more sensitive to poor driver attitudes, a lack of confidence, a lack of cycling facilities and having to share road space with other modes of transport (Bernhoft and Carstensen, 2008; Emond et al., 2009; Garrard et al., 2006; Krizek et al., 2005). Male cyclists are willing to take more risks to avail of fast and direct routes between origin and destination. An increased perception of risk among women towards cycling has also been cited as a factor inhibiting the number of female cyclists in cities where cycling is a developing mode of travel (Emond et al., 2009). Older cyclists hold similar risk perceptions to female cyclists; preferring to make use of cycling facilities, signalized intersections and crossings, rather than faster, more direct routes (Bernhoft and Carstensen, 2008).

A significant amount of work is present in the field of transportation engineering employing Logistic Regression (LR) models to relate to accidents (Dupont et al., 2010; Ma et al., 2009; Yannis et al., 2005; Yau, 2004) and route choice options (Ben-Elia and Ettema, 2011; Popuri et al., 2011). Logistic regression is a powerful tool in establishing probabilities related typically to binary choices. However there can be ordinal dependent variables for which an extension of the binary model, an ordered logistic model may be used successfully.

The remainder of the paper is divided into six sections. The next section gives a description of the survey data collected, the section following that describes the OLR for the model investigating cyclist compliance with the rules of the road, the forth section describes the model investigating the perceived safety of those with and without the option to drive for their trip. While the fifth section discusses the policy implications of the findings and the final section concludes the paper.

DESCRIPTION OF SAFETY SURVEY DATA

Dublin City is the capital of Ireland and the largest city in terms of area, residing and working population of the country. The transport network in Dublin, however, is primarily designed for the use of private vehicles. Other main modes of motorized transport in Dublin City are Dublin Bus, Luas (tram), Dublin Area Rapid Transport (light rail) and Commuter trains (suburban railway networks). The network also contains approximately 120km of on-road cycle tracks, 50kms of shared bus-cycle lanes and 25kms of off-road cycle tracks. Figure 1 presents a map published by the Dublin Transportation Office in 2008 of the available cycling facilities. Despite the presence of these facilities there exist many threats to cyclists in Dublin. Vehicles frequently make unforeseen stops and turns, forcing cyclists into oncoming traffic from behind. Cycle lanes end abruptly, exposing cyclists to suddenly share their commuting space with other modes of high speed-differential. These conditions naturally lead to perceived and actual discomfort and a lack of safety for the cyclists. Cycling surfaces are poorly maintained, often resulting in falls causing injury and damage to property. The attitude of other users and travel modes in the transport network such as pedestrians, buses, taxis, car-drivers etc. also affect the perception

of safety of cyclists. The use of safety accessories, though not mandatory, influences the perception of safety of a cyclist. To understand which aspects of the transport network prove most hostile to cyclists, a detailed analysis is required to track the factors that most strongly affect the perceptions of safety of the cyclists in this network. There seems to be an image being created among the population of Dublin of cycling as an unsafe mode of travel. Such an image may negatively affect the popularity and the choice of cycling as a clean, sustainable, efficient and healthy mode of travel. To understand and establish the perceptions of the current cyclists is the first step to be able to create a network in which cyclists can feel safe.

A questionnaire based survey was conducted in Dublin to analyze the safety behavior and perceived safety of cyclists in Dublin city. 1954 responses were collected from existing cyclists in Dublin, of which 1732 responses were eligible for use in the analysis. It was decided to focus on the experiences and perceptions of existing cyclists, as this is the population that has firsthand knowledge of the safety problems and concerns associated with cycling in Dublin.

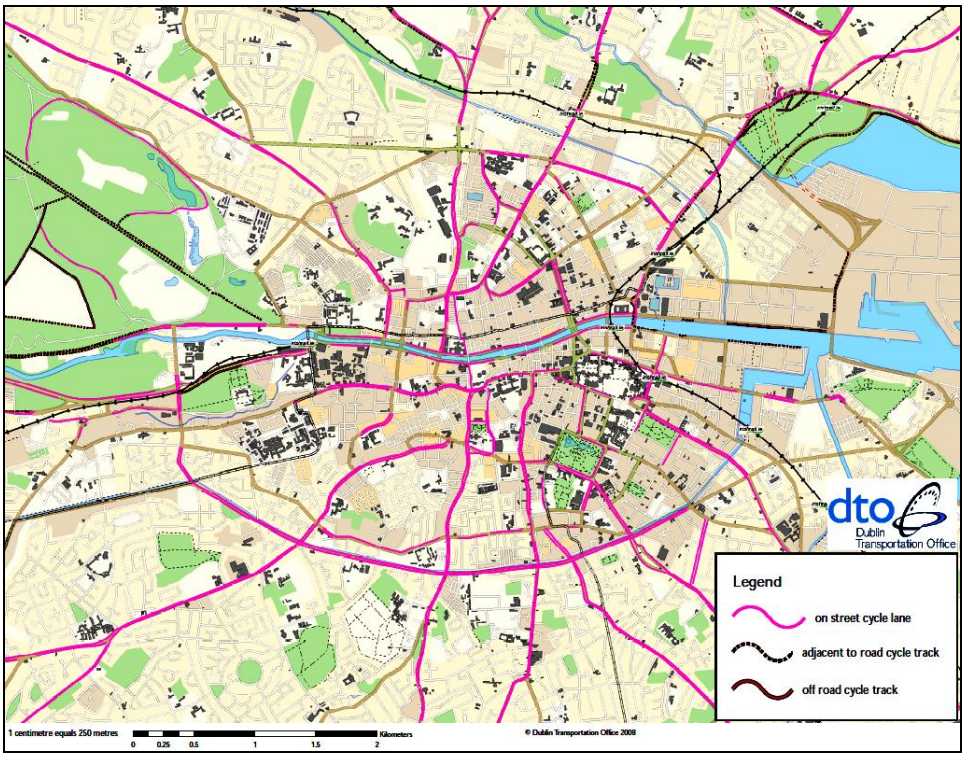

FIGURE 1 Map of current cycling facilities in Dublin City.

Of the respondents 63.7% were male. The majority of these cyclists were less than 45 years old. Above 45 years, the number of cyclists dramatically decreased. Over 55% of respondent cyclists cycle 3 to 5 days a week while nearly 31% cycle 6 to 7 days a week. The survey suggests high rates of safety accessory use, when compared to similar studies (Ferguson and Blampied, 1991; Hagel et al., 2007; Osberg et al., 1998; Robinson, 1996); nearly 54% of cyclists claim to wear a helmet and 88% use lights or reflective accessories while cycling at night. These differences

may be due to legal, cultural and social differences between the various cities and countries. For a more detailed description of survey respondents please refer to Lawson et al. (2012). It was seen that, almost 98% of the respondents in Dublin would describe themselves as being either a competent or highly skilled cyclist. Consequently, it is of significant concern if confident cyclists perceive the network to be potentially unsafe from a number of perspectives.

Figure 2 shows the preference of each experience group to where they cycle. Among all groups there is a strong preference to avoid urban roads, although it can be seen that the tendency lessens slightly with experience. This may be because of the high traffic volumes, higher traffic speeds and sometimes a larger number of vehicle lanes all induce a feeling of vulnerability among cyclists. In contrast, more than half of the respondents would prefer the use of parks and scenic trails in which to cycle. These facilities usually offer a more pleasant and relaxed experience for a cyclist as they are separated from traffic. In figure 3, the perception of safety among respondents while cycling in comparison to driving a car in Dublin city is studied. It can be seen that only the risk-averse, but even the adventurous and balanced cyclists view cycling as somewhat less safe or much less safe than driving in the city. If cycling is to become a popular mode of transport in Dublin, this is a problem which must be addressed.

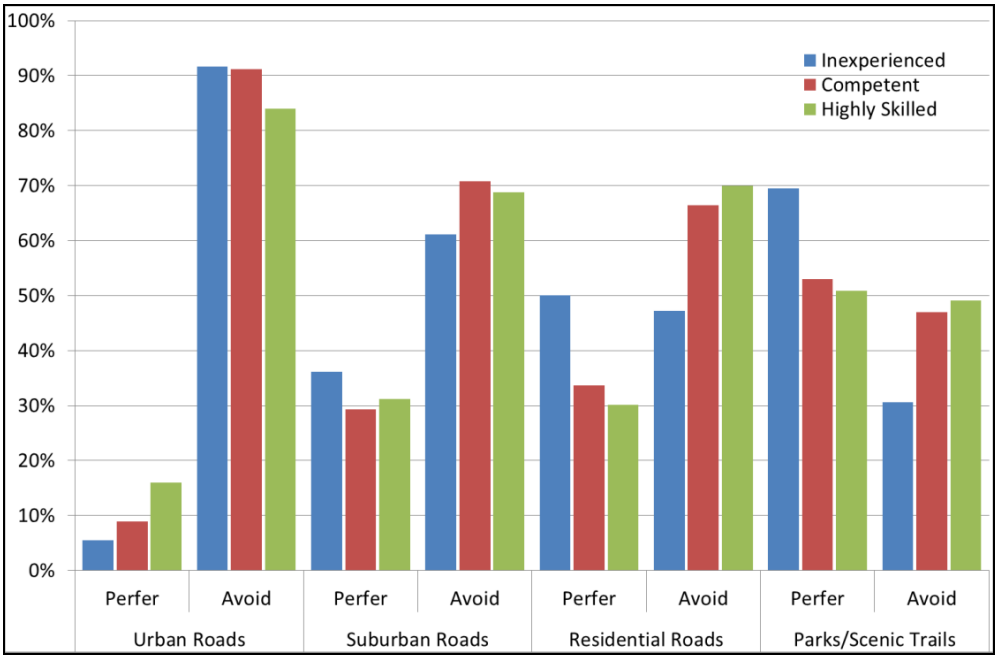

FIGURE 2 Preference of cyclists to type of road, according to cyclists' experience.

The survey responses were analysed using an OLR model to identify the determinants of perceived safety among cyclists (Lawson et al. 2012). It was concluded that, age, regularity of cycling, use of urban roads and roads with no special bicycle infrastructure, use of reflective accessories, compliance with the rules

of the road and the attitude of vehicle drivers are factors that influence the safety perception of cyclists.

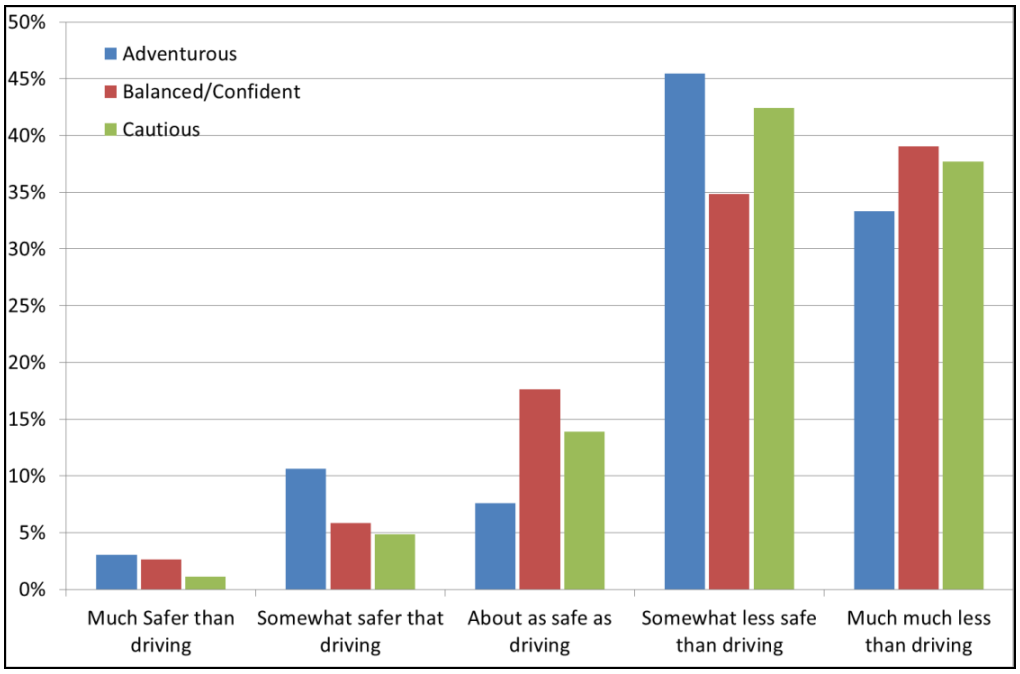

FIGURE 3 Views of cyclists when comparing cycling with driving in Dublin, according to cyclists' confidence

Analysis showed that 74% of the cyclists, who claim to be fully compliant with the rules of the road, were likely to consider cycling as safer than or at least as safe as driving in Dublin, yet the survey has revealed that 87.5% of participants admit to breaking the rules of the road. This provides a scope of further investigation in identifying the factors which influence such cyclist behavior.

CYCLIST COMPLIANCE WITH TRAFFIC RULES

This model investigates the determinants which influence a cyclist's compliance with the rules of the road while cycling in Dublin city. The modelling is carried out employing an OLR model of respondent cyclists. Table 1 shows the odds ratios, coefficient values, standard errors and 95% confidence intervals for each variable considered in the model. The model has found 9 factors to be associated with a cyclist's compliance with the rules of the road: age, whether a respondent is a student or working, confidence, use of urban roads, use of kerb-side cycle lanes, use

of helmets and hi-visibility clothing, a reckless driver attitude and feeling cycling to be as safe as driving in Dublin.

Table 1 Coefficients, odds ratios, the standard errors & the 95% confidence interval of these coefficients of the model investigating cyclist compliance with traffic rules

Is cycling safer than driving in Dublin?	**Coeff.**	**Odds Ratio**	**Std. Err.**	**[95% Conf. Interval]**	
Gender	-0.250	0.779	0.164	-0.571	0.072
Age	0.019	**1.019***	0.009	0.002	0.036
Employed	0.392	**1.480***	0.197	0.007	0.778
Regularity of bicycle use	-0.049	0.952	0.045	-0.138	0.040
Cyclist's experience	-0.201	0.818	0.156	-0.507	0.105
Balanced cyclists	-0.679	**0.507****	0.164	-1.000	-0.358
Confident cyclists	-2.653	**0.070****	0.352	-3.342	-1.964
Distance travelled	0.004	1.004	0.002	-0.001	0.008
Use of urban roads	-0.495	0.609*	0.237	-0.960	-0.031
Use of suburban roads	0.209	1.233	0.175	-0.134	0.553
Use of residential streets	0.057	1.058	0.171	-0.279	0.392
Use of park/scenic trials	0.076	1.079	0.184	-0.286	0.438
Use of cycle lanes on the footpath	-0.026	0.975	0.157	-0.333	0.282
Use of off road scenic cycle paths	-0.096	0.908	0.191	-0.471	0.279
Use of kerb-side cycle lanes	-0.332	**0.717***	0.153	-0.632	-0.032
Use of shared bus-cycle lanes	-0.148	0.862	0.192	-0.525	0.229
Use of roads with no cycle facilities	0.171	1.186	0.194	-0.209	0.550
Would alter route to use continuous facilities	0.135	1.145	0.153	-0.165	0.435
Use of helmets	0.491	**1.634****	0.173	0.153	0.830
Use of bright coloured/hi-visibility	0.375	**1.455***	0.177	0.028	0.721
Use of reflective accessories/lights	0.395	1.485	0.230	-0.056	0.847
Attitude of driver towards cyclists is usually reckless	0.081	1.085	0.165	-0.242	0.405
Attitude of driver towards cyclists is always reckless	0.383	**1.467***	0.185	0.021	0.746
Feel cycling is as safe as driving	0.503	**1.654****	0.194	0.123	0.884
Feel cycling is safer than driving	0.202	1.224	0.273	-0.333	0.737

** represents a *p* value of 0.01, * represents a *p* value of 0.05

From Table 1 it can be seen that as the age of the respondent cyclists increase, so too does the likelihood of the cyclist complying with the rules of the road. It is also seen that respondents in full-time employment are almost 1.5 times more likely to obey the rules of the road compared to students, again highlighting the lower compliance among younger cyclists. A preference to cycling on urban roads is associated with a decrease in the likelihood of a cyclist following traffic rules. A similar result is found for those who prefer to use kerb-side cycle lanes in the city. In terms of safety accessories, the use of helmets and hi-visibility clothing are both found to increase the likelihood of compliance with the rules of the road. Cyclists who perceive that car/bus/taxi drivers always behave recklessly towards cyclists are almost 50% more likely to be compliant the rules of the road.

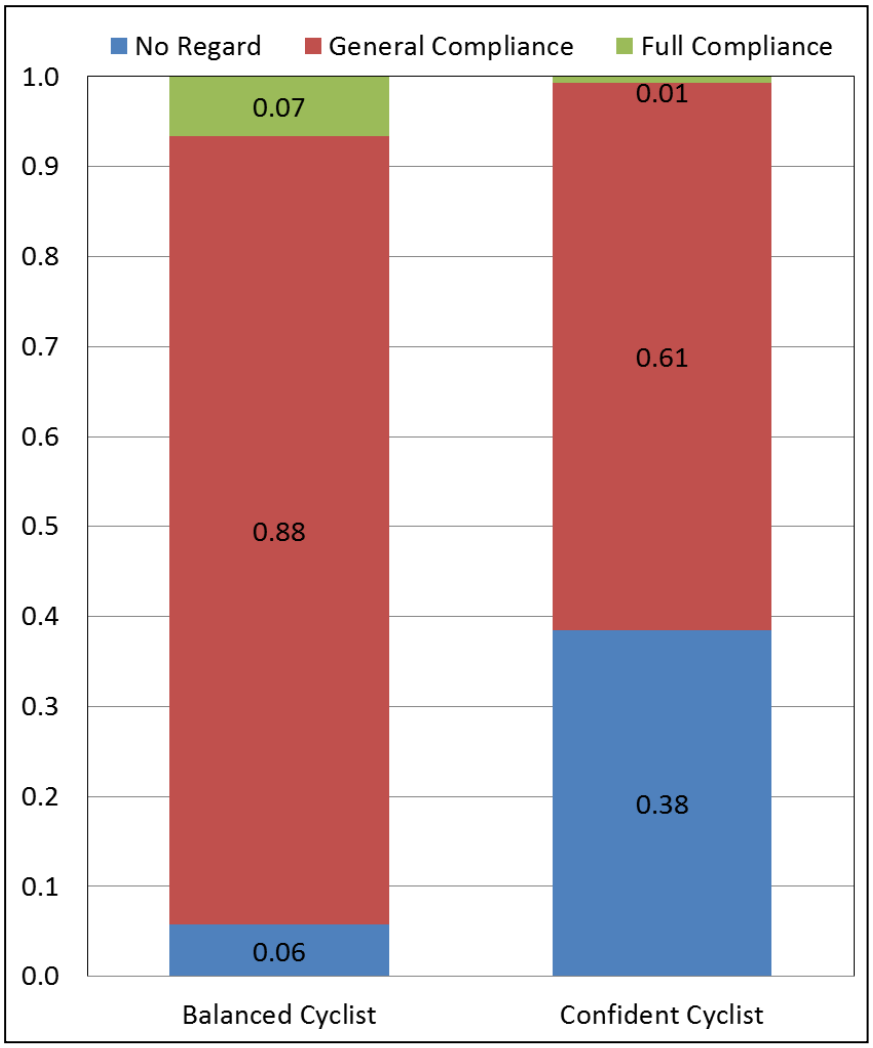

FIGURE 4 Probability of an event for significant factors of the OLR model for the model investigating cyclist compliance with traffic rules

From Table 1 and Figure 4 it can be seen that the level of confidence of a cyclist has a considerable effect on traffic rule compliance; the probability of a balanced cyclist showing no regard for traffic laws is 5.7%, whereas for a confident cyclist this probability increases to over 38%. This is the only factor for which the probability of cyclists having no regards for the traffic rules is greater than 10%. Finally, it can be seen that persons describing cycling to be as safe as driving in Dublin, are 1.6 times more likely to follow the traffic rules. It is also interesting to note from this model that gender is not found to be significant to whether a cyclist is compliant with traffic rules.

INFLUENCE OF CAR-OWNERSHIP ON SAFETY PERCEPTIONS

It is obvious from the previous model, that compliance with traffic rules is very much related to the perceptions of risks associated with cycling. As cyclists receive no mandatory training on the rules of the road prior to using a bicycle in Ireland, it was

decided to investigate the determinants of the perceived safety of cyclists based on whether or not they had previous experience of driving and hence knowledge of the rules of the road. The model applies an OLR method, with the feeling of safety compared to driving in Dublin as the dependent variable in the model. The models show that the number of days cycled, preference for cycling on roads with facilities, preference for the use of bright coloured/hi-visibility clothing and the reckless attitude of vehicle drivers towards cyclists are significant to the perceived safety experience of those with the option to drive on a day-to-day basis. For those with no option of driving, the significant factors are the age of the cyclists, preference to using urban roads, preference to using residential streets, compliance with the rules of the road and the reckless attitude of drivers towards cyclists. The factors influencing the perceived safety experience of each group are quite different. Table 2 gives the odd ratios for each model. Figures 3 and 4 displays the probabilities of belonging to the group which feel cycling is less safe than, as safe as or safer than driving in Dublin for the significant factors in each model.

TABLE 2 Coefficients, odds ratios, the standard errors & the 95% confidence interval of these coefficients of the model investigating perceived safety of cyclists

Is cycling safer than driving?	**Driving is an option**	**Driving is not an option**
Gender	1.788**	-
Age	-	1.037**
Cyclist's experience	-	-
Days cycled per week	1.218**	-
Average distance cycled	-	-
Use of urban roads	-	1.808*
Use of suburban roads	-	-
Use of residential streets	-	1.517*
Use of park/scenic trials	-	-
Use of cycle lanes on the footpath	-	-
Use of off road scenic cycle paths	-	-
Use of curb-side cycle lanes	-	-
Use of shared bus-cycle lanes	-	-
Use of roads with no cycle facilities	2.084**	-
Use of helmets	-	-
Use of bright coloured/hi-visibility clothing	0.552**	-
Use of reflective accessories/lights	-	-
General compliance with rules of the road	-	-
Full compliance with rules of the road	-	2.777*
Balanced cyclists	-	-
Confident cyclists	-	-
Attitude of driver towards cyclists is usually reckless	0.577**	0.647*
Attitude of driver towards cyclists is always reckless	0.498**	-
** p value less than 0.01 *p value less than 0.05		

From Table 2 it can be seen that the level of experience of a cyclists is not a significant factor influencing the safety experience of either group of respondent cyclists. This confirms with the bar chart as shown in Figure 2, where similar proportions of respondent cyclists of the three different levels of experience groups stated that they prefer/avoid each different type of road. From a practical perspective, this is a cause for concern if non-cyclists are to be encouraged to consider cycling as a mode of travel based on the safety experiences of existing cyclists. The distance cycled by respondents is another factor which is not shown by the model to be significant to the respondents in influencing their safety experience.

For those who could drive on a day-to-day basis, cycling a greater number of days per week is associated with an increasing feeling of safety compared to driving in Dublin. This may suggest that regular cyclists are more conversant/familiar with the network and therefore feel more comfortable and safer cycling in it. This may be an important policy consideration; if cyclists are encouraged to cycle more regularly each week their safety experience could be improved.

Respondents with no choice of a car, who prefer to cycle on urban and residential roads are shown to feel 1.7 and 1.5 times safer while cycling, than those who prefer to avoid cycling on these roads. As the survey was circulated among cyclists who cycle within Dublin and its hinterlands, urban and residential roads are the most commonly cycled roads and therefore cyclists may feel safer on these roads than on less familiar suburban roads and off-road parks and trails. The models also show that a preference for any of the cycling facilities currently available in Dublin has no significance to the safety experience of respondent cyclists in either group. The model for those with access to a car on a day-to-day basis does in fact show that respondents who stated a preference for cycling on roads with no cycling facilities feel more than twice as safe cycling in Dublin than those who avoid these roads. This may be due to the fact that these respondents feel more comfortable cycling in traffic lanes as they have a better understanding of the how car drivers behave within the network. The use of safety accessories such as the use of bright/hi-visibility clothing is significant to the safety experience of the respondent cyclists in the case where respondents have the option to drive instead of cycle. For respondents with no access to a car, full compliance with the rules of the road is an important factor in significantly improving how safe they feel while cycling. This may prove to be important to the safety experience of new cyclists with no previous experience of the use of the transport network in Dublin, either by bicycle or vehicle. The models also show correlations between the reckless attitudes of drivers towards cyclists and how safe both groups of cyclists feel compared to driving in Dublin. Among both groups of cyclists, a belief that drivers display a reckless attitude towards cyclists is associated with a decreased safety experience while cycling. Dublin is a city dominated by vehicular traffic. Cycling as a mode of transport is a relatively new mode within the city and many vehicle drivers do not understand how road share can be harmoniously achieved with non-motorised modes of transport. Interestingly, the model of respondents with access to a car has shown females to feel significantly safer than males while cycling in Dublin. This may be due to the fact that female cyclists with knowledge and experience of driving in the city, feels more in control while cycling and this improves their safety experience.

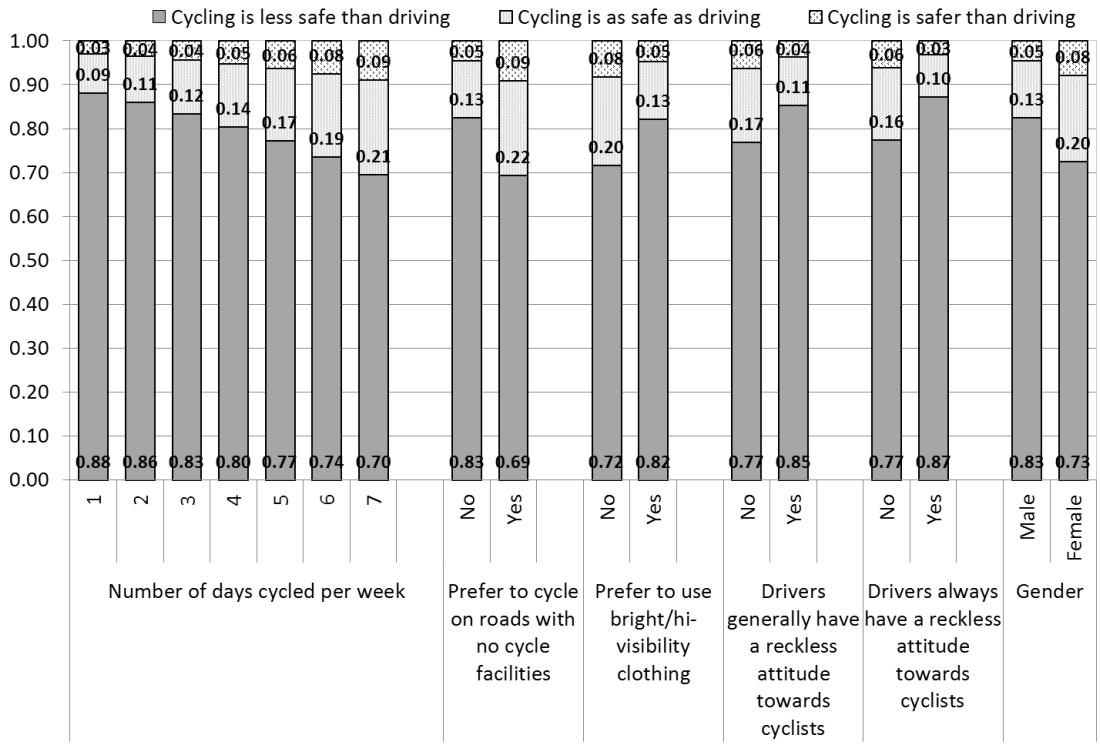

FIGURE 5 Probability of an event for significant factors of the OLR model for cyclists with access to a car on a day-to-day basis

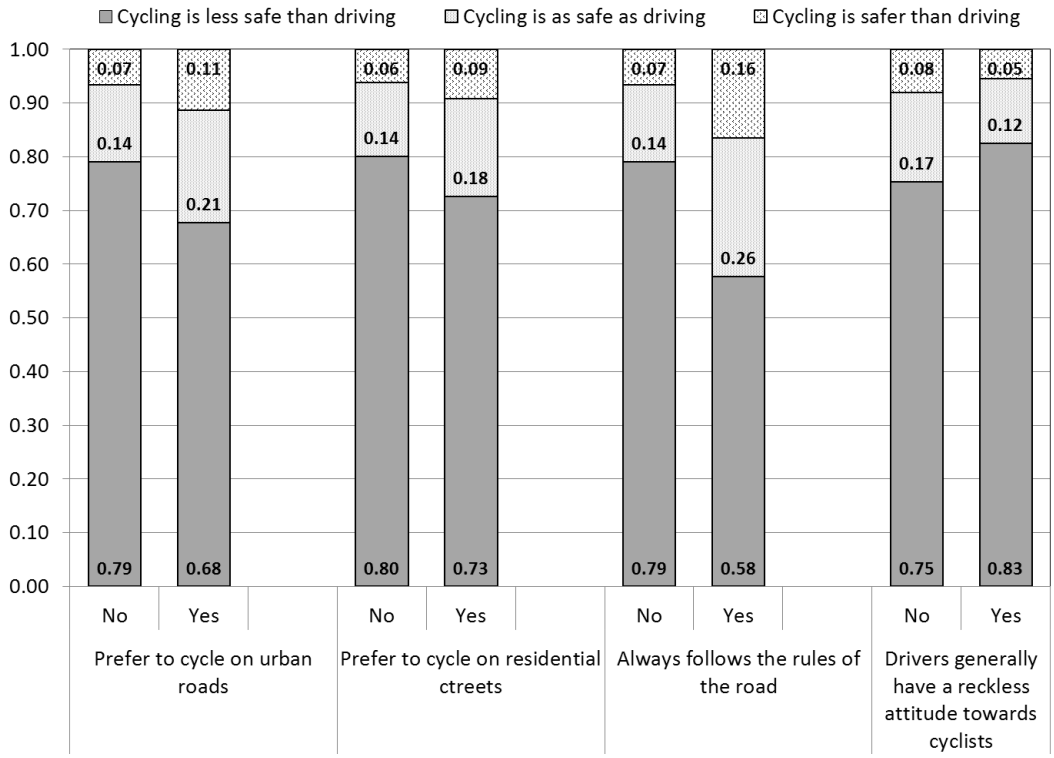

FIGURE 6 Probability of an event for significant factors of the OLR model for cyclists with no access to a car on a day-to-day basis

It is interesting to observe that the probability of describing cycling as safer than or as safe as driving grows with age. Consequently, older people are more likely to deem

the cycling network as safer than the relatively younger population. This observation is a cause for concern, since it is the younger population who are and will constitute the largest proportion of beginner cyclists to contribute to the growing bicycle mode share in Dublin. Additionally, it is the younger population who will play a major role in influencing the growth and evolution of cycling as a preferred choice of travel mode.

POLICY IMPLICATIONS

From the analysis it is seen that with increasing age cyclists are likely to become more compliant with the rules of the road. It is also seen that younger cyclists who are not driving in the city experience feel cycling to be less safe. Encouraging increased compliance with traffic rules among younger cyclists, especially students and non-drivers, through policy and campaign may increase both the perceived and actual safety of cycling among these cyclists.

Analysis has shown that those who use of safety accessories while cycling are more likely to comply with traffic rules, but use of these accessories is not associated with increases in the perceived safety of cyclists in Dublin. It must be noted here that these compliant cyclists make a choice to use safety accessories; as such use is not mandatory in Ireland. Enforcing mandatory use of helmets, lights and hi-visibility clothing on all cyclists will not result in increased compliance with other traffic rules, without these traffic rules in themselves being enforced. It may in fact be detrimental to cycling mode shares to do so; Robinson (2007) suggests that the reduced injury costs due to mandatory helmet use may not outweigh the benefits cycling has to offer as an active travel mode, increasing personal health and fitness.

Perceiving motorists to be reckless or careless to the presence of cyclists on roads has been found to be associated with increased compliance with the rules of the road and decreased perceived safety compared to driving. Cyclists may feel they need to be more compliant with the rules of the road in order to avoid interaction/collision with motorists who they feel disregard the presence of cyclists. Although improving driver-cyclist cooperation within the network is necessary to improve the safety of cycling, policy must ensure that while it does this, cyclist's compliance with the rules of the road is maintained or improved.

The initial model has found a high level of confidence to have a considerable effect on the likelihood of a cyclist breaking traffic rules. The probability of a confident cyclist having no regard for the rules of the road is over 6 times higher than for a balanced cyclist. Dublin city is dominated by vehicles and as such the transport network (such as, traffic signal times, road widths and junction layouts etc.) is designed for motorists; catering poorly for the needs of cyclists. This may lead to more cyclists breaking the traffic laws. If cycling is to become a major travel mode in Irish cities altering traffic designs/laws to prioritize cyclists is required. Removing situations in which cyclists feel it is necessary to break the rules of the road would increase compliance and hence reduce conflicts between cyclists and other road users. Countries such as the Netherlands and Denmark have successfully altered traffic law to prioritize cycling within cities.

Overall, cycling is perceived as an unsafe travel mode in Dublin, and with 87.5% of respondent cyclists admitting to breaking the rules of the road, implementing the

recommended policy changes is important to improving both the perceived and actual safety of cycling in Dublin.

CONCLUSIONS

The paper presents one of the first studies on the influence of the elements of the transport network with which the cyclists interact on a regular basis but might be viewed as a hindrance to their safety. A questionnaire based survey was conducted on 1954 cyclists in the city of Dublin Ireland to gain a better understanding of their perceptions of safety while cycling. The responses were analysed within an ordered logistic regression modelling framework to establish the factors influencing compliance with the rules of the road. Based on the result of this analysis a second was conducted by dividing cyclists into two groups; those who have the option to drive on a day-to-day basis and those without, in order to evaluate the differences in their safety preferences. This is the first such study to analyse cyclists in this way.

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