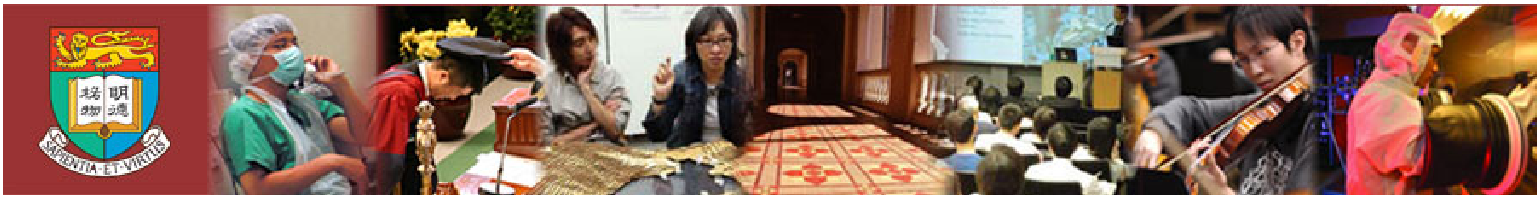

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Perception of Safety of Cyclists in Dublin City

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Abstract

In recent years, cycling has been recognized and is being promoted as a sustainable mode of travel. The perception of cycling as an unsafe mode of travel is a significant obstacle in increasing the mode share of bicycles in a city. Hence, it is important to identify and analyze the factors which influence the safety experiences of the cyclists in an urban signalized multi-modal transportation network. Previous researches in the area of perceived safety of cyclists primarily considered the influence of network infrastructure and operation specific variables and are often limited to specific locations within the network. This study explores the factors that are expected to be important in influencing the perception of safety among cyclists but were never studied in the past. These factors include the safety behavior of existing cyclists, the users of other travel modes and their attitude towards cyclists, facilities and network infrastructures applicable to cycling as well as to other modes in all parts of an urban transportation network. A survey of existing cyclists in Dublin City was conducted to gain an insight into the different aspects related to the safety experience of cyclists. Ordered Logistic Regression (OLR) and Principal Component Analysis (PCA) were used in the analysis of survey responses. This study has revealed that respondents perceive cycling as less safe than driving in Dublin City. The new findings have shown that the compliance of cyclists with the rules of the road increase their safety experience, while the reckless and careless attitudes of drivers are exceptionally detrimental to their perceived safety. The policy implications of the results of analysis are discussed with the intention of building on the reputation of cycling as a viable mode of transportation among all network users.

Keywords: Perceived safety, Multi-modal transportation network, Urban cycling, Questionnaire survey

1. Introduction

There has been an increasing dependency of society on motorized vehicles in Dublin City over the past number of decades. This has raised significant concerns regarding growing traffic congestion, harmful vehicle emissions and associated public health problems. In 2005, the cost of congestion alone to the Greater Dublin Area was €2.5 billion (Dublin Chamber of Commerce, 2005). This is a huge threat to the competitiveness of Dublin as a city trying to attract investments. To combat these problems, non-motorized modes of transportation, like walking and cycling, are gaining attention from policy makers in recent years. Increased mode share of these sustainable modes of travel are expected to reduce vehicle numbers on the roads within the city, thereby reducing traffic congestion, vehicle emissions, and health problems associated with these vehicle emissions. In 2009, the Department of Transport published Ireland's first National Cycle Policy Framework (NCPF) (Department of Transport, 2009), which aims at increasing the bicycle commuter mode share to 10% by 2020. At the time of publication of the NCPF, the mode share in Ireland stood at 1.9%. The cycling mode share in Dublin City stood at 3.2% in 2006 (Central Statistics Office, 2006; McMorrow and Ghosh, 2011). This is higher than the average rate in Ireland, but remains far below the 2020 target set out in the NCPF. In comparison with other cycling friendly countries and cities in Europe, the mode share is extremely low. Cycling mode shares in countries like the Netherlands, Denmark and Germany are on an average between 10% and 26% with some cities reaching 35%-40% (Ministerie van Verkeer en Waterstaat, 2009).

A significant obstacle to achieving this targeted mode share in Dublin City is the fact that cycling is perceived as an unsafe mode of travel. Studies have shown the risks of accident or injury due to cycling are much higher than while driving (Aultman-Hall and Kaltenecker, 1999; Zegeer, 1994). A study of the attitudes of cyclists and drivers in Dublin found that 21% of drivers do not cycle because they feel it is "too dangerous because of traffic" (Keegan and Galbraith, 2005). A report from the Irish Road Safety Authority (RSA) (Road Safety Authority, 2010) states that between 1998 and 2008 there were 144 cyclists (43 in County Dublin) fatally injured and 335 (115 in County Dublin) seriously injured on Irish roads. Despite the percentage of fatalities among cyclists contributing only 3.5% of all road fatalities between these years in Ireland, cycling remains a low preference mode of travel. This may be due to a large number of minor accidents unreported to authorities. The RSA report does not distinctly address minor injuries due to cycling accidents, although the RSA does recognize that cyclists are the most vulnerable road users (Road Safety Authority, 2010). Due to limited information, it is not possible to gauge the actual number of minor cycling accidents in Dublin. Many studies have estimated the extent to which underreporting of cycling accidents and underreporting of the severity of reported accidents occur across Europe (Waldman, 1977), Canada (Doherty et al., 2000) and the USA (Stutts and Hunter, 1998).

Previous research on cycling safety has mainly focused on the placement of cyclists within a multi-modal network and on the use of safety accessories such as helmets and light/reflectors. There are mixed opinions on the integration (Aultman-Hall and Hall, 1998b; Aultman-Hall and Kaltenecker, 1999; Forester, 1993; Moritz, 1997) or separation (Bíl et al., 2010; Hopkinson and Wardman, 1996; Parkin et al., 2007; Pucher, 2001; Tilahun et al., 2007; Wardman et al., 2007; Wegman et al., 2012) of cyclists from other road users. Separation within the road has been suggested as less safe for cyclists as drivers pay less attention and leave less space when overtaking (de Lapparent, 2005; Parkin and Meyers, 2010). There are studies which suggest that a well-connected network of various types of facilities is required to ensure cyclist safety (Dill, 2009; Pucher et al., 2010). There also exists much debate in relation to the use of safety accessories (Cameron et al., 1994; Depreitere et al., 2004; Ekman et al., 1997; McIntosh et al., 1998; Povey et al., 1999; Robinson, 2001; Scuffham et al., 2000; Scuffham and Langley, 1997; Welander et al., 1999). Recommending or making their use mandatory has been shown to be unsuccessful in encouraging their use among all cyclists (Ferguson and Blampied, 1991; Hagel et al., 2007; Osberg et al., 1998) and although their use decreases the risk of head injuries, enforcing mandatory use has had a detrimental effect on mode share which does not outweigh the health benefits of cycling.

Less research attention has been focused on investigating the perceptions of safety among cyclists. The majority of existing research conducted in this field is presented in Table 1, including variables collected as part of each study (not all variables were considered in the analysis of each study; not all analyzed variables were found significant). These studies have mainly been conducted in order to aid engineers and planners in the design, improvement and prioritization of road and intersection works to cater for cyclists. The majority of these studies asked cyclists to rate their overall risk perception of a route described by video-clips, simulations, survey or by completion of a test course. Each study examined a number of network geometry and operation specific variables in relation to the safety perceptions of cyclists which are listed as network specific variables in Table 1. Only two of the studies (Møller and Hels, 2008; Noland and Kunreuther, 1995) considered cyclist characteristics which are listed as cyclist specific variables in the table. Among the network specific variables, outside lane width, motorist speed and volume were considered by almost all studies mentioned in Table 1. The other popular operational variables considered in the literature include pavement surface quality, the trip generation potential of the surrounding area, the number of traffic lanes, the number of side roads, facility characteristics, turning vehicles and traffic mix at specific locations identified by the researchers. Parkin et al. (2007) uniquely considered the majority of the remaining operational variables as indicated in Table 1. Each of these analyses have tended to consider only a small number of variables and are usually specific to certain locations within the network, such as link segments, vehicle or bicycle crossings and roundabouts. The restricted nature of these previous researches establishes scope for the development of an exhaustive study on cyclist safety perceptions, containing all variables considered in previous research along with new variables which are expected to have an impact on cyclist safety perception and were not studied in the past.

This paper aims to investigate the overall perceptions of cyclists in a multi-modal, signalized transportation network, rather than targeting specific locations within the network. The network agents explored include existing cyclists and road users of other transportation modes, facilities and network infrastructures applicable to cycling as well as to other modes. The new variables investigated in this study include safety accessory use, bus, taxi and car driver’s behavior, cyclist experience and confidence, trip purpose, weather conditions and the presence of accident ‘black spots’, etc. In particular, through Ordered Logistic Regression (OLR) and Principal Component Analysis (PCA) based models, all the aforementioned variables are found to be significant and have an impact on cyclist safety perception. More importantly, both the compliance of cyclists with the rules of the road and uncooperative driver attitudes are found to have direct implications on cycling policy.

In this study, a questionnaire based survey on the different aspects of the safety of cyclists in an urban transportation network has been conducted on a large number of existing cyclists in Dublin City, Ireland. The survey responses have been analyzed to explore the aspects of safety of the cyclists in three main categories; the current safety behavior of the cyclists, the perception of safety of the cyclists, and the interaction of the cyclists with the elements of the network within a multi-modal transportation system. Three models, namely the safety behavior model, the perceived safety model, and the cyclist-network interaction model, have been developed via PCA or OLR to explore the three aspects. The perceptions studied are based on the self-reported personal experiences of cyclists in the transportation network of Dublin city. This investigation is complex, yet interesting, since the transportation infrastructures along with the conditions for cycling vary widely throughout the city.

The next two sections of this paper depict the data and the methods respectively, followed by the analysis section employing the three aforementioned models. The discussion on the policy implications and the limitations of this study are provided next. Finally, a conclusion is given.

2. Data

This section presents the transportation network characteristics of the study region, Dublin city, Ireland. This is followed by a sub-section pertaining to the collection of data. The profile of the respondent cyclists and a description of the survey data collected are presented next in two subsections, respectively.

2.1 Study Region

Dublin City is the capital of Ireland and the largest city in terms of area, residing and working population of the country (Central Statistics Office, 2006). The transportation network in Dublin City is primarily designed for the use of private vehicles. Other main modes of motorized transportation in Dublin City are Dublin Bus, Luas (tram), Dublin Area Rapid Transport (light rail) and Commuter trains (suburban railway networks). In 2006, nearly 16.4% of the commuter trips were made using non-motorized modes of transportation (McMorrow and Ghosh, 2011). However, the percentage of employees walking to their workplaces was much higher than that using bicycle as their preferred mode of commuter travel. The transportation network in Dublin City contains cycling facilities mainly in the form of cycle lanes; approximately 120 km of on-road cycle tracks, 50 km of shared bus-cycle lanes and 25 km of off-road cycle tracks exist in the network.

Despite the presence of these facilities, many threats exist to the cyclists in Dublin. A few of these threats are unforeseen ending of cycle lanes which expose cyclists to suddenly share their commuting space with other modes with high speed-difference; cars and taxis frequently making unexpected stops and turns, forcing cyclists to join oncoming traffic from behind. Also, poorly maintained cycling surfaces often result in falls causing injury and damage to property. Abrupt barriers in the form of signposts, on-street parking and the presence of bus-stops tend to encroach on the cycle lanes; entries to the cycle lanes are often not ramped and are unsafely kerbed. Also, new designs like speed breakers on cycle lanes near bus-stops have been reported to be uncomfortable, unsafe and unnecessary by many cyclists. These conditions and/or threats naturally lead to actual and perceived discomfort and a lack of safety for the cyclists. There are many more such factors or conditions which influence a cyclist's perception of safety in Dublin City. To understand which aspects of the transportation network prove most hostile to cyclists, a detailed analysis is required to track the factors that most strongly affect the actual and perceived safety of the cyclists in this network.

2.2 Data Collection

A fixed-response questionnaire based survey was conducted in order to gather information, previously unavailable in Dublin, on the perceived safety and safety behaviors of cyclists, with regards to the available cycling infrastructures, the use of safety accessories, the effect of prevalent road and weather conditions, as well as various other aspects of traveling by bicycle in Dublin's multi-modal network. The survey, conducted over a 3 month period between 7th March and 1st June, 2011, receiving 1,954 responses, collected information from existing cyclists, who regularly cycled in Dublin within the previous 12 months. The questionnaire was distributed among major Irish and multi-national companies, major universities in Dublin, governmental departments and through word of mouth. The questionnaire was also available on-line; the link to which was circulated via e-mail, posts on cycle club and group websites, cycling forums, and posts on social networking web-sites. Hardcopies of the questionnaire were available from local cycle repair shops and from the authors, upon request.

The survey questionnaire was divided into 3 sections, each corresponding to the focus of the separate models used in the analysis, collecting information on socio-demographics, trip purposes, trip distance, trip time, cycling infrastructure preferences, safety equipment preferences, information on the effects of adverse road and weather conditions as well as information on effects of interaction with other travel modes. At the beginning of each section of the survey, a short explanation of the focus of the section was given so that respondents were aware of why the questions were being asked. In particular, models related to safety behavior and cyclist-network interaction involved questions based on extensive literature review and discussions with cycling experts from the city council, National Transport Authority and cycling forums. These bodies were considered influential to the focus of the section. For the perception of safety model, the perceived safety was measured by asking specific questions on how safe the cyclist feels compared to driving in Dublin on a Likert scale (Jambu, 1991).

2.3 Profile of Cyclists

1,732 out of 1,954 responses were eligible for use in the analysis. The profile of the cyclists of Dublin who gave eligible responses to the survey has been presented in Table 2. The profile has been summarized according to the self-reported experience of the cyclists ('Inexperienced', 'Competent', or 'Highly Skilled'), socio-demographic characteristics (e.g., 'Age') and cyclists' trip characteristics (e.g., 'Regularity of Cycling') with a count and the corresponding percentage given for each combination of self-reported experience and characteristic (e.g., 'Male'). The percentage is calculated by dividing the count by the total number of eligible responses, 1732, and multiplying the resulting quotient by 100%. Hence, the sum of all the percentages under the same characteristic (e.g., age) equals 100%.

The majority of the respondents were male (63.7%) and were aged less than 45 years. According to the available statistics, the majority of the cycling population in Dublin City is male and less than 40 years of age (Central Statistics Office, 2006). Consequently, the respondent demographic of the survey is an unbiased representation of the cycling population of the city. The majority of respondents were either students (46.1%) or in full-time employment (44.4%). Respondents were mainly single, living in shared accommodation (35.8%), couples with resident child(ren) (24.1%) or couples with no resident child(ren) (17.0%). All respondents live within the Dublin area, as this is the study area of interest and 51.8% of respondents have a car that can be used on a day-to-day basis. Although the survey collected anonymous responses, no information on household income was collected as it was felt such a question may hinder the survey response rate.

2.4 Data Description

On average, the respondents cycle 9.54 km on a weekday and 6.85 km on a weekend day. Other studies of cyclists observed that the average distances for utilitarian trips are between 3.5 km and 7 km (Broach et al., 2011; Howard and Burns, 2001; Nankervis, 1999; Winters et al., 2010a; Winters et al., 2010b). These figures may be lower than what have been observed here as these studies do not include exercise trips or social and recreational trips. In terms of time spent cycling, the respondents cycle 42.6 min on a weekday and 31.9 min on a weekend day on average. Table 2 also shows that generally the cyclists travel at speeds of 10-20 km/hr. Although a great number of respondents describing themselves as highly skilled cyclists travel at higher speeds. In this survey, nearly 98% of the respondents describe themselves as being either competent or highly skilled cyclists. It has also been observed that, over 85% of the respondents are regular cyclists and cycle at least 3 days per week. The survey reveals that bicycles are used for social and recreational trips by the greatest number of respondents (65.4%), and such trips consume on average 7.6% of their total time spent cycling. Bicycles are used for commuting trips by 58.2% of the respondents and on average such trips take 37.8% of their total cycling time. In 2006, only 45% of these respondents cycled in Dublin; this figure grew each year to 90.9% in 2010. Over 90% of the respondents, cycle from spring to autumn and 74.1% continue to cycle during the winter months. 93.7% of the respondents own a bicycle; it is thought that the remaining respondents make use of the bicycle sharing scheme available in the city. The survey also suggests high rates of safety accessory use; nearly 54% of the cyclists claim to wear a helmet and 88% use lights or reflective accessories while cycling at night. Similar studies from other countries, suggest lower rates of safety accessory use; 2.2% of the cyclists in Paris, 31.5% in Boston (Osberg et al., 1998) and 44% in Victoria (Robinson, 1996) wear helmets while cycling and 14.8% of the cyclists in Boston, 46.8% in Paris (Osberg et al., 1998), 40-60% in Christchurch (Ferguson and Blampied, 1991) and 50% in Edmonton (Hagel et al., 2007) use lights or reflective accessories while cycling at night. These differences may be due to the legal, cultural and social differences among the various cities and countries.

Initial analysis of the survey data looked at the travel behavior of the respondents while cycling in the city. In the survey questionnaire, the cyclists were presented with various alternative route choice scenarios and they were asked whether they would alter their routes under these scenarios. A qualitative Likert scale, with 5 options, was used to measure the likelihood of route alteration. 57.8% of the respondents stated that they would alter their routes to make use of continuous cycle lanes, while 50.4% and 50.6% of the respondents would alter their routes to use quiet roads and routes perceived as safe by the cyclists, respectively. There are a number of elements in a transportation network which are generally considered as hindrances to the cyclists and would often compel them to change their routes. The strongest aversion felt by the respondents was for roads with higher speed limits and for roads with poor quality surfaces, with 32.9% and 31.7% of the respondents respectively, stating they would alter their routes in order to avoid these roads. Only 10.9% of the respondent cyclists stated that they would alter their routes to avoid inconvenient right turn movements. Infrastructure to allow easier right turn movements for cyclists has recently been introduced to Dublin; however, such implementation may not improve the attractiveness of a route according to this survey. The respondents were also asked if they would consider changing to another mode of transportation under various weather conditions; 79.8% would change to an alternative mode under icy road conditions; 55.6% in heavy rain and 30.3% in temperatures below freezing. A study on students in the universities of Melbourne, Australia found that 40% of the respondent cyclists would change to another mode in rain and 66% would do the same in icy and snowy conditions (Nankervis, 1999). In Dublin, more survey respondents are likely to change their mode of travel under adverse weather conditions as they may have better access to alternative modes, such as private cars, than a student-only population.

3. Methods

This section describes the survey method, its organization and distribution, as well as the methods used to analyze the survey data. In examining this data, it must be taken into consideration that the data collected from the survey is self-reported and may vary from the actual behavior of the respondent cyclists.

Principal Component Analysis (PCA) and Ordered Logistic Regression (OLR) are the chosen methods for analyzing the survey responses. PCA is a multivariate data analysis methodology similar to Factor Analysis (FA). 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 regression model should be used. For detailed discussions on PCA and OLR, the reader is advised to refer to Hair (2010), Semmlow (2009), Hosmer and Lemeshow (2000), Jolliffe (2002) and Jambu (1991). Both of these methods have been widely used in the areas of cycling and other transportation studies (Ben-Elia and Ettema, 2011; Borgnat et al., 2011; Brown et al., 2009; Dupont et al., 2010; Heinen et al., 2011; Kiryu et al., 1997; Kiss et al., 2010; Ma et al., 2009; Morrongiello et al., 2010; Popuri et al., 2011; Winters et al., 2010a; Yannis et al., 2005; Yau, 2004).

Three models, namely the Safety Behavior Model, the Perceived Safety Model and the Cyclist-Network Interaction Model, were developed to analyze the survey responses using the above-mentioned methods. The Safety Behavior Model was developed to investigate the safety behavior of the cyclists in an urban multi-modal network of Dublin City. PCA was used to develop the model to analyze survey responses related to their attitudes and behaviors towards safety while cycling. The Perceived Safety Model was developed via OLR to investigate the determinants which influence a cyclist’s perception of safety as compared to driving in the shared multi-modal transportation network of Dublin City. The final model, the Cyclist-Network Interaction Model was built via PCA to investigate the interaction between the cyclist and the elements of the shared multi-modal transportation network of Dublin City and to understand the perception of safety of the cyclists in relation to the existing infrastructures. The results from each of these models are discussed in the Analysis section of this article.

4. Analysis

The following subsections contain the findings of analysis according to each of the models conducted, namely the Safety Behavior Model, the Perceived Safety Model and the Cyclist-Network Interaction Model.

4.1 Safety Behavior Model

This model was developed to analyze the survey responses related to their attitude and behavior towards safety while cycling in a shared urban multimodal network of Dublin City. PCA was used to reveal the guiding factors. Initially, 31 variables were included in the analysis; of these, 5 were found to be insignificant (the use of a bicycle for travel to school/college, the use of a bicycle for organized racing, the distance and time cycled on an average weekday/weekend-day and average cyclist speed) and were therefore removed from the analysis. Performing PCA with the remaining variables, 8 eigenvectors were found to remain significant after having taken the latent root criterion into account.

Table 3 presents the results of the final analysis but it is noted that the model revealed a number of other results during analysis which are not displayed in this table; the respondent cyclists are significantly confident regarding their skills; people who wear safety accessories (helmets, high-visibility clothing, reflectors and lights) tend to claim that they are more compliant with the rules of the road; the majority of these cyclists tend to be commuters; and only the more experienced cyclists felt comfortable when cycling during night-time. Table 3 presents the significant eigenvalues, percentage of variance explained, factor loadings, means and standard errors of the variables grouped together according to factors which are related to each other. From this table, a number of interesting results can be inferred.

The likelihood of an accident due to pedestrians, rush-hour traffic, road surface quality, parked vehicles along road sides, buses and taxis in shared lanes are grouped together according to the similarity of the perceived risk that they present to the cyclists. This grouping indicates that if a cyclist feels the threat of an accident due to the presence of one of these factors, they will feel similarly about the other factors within this group. This result may be a cause of concern as these elements are encountered by cyclists on a regular basis within the transportation network. These above-mentioned factors move independently of the likelihood of an accident due to poor bicycle maintenance and lack of cycling skills. Table 3 shows that safety accessory use is not associated with the confidence of cyclists, regularity of cycling or the level of experience of cyclists, as the group containing variables related to safety accessory use moves independently from all other groups. The interim results of the PCA also revealed that the cyclists who use safety accessories are more compliant to the rules of the road. A lack of compliance with the rules of the road is associated with the cyclists who described themselves as being more experienced and confident and who tend to cycle more regularly within the network, as all these factors move together within a group. Another interesting point revealed by PCA is that the trip purposes are not related to any of the safety aspects and variables considered within the model. Finally, Table 3 indicates that the cyclists feel motorists to be both reckless and careless with regard to the presence of cyclists in Dublin’s transportation network. This is a major cause for concern; as it is vital that all the modes cooperate with each other to ensure the safety of the shared space.

The overall ranked scores for the variables of the Safety Behavior Model are presented in Figure 1. The bar graph shows the degree of significance of the variables. The scores signify that the variables of similar signs are interpreted to be of similar influence in a binary sense. The policy implications of the findings of this model are discussed in further detail in the Discussion section.

4.2 Perceived Safety Model

The Perceived Safety Model was developed using the OLR technique to investigate the determinants which influence a cyclist's perception of safety as compared to driving in the shared multi-modal transportation network of Dublin City. Initially, 23 variables were included as explanatory variables in the Perceived Safety Model (Table 4). In Table 4, the coefficients, odds ratios, standard errors of the coefficients, indicative significance according to p-values and 95% confidence interval of the coefficients of the explanatory variables are presented. Age, regularity of cycling (number of days per week), use of urban roads, use of roads with no cycling facilities, use of bright colored/high-visibility clothing, compliance with the rules of the road and the attitude of vehicle drivers were identified as the significant determinants to influence the perception of safety of a cyclist when compared to driving.

The probabilities of describing cycling as safer than, as safe as, or less safe than driving, while the other explanatory variables were assumed constant, are displayed in Figures 2 and 3. Figure 2 indicates that, in all cases the respondent cyclists perceive cycling to be less safe than driving in Dublin, except with regard to compliance with the rules of the road. In this exceptional case, it is quite interesting to see that cyclists who claim to always follow the rules of the road are much more likely to describe cycling as safer than or as safe as driving in Dublin. The use of safety accessories do not have a large influence on the probability of describing cycling as less safe than driving. The cyclists who do not prefer to cycle on urban roads and on-road with no cycling facilities are nearly 80% likely to consider cycling to be less safe than driving. The cyclists who tend to prefer to do so are nearly 70% likely to consider cycling to be less safe than driving. This slight reduction in percentage of perceived risk may be related to the experience and the skills of the cyclists who are used to cycling in urban roads with higher traffic volume. The probability of describing cycling as safer than driving increases with the increased number of days cycled per week. This result may indicate that familiarity with the network, due to regular use, may decrease a cyclist's probability of describing cycling as less safe than driving within the network. Møller & Hels (2008) also found that increased regularity decreased the perceived risk, for the specific case of the use of roundabouts. The results of the OLR model also indicate reckless and careless driver behavior is one of the major factors in cycling being perceived as less safe than driving.

Figure 3 presents the probability of cycling being perceived as a safe mode when compared with driving in Dublin according to the age of the cyclists. 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 is 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. This warranted further analysis in this regard.

In addition to this model of all participants, further analysis was conducted to analyze and compare responses according to age (under 25 years of age, and 25 years of age or older) and gender. This analysis was also carried out using the OLR method. Table 5 shows the odds ratios of the variables of each of these models. The age specific model indicates that the factors that improve the perceived safety of cycling is quite different between the two age groups, except in two cases; first, the respondent cyclists of both age groups who tend to use safety accessories are more likely to describe cycling to be less safe than driving and second, the respondent cyclists of both age groups associated reckless attitude of drivers with a reduced perception of safety. Compliance with the rules of the road is another factor, where both age groups show similar choice behavior. Full compliance with the rules of the road among the older age group increases their perceived safety by 2.7 times compared to the older cyclists who do otherwise, while a general compliance with the rules among the younger cyclists increase their perceived safety by 4.2 times compared to others.

From the results in Table 5, it can be seen that the older cyclists experience an increased feeling of safety with a greater number of days cycled within a week. Among the younger age group, the more experienced cyclists are 1.8 times more likely to describe cycling as safe, than their less experienced colleagues. This is the only case where the experience of the respondents has been shown to be significant in influencing the perceived safety of the mode. The cyclists aged under 25, who prefer to cycle on urban roads tend to describe cycling in Dublin city to be safer than those who prefer to avoid this type of road. For the older cyclists who prefer to cycle on roads with no cycling facilities also tend to describe cycling in Dublin city to be safer than those who prefer otherwise.

The gender specific model shows that older female cyclists tend to perceive cycling to be safer than the younger ones. The regularity of cycling is significant to both male and female groups in increasing their perception of safety. The preference for cycling on urban roads for male cyclists and for cycling on shared bus-cycle lanes for female cyclists improve their tendency of describing cycling to be as safe as or safer than driving in Dublin city. A preference for using roads with no cycling facilities is also significant in improving the likelihood of describing cycling to be as safe as or safer than driving for both genders. Similar to age specific model, both male and female cyclists who tend to use safety accessories are more likely to describe cycling to be less safe than driving. The policy implications of the findings of this model are discussed in further detail in the discussions section.

4.3 Cyclist-Network Interaction Model

The interaction between the cyclists and the elements of the shared multi-modal transportation network of Dublin was investigated through PCA to understand the perception of safety of the cyclists in relation to the existing infrastructures. Initially, the Cyclist-Network Interaction Model included 28 variables, of which 3 were found to be insignificant (the use of off-road paths and trails, light rain and strong winds) and therefore were removed as they are not related to the interaction of a cyclist with the elements of the transportation network.

Table 6 presents the significant eigenvalues, the percentage of variance explained, factor loadings, and means and standard errors of the variables of the Cyclist-Network Interaction Model. Respondents were asked if they would alter their routes to avoid or make use of various factors encountered within the network that are often described as hindrances or beneficial to cyclists. The results reveal that the likelihood of cyclists altering their routes to make use of routes perceived as safe, quiet roads, well-lit streets, continuous cycle lanes and amenities are grouped together. This means that the cyclists who tend to (or not to) alter their routes for one of these factors will do similarly for all other factors within the group. Interestingly, all factors studied, and viewed as beneficial to the cyclists are contained within this group, explaining the largest amount of variance within the data modeled. This indicates that the presence of one or more of these factors improves the attractiveness of a route. Factors considered as hindrances move in 2 separate groups; the first of these groups includes stop signs and traffic lights, while the second includes steep gradients, roads with high speed limits, traffic congestion, right turns, parked cars along road-side and roundabouts. This implies that those cyclists who will change their route to avoid stops signs and traffic lights will not necessarily do the same for the second group of factors considered as hindrances. It is interesting to note that right turns are not included in the first group along with stop signs and traffic lights.

In terms of road types studied, urban, residential and suburban roads are grouped together (off-road paths and trails were found to be insignificant in this analysis). In terms of bicycle infrastructure, the cyclists preferring to use kerb-side cycle lanes also prefer to use shared bus-cycle lanes, while those who prefer roads without cycling facilities prefer not to cycle on footpaths. These cyclists will also alter their routes to avoid roads with poor quality surfaces. The final point displayed by this model shows that with increased regularity of cycling, the tendency to change to alternative modes in adverse weather conditions decreases.

Figure 4 represents the ranked scores for the variables of the Cyclist-Network Interaction Model. The figure shows the degree of significance of each variable within the model and the scores signify that the variables of similar signs are interpreted to be of similar influence in a binary sense.

5. Discussion

Analysis of the survey responses of the cyclists in Dublin City has revealed several new areas, in which improvement could increase the perceived safety of cyclists. The effects of such improvements and their policy implications are discussed in details in the next subsection. Then, the limitations that should be considered while developing or implementing policies based on the findings of this study are mentioned.

5.1 Policy Implications

The analysis has shown that the use of safety accessories (helmets, high visibility/bright colored clothing and lights/reflective accessories) is not associated with an improvement in perception of safety among cyclists' compared to driving in Dublin, but instead is shown to be associated with a decreased safety experience. The presence of situations perceived by cyclists as potentially unsafe has led the cyclists to make use of such safety accessories, but has not helped them to overcome their fear of such situations. Therefore, making their use mandatory among cyclists may be of little or no benefit to the improvement of the perceived safety of cyclists which is required to promote cycling as a viable mode of transportation in Dublin. Such a measure may even prove counteractive to improve cycle mode share, as has been presented by a before-and-after study of the mandatory helmet use for Australian cyclists (Robinson, 1996). Following the findings of the analysis in this paper, it can be expected that mandatory use of other safety accessories may result in similar outcomes.

To promote cycling as a major mode of transportation it is important to improve the perceived safety of the mode to be at least comparable to the level of other existing major modes of travel, such as driving. This research highlights the importance of considering policy variables, such as the cyclists' compliance with the rules of the road, in the study of cyclist safety perceptions. Analysis has shown that 74% of the cyclists, who claim to be fully compliant with the rules of the road, are 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 the participants admit to breaking the rules of the road. Road safety initiatives encouraging improved compliance among cyclists can therefore be beneficial in improving the perceived safety of cycling. Increased compliance with the rules of the road can also be achieved through enforcement as is done for cars in the form of fines and 'points' on offenders. However, such enforcement may decrease the attraction of the mode to a certain population of cyclists and hence a debate is necessary to reach consensus. It is important to note, regular, confident and experienced cyclists have reported to be less compliant with the rules of the road.

To maximize safety, urban road networks are designed for motor-vehicle drivers to accommodate variable competence levels among users and some non-compliance with the rules of the road. Establishing cycling as a major mode of travel would also require such design considerations for bicycle infrastructures to be in place. The analysis shows that regular, confident and experienced cyclists prefer to cycle on-road and not on segregated facilities. Hence, policies and network design should consider that on-road cyclists may infringe the rules of the road, and design for these cases bearing in mind that cyclists are categorized as vulnerable road users.

Similar to Parkin et al. (2007), it was found that the provision of infrastructures does not necessarily correspond to an increased attractiveness of a route. Segregated facilities provide a more comfortable environment for beginner/learner cyclists, but for more conversant cyclists, improvement of driver attitudes may prove more beneficial to their perceived safety as they often prefer to cycle on-road. This study is the first of its kind to analyze the effect of driver attitudes on the perceived safety of cyclists. Careless and reckless driver behavior have has been shown by analysis to have a major detrimental effect on the safety experience of cyclists. Campaigns to encourage cyclist-driver cooperation within the network may help combat Dublin's 'road rage' problems.

The respondent cyclists also believed that there are potential accident risks due to lack of cycling skills and poor bicycle maintenance skills. Cycling workshops and community initiatives, for young, new and improving cyclists may prove beneficial for providing education and information about the rules of the road, bicycle care and safe cyclist practices for cycling in a multi-modal shared space. With this increased knowledge, cyclists can feel more confident and conversant within the transportation network.

The analysis demonstrates that the cyclists prefer less busy and quiet roads, roads with street lights, routes perceived as safe and routes with continuous cycling facilities. Cycling policy, based on user feedback, should emphasize on improving safety along routes which have been identified by cyclists as unsafe. Provision of street lights, signs for alternative routes to busy roads and continuous cycling facilities on priority routes should be considered to attract more non-cyclists into cycling. The provision of more information through websites and social networks on alternative routes within the road network which are viewed as safer and more comfortable by cyclists may be advantageous to cyclists.

Young cyclists were identified as more likely to perceive cycling to be less safe than driving, than older cyclists. The economic boom in the nineties saw a drastic drop in bicycle mode share throughout Ireland and therefore the younger generations have not been exposed to the culture of cycling; feeling less comfortable and less safe than older generations when using a bicycle in a multi-modal network. To make cycling an intrinsic part of Irish mobility, it may be beneficial to introduce the knowledge and culture in school. Introducing cycling education at the primary school level could encourage cycling among a younger population, would inform them on the safe and responsible use of the shared multi-modal transportation network and would also educate the future drivers to appreciate the safety requirements of cyclists within the network.

Analysis has revealed the perceived safety of cycling increases with regularity of use and with an increasing number of days cycled per week, the probability of considering cycling as less safe than driving in Dublin falls. Therefore, it is suggested that transportation policies which encourage regular cycling activities such as the 'Bike to Work' scheme should be expanded and further encouraged. The 'Bike to Work' scheme promotes regular commuting activity by bicycle through tax-break incentive. This scheme is currently available in Ireland solely to employees of companies registered to the scheme. Further provision of incentives which encourage regular bicycle use for additional activities would broaden the scope of the scheme to other areas of bicycle use, and hence to a larger population of cyclists and potential cyclists.

The respondent cyclists (79%) envisage that the presence of pedestrians and cycle lanes on footpaths are likely causes of an accident. This result confirms the findings of previous studies investigating the relative safety of various types of cycling infrastructure that shared use (pedestrian-cycle) paths are one of the least safe options for cyclists (Aultman-Hall and Hall, 1998a; Aultman-Hall and Kaltenecker, 1999; Lam and Huang, 1992; Moore et al., 2011; Moritz, 1997; Si et al., 2011). This could suggest that the introduction of new cycle lanes on footpaths and busy shopping districts may not be beneficial. Poor road condition was identified by 81% of the respondents as another major factor negatively influencing the perception of safety, which is similar to the findings of studies elsewhere (Doherty et al., 2000). It is therefore recommended that the National Roads Authority and town/city councils should focus on maintaining the kerb-side surfaces on the on-road cycle lanes and roads with no cycling facilities.

Overall, current cyclists feel that cycling is less safe than driving in Dublin city. Hence, it is important to implement the recommended policy changes towards the safety of cycling and to inform cyclists of such changes. Policy considerations directly related to the safety of cyclists can establish the viability of cycling as a safe mode of travel.

5.2 Limitations

The following three limitations should be considered while developing or implementing policies based on the findings of this study. First, the study was based on a fixed-response questionnaire survey and has associated limitations. The majority of the respondents were young and male cyclists. Although this over-representation was also evident in the anonymous journey-to-work travel survey dataset available for the entire population of

Dublin City (Central Statistics Office, 2006), there remains *a possibility of residual bias* in our study.

Second, the study was based on responses of existing cyclists; majority of whom were *self-reported experienced cyclists.* This *may not correspond to their actual skill levels. Consequently, their perception of safety and their safety behavior may be influenced by their perceived skill levels.*

Third, the study has assessed perceived safety through self-reports as opposed to utilizing data on actual collisions and injuries. *Cycling incidents are severely underreported and consequently it is difficult to study the relationship between perceived and actual safety for a large population of existing cyclists in a city*. For successful policy implementation, the actual incident reports of both minor and major accidents should be investigated and taken into account.

6. Conclusion

This paper presents a comprehensive study on cyclists' perception of safety while using a shared multi-modal urban transportation network. A questionnaire based survey of 1954 existing cyclists was carried out in Dublin to obtain an overall view of how the network, its users and their attitudes impact on the perceptions of safety of cyclists. The study considered a wide range of variables from all parts of the network, such as cyclists' compliance with the rules of the road, attitudes of bus/taxi/car drivers, weather conditions, presence of accident blackspots on the route, etc. These variables are expected to be important in influencing the perception of safety among cyclists but were never studied in the past. The analysis showed many of these variables are critical in improving the perceived safety of cyclists and possible policy changes to make such improvement were suggested in the paper. The main inferences from the study are the following:

- Cycling is truly perceived as an unsafe mode of travel compared to driving even by the existing cyclists who consider themselves to be competent users of the mode. Hence, it is important to identify the determinants of perceived safety among cyclists and to recommend policy changes accordingly to improve such perception.
- In understanding the safety experience of cyclists the behavioral dynamics of shared space is often overlooked and this study addresses that by considering the attitude of bus/taxi/car drivers, presence of local amenities, presence of accident blackspots, etc. Among other factors, negative driver attitude has been identified as a key factor which affects the perception of safety of cyclists.
- Cycling is not envisaged as a major mode of travel either by cyclists or by planners or other users of the transportation network. As a result, enforcement and infrastructure design for the comfort and non-compliance of cyclists are not considered in multi-modal urban transportation networks. However, such considerations may prove beneficial.
- The analysis also identified variables which are often considered as essential for perceived safety of cyclists but are not that critical in reality and the policy changes related to these variables which might affect the attractiveness of the mode were discussed.

The policy recommendations based on the findings of the analysis, if implemented, should positively influence how cycling is perceived among both cyclists and non-cyclists in terms of safety and in turn may establish cycling as a viable major mode of travel.

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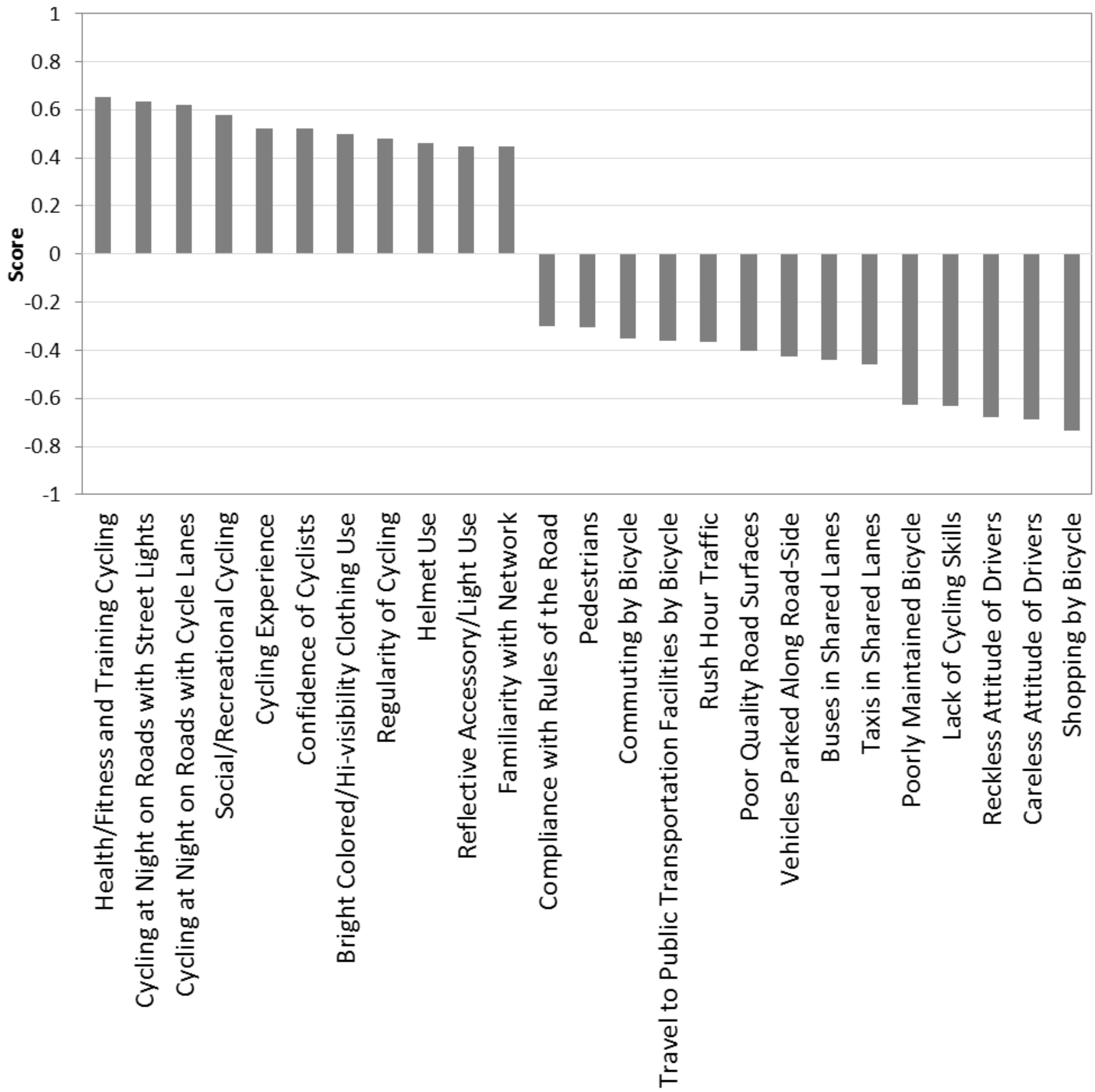

Figure 1 Scores for the variables of the Safety Behavior Model

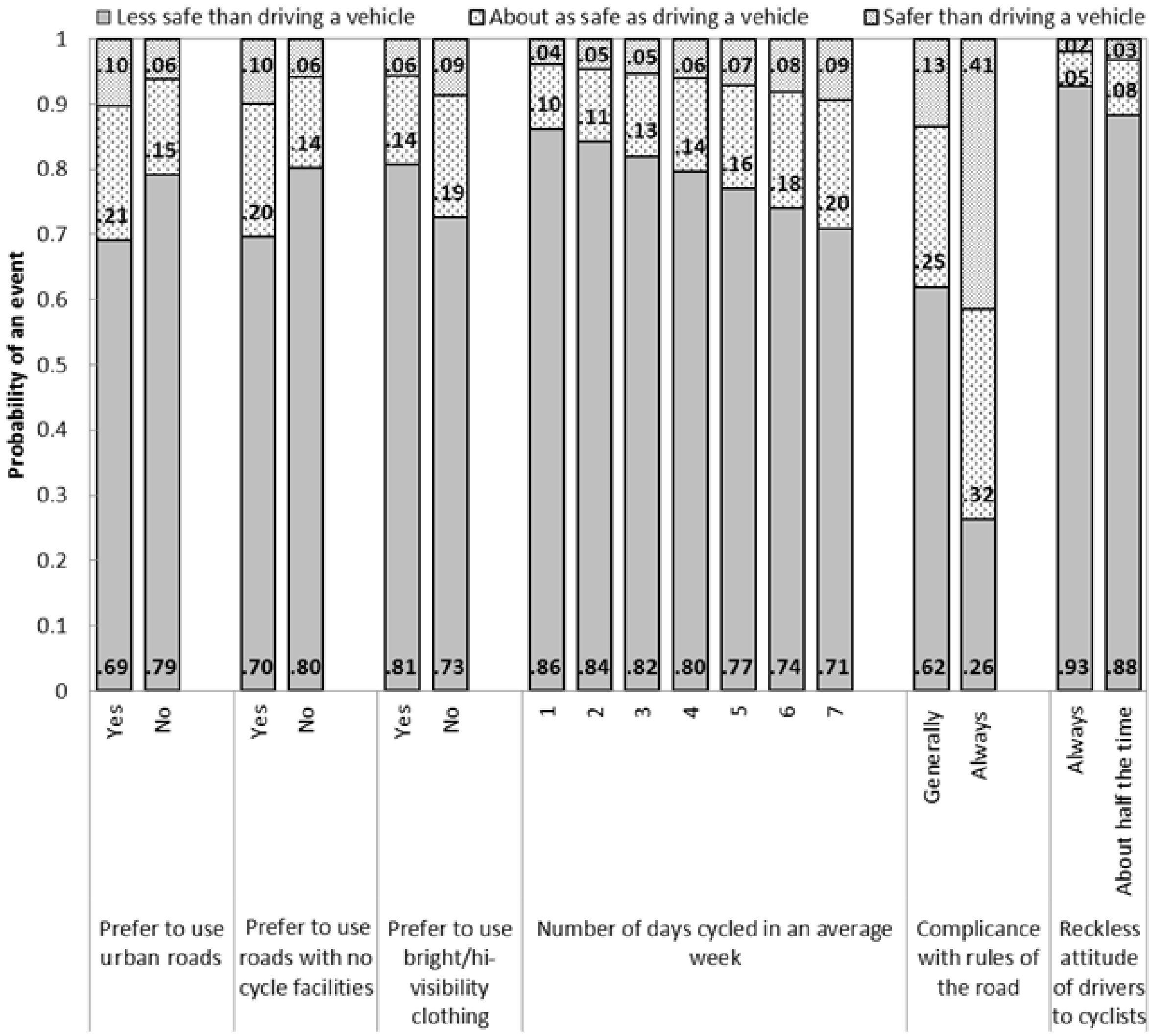

Figure 2 Probability of the occurrence of an event under various factors considered by the Perceived Safety Model

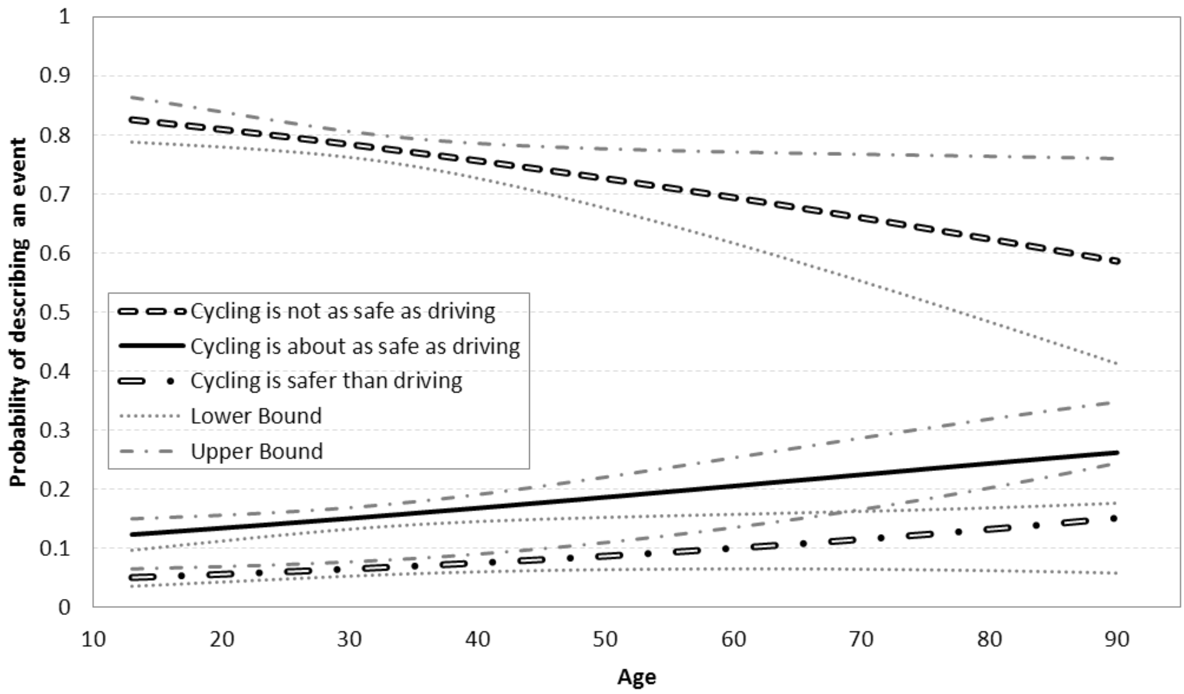

Figure 3 Probability of describing cycling as being safer, about as safe or less safe than driving according to the age of cyclists for the Perceived Safety Model

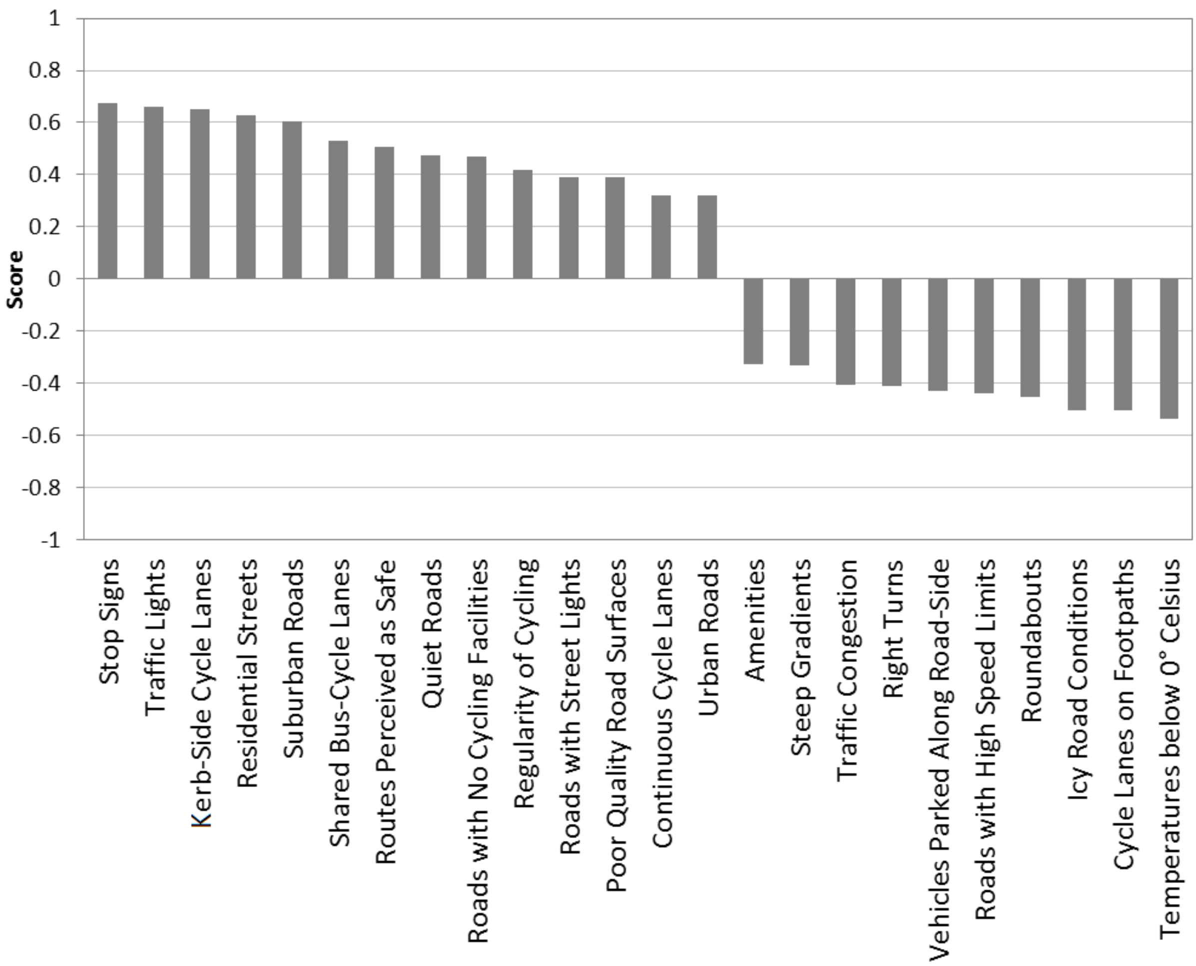

Figure 4 Scores for the variables of the Cycling Network Interaction Model

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Table 1 Cyclist safety/risk perception literature and variables collected by each study

					Cyclist Specific							
Author, Year	**Location**	**Who was asked?**	**Perception of**	**Method**	Age	Gender	Helmet use	Regularity of cycling	Trip Distance	Trip travel time	Holds drivers licence	Accident History
Moller & Hels, 2008	Roundabout	Cyclists	Risk & danger	Interview at roundabout site	*	*	*	*	*		*	*
Parkin et al., 2007	Link & intersection (route as a whole)	cyclists and non-cyclists	Risk	Video clips								
Klobucar & Fricker, 2007	Link	Cyclists	Safety & discomfort	Video clips								
Landis et al., 2003	Intersection	Cyclists	Safety	Test course								
Leden et al., 2000	Bicycle crossing	Cycling experts	Risk	Survey								
Hughes & Harkey, 1999	Link, curb-side lane	Cyclists	Risk	Video simulations								
Harkey et al., 1998	Link	Cyclists	Comfort	Video clips								
Hughes & Harkey, 1997	Link, curb-side lane	Cyclists	Risk	video simulations								
Landis et al., 1997	Link	Cyclists	Hazards (stress/comfort)	Test course								
Landis, 1996	Link	Cyclists	Hazards									
Noland, 1995		Walkers, cyclists, transit users & vehicle drivers	Risk	Survey	*	*				*		
Landis, 1994	Link	Cyclists	Hazards	Survey								
Sorton and Walsh, 1994	Link	Cyclists	stress	Video clips								

Table 1 cont. Cyclist safety/risk perception literature and variables collected by each study

	Network Specific																						
Author, Year	Cyclist Volume	Cyclist speed	Motorist Volume	Motorist speed	Presence of a cycling facility	Type of cycling facility	Continuity of cycling facility	Outside lane width	Lane markings	Number of junctions (on route)	Traffic signals	Intersection crossing distance	Intersection advanced stop lines	Turning vehicles	Roundabouts	Pavement surface	Link length	Number of lanes	Number of side roads	Parked cars	Pedestrians	Traffic mix	Trip creation of surrounding area
Moller & Hels, 2008	*		*	*	*									*	*								
Parkin et al., 2007			*			*	*			*	*		*	*	*					*	*		
Klobucar & Fricker, 2007			*	*				*								*	*	*	*				*
Landis et al., 2003			*	*				*				*		*				*					
Leden et al., 2000	*	*		*										*									
Huges & Harkey, 1999			*	*				*	*														
Harkey et al., 1998			*	*				*								*		*	*				*
Huges & Harkey, 1997			*	*				*	*														
Landis et al., 1997			*	*				*	*		*					*		*				*	*
Landis, 1996			*	*				*								*		*	*			*	*
Noland, 1995																							*
Landis, 1994			*	*				*								*		*	*			*	*
Sorton and Walsh, 1994			*	*		*																	

Table 2 Survey data description

Socio-Demographic Characteristics	Inexperienced		Competent		Highly Skilled	
	36	2.08%	871	50.29%	825	47.63%
Gender						
Male	4	0.23%	445	25.69%	654	37.76%
Female	32	1.85%	418	24.13%	167	9.64%
Age						
Less than 25 years old	19	1.10%	283	16.34%	255	14.72%
25 to 44 years old	11	0.64%	400	23.09%	423	24.42%
45 to 64 years old	0	0.00%	98	5.66%	90	5.20%
More than 64 years old	0	0.00%	7	0.40%	4	0.23%
Employment Status						
Full time	7	0.40%	360	20.79%	399	23.04%
Part-time	0	0.00%	31	1.79%	29	1.67%
Student	26	1.50%	419	24.19%	350	20.21%
Unemployed	0	0.00%	12	0.69%	7	0.40%
Other	3	0.17%	49	2.83%	40	2.31%
Household Structure						
Single person - shared accommodation	14	0.81%	327	18.88%	276	15.94%
Single person - unshared accommodation	1	0.06%	62	3.58%	65	3.75%
Lone parent with resident child(ren)	3	0.17%	21	1.21%	22	1.27%
Couple with resident child(ren)	4	0.23%	195	11.26%	216	12.47%
Couple with no resident children	7	0.40%	147	8.49%	138	7.97%
Other	7	0.40%	119	6.87%	108	6.24%

Table 2 cont. Survey data description

Cyclists' Trip Characteristics	**Inexperienced**		**Competent**		**Highly Skilled**	
	36	2.08%	871	50.29%	825	47.63%
Regularity of Cycling (days/week)						
1 to 2 days every week	14	0.81%	170	9.82%	56	3.23%
3 to 5 days every week	20	1.15%	519	29.97%	419	24.19%
6 to 7 days every week	2	0.12%	182	10.51%	350	20.21%
Time Spent on Cycling on an Average Weekday						
Less than 30 min	17	0.98%	325	18.76%	209	12.07%
30 min to 1 hour	17	0.98%	418	24.13%	415	23.96%
More than 1 hour	2	0.12%	128	7.39%	201	11.61%
Time Spent on Cycling on an Average Weekend Day						
Less than 30min	30	1.73%	585	33.78%	429	24.77%
30 min to 1 hour	6	0.35%	145	8.37%	155	8.95%
More than 1 hour	0	0.00%	141	8.14%	241	13.91%
Distance Cycled on an Average Weekday						
Less than 5 km	26	1.50%	372	21.48%	225	12.99%
5.1 to 10 km	6	0.35%	224	12.93%	209	12.07%
10.1 to 15 km	2	0.12%	124	7.16%	137	7.91%
More than 15 km	2	0.12%	151	8.72%	254	14.67%
Distance Cycled on an Average Weekend Day						
Less than 5 km	32	1.85%	619	35.74%	425	24.54%
5.1 to 10 km	2	0.12%	74	4.27%	102	5.89%
10.1 to 15 km	1	0.06%	50	2.89%	47	2.71%
More than 15 km	1	0.06%	128	7.39%	251	14.49%
Average Travel Speed						
Less than 10 km/hr	5	0.29%	45	2.60%	11	0.64%
10 to 20 km/hr	15	0.87%	409	23.61%	317	18.30%
More than 20 km/hr	0	0.00%	148	8.55%	334	19.28%
Don't know	16	0.92%	269	15.53%	163	9.41%
Trip Purpose						
Commute to/from work	16	0.92%	502	28.98%	545	31.47%
Commute to/from school or college	24	1.39%	458	26.44%	408	23.56%
Travel to other forms of public transport	7	0.40%	130	7.51%	134	7.74%
Shopping	19	1.10%	443	25.58%	423	24.42%
Social/recreation	24	1.39%	561	32.39%	557	32.16%
Health/fitness training	13	0.75%	412	23.79%	460	26.56%
Organized racing	1	0.06%	37	2.14%	130	7.51%
Driver's Attitude (Perceived by the Cyclists)						
Always reckless	3	0.92%	25	28.98%	40	31.47%
Usually reckless	6	1.39%	151	26.44%	134	23.56%
Reckless about half the time	12	0.40%	260	7.51%	238	7.74%
Seldom reckless	12	1.10%	417	25.58%	395	24.42%
Never reckless	3	1.39%	18	32.39%	18	32.16%

Table 3 Eigenvalues, percentage variance explained, factor loadings, means and standard errors of the variables of the Safety Behavior Model

Eigen-value	% variance explained	Loading	Variable	Mean	Std. Error
3.06	12.22	-0.304	Likelihood of an accident due to pedestrians	2.335[b]	0.024
		-0.366	Likelihood of an accident due to rush hour traffic	1.924[b]	0.021
		-0.403	Likelihood of an accident due to poor quality road surfaces	2.386[b]	0.024
		-0.425	Likelihood of an accident due to vehicles parked along road-side	2.574[b]	0.023
		-0.439	Likelihood of an accident involving a bus in a shared cycle lane	2.237[b]	0.024
		-0.459	Likelihood of an accident involving a taxi in a shared cycle lane	2.611[b]	0.025
2.28	9.10	0.499	Bright colored/hi-visibility clothing use	3.641[c]	0.037
		0.460	Helmet use	3.234[c]	0.044
		0.449	Reflective accessory and/or light use	4.463[c]	0.025
1.78	7.12	0.521	Experience of cyclists	2.478[a]	0.013
		0.520	Confidence of cyclists	3.052[c]	0.025
		0.478	Regularity of cycling	4.636[d]	0.041
		-0.301	Compliance with rules of the road	2.539[c]	0.020
1.65	6.61	0.636	Use of roads with street lights while cycling at night	1.194[a]	0.018
		0.621	Use of cycle lanes while cycling at night	1.378[a]	0.022
		0.445	Familiarity with cycling in Dublin	3.231[c]	0.039
1.57	6.29	0.652	Cycling for health/fitness and training	17.904[e]	0.658
		0.580	Cycling for social/recreational purposes	15.283[e]	0.515
		-0.350	Cycling for commuting purposes	37.846[e]	0.912
1.23	4.92	-0.677	Reckless attitude of drivers	3.279[c]	0.023
		-0.688	Careless attitude of drivers	2.615[c]	0.022
1.18	4.70	-0.363	Cycling to public transportation facilities	3.124[e]	0.273
		-0.736	Cycling for shopping purposes	7.558[e]	0.294
1.02	4.09	-0.625	Likelihood of an accident due to a poorly maintained bicycle	3.379[b]	0.022
		-0.631	Likelihood of an accident due to lack of cycling skills	3.695[b]	0.016

[a] range of values: 1-3 [b] range of values: 1-4 [c] range of values: 1-5 [d] range of values: 1-7

[e] range of values: 0-90% [f] range of values: 7.5-75 min [g] range of values: 0.5-20 km

Table 4 Coefficients, odds ratios, the standard errors & the 95% confidence interval of these coefficients of the Perceived Safety Model

Is cycling safer than driving in Dublin?	**Coeff.**	**Odds Ratio**	**Std. Err.**	**[95% Conf.**	**Interval]**
Gender	0.794	0.825	0.118	0.133	1.456
Age	0.042	1.016*	0.006	-0.247	0.331
Regularity of bicycle use	-0.053	1.170**	0.049	-0.773	0.666
Cyclist's experience	0.147	1.159	0.156	-0.117	0.412
Balanced cyclists	-0.445	1.043	0.154	-0.732	-0.158
Confident cyclists	-0.461	0.948	0.348	-0.806	-0.116
Distance traveled	0.157	1.001	0.002	0.074	0.240
Use of urban roads	0.001	1.700**	0.315	-0.003	0.005
Use of suburban roads	0.530	1.055	0.165	0.167	0.894
Use of residential streets	0.053	1.167	0.176	-0.254	0.360
Use of park/scenic trials	0.154	1.031	0.170	-0.142	0.451
Use of cycle lanes on footpath	0.030	0.863	0.121	-0.293	0.353
Use of off-road scenic cycle paths	-0.147	1.033	0.176	-0.423	0.128
Use of kerb-side cycle lanes	0.033	0.837	0.112	-0.302	0.367
Use of shared bus-cycle lanes	-0.178	1.173	0.185	-0.440	0.085
Use of roads with no cycling facilities	0.160	1.765**	0.276	-0.149	0.468
Use of helmets	0.568	0.790	0.113	0.262	0.875
Use of bright colored/hi-visibility clothing	-0.236	0.637**	0.090	-0.516	0.044
Use of reflective accessories/lights	-0.451	0.861	0.171	-0.729	-0.173
Full compliance with rules of the road	-0.150	1.928*	0.543	-0.538	0.238
General compliance with rules of the road	0.657	2.213*	0.747	0.105	1.209
Attitude of drivers towards cyclists is usually reckless	-0.193	0.641**	0.094	-0.474	0.088
Attitude of drivers towards cyclists is always reckless	0.016	0.631**	0.111	0.004	0.028

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

Table 5 Odds ratios of the variables of the Perceived Safety Models, categorized by age and gender

Is cycling safer than driving in Dublin?	**Under 25**	**25 and over**	**Male**	**Female**
Gender	0.818	1.483*	-	-
Age	-	-	1.009	1.024*
Regularity of bicycle use	1.152	1.167**	1.161**	1.149*
Cyclist's experience	1.792*	0.951	1.207	1.025
Balanced cyclists	0.757	0.982	0.969	1.175
Confident cyclists	0.735	1.347	0.769	3.786
Distance traveled	1.000	1.002	1.001	1.003
Use of urban roads	1.804*	1.465	1.989**	0.779
Use of suburban roads	0.895	1.146	1.146	0.813
Use of residential streets	1.219	1.235	1.322	1.104
Use of park/scenic trials	0.961	0.985	0.942	1.149
Use of cycle lanes on footpath	0.942	0.911	0.896	0.740
Use of off-road scenic cycle paths	0.930	1.065	0.963	1.181
Use of kerb-side cycle lanes	0.851	0.789	0.889	0.689
Use of shared bus-cycle lanes	0.879	1.367	0.983	1.890*
Use of roads with no cycle facilities	1.333	1.908**	1.604**	2.444**
Use of helmets	1.013	0.707*	0.906	0.591*
Use of bright colored/hi-visibility clothing	0.539*	0.664*	0.644*	0.753
Use of reflective accessories/lights	1.149	0.618	1.047	0.496*
Full compliance with rules of the road	1.617	2.709*	1.756	3.118
General compliance with rules of the road	4.204*	2.408	1.742	4.517
Attitude of drivers towards cyclists is usually reckless	0.483*	0.645*	0.633*	0.558*
Attitude of drivers towards cyclists is always reckless	0.979	0.466**	0.735	0.507*

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

Table 6 Eigenvalues, percentage variance explained, factor loadings, means and standard errors of the variables of the Cyclist-Network Interaction Model

Eigen-value	% variance explained	Loading	Variable	Mean	Std. Error
3.44	13.76	0.531	Alter route to use routes perceived as safe	3.936[b]	0.032
		0.507	Alter route to use quite roads	3.956[b]	0.032
		0.416	Alter route to use roads with street lights	3.864[b]	0.032
		0.390	Alter route to use continuous cycle lanes	4.005[b]	0.033
		0.320	Alter route to use amenities (e.g. Shops and cafes)	2.509[b]	0.040
2.19	8.74	0.675	Alter route to avoid stop signs	2.171[b]	0.034
		0.662	Alter route to avoid traffic lights	2.498[b]	0.036
1.92	7.69	0.630	Use of residential streets	1.763[a]	0.022
		0.620	Use of suburban roads	1.726[a]	0.021
		0.320	Use of urban roads	1.278[a]	0.016
1.61	6.43	0.471	Regularity of cycling	4.636[c]	0.041
		-0.453	Icy road conditions	4.115[b]	0.027
		-0.504	Heavy rain conditions	3.236[b]	0.035
		-0.539	Temperatures below 0°	2.605[b]	0.032
1.40	5.60	0.474	Use of roads with no cycling facilities	1.469[a]	0.020
		0.391	Alter route to avoid poor quality road surfaces	3.469[b]	0.033
		-0.503	Use of cycle lanes on the footpath	2.122[a]	0.021
1.24	4.94	-0.325	Alter route to avoid steep gradients	1.823[b]	0.038
		-0.334	Alter route to avoid roads with high speed limits	2.161[b]	0.039
		-0.408	Alter route to avoid traffic congestion	1.898[b]	0.038
		-0.409	Alter route to avoid right turns	1.498[b]	0.036
		-0.431	Alter route to avoid parked cars along road-side	1.885[b]	0.032
		-0.441	Alter route to avoid roundabouts	1.681[b]	0.037
1.11	4.45	0.649	Use of curb-side cycle lanes	1.998[a]	0.023
		0.603	Use of shared bus-cycle lanes	1.481[a]	0.020

[a] range of values: 1-3 [b] range of values: 1-5 [c] range of values: 1-7