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Spatial Planning & Transport Engineering Using Children's Maps to Locate Areas of Perceived Danger on Children's Routes to School

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Using children's maps to locate areas of perceived danger on children's routes to school.

By

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DECLERATION

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ABSTRACT

Dublin faces many of the modern day transport problems associated with automobile transport. The bicycle is increasingly being viewed by Urban Planners as an interesting form of individual transportation which can form part of an integrated transportation solution to this problem. For cycling to be a sustainable mode of transport it must be all inclusive. However, there are some identifiable barriers which prevent certain groups in society from cycling. Barriers to children cycling are directly linked to safety concerns and strategies to encourage cycling to school in Ireland currently focus on promotion and cycle training with road safety engineering measures playing a minor role.

This research developed a new, ethically sound methodology to locate areas of danger or perceived danger to children in an existing road network. The aim of the study was to improve the decision making process of planners and engineers when designing cycling infrastructure and road safety measures for children. This was achieved using spatial data within a Geographical Information System (GIS) and incorporated experiential data from children in three target schools in the Greater Dublin Area (GDA) and quantitative road data from the road Safety Authority (RSA).

Findings from the study indicate that the two existing road safety tools currently used in Ireland, the RSA Accident Black Spot Map and the NRA Road Safety Audit, are inadequate when locating areas of perceived road danger to children. It was found that children cycling and walking to school could pinpoint locations in the road network where they experienced dangerous situations or where they did not feel safe. In both instances road types 5 (Regional Roads) and 6 (Local Roads) were identified by children as the most problematic roads. It is exactly these roads that provide the main part of the local cycle infrastructure.

An important aspect of the proposed method is that the map gives children the opportunity to participate and provides valuable information which could enable

Planners and Traffic Engineers to implement measures from The National Cycle Manual to help to realise the full potential of Dublin for cycling to school.

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SYMBOLS AND ABBREVIATIONS

BBC	British Broadcasting Corporation
BMP	Bicycle Master Plan
BSM	Black Spot Management
CSO	Central Statistical Office
CTSB	Cycle Training Standards Board’
DCC	Dublin City Council
DIT	Dublin Institute of Technology
DOT	Department of Transport
DTI	Dublin Transport Initiative
DTO	Dublin Transportation Office
EC	European Community
ESRI	Environmental Systems Research Institute
EU	European Union
FRI	Field Research Ireland
GAD	Greater Dublin Area
GDB	Geographical Data Base
GIS	Geographical Information System
HGV	Heavy Goods Vehicle
ID	Identifier
ING	Irish National Grid
ISME	Irish Small & Medium Enterprises Association
LUAS	Dublin Light Rail System (Irish for speed)
MVA	MVA Consultancy
NDP	National Development Plan

NGO	Non-Governmental Organisation
NHS	National Health Service
NRA	National Roads Authority
NTA	National Transport Authority
RDB	Relational Database
RSA	Road Safety Authority
SCN	Strategic Cycle Network
SQW	SQW Consultancy
TERN	Trans-European road network
UK	United Kingdom
UN	United Nations
USA	United States of America
VHI	VHI Healthcare
WHO	World Health Organisation

1.0 INTRODUCTION

1.1 Cycling: Sustainable Transport

The bicycle as a sustainable mode of transport is fundamental in many modern urban transport scenarios. One of the greatest challenges facing cities today is to plan and invest wisely in infrastructure for sustainable urban transport (UN, 2010). The culture of urban mobility needs to focus on more sustainable transport modes which provide benefits to citizens (EU, 2011).

The National Cycle Manual (DCC, 2010) found that Dublin faces many of the modern day transport problems associated with automobile transport. Although the number of cars entering Dublin city decreased by 7.5% between 2000 and 2010 (Gormley, 2011) in 2009, the car was still the dominant mode of transport, with 54% of all journeys in Dublin made by private car. Walking was the second most common mode of travel with a share of 21% of all journeys and 13% of journeys were made by public transport, whilst cycling accounted for only 2% of journeys (CSO, 2009). In 2007 in Dublin, the average speed of a car journey had fallen to 12.4 km/h (DTO, 2007). This is less than that of a horse-drawn carriage of the 19th century. Thus the bicycle should be viewed as an interesting form of individual transportation which is an inexpensive and green alternative to motorised transport. In addition, it can form part of an integrated transportation solution joining individual and public transport.

1.2 Benefits to Society

The adoption of transport policies which include cycling have been shown to benefit society in a number of ways including:

1. Economically; the cost to society of automobile based transportation can be measured in a number of ways including man-hours lost due to traffic congestion and pollution in terms of noise and air quality which in particular, can damage the reputation of a city and make it a less desirable place to work or live. An increase use of bicycles would reduce each of

these negative economic indicators. Dr Alexander Grous, of the London School of Economics has calculated that cycling produces a benefit of £2.9 bn every year to the UK economy (Grous, 2011).

2. Socially; the increase use of cycle networks could help alleviate problems related to poor planning which has resulted in urban sprawl and thus lead to greater local participation increasing local identity. By improving road safety for cyclists, local streets can provide a space for neighbours to meet and for children to play. As a mode of transport the bicycle has great potential in supporting sustainable forms of public transport such as trams, metro lines, trains and busses as distances to local public transport, which are considered too far to walk, may be cycled.

3. Personally; the health benefits of regular cycling to the individual are well documented (Carnall, 2000 ; Pucher *et al*., 2010) and although cycling carries a number of risks it has been shown that the health advantages of cycling outweigh the risks of cycling (de Hartog, 2010). Increasingly higher levels of cardio vascular diseases and obesity are registered in high income countries which have higher car ownership percentages (WHO, 2012). Overweight and obesity, now the most common childhood disorder in Europe (WHO, 2002), are prevalent in Ireland with one in five teenagers classified as either overweight or obese. (Irish Heart Foundation, 2012).

1.3 Model for Change

For cycling to be a sustainable mode of transport it must be all inclusive. Whilst almost everyone, independent of sex, age, economic background or race can physically ride a bicycle, there are some identifiable barriers which prevent certain groups in society from cycling. Countries with low rates of utilitarian cycling have been found to have substantial gender differences in bicycle use (Pucher and Dijkstra, 2003). This trend is also evident in Dublin. Murphy (2011) analysed a database of users of the 'Dublin Bikes' scheme and found that 78% of the 'Dublin

Bikes' users were male and that these users came overwhelmingly from what was described as middle-class and upper middleclass backgrounds (Murphy, 2011).

In many cases barriers to cycling can also be directly linked to safety concerns and research has shown that road safety concerns deter more women than men from cycling (Hajinikitas, 2001), as women are more risk averse than men (Byrnes *et al*., 1999). Road safety concerns also affect the number of children cycling (DTO, 2007) and as Timperio (2004) has shown parent's perceptions of the local neighbourhood may influence children's physical activity. Strategies to encourage cycling to school in Ireland focus on promotion (An Taisce Green schools and Road Safety Authority 'Bike Week') and cycle training (Dublin City Council (DCC) 'Bike It'). Cycle training for children focuses mainly on educating children to learn the necessary skills to take part in road traffic. Such educational strategies have been criticised as they aim to teach children to conform to the needs of motor traffic and children are expected to fit in to, and understand a system that can be challenging for adults (Bleyer, 1997). Generally, it can be said that higher levels of children cycling in countries such as the Netherlands, Denmark or Germany can be explained by the safer (segregated) cycle infrastructure (Pucher, 2008). Despite this evidence, when attempting to encourage children to cycle to school in Dublin, child specific road safety engineering measures currently play a minor role.

1.4 Gap in the current knowledge

Road safety and perceived road safety of children is a major factor in children cycling to school (Sigl and Weber, 2002; Timperio, 2004; DTO, 2007). Dumbaugh and Frank (2007) found that there is a distinct lack of knowledge relating how common road safety measures affect children's road safety, and they noted only few examples where road safety measures are directed specifically at children.

Road safety effects all cyclists and it has been shown that such concerns deter more women than men from cycling (Hajinikitas, 2001), as women are more risk averse than men and tend to use safer routes while men use more direct routes when commuting to work in Melbourne, Australia (Byrnes *et al*., 1999). It is not known if this is true for children.

A further research area with respect to children cycling that requires attention is the collection of data relating to actual distances travelled by bicycle. A number of studies have used assumed routes and presumed that a cyclist would use a most direct route to get from start to finish of a journey (Byrnes *et al*., 1999; Rybarczyk, 2010; Panter, 2010; Yiannakoulias, 2012). There is currently no data available about the actual distance travelled by children on route to school by foot, bicycle or car. Furthermore, there is no available data on what children perceive as dangerous, unpleasant or conversely what they perceive to be safe or pleasant when travelling to school.

Berglund (2008) has used Maps and GIS to answer similar questions in Sweden. Aultman-Hall (1997) also made use of a GIS network database to determine the characteristics of 397 routes used by commuter cyclists in Guelph, Ontario, and compared them to the shortest path routes between each origin and destination. This analysis provides useful insight for understanding factors affecting travel behaviour such as grades, intersections, etc. and recommends different priorities for improving conditions for existing cyclists and for attracting new cyclists to the network (Aultman-Hall, 1997). Thus the question arises could a mapping and GIS analysis approach based on the work of Aultman-Hall (1997); Berglund (2008) and Children's Tracks (1998) be effectively adopted in a Dublin sub-urban location to solve some of the research issues mentioned and if so how can data originating from young children commuters be effectively used?

Berglund (2008) developed a method called Children's Maps in GIS to involve children and teachers in the urban planning process. In Berglund's (2008) survey children drew maps of their routes to school and answered a number of questions about the local area from a drop-down menu. This survey produced accurate route data of the children's routes to school. However, the focus of this study was the children's use of the area in general, and the resulting data was of value mainly to urban planners.

While this research builds on the method used by Berglund (2008) the focus of this study is primarily on road safety and perceived danger on route to school. Previous studies have not gathered real data from children on their daily commute to school in Dublin and their interaction with the local road network.

A problem that Dublin shares with many other cities, are the low numbers of children cycling to school. As a result there are a relative low number of accidents recorded involving children cycling. This could be incorrectly judged as a sign of safety. There is a possibility that the number of accidents may increase if the promotion of cycling to school is successful. The relative small number of recorded accidents can also be explained by the fact that these accidents are only recorded if they are so severe that they are recorded by the Gardai or as a result of hospitalisation. Studies by Zippel (1990) and Hautzinger (1993) have found that 90% of bicycle accidents involving children and half of all pedestrian accidents in Germany were not registered by the Police. In Ireland, Sheridan *et al.* (2011) found that a great number of traffic accidents resulting in hospitalisation, were not recorded by the Road Safety Authority (RSA). Yet, it is entirely possible that many unrecorded close calls or less severe accident experiences would have a serious negative effect on the perception of safety on route to school. Sota (2011) overcame a similar data issue in Thailand, where sufficient accident data to populate an Accident Black Spot Map was unavailable he used near accident experiences of local inhabitants**.** The resultant maps are populated with markers that show a location were an accident nearly happened as opposed to actual recorded accident locations. By following the principals of Near Miss Reporting (Manuele, 2011) a clustering of near misses can indicate locations with a high potential for the occurrence of an actual accident.

Data of children's bicycle accidents is not available for many areas in Dublin. This research attempts to use the principles of Near Miss Reporting in combination with the principles of Accident Black Spot Maps to overcome this lack of data. This innovative method, when extrapolated could provide a method to enable traffic planners to evaluate road networks for potentially dangerous locations for children cycling. As such data would generate potential Accident Black Spot Maps they could help to prevent the future occurrence of actual accidents.

1.5 Research Questions

This study aims to answer the following research questions:

1. Does Dublin have the potential to attract a higher modal share of active travel to school?
2. What the exact distances children travel to school in Dublin using different modes of transport?
3. Do children use the shortest possible routes when travelling to school?
4. Can children locate areas of perceived danger in a local road network using a map?
5. Can the data gained through children's maps be used on an accident black spot map in lieu of actual accident data?

1.6 Research Aim and Objectives

The aim of this research is to develop a methodology that enables road traffic engineers and planners to use children's maps to locate areas of perceived danger to children in a local road network. To achieve this aim the following objectives were identified:

i. Spatially analyse the potential for cycling to school in Dublin
ii. Collect children's travel to school route data for a local road network.
iii. Locate areas of perceived danger for child cyclists and pedestrians in a local road network.
iv. Assess the viability of the use of children's incident reporting to locate areas of perceived danger on routes to school in Dublin.
v. Identify an appropriate research technique to populate accident black spot maps in lieu of existing data.

This research is novel in its approach as it brings together data and methodologies from different sources including Road Safety Authority data, children's data, accident reporting and industrial safety. When combined, these can form a progressive method in the advancement of safe sustainable transport for children in Dublin. This is the first time such as study has been undertaken in Ireland.

2.0LITERATURE REVIEW

CYCLING POLICY

This literature review begins with a focus on the benefits of cycling and the policies that have been implemented, internationally and in Ireland, to promote cycling and make cycling safer. Special attention is given to policies that are aimed at children, and in particular those aimed at cycling to school. This is followed by an overview of the area of children's participation and outlines a number of the tools used in children's participation that are relevant to this study. The literature review subsequently examines cycling practice and research.

2.1 Health Benefits of Cycling

In general cycling is regarded as a healthy activity (WHO, 2010; Pucher *et al*., 2010) and it has been shown to reduce the risk of serious conditions such as heart disease, high blood pressure, obesity and the most common form of diabetes (Mersy, 1991; Fagard, 1995; Dora, 1999; Carnall , 2000). In the UK SQW (2008) estimated that everyone who cycles regularly saves the National Health Service (NHS) £28.30 a year. It is an emission free form of transport that also benefits other city dwellers by reducing air and noise pollution and reducing congestion (DoT, 2009). Cycling is recommended as a healthy exercise by Irish health insurers including the Voluntary Health Insurance Board (VHI) and Bupa (Bupa UK, 2010; VHI, 2011) and research suggests that the health advantages of cycling outweigh the risks of cycling (de Hartog, 2010).

2.2 Children's Health Benefits of Cycling

The benefits that cycling provides for children by improving their health through exercise has been established by numerous researchers (Davis and Jones, 1996; Brody, 2001; Pucher and Dijkstra, 2003; Department of Health, 2004;, Hallal, 2006; Cooper *et al*., 2008; Colley 2011). The World Health Organisation (WHO) notes that physical inactivity has become the second most important risk factor to health in the industrialised world. Walking and cycling as part of normal daily activities and as part of travelling to school could play a major role in reversing this trend (Sirard, 2005; Davison, 2008). Coronary heart disease, diabetes and hypertension, in addition to obesity and overweight, also affect children (WHO, 2002) and it is estimated that only 30 minutes per day of moderate physical activity, such as walking or cycling would be highly effective measure to prevent these diseases. However, to enable this, the conditions to make walking and cycling a feasible, safe and attractive conditions need to be created or re-established. In many cases this requires substantial revision of present transport policies. There is currently a lack of information of how to make cycling safer and more enjoyable for children, and insights into what choices children would make when creating a cycle–friendly environment are required (WHO, 2002).

Cycling has many health benefits it is beneficial for both the individual and society simultaneously. For children in particular the benefits of an active life style have been documented (WHO, 2002). One area that has seen a decline in active travel for children in Dublin is their journey to school. The following section examines what is needed to create a cycle friendly environment that will encourage children to cycle.

2.3 Cycle friendly environments

Creating a cycle and pedestrian friendly environment involves a wide range of measures, to ensure that cycling/walking conditions are safe and convenient for everyone. Southworth (2005) describes six parameters that define the walkability of an area, these include:

1. Good connectivity;
2. Linkage with other modes;
3. Fine grained land use patterns;
4. Safety;
5. Quality of path; and
6. Path context.

These parameters are very similar to the five main transport requirements for cyclists that according to Crow (2006) should be met in designing and implementing cycle routes. These are:

1. Coherence;
2. Directness;
3. Attractiveness;
4. Safety;
5. Comfort.

Winters *et al,* (2007) found that cycling patterns were associated with individual demographic characteristics and also with the local climate.

An obvious method to determine what constitutes a cycle friendly environment would be to examine cities and communities that have developed a good cycling culture or have successfully introduced policies to increase the modal share of the bicycle and walking. Cities such as Amsterdam, Freiburg, Portland, Groningen or Copenhagen have been shown to have a vibrant cycle culture (Pucher *et al.,* 2008). A common belief is that these success stories for cycling can be explained by the fact that these cities always had a strong cycling tradition. However, evidence suggests that in all these cases a strong investment into cycling infrastructure and a political will to promote the bicycle as a mode of transport are at the heart of creating a cycling culture (Mohnheim, 2003; Pucher *et al.,* 2008). The afore-mentioned cities have shown that a dedicated policy towards sustainable transport and away from a car orientated transport policy can solve a lot of the problems that modern cities face. Improved mobility and a healthier environment are an achievable goal.

Recent data from the Dublin bicycle-sharing scheme (Dublin Bikes) found that 78% of Dublin Bikes users were male and stated that "users came overwhelmingly from middle-class and upper middleclass backgrounds" (Murphy *et al.*, 2011). High bicycle transport mode share for both males and females has been found to occur mainly in countries and cities with extensive networks of separate bicycle paths and lanes (Purcher, 2003, 2010; Garrard, 2008). Thus the specific cycle environment which currently exists in Dublin may be unsuitable or undesirable to many demographic groups, including children.

The declining trend of cyclists in Dublin as measured by the Department of Transport in 2008 is despite a €30 m investment into Dublin's cycling infrastructure (DoT, 2008). Fulcher (2004) believes that cycling infrastructure has been partly to blame for the decline of cycling in Dublin.

Yet, the annual cordon count by Dublin City Council shows that in the time period from 2002 to 2012 the volume of pedal cyclists crossing the canal cordon during the morning peak period increased by 68.5%. There was a 39.9% increase in the five year period from 2007 to 2012 and a 15.6% increase from 2011 to 2012. However, cycling numbers remain relatively low compared to other modes of transport. At its peak in 2012 the number of cyclist crossing the cordon was 7943 compared to 60620 cars in the same time.

The provision of a dedicated cycle infrastructure is a main component of a cycle friendly environment. Low cycling numbers in Dublin suggest that there is a problem with the cycle infrastructure in Dublin. Section 2.4 examines the provision of cycling infrastructure in Dublin.

2.4 Cycling infrastructure In Dublin

The (Dublin) Strategic Cycling Network (SCN) was proposed as part the Dublin Transportation Initiative (DTI) and adopted in 1995 to reduce traffic congestion and improve the city environment by encouraging greater use of public transport, cycling and walking in Dublin. It was based on the 1995 Report to the Lord Mayors Commission on cycling that identified a latent demand for cycling in the city. The report concluded that the introduction of a cycle network could help to realise this potential. The DTI identified fourteen radial routes that would form the SCN at an estimated cost of £12-15 million Irish Pounds. The SCN was also implemented through the DCC Development Plans in 1999 and 2004. This was important as a major part of the SCN is located within the DCC area. Both the DTI and the DCC Development Plans saw the provision of well-designed on-street cycle lanes as the key to attracting more people to cycling. In 2013 this cycle network of approximately 220 km (including Quality Bus Corridors) formed the vast majority of cycle infrastructure in Dublin. However, despite this investment of almost €30 m the number of people travelling by bicycle declined in the period from 1994 to 2005 (DoT, 2008). In recent years this downward trend has been reversed. The 2012 Dublin City Cordon count has shown that the number of cyclist travelling into town in the morning increased by 39.9% in the 5-year period from 2007 to 2012 and by 15.6% from 2011 to 2012 (Dublin City Council, 2013).

From 1995 to 2010, cycle infrastructure in Ireland has been designed in accordance with the 'Provision of Cycle Facilities – National Manual for Urban Areas, 1998'. One of the main points of critique of this manual has been its focus on the provision of cycle infrastructure and lack of supporting cycle-friendly policies (Fulcher, 2004). Even though the focus of the manual has been the implementation of on-street cycle infrastructure, the resulting SCN has been the source of some criticism. In a review of Dublin's Strategic Cycling Network, Fulcher (2004) concluded that the network is 'inconsistent' and of 'poor quality of design'. This view is echoed in the 'The New National Cycling Framework' for Ireland, as it acknowledges that "*the quality of the dedicated cycling facilities designed and constructed to date in Ireland has been inadequate."* (Fulcher, 2004). Today the National Transport Authority (NTA, 2009) has a statutory obligation to prepare a Strategic Transport Plan for the Greater Dublin Area and the Strategic Cycling Network is now part of the NTA planning (NTA, 2009).

Since 2010 the 'Provision of Cycle Facilities – National Manual for Urban Areas, 1998' has been superseded by 'The National Cycle Manual' (NTA, 2009) and together with the 'National Cycle Planning Policy Framework' (NTA, 2009), published in 2009, is one of key national policy documents shaping the Strategy objectives and targets of the Strategic Transport Plan.

The National Cycle Manual is a more refined and detailed document than its precursor. It places a significant emphasis on strategic planning and has a catalogue of highly detailed solutions for the provision of cycle infrastructure (Figure 1.0) that is accessible online (NTA, 2009). Ciaran Fallon, former Dublin City Council Cycling Officer, stated on the current implementation of the National Cycle Manual in Dublin that: '*The manual demands a substantial allocation of road space (min 1.75 m width) which would require a major reallocation of space from motorised modes to cycling and this is not currently considered to be achievable'* (Fallon 2012).

Figure 1.0: The National Cycle Manual' Cross roads planning detail (NTA, 2012).

Figure 1.0 illustrates an example of the high standard of design for cycling infrastructure in the National Cycle Manual. The manual has not yet been implemented and there is no evidence that it has ever been used to design any cycle infrastructure within the DCC area.

Figure 2.0 shows that in the National Cycle Manual the local county/city council plays an important role in preparing the actual design drawings for new cycling infrastructure. It is important to note that the current DCC Development Plan (2011-2017) has a section on the SCN, but does not mention the National Cycle Manual as a guidance document (DCC, 2010).

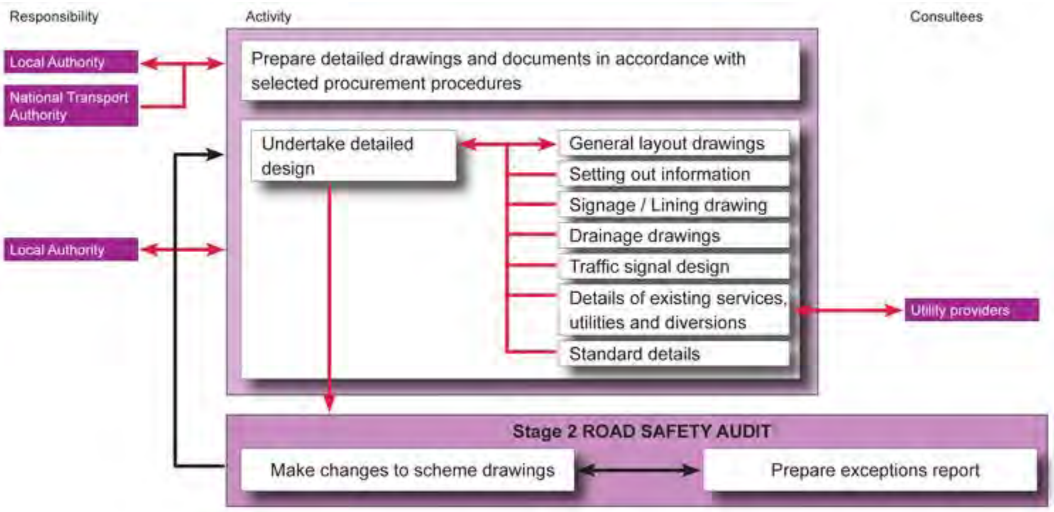


Figure 2.0:'The National Cycle Manual' Planning Cycle Infrastructure (NTA, 2012).

The provision of cycling infrastructure in Dublin is in a state of limbo. The current cycle infrastructure in Dublin is subject to criticism from cycling campaigners and planners alike. In addition the new cycling manual is not being implemented as currently, traffic planners are unwilling to relocate road space used by motorised traffic to non-motorised traffic (Fallon, 2012). Thus a major problem exists for planning cycle infrastructure. When cycling numbers are very low it appears illogical to relocate road space from motor traffic to cycling. However, as argued by a number of researchers (Mohnheim, 2003; *Pucher et al.,* 2008), increasing the quality of the cycling infrastructure plays a key role in achieving an increase in cycling as a mode of transport.

The current provision of cycle infrastructure in Dublin is at best difficult to use for adults and open to criticism. Thus it is most likely even less suitable for child cyclists and cannot be seen as a good cycling environment. Despite the short comings of the current cycling infrastructure, Traffic Education and Cycle Training is used in Dublin to boost cycling to school.

2.5 Traffic Education and Cycle Training for Children

Cycle training is in general designed to get more children cycling, more safely and more often (Bikeability, 2010). The provision of cycle training courses varies greatly from country to country and includes private companies, local authorities and/or nongovernmental organisations (NGOs). Dutch, Danish, and German children receive extensive training in safe and effective cycling techniques as part of their regular school curriculum (Pucher and Buehler, 2008). In Germany, 95% of children receive traffic safety education from primary school age. Special courses for cycle training are organised in conjunction with NGO's including Deutsche Verkehrswacht (Verkehrswacht, 2012). In Australia cycle training is provided by AustCycle, a joint venture between the Amy Gillett Foundation (a charity), the Bicycle Federation of Australia and Cycling Australia. The Australian Government co-funds this organisation (AustCycle, 2012). In the United Kingdom private operators and NGO's such as Bikeability conduct cycle training for children in accordance to 'The National Standards' whereby 'The National Standards' are the Government approved standards for cycle training which are established by 'The Cycle Training Standards Board' (CTSB). The CTSB was formed in February 2007 by the Department for Transport as the custodian body of the National Standards for Cycle Training (The Cycle Training Standards Board, 2011) .

Irrespective of the cycle training provider most cycle training programs are divided into a number of different stages. Children may first simply learn the rules of the road and begin with basic cycling skills away from public roads. Subsequently, to gain confidence, children move on to the next level where they can practice basic skills on quiet roads. Finally, children then test their skills on busier roads and may learn some mechanical skills (Bikeability, 2010; AustCycle, 2012; Cycle Training Ireland, 2012).

Macarthur *et al*., (1998) found that a brief skills training program was not effective in improving safe cycling behaviour. Carlin *et al*. (1998) concluded that school based bicycle education does not reduce the risk of bicycle related injuries in children, but may even produce harmful effects in some of the children. Of significance is the fact that two studies identified boys as having a higher risk of being involved in an accident than girls (Macarthur *et al*., 1998; Carlin *et al*., 1998). In a study of 336 pupils in the London Borough of Bromley no relationship could be found between cycle training and a reduction in the number of accidents (Colwell and Culverwell, 2002). On the basis of empirical evidence, the effectiveness of Child Pedestrian Education Programs was found to be mixed by Dumbaugh *et al.,* (2007).

Two programmes are currently in operation in Dublin which advocate the use of bicycles and promote cycling to school through the provision of cycle training, these are the An Taisce 'Green Schools Travel Program' and the DCC 'Bike Start' program. The An Taisce 'Green Schools Travel Program' encourages sustainable travel to school by working closely with schools (Green Schools Ireland, 2012), whereas the Bike Start program teaches children the rules of the road and how to cycle and behave in traffic (DCC, 2009). This program is very similar to the British 'Bike it' (Sustrans, 2010), the Belgium 'Pro Velo' (Pro Velo, 2012) or the Australian 'Bike Ed' (BIKeSA, 2012). Both DCC and An Taisce believe that their programs are effective in promoting more cycling to school (DiPietro and Hughes, 2003; An Taisce, 2008; Bikeability 2010). However, Carlin (1998) found that for instance the 'Bike Ed' program had a negative effect on children's road safety as it could encourage risk taking in some children or may cause parents to let children cycle without adequate supervision. A further concern relates to the increased responsibility for road safety placed on children, while little attempts are made to change the surrounding circumstances which make cycling safer and more enjoyable. Children are simply trained to fit into an environment that was designed for the needs of adults and motor traffic (Davis, 1996; Limbourg, 1997; Hobbs, 2001). Therefore it can be said that it is not ideal to train children in the rules of the road and bike skills in lieu of providing a safe cycling environment.

As will be shown in Section 2.11.3.2, there are a number of skills and abilities that children only develop through childhood to make them fully functional in traffic. When they do not possess these skills, it is often other road users that cause the danger, or it is the perception of danger that prevents children from cycling. Thus if there is a greater focus on how to make the current road network more cycling friendly for children, then they should be involved in that process.

2.6 Children's Rights in Urban Planning

The Convention on the Rights of the Child (UN, 1989) reminds societies of their obligation to keep children at the centre of their vision for development. This convention was ratified by Ireland on 28th of September 1992 (Department of Foreign Affairs, 1992). Article 12 of the Convention on the Rights of the Child identifies Participation as a guiding principle which involves encouraging and enabling children to make their views known on the issues that affect them (UNICEF, 1997). The implication of this convention on town and traffic planning can be described as follows:

> '*Towns and cities must enable children and adolescents to move around by foot, bicycle and public transport, and freely experience and learn from their surroundings. Communities must be planned to minimize risks to children from traffic, unexploded landmines and other dangers*.' (UNICEF 1997)

Streets, together with independent and active mobility, have been shown to play an important role in children's everyday lives (Armstrong, 1993; Huttenmoser, 1995) and child road safety is an important issue as a great deal of this mobility will take place in public streets. This is reflected in town and road planning in various European countries. In Norway the Planning and Building Act of 1989 requires that the municipal council appoint the head of one of the municipal services or another official special responsibility for safeguarding the interests of children and young people in the planning process (Government of Norway, 1989). The Italian government enacted a law which regulates the promotion of the rights and opportunities for children and adolescents (Government of Italy, 1997). In 1998, the Italian Ministry for the Environment instigated an award for 'Sustainable Cities for Boys and Girls', which is awarded to Italian municipalities committed to improving opportunities for children, the urban economy, area planning and transport, with the involvement of the local community and – most especially – of children (Corsi, 2002).

Participation is generally a democratic process (Hart, 1997). Article 12 of the Convention on the Rights of the Child states that children have the fundamental right of citizenship and are entitled to be actors in their own lives and to participate in the decisions that affect them (Hart, 1997; Lansdown, 2001; UNICEF, 1997). According to Hart (1997) there are four requirements for a project to be truly labelled as participatory, including:

1. The children understand the intentions of the project;
2. They know who made the decisions concerning their involvement and why;
3. They have a meaningful (rather than 'decorative') role;
4. They volunteer for the project after the project was made clear to them.

These requirements are intended to prevent 'Tokenism', where a project claims to be participatory, but the views of children are not really taken into account.

2.6.1 Child Participation Tools

A variety of methods have that been used in children's participation projects including drawing, mapping, interviews, time schedules, photographs, model building, child-led tours through local communities, focus group discussions, role play, visioning and ranking exercises (Chawla, 2002; Francis, 2002). Information gathering may also include observations of public places and other spaces that children use, maps and photo grids to document local environmental conditions (Chawla, 2002).

2.6.2 Children's Maps

The use of maps as a child's participation tool was considered most appropriate for this study (see Section 3.5.2) because they are a proven medium for children that allow them to express their own perceptions about their daily journey to school and give planners direct access to children's local spatial knowledge. The information contained in these maps can be directly transferred to maps that display survey results. Using children's maps can also solve a methodological issue. It is ethically questionable to directly observe children in public spaces. Also, the researcher might trigger situations where children engage in dangerous behaviour by observing them. Since all map data is retrospective the researcher can have no influence on the children's behaviour.

Figure 3.0 illustrates a child's cognitive map drawn to illustrate a child's use of the local environment. The map demonstrates this child's ability to draw a map from memory showing the spatial relations between landmarks that are of importance to the child.

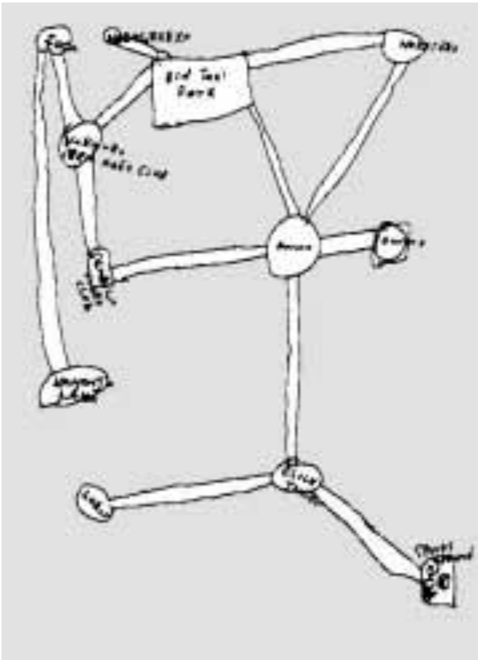


Figure 3.0: Children's Map (Young and Barrett, 2001)

UNICEF describes maps as tools that are '*appropriate for empowering young people to formulate and share their views and experience'* (UNICEF, 2005). With it children can map valuable data about their community that no one is likely to have mapped before. In a participatory project in southern Karnataka, southern India, children conducted a study that was concerned with their own mobility problems (Lolichen, 2007). One of the methods developed and used by the children to locate routes in their local area they found difficult to travel on was observation maps. In this method the children developed a number of symbols which identified problematic locations such as potholes, trees, drainages, bridges, culverts, school, crèche, houses, agricultural fields, forest, wells, ration shop, mud road, and black-topped road. These symbols were placed on a map of the local area. These maps and other materials used by the children better enabled the children later to make presentations on their own behalf to decision makers in the community by substantiating their argument with appropriate data (Lolichen 2007).

The 'Children's Tracks' project, implemented in the Municipality of Andebu/Vestfold, Norway, also used mapping data collected by children aged between eight and thirteen to identify play-areas and tracks or paths that were important to them as well as any areas that were dangerous to them (Children's Tracks, 2012). Berglund (2007, 2008) developed this method to track children's movements in a road network using GPS. Thus it can be seen that the use of maps in participatory research is very effective when working with children.

CYCLING PRACTICE AND RESEARCH

The literature review now gives a general overview over the revival of cycling as a mode of transport internationally and in Ireland. It examines the current research and literature with respect to cycle safety both internationally and in Ireland. Special attention is given to the review of the actual and perceived dangers children face in traffic. Further attention is given to the use of maps and GIS in research on how children travel and play in their living environments. Finally Accident Black Spot maps and Near Miss Reporting are reviewed as two techniques to detect locations of perceived and actual danger to children in a local road network.

2.7 The Revival of Cycling as a Mode of Transport

Until the oil crisis of 1973 the car was virtually unchallenged as a mode of transport, and propagated the way forward. The resulting dominance of the car as the main mode of transport resulted in many problems regarding traffic safety, healthy environment, urbanity and mobility itself (Appleyard, 1981; Moore and Scott, 2005). Even though there are many people who love their car, as it promises status, individualism and freedom (Conley and McLaren, 2009), the dominance of the car as a mode of transport is the result of decades of car orientated policies (Mohnheim, 2003; Conley and McLaren, 2009). Heavy investments into road infrastructure, the neglect of public transport and other forms of individual transport, changes in the social and economic constellation of society began to change the fabric and appearance of many cities in the west after the Second World War (Ministry of Transport, 1999; Litman and Laube, 2002). In Europe many cities either had to be rebuilt after being bombed in World War 2 (WW2), or were redesigned to cope with ever greater numbers of cars on their roads. The traffic jam was ‘invented’, something that was virtually unknown before and is a misnomer, as it should have been called a ‘car jam’, since it was, and is, almost exclusively a problem of motor traffic. Despite this only a few questioned car dependency and its ill effects and the answer to gridlock was to build more and bigger roads. Dr. Mohnheim sees this static mobility policy of many countries in the west as the root of the traffic problems they are facing today (Mohnheim, 2003).

One country that was able to implement policies to boost cycling as a mode of transport successfully is the Netherlands, a country, which to this day, is seen by some as possibly the most bicycle friendly country in the world. However, the perception that this is due to a long lasting, loving relationship between the Dutch and the bicycle is not true. In fact, in the 50's and 60's the Netherlands were beginning to experience many of the transport related problems that other cities and countries face today (Fietsberaad, 2006). The Dutch Ministry of Transport, Public Works and Water Management published its Bicycle Master Plan (BMP) in 1997. This plan included a historical context for the decline of bicycle use in the Netherlands in the 1950's and 60's and its subsequent rise from the 1970's (Ministry of Transport, 1999). The BMP of the Netherlands illustrates how the investment into car orientated infrastructure after WW2 increased significantly (Ministry of Transport, 1999). Better economic circumstances in the 50's and 60's, together with a spatial policy that resulted in lower densities in urban areas and therefore longer commuting distances, led to an increased use of the motorbike and car. This was not accidental, but seen as a positive development and was actively supported in Dutch planning and politics. As the bicycle became more marginalised in the public space it became more dangerous to use it, which in itself contributed to the decline of utilitarian bicycle use.

By 1972 the Dutch Economics Institute published a report which was to serve as the foundation for future 'integral traffic and transport policy'. It predicted that up to 22 billion guilders (€10 billion) would be required to maintain, upgrade and build roads for the car traffic demands to the year 2000. Together with the shock of the 1973 oil crisis this led to a rethink of transport policies in the Netherlands, and a subsequent renaissance of the utilitarian bicycle use (Ministry of Transport, 1999).

Cycling as a mode of transport declined in many places with the rise of motorised traffic after World War 2. The 1970's oil crisis and the traffic grid lock that many cities faced caused an international rethinking of mobility policies.

2.8 Cycling In Ireland

Dublin today, has a lot in common with the Netherlands in the late 1960's. The modal share of the bicycle in Dublin is currently very modest with only 2% for people over 18 years of age (CSO, 2009). The reasons for this modest modal share appear similar to many of the problems that led to a decline in bicycle use in the Netherlands in the 1960's. The 'Celtic Tiger' of the 1990's brought Ireland an unprecedented economic boom and led to an considerable suburban expansion of Dublin (Moore and Scott, 2005) and a dramatic rise in car ownership. Car ownership among Irish households continued its upward trend with 1.36 Million households having at least one car in 2011 – an increase of 186,000 from 2006. Faced with chaotic car traffic the sum of €30 Million has been invested in a Greater Dublin Area (GDA) cycle network, yet cycling in Dublin has declined (DoT, 2008). Table 1.0 shows the breakdown of Dublin commuters aged 15 and over walking to work between 1996 and 2011 and Table 2.0 outlines the breakdown of cyclists in the same age category during the same period.

Table 1.0: Dublin commuters aged 15 years and over, walking to work (1996-2011)

Year	1996	%	2002	%	2006	%	2011	%
Total Pedestrians	45915	8.41	62657	12.95	70688	12.94	62693	13.66
Male	18572	3.40	25084	5.18	29100	5.33	25321	5.52
Female	27343	5.01	37573	7.76	41588	7.62	37372	8.15
Total Commuters	546096	100.00	483964	100.00	546096	100.00	458833	100.00

(Source: CSO, 2011)

Table 2.0: Dublin commuters aged 15 years and over, cycling to work (1996-2011)

Year	1996	%	2002	%	2006	%	2011	%
Total Cyclists	20644	3.78	19311	3.99	20644	3.78	25539	5.57
Male	15821	2.90	14891	3.08	15821	2.90	18389	4.0
Female	4823	0.88	4420	0.91	4823	0.88	7150	1.56
Total Commuters	546096	100.00	483964	100.00	546096	100.00	458833	100.00

(Source: CSO, 2011)

From Tables 1.0 and 2.0 it can be seen that the percentage of commuters both walking and cycling to work are extremely small. In the case of cycling (Table 2.0) the modal share climbed from 3.78% in 2006 to 5.57% in 2011. Yet, this constitutes no significant change in the overall share of transport modes in the last decade.

Spending on infrastructure still heavily favours the car as a mode of transport. Politicians find themselves faced with demands for more roads from the public and lobby groups, despite the fact that the annual cost of gridlock to the Irish economy, caused by motorised traffic, was estimated by The Irish Small and Medium Enterprise Association (ISME) as €2.5 bn (O'Doherty, 2008).

Guckian (2007) stated in a report to the 'Foundation of the Economics of Sustainability' that *"The NDP unfairly and inequitably focussed on road-building to the great detriment of public transport development and the more sustainable modes of rail and coach, based on an unscientific and challengeable belief that roads were essential to economic growth"*. Little has changed since then; the investment in road infrastructure is still twice as high annually as investment into public transport (Transport21, 2010). The construction of 750 km of motorways linking Dublin with other cities alone has cost €8 billion (Transport21, 2010). The then Minister for Transport announced an additional €1.115 billion investment into the National Roads Programme from 2010 (NRA, 2010) under the Transport 21 Programme and the National Development Plan (NDP). This investment demonstrates Government's continued commitment to upgrade the State's national road infrastructure (NRA, 2010) and thereby favour the car as the main mode of transport in Ireland.

However, sustainability as a paradigm has entered the realm of urban, traffic, social and infrastructure planning. 'Sustainable Development - A Strategy for Ireland – 1997' (DoE, 1997), 'A Platform for Change (DTO 2001) and 'The Irish Transport Strategy Vision 2020' (DoT, 2008) all make reference the need to change existing transport policies and the need of future transport policies to be guided by the principle of sustainability.

In Ireland sustainable transport and cycling in particular suffer on a national level from a lack of recognition and uneven funding compared to spending on infrastructure for the car. Although the NDP aims to create a sustainable transport network in Ireland, the actual spending on motor traffic infrastructure indicates that Irish politicians still favour the car as the main form of individual transport. This apparent dependence on the car as the most important form of transport is resulting in enormous cost for both economy and society (DTO, 2001; Scallan, 2007).

Thus it can be seen that Dublin is a car dependent city with low modal share for cycling. This fact has been recognised by strategic development plans as early as 1997 (DoE, 1997). Subsequent strategies to revive cycling as a mode of transport have however been unsuccessful. This is especially true for the implementation of the Dublin Strategic Cycle Network that was aimed to boost cycling in Dublin by supplying quality cycling infrastructure (DoT, 2008). The following sections will examine the advantages of cycling to school and the modal share of cycling to school in Dublin, respectively.

2.9 Cycling to School

The acknowledgement of the importance of an active life style for children and youth has led to a search for ways to improve on the levels of physical activity in everyday life. The journey to and from school can be an important part of a physical activity regimen (WHO, 2002).

Cycling to school often becomes a focus of attention as the numbers of children cycling to school can be very low while the numbers of children walking to school remain relatively high (DTO, 2007). The distance from home to school is an important factor in children's transport mode choice. Jensen *et al.* (2006) conclude that an important reason for a high percentage of Danish children to walk and cycle to school is to be found in the decentralised school structure in Denmark. As a result of this decentralisation about half of Danish children live less than 1.5 km distance from school.

Cycling also increases the range that children can travel without relying on motorised transport. Research has shown that children who cycle to school travel an average 0.2 miles (0.32 km) further than children who walk to school (Kweon *et al.*, 2006). The distance of 0.2 miles is not far however, it has been shown that a 1 mile (1.6 km) increase in distance decreases the odds of active commuting to school by 71% (Nelson *et al.,* 2008). Nelson *et al*., (2008) also showed that in Ireland the majority of walkers lived within 1.5 miles (2.4 km) and cyclists within 2.5 miles (4.0 km) of their school, with approximately 4 in 10 car users living within 2.49 miles (4.0 km) of their school. Dessing *et al.* (2014) found that the proportion of walking trips declined significantly at increased school trip distance, whereas the proportion of cycling trips and motorized transport increased for children aged between 6 and 11 years in six schools in the Netherlands. Thus cycling to school can have a significant potential for a shift from inactive transport to school to active transport to school.

2.9.1 Cycling to School in Dublin

In Dublin the modal share of the bicycle in general and for children cycling to school is quite low. Tables 3.0 and 4.0 show the means of travel to school for Dublin school children between 1996 and 2011.

Table 3.0: Dublin children aged between 5 and 12 years, means of travel to school, 1996 to 2011 (CSO, 2011)

Year	1996	%	2002	%	2006	%	2011	%
Means of Travel								
On foot	55896	50.43	47121	42.42	46453	41.87	43223	41.8
Bicycle	1370	1.24	1590	1.43	1942	1.75	2534	2.45
Bus	13304	12.00	9622	8.66	8154	7.35	6053	5.85
Rail	360	0.32	327	0.29	462	0.42	488	0.47
Car Passenger	29914	26.99	45458	40.92	47779	43.07	46526	45.0
Total	110833	90.99	111077	93.73	110943	94.45	103412	95.57

Table 4.0: Dublin children aged between 13 and 18 years, means of travel to school, 1996 to 2011 (CSO, 2011)

Year	1996	%	2002	%	2006	%	2011	%
Means of Travel								
On foot	35608	43.90	31862	39.97	29311	38.86	25741	37.67
Bicycle	8624	10.63	5480	6.88	4374	5.80	4194	6.14
Bus	21616	26.65	20400	25.59	18985	25.17	15983	23.39
Rail	2390	2.95	2814	3.53	3702	4.91	3226	4.72
Car Passenger	11698	14.42	15008	18.83	15992	21.20	16826	24.62
Total	81118	98.54	79705	94.80	75418	95.95	68333	96.54

The DTO found that in the GDA the percentage of students that cycle to school had fallen from 4% in 2002 to 3.6% in 2006 (DTO, 2007). One of the main reasons provided by parents for not letting their children cycle to school was traffic safety concerns. The importance of children's independent travel recreational cycling is reviewed in the following section.

2.10 Children's independent travel and recreational cycling

Allowing children to explore their local build environment without the supervision of an adult is of significant benefit to them, as independently deciding where to go and what to do is an important part of growing up (Mackett *et.al.*, 2007). The utility of cycling is important for children's independent mobility. Cycling can improve the independence of children by increasing the range of their movement (Kweon *et al*., 2006) as it enables them to visit friends, commute to school or sports activities, or to explore their living quarters (Huttenmoser, 1995). The street itself is an important area for children's play and is not simply an infrastructural component. Abu-Ghazzeh (1998) found that the street functioned as an agent of socialisation and plays a central role in the physical, cognitive, social and emotional development of a child. Children seek streets and roads as places to play, even when presented with a diverse range of play opportunities (Francis, 1985). Interpreting children's cognitive maps Halseth *et al.,* (2000) found that all children had a strong sense of roads and pathways as they play a major role in their daily lives.

The bicycle can also be considered a toy. Children enjoy cycling as a recreational pastime and a form of transportation (Macpherson *et al.,* 2001). Sports including mountain biking benefit children through experience of the natural environment and may encompass multiple benefits for well-being and the future development of healthy lifestyles (King, 2010).

Cycling to school can be a healthy and independent mode of transport. Distance and safety are important factors that influence the modal share of cycling. Dublin has seen a drop in cycling to school in recent years that coincides with a general drop in cycling in Dublin. While there are no figures on children's recreational cycling numbers, it is shown that exploring the local area independently by foot or by bicycle is an important part of growing up for children.

As safety is essential for a cycle friendly environment, the issue of perceived and actual dangers when cycling is reviewed in the following sections. Special attention is given to children's traffic safety when travelling independently.

2.11 Cycling Safety

Cyclist's road safety can be divided into three themes as follows:

1. Engineering and Town Planning: In EU countries motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians and cyclists (Hobbs, 2001; Lynam *et. al.*, 2005). Years of car orientated traffic planning have led to road spaces which are often alien to cyclists. In many European cities traffic engineers and town planners are now attempting to re-design road space in a way that allows bicycles and pedestrians to travel more safely. These measures include:
    - Motorised traffic with a flow or distribution function which must be segregated from non-motorised transport.
    - A network of main traffic routes should be created for pedestrians and cyclists.
    - A fair balance between motorised and non-motorised traffic for priority facilities at crossings should be achieved.
    - The maximum speed of motorised traffic should be limited on roads where it mixes with non-motorised traffic (SafetyNet, 2009).

2. Law and Enforcement: The rules of the road play a major part in road safety. Speed limits for motor traffic, rules and regulations on wearing bicycle helmets, bicycle lights and reflectors are just some examples that show how cycling is believed to be made safer by introducing laws aimed at changing unsafe behaviour of road users. The presence of a policeman or lollipop lady on an accident black spot would be another one (SafetyNet, 2009).

3. Education: The education of motorist and cyclist is a tool which can improve roads safety (SafetyNet, 2009).

Road safety concerns are often given as the main reason for people not to cycle (Pucher *et. al.*, 2003; Sonkin *et. al.*, 2006; DTO, 2007; Parkin, 2007; Dumbaugh, 2007) however, many other reasons exist including:

- Distance (DTO, 2007; Parkin, 2007; Muller *et. al.,* 2008; Nelson, 2008; Wen *et al.,* 2008)
- Weather (Parkin, 2007)
- Topography (Parkin, 2007)
- Neighbourhood layout (density, land use and mixture) (Handy, 2002)
- Stranger danger or fear of animals (Limbourg, 2001)
- Car ownership (Wen *et al.,* 2008)
- Age (CSO, 2009)
- Gender (CSO, 2009)
- Ethnicity (Limbourg, 2001)
- Parental perceptions of (the safety)the environment (Timperio *et al.,* 2004)

Local governments in The Netherlands, Denmark and Germany have already defined the solutions required to ensure that cities are cycle friendly (Pucher, 2008). In particular, the Dutch extensive cycling infrastructure is seen by many as exemplary. However, the Irish cycling lobby group Cyclist.ie does not believe that the Dutch and Danish solutions to make cycling safer can be simply transplanted into Ireland and instead advocates a hierarchical approach, where built cycle facilities get the lowest priority coming behind traffic reduction, speed restraint, traffic management and junction treatment that recognises the needs of cyclists and allocating existing traffic lanes in a way that gives them more space (Cyclist.ie, 2010). Key measures to promote cycling include:

- Motorised traffic speed reduction
- Traffic volume reduction

- Driver instruction and testing regimes that include safe interaction with cyclists
- Traffic skills training for cyclists starting at school level
- Comprehensive provision of secure cycle parking
- Elimination of urban multi-lane one-way streets
- Two-way access for cyclists to one-way streets
- Elimination of cyclist-hostile road features such as slip roads and large roundabouts
- Bicycle friendly adaptations to traffic signals
- Adequate road surface drainage and maintenance
- Creation of a "cyclist permeable" urban environment
- Restrictions on HGV access to urban areas
- Shared bus/cycle lanes of appropriate safe width
- Where appropriate, cycle lanes/hard shoulders of adequate width (2m minimum) (Cyclist.ie, 2011)

This list, which excludes segregated cycle lanes completely, is contradictory to the results of many diverse research projects as a means to ensure cycling is safer and more pleasurable and especially well suited to attract demographic groups less associated with cycling (Garrard, 2003; Garrard *et al.,* 2008; Pucher, 2008). It is however important to note that segregated cycling infrastructure is only part of the solution. Safety, convenience, and attractiveness have to be reinforced through a number of measures, including cycle friendly rules of the road, extensive bike parking, integration with public transport, comprehensive traffic education and training of both cyclists and motorists and promotion (Pucher, 2008).

2.11.1 Cycling / Pedestrian Risk

Assessing the danger which cyclists are exposed to is very difficult when considering the nature and versatility of the bicycle. It is many things to many people and easily jumps between its different uses and users. In Ireland, everyone is allowed to cycle on public roads and in public spaces, unless specifically prohibited to cycle. As soon as a person is able to ride a bike, he or she can do so until it becomes physically impossible and there are no exceptions to this rule. Cyclists are obliged to obey the rules of the road and in some countries there are specific rules concerning riding a bike in public. In Australia and New Zealand it is mandatory to wear a bicycle helmet, whereas in Germany bicycles by law must be equipped with lights, brakes and reflectors (Verkehrsportal, 2012).

Assessing how safe or dangerous cycling and walking are compared to other modes of transport is difficult. Reliable figures of travelled kilometres or time spent travelling as per mode of transport per capita are difficult to obtain, and there are gray areas including near misses and unreported accidents. Sonkin (2006) used data from the Office for National Statistics and Department for Transport's National Travel Survey in England and Wales to estimate death rates per 100,000 children and per 10 million child passenger miles for pedestrians, cyclist and car passengers aged 0-14. This research concludes that in England and Wales for each mile travelled child cyclist are 50 times and child pedestrians are nearly 30 times more likely to be killed than child car passengers. However Wardlaw (2002) found that British cyclists in general do not face a higher risk of road death than motorists and could even be considered safer as the higher user risks were balanced by reduced risks imposed on third parties. Pucher *et al.*, (2003) suggests that American pedestrians and cyclists were much more likely to be killed or injured than Dutch and German pedestrians and cyclists, both on a per-trip and on a per-kilometre basis. For Ireland only absolute numbers are available for cycle and pedestrian injuries through the RSA**.** In 2011, nine pedal cyclists were killed and 395 were injured in collisions. Cyclists made up approximately five per cent of all fatalities. 47 pedestrians were killed and 930 were injured, while 95 car occupants were killed in collisions accounting for 51 per cent of all fatalities. An additional 4,930 were injured (RSA, 2011).

2.11.2 Traffic Safety for Cyclist and Pedestrians in Dublin

There were 388 minor and 28 serious collisions involving cyclists reported to the Garda in Dublin city over the period from 2002 to 2005, 11 of which were fatal.

Eight of these cyclists were killed by left-turning lorries, one death involved a vehicle hitting a cyclist when changing lanes, in one case a vehicle rear-ended a cyclist and one another death was caused by a stolen vehicle driving head on into a cyclist (Conlan, 2009).

The most common minor collisions involved right-turning cars which accounted for 20% of incidents. The second most common collision type is classified as 'side swipes', which occur where a vehicle overtakes a cyclist or changes lanes and subsequently hits the bicycle. These accounted for 15% of collisions. Unexpected or sudden vehicular door opening accidents accounted for about 14 % of incidents and 12% of cyclists were injured by left-turning vehicles (Conlan, 2009). Crashes, where the fault could be attributed to the cyclist, accounted for a much smaller proportion of incidents. In just over 4% of incidents a cyclist hit a pedestrian, while in fewer than 3% of collisions a cyclist turned right into on-coming traffic (Conlan, 2009).

The more serious a crash, the more likely it was to involve a vehicle turning left. Almost one-third of accidents resulting in serious injury to a cyclist involved a left-turning vehicle. In the majority of left-turning collisions the HGV driver did not see the cyclist (Conlan, 2009). November was found have the highest rate of collisions and cyclists between the ages of 20 and 29 were the most likely to be involved in incidents. Several collisions occurred when cyclists were forced to move out of the lane to avoid potholes or sunken gullies. From this evidence the top four types of minor cycle accidents are:

- Drivers turning right in front of an oncoming bicycle.
- Drivers hitting a bicycle when overtaking or changing lanes (Sideswipe).
- Car doors being opened in front of cyclists.
- Drivers hitting cyclists when turning left.

The top three types of serious cycle accidents are:

- Drivers hitting cyclists when turning left
- Drivers turning right in front of an oncoming bicycle.
- Drivers hitting a bicycle when overtaking or changing lanes (Sideswipe).

Recommendations by DCC include:

- "Cyclops" mirrors made compulsory on all HGVs.
- Segregation of bicycles and HGVs where possible.
- Awareness campaign on the danger of left-turning HGVs.
- Upgrade of cycle lanes to remove potholes, sunken gullies and poor surfaces.
- Enforcement of legislation regarding the use of bicycle lights.
- Encourage more cycling to produce a "safety in numbers" effect.
- Provide additional cycling infrastructure on a "most used routes" priority basis.
- Inspect all cycle lanes annually.
- Further research; Identify why certain locations recorded lower cycle numbers. Was it as a result of population size, infrastructure or general attitudes towards cycling? If either of the latter two applies, target potential cyclists in these areas using improved infrastructure and local advertising.

Pedestrians are an especially vunerable road user group in Dublin. On average over the period 1998 to 2007, 47% of fatalities and 24% of injured persons were pedestrians. When pedestrians are involved in collisions with motor vehicles, it is highly likely that their injuries will be serious (DCC, 2009).

Yet, these figures are only the tip of the iceberg. A 2011 study on road traffic collisions (RTCs) requiring hospitalisation in Ireland by the HSE (Health Service Executive) showed that a vast number of traffic accidents requiring hospitalisation go unreported by the RSA (Sheridan, 2011). This report showed there were 14,861 persons treated as inpatients in hospital with RTC-related injuries from 2005-2009. This number is 3.5 times greater than the number of serious injuries reported by the RSA using An Garda Síochána data (4,263). In particular, the number of cyclists injured is under-estimated in the RSA figures. The hospital data shows that there were 1,050 cyclists admitted to hospital between 2005 and 2009. Over the same period, just 109 serious injuries among cyclists were reported by the RSA. The report also showed that a great number of road traffic collisions involving children are not recorded by the RSA.

2.11.3 Children's Traffic Safety

Road infrastructure is in many cases designed to cater for adults (Limbourg, 1997). On reviewing the current literature on how certain road safety measures affect children's safety on route to school, Dumbaugh and Frank (2007) concluded that children and adults behave so differently in traffic that strategies designed to enhance traffic safety for adults might have no effect on the traffic safety of children. To fully participate in traffic in a safe way children have to rely on abilities that are usually acquired on a step by step basis throughout childhood (Limbourg, 1997) and so may be ill-equipped to partake of the existing infrastructure. A survey of primary school children in Essen, Germany, found that only 30% of children considered their route to school to be safe and 70% could locate potentially dangerous points on their route to school (Limbourg *et al.,* 1996). Limbourg *et al.* (1996) also found that speeding cars, heavy traffic, motorists being careless when turning, cars parked on cycle lanes and inadequate infrastructure were the main sources of danger to children in traffic.

Further studies in Germany show that depending on their mode of transport, children face considerable risks on their journey to school (Limbourg, 1994; Obertacke *et al.,* 1996; Statistisches Bundesamt, 1997; Flade *et al.*, 1997). A survey of pupils in the age groups of 10/12 to 14/16 years in six German cities (Hamburg, Darmstadt, Münster, Bielefeld, Bottrop and Oberhausen) found that an average of 26% of pupils had been involved in traffic accidents, indicating that a high number of accidents are not reported to the police. The highest type of traffic conflict in these studies was found to be between the bicycle and the car (Flade *et al*, 1997). Previously research by Zippel (1990) and Hautzinger (1993) into collisions between bicycle and car also found that a large number of accidents go unreported and that 90% of bicycle accidents involving children and half of all pedestrian accidents were not registered by police.

The perceptive view of parents, judging the road safety of their children, has been shown to have a strong influence on the child's ability to independently take part in road traffic (Sigl and Weber, 2002; Timperio, 2004). A main contributor to the parent's perception of danger is the volume of traffic in a specific area (Gärling *et al.* 1984; Gärling, 1988; Gärling, 1990). A further worry for parents is the fear of child molestation and kidnapping. Anti-social behaviour and aggressive dogs are often given as reasons for children not feeling safe, which can lead them to stray from their usual route to school. Thus for parents to be confident to let children travel by themselves children should be safe from dangers posed by traffic or social concerns on the route to school.

It should also be noted that transporting children to school by car is not necessarily less dangerous. German traffic statistics show that children as car passengers (especially when unrestrained) are more likely to be fatally injured than cyclists or pedestrians (Statistisches Bundesamt, 2001). In 2001 in Germany, 42 805 children under the age of 15 were injured in road traffic accidents, of which 35.5% were car passengers 32.4% were cyclists and 27.2% pedestrians. On route to school most accident victims were cyclists and aged between 10 and 14 years (Statistisches Bundesamt, 2001).

2.11.3.1 Frequency of Child Traffic Accidents

A number of factors have been found to have a significant relationship with the frequency of child traffic accidents these include:

1. Time of Day: 15% of all child traffic accidents happened in the time before classes start and 11% just after classes end and in the afternoon. (Statistisches Bundesamt, 2012).

2. Time of Year: In Germany cyclists between the age of 6 and 14 are more likely to be involved in an accident between April and September when 70% of accidents happen. For pedestrians of this age group no significant

differences between the seasons are noticeable. (Statistisches Bundesamt, 2012).

3. Place: Most child traffic accidents happen close to home, child pedestrian accidents mainly occur away from cross roads, child cycling accidents tend to happen at turn offs (Statistisches Bundesamt, 2001).

4. Age: Children contribute to accidents as pedestrians: The sudden crossing of roads and the sudden appearance from behind obstructions without checking the traffic. Or as cyclists: Faulty turns, faulty stopping or starting, not yielding right of way. The main age of child pedestrians involved in traffic accidents is 7-9 years for boys and 10-11 years for girls. At this age children often walk to school. For cyclists, children between the ages of 12 and 15 are often involved in road traffic accidents. At this age children use the bike frequently (Funk and Fassmann, 2002).

5. Motorists: Motorists are found to be at fault in 50% of all accidents (Statistisches Bundesamt, 2001). The most common mistakes made by motorist are overlooking cyclist and pedestrians when turning off, overlooking traffic lights and disobeying speed limits.

6. Gender: In Germany Boys under the age of 15 are more often involved in road traffic accidents than girls. Per 100 000 residents 297 boys are involved in traffic accidents, compared to 243 girls per 100 000 residents. (Statistisches Bundesamt, 2012).

7. Social background and place of residence: Children from poorer socio-economic background are more often involved in traffic accidents than children with a better off background (Kendrick, 1993). Poorer areas are generally more densely populated, with more car traffic and fewer

playgrounds. Research from Dortmund (Germany) found correlations between child traffic accident ratio, social structures and housing structure (Kenneweg, 1997). The children most at risk are those from "families on lower incomes who often live in large council estates where there is little owner-occupation" and are found in most regions in the UK (Road Safety Analysis, 2010)

8. Temperament and personality: Hyperactive, impulsive and easily distracted children are more likely to be involved in a road traffic accident (Limbourg, 1995).

9. Clifton *et. al.,* (2006) found that on schools in Baltimore City (USA) the presence of a drive way or turning bay at the entrance of a school decreased both crash occurrence and severity, while the presence of recreational facilities is associated with a higher number of crashes and a greater severity of injuries.

Many of these factors and their respective statistics correlate with research findings from the United Kingdom where postcodes were used to compare risk levels among children aged up to 15 years across 408 local authority areas (Road Safety Analysis Ltd, 2010). On analysing more than 120,000 road casualties influencing factors were found to be:

1. Age: even from the age of one; boys are more likely to be injured on the roads than girls.
2. Day: road safety danger was found to reach a peak on Friday, followed by Saturday with Sunday notable the safest day.
3. Month: May was found to be the month with the highest number of recorded child casualties, with around 25% more injuries reported than in the winter months (Road Safety Analysis Ltd, 2010).
4. Socio-Demographic: The children most at risk are those from "families on lower incomes who often live in large council estates

> where there is little owner-occupation" and are found in most regions in the UK, with the exception of the South East and London. (Road Safety Analysis Ltd, 2010)

2.11.3.2 Child Specific Road Traffic Problems

To avoid road traffic accidents there are a number of recognised abilities which are only learned and developed through childhood (Limbourg, 1995; Limbourg, *et al.,* 2000) which are discussed here in more detail. The ability to realise and judge dangers and to learn how to avoid them develops at an age of about 8-10 years. Where vehicles are travelling at speeds above 20 mph, children of primary school age, 6-11 years, may not be able to determine that a car was approaching them (Wann, 2011). Learning to concentrate and not to be distracted will generally begin at about 8 years and is only fully developed at approximately 14 years of age, before that children in traffic are not able to concentrate on two things at the same time (Limbourg, 1995). Before the age of 7 children are not able to pre-emphasise the actions of other road users, they believe that if they can see someone, they are seen themselves (Limbourg *et al.,* 2000). Children have a great urge to move and be active, up to the age of 8 they find it difficult to stop a motion once they have begun and only when they reach the age of 8 to 10 years do they develop the necessary motor skills to ride a bicycle independently in traffic, being able to balance, break and steer through curves (Basner and de Marées, 1993; Borgert and Henke, 1997) and at the age of 12 they have required the necessary understanding of the road traffic.

Cyclists in general and children cycling in traffic are in danger from road traffic accidents, and this danger can negatively influence the number of children using active modes of transport negatively. A number of these dangers are child specific and show that it is not a given that road safety features designed with adults in mind necessarily increase road safety for children.

The following Sections review the literature on the use of GIS in cycle research and children's ability to use and understand maps.

2.12 GIS in Pedestrian and Bicycle Research

The analytical potential of maps has been greatly improved through the development of GIS and many research projects which undertake spatial analysis of pedestrian and cycling related issues have successfully used GIS. For example, Lightstone (2001) used GIS to illustrate the relationship between age and the specific location on a road in the occurrence of child pedestrian accidents in Long Beach USA. In this study children less than 5 years of age were found to be significantly more likely to be hit at a midblock location, while those aged 5–9 and 10–14 were more often hit at an intersection (Lightstone, 2001). A separate GIS analysis of pedestrian injury data in Vancouver, Canada highlighted 32 pedestrian injury hotspot locations (Schuurman, 2009).

GIS has been used to combine different data sources to create an in-depth analysis of complex dependencies in terms of cycling safety and traffic management. For example, by combining origin and destination data for cyclist commuters in the City of Hamilton, Canada, with a detailed street network to estimate the routes of commuter cyclists, allowed researchers to calculate a collision risk at neighbourhood level for cyclist collisions with motor vehicles (Yiannakoulias, 2012). Whereas Aultman-Hall (1997), Klobucar (2006), Rybarczyk (2010) and Panter (2010) used GIS to examine the influence road networks, demographics, and urban environment have on cycling and walking as mode choices. Klobucar (2006) used bicycle accident data to design a GIS based Bicycle Network Analysis Tool to assess the bicycle friendliness of a local road network. Rybarczyk (2010) also used GIS to combine detailed road network data and demographic data to develop a supply- and demand-based bicycle facility planning tool. GIS has also been previously used to examine 2012 children’s active commuting behaviour in the county of Norfolk, United Kingdom where Panter (2010) found that neighbourhood and route factors are associated with the level of walking and cycling to school. These studies however, depend on presumed route data, obtained using existing origin/destination data and digitised road networks to determine the routes that cyclist or pedestrians are likely to take, as the exact actual route, consisting of the series of links, used by a person to travel through a transportation network is rarely collected (Aultman-Hall, 1997).

2.13 Children and Maps

Surveying children poses distinctive methodological problems. Surveying children by questionnaire for instance requires the researcher to tailor questions to suit the specific age groups or developmental stages of child respondents (Borgers, 2000). Children's concentration span, reading and writing abilities, the survey environment and presence of teachers or peers can influence the answers given in written questionnaires or structured interviews (Borgers, 2000). Thus to research complex questions such as children's travel and outdoor play behaviour, or their use of urban space, a number of survey tools have been developed as outlined in the literature (Meire, 2007). For the purpose of this research only the area of Children's maps will be considered here.

Mapping is a very commonly used visual technique in children's participation (UNICEF, 2005). That children are capable of reading and understanding maps was shown by Lolichen (2007) when children between the ages of 6 to 18 conducted their own survey in the town of Karnataka, India, identifying and mapping local resources and listing the problems and issues related to them in their local district. Blanchet-Cohen (2003) also found the use of visual maps to be an effective research tool with children. In this study 400 children aged 10 and 12 years old representing 60 countries found coding maps to be both fun and meaningful in addition to providing a rich source of data for further analysis.

The age at which children can use and understand maps is debatable. Piaget (1929) asserts that young children up to the age of seven cannot conserve or use logical thinking whereas more recent research by Plester (2002) found that four- and five-year old children were able, if not perfect, young navigators, in a large scale familiar environment, whether using small or large scale aerial photographs or a large scale oblique map. Sobel (1998) showed how children made sense of places in different ways at various ages - when asked to draw maps of places that they know and value, young children's (aged six) representation of place changes from pictorial and home-centred maps through to neighbourhood maps incorporating dimensionality, pathways and special places when aged seven to eight. Older children (aged eleven to twelve) begin to produce abstract, aerial and wide area maps, differentiating between residential and business areas, and from thirteen years upwards are able to create formalised maps that would be comparable to street maps. This indicates that, children's mapping skills become more sophisticated as they mature. Kitchen (1994) and Golledge (2003) describe cognitive maps as a multidisciplinary research tool. They can explain spatial behaviour, spatial choice and decision making and have an applied worth in researching children's environments (Kitchen, 1994). Research into children's cognitive maps by Halseth (2000) also found that younger children (aged five) drew mostly roads, whereas older children up to age thirteen tended to draw a greater variety of paths and that children were able to identify places, paths, landmarks, and other features in the local environment through the medium of maps, thus indicating that children's maps can provide a valuable source of information.

2.13.1 Child Cartographers

Valuable insights into children's use of open space was observed by Winter (1985) who used a behaviour map of the Village Homes Estate in California, USA to show locations of children's outdoor activity, the technique applied here was to observe children's outdoor behaviour and mark them on a map. However, children are also accurate cartographers and navigators as shown by Rissotto (2002) who used maps drawn by eight - eleven year old children in the city of Rome to prove that children who walked to school had greater environmental (local area) knowledge than children who are driven to school. In Rissotto's (2002) study children going to school on their own performed better in drawing their movements on a blank map of the quarter than children who are driven to school. The 'Children's Tracks' project, implemented in the Municipality of Andebu/Vestfold, Norway, also used mapping data collected by children aged between eight and thirteen to identify play-areas and tracks or paths that were important to them as well as any areas that were considered dangerous (Children's Tracks, 2012). The 'Childrens Tracks' project is of significance to this research because of the following:

- Children drew routes on provided maps.
- The maps were physical representations of their activities and required little, if any, interpretation.
- The gathered information could be used as either qualitative or quantitative data.
- The process was participatory.
- This process now forms part of the planning process in Vestfold and has been adopted throughout Norway and Sweden.

Based on the 'Children's Tracks' method (Berglund, 2008; Nordin *et al.,* 2010) developed a mapping exercise for children between ten and eleven years of age using standard maps which found that in the majority of cases the children could orient themselves on the map relatively easily when first shown how to locate their school and home.

The use of GIS has greatly improved the analytical potential of maps. This analytical potential has also been used successfully in cycling research. GIS depends however on accurate data to fulfil its full potential. The availability and acquisition of this data can be problematic when it comes to a subject like cycling, as the use of the bicycle is dependent on a number of factors. Maps can play an important role in acquiring this data.

Maps are also an important medium in researching children and in child participation as outlined in Section 2.6.1. Children are able to understand maps and to use them to communicate issues that affect them. The maps produced in this research greatly resemble Accident Black Spot Maps and rely on the same principle: that if a location attracts a high number of negative markings then this is related to a problem that is inherent to this location. The following sections will examine the use of accident black spot detection in road engineering.

2.14 Road Traffic Accident Black Spots

The complex character of road traffic has led some EU countries to the development of highly sophisticated procedures and models to determine what and where Black Spots actually are. The EU Directive (2008/96/EC) on road infrastructure safety management is intended to improve safety on the Trans European Road Network (TERN) (EU, 2008) and the (Accident) Black Spot Management (BSM) tool is intended to help achieve this Directive.

A great number of variables can be present and decisive in the case of any road accident. Factors that can contribute to an accident range from the nature and state of traffic infrastructure to vehicle type and condition, accident victims, weather and light condition and a range of other local conditions. However, there is no universally accepted definition of an accident black spot and according to Hauer (1996) researchers rank locations by different methods including:

- Accident rate (accidents per vehicle-kilometres or per entering vehicles)
- Accident frequency (accidents per km-year or accidents per year)
- A combination of accident rate and frequency
- Accident types considered susceptible to treatment
- The magnitude of either of rate or of frequency
- By the amount by which the rate or frequency exceed what is normal for such sites.

Thus, although accident black spot detection has been proven to be a valuable tool in traffic safety and traffic engineering (Sørensen, 2007), this tool has certain limitations depending on its design and intended use.

2.14.1 Road Traffic Accident Black Spot Detection

The identification of possible Black Spot locations has been established under two principles which can be used either independently or together as outlined by Sørensen (2007) these are:

1. Accident based Principals.

   Accident based principles are divided into model based, not model based and accident specific principles.

2. Non accident based principles.

   Non accident based principles are divided into quantitative and qualitative principles.

Each of these principles will be explained in detail in the following sections.

2.14.1.1 Accident Based Principles

The most commonly used accident based principles include frequency, rate, frequency rate, rate quality control and severity methods. However, one of the main problems in identifying Black Spots on accident based principles derives from data availability, data quality and the long time spans required to collect the necessary data (Elvik and Mysen, 1999; Sørensen, 2007, 2009). To overcome this statistical models are generally used to estimate accident rates and/or accident frequencies at a specific location over a given interval of time. In the Empirical Baysian method, the expected number of accidents at a specific location is estimated by weighting the registered number of accidents at the location and the general expected number of accidents for similar sites estimated by accident prediction models (Sørensen, 2007). The accident data for such a model needs to be detailed, extensive and regularly updated and these models must be established and monitored by specialists as the road network is subject to constant change. This process is difficult, lengthy and expensive and is probably only workable in the context of a national road network.

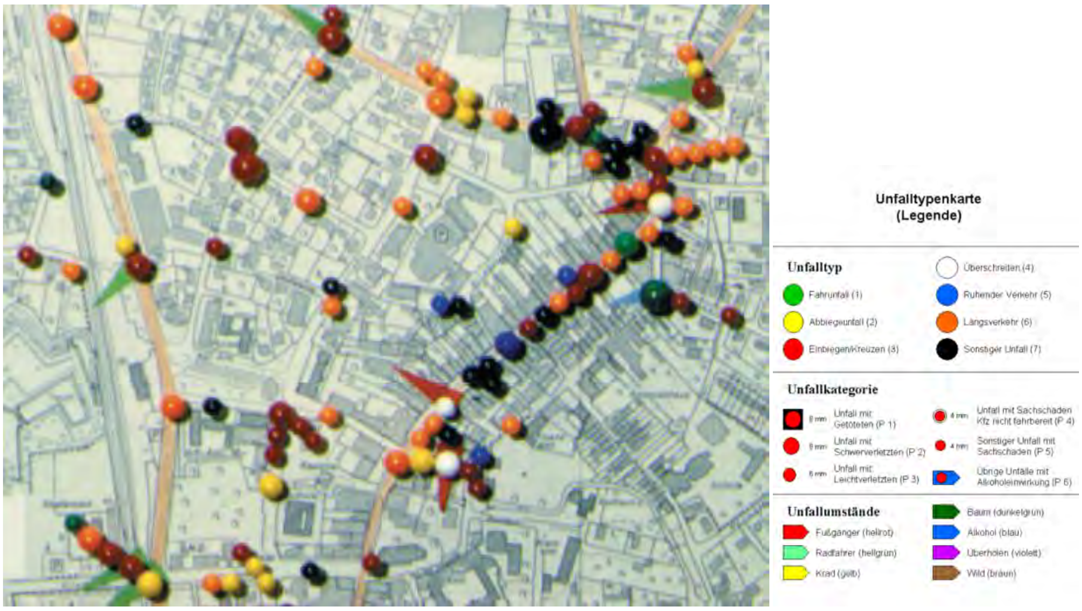


Figure 4.0: Unfalltypenkarte (Accident Typology Map) (GDV, 1974)

More basic versions of Black Spot detection include the Unfalltypenkarte (Accident Typology Map) whereby accidents on a map are simply located using a pin (GDV, 1974). Such typology maps as shown in Figure 4.0 above are relatively easy and cheap to set up. However, they too depend on accident data, and share the problem of a lengthy build up time with the model based method.

2.14.1.2 Non Accident Based Principles

Although accidents are still considered to be the best indicators to detect black spot locations several attempts have been made to incorporate non accident based data into Black Spot detection, whereby these methods aim to tackle the problem of data availability in statistical models (Hauer 1996, Sørensen 2009). Hauer (2002) proposed a cost effective method to manage road networks by 'Screening the Road Network for Sites with Promise' to prioritise sites for a later, detailed examination by road engineers. A different approach used in Thailand was based on the principal of Hiayri Hatto or 'Small Incident Reporting' whereby the near accident experiences of local inhabitants were used to create an accident black spot map, as actual accident data was missing (Sota, 2011).

Accident Black Spot Maps are a proven tool in road traffic safety. However, since this research attempts to substitute actual accident data with self-reported accident and near miss data the next section will examine at the principle of causality, deriving from the assumption that for every accident happening there are a number incidents that have the same root cause as the accident. Identifying these incidents enables one to remove the root cause and thereby preventing a more serious accident from happening. The following Section gives an overview of research into Near Miss Reporting.

2.15 Near Miss Reporting

The Heinrich Law (1931) theorises that for every accident that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries. As many accidents share common root causes, addressing more commonplace accidents that cause no injuries can prevent accidents that cause injuries (Manuele, 2011). Heinrich's Law (also known as the 'Iceberg Model') is illustrated in Figure 5.0. Although Heinrich's Law was challenged, most notable by Manuele (2011), a study of industrial accidents by Bird (1969) reached very similar conclusions to Heinrich.

Figure 5.0: Heinrich's Law (Manuele, 2011)

Today the method of Near Miss Reporting is regarded as a preventative measure in a number of different areas including Nuclear Safety, Hospital Safety Management, Air Traffic Safety, Marine Safety and Railway Safety (Van der Schaaf *et al.*, 1991; Davies *et al.*, 1998; Williams, 2001; Wright *et al.,* 2004)

In road traffic safety Von Klebelsberg (1982) linked driver behaviour to the frequency and severity of traffic accidents, and came to a similar conclusion as Heinrich. Although Klebelsberg does not provide ratios, he shows that the frequency of events declines with the severity of events (Figure 6.0).

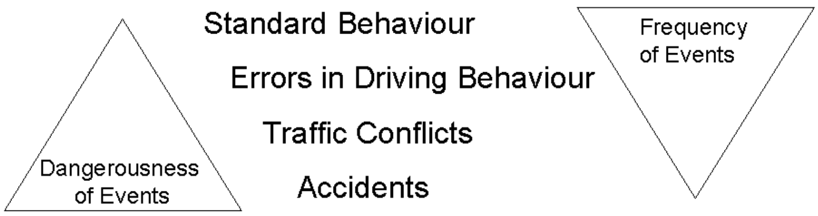


Figure 6.0: Road Safety Continuum Model (Von Klebelsberg, 1982)

Heinrich's assumption, formulated in 1931, that most accidents and near misses share the same root cause (Common Cause Hypothesis) is extremely important if this method is to be used in accident prevention. Yet, as far as Heinrich is concerned it was only that, an assumption, since he never proved this relationship (Manuele, 2011). In traffic research the hypothesis that accidents and near misses in the same area actually have the same root cause have only been proven to be true in a relative small number of studies. Wright *et al.,* (2004) have shown a close relationship between accident preceding factors and accidents in railway safety. Roberts *et al.*, (2004) found in an in-depth study of 98 company drivers a significant correlation between near accidents and actual self-reported accidents. Using structured interviews with 1,019 cyclists in Denmark, Møller *et al.*, (2008) also found that there a correlation between the perceived and actual risk of cyclists, his study focused on cyclists use of roundabouts. Route choice studies imply that these perceptions of risk might be a significant variable affecting route choice.

2.16 Gap in the Current Knowledge

As shown by the DTO (2007), Sigl and Weber (2002) and Timperio, (2004) actual road safety and perceived road safety of children is a major factor in children cycling to school. Dumbaugh and Frank (2007) found that there is a distinct lack of knowledge relating how common road safety measures affect children's road safety, and they noted only few examples where road safety measures are directed specifically at children. In the case of Dublin these measures usually consist of a lollipop lady, controlled crossings or speed restrictions in the vicinity of schools.

However, a safe route to school by bicycle would require that the road network surrounding a school has to be safe for children of various ages to use Johnston (2008), as the distance they travel by bicycle or on foot often exceeds the close vicinity of the school (Rissotto, 2002; DTO, 2007; Nelson *et al.,* 2008; Berglund, 2008).

Road safety effects all cyclists and it has been shown that such concerns deter more women than men from cycling (Hajinikitas, 2001), as women are more risk averse than men and tend to use safer routes while men use more direct routes when commuting to work in Melbourne, Australia (Byrnes *et al*., 1999). It is not known if this is true for children. Yet, if a road network was to be made cycle friendly for children it would be of great value to know where and how children travel within a road network.

A further research area with respect to children cycling that requires attention is the collection of data relating to actual distances travelled by bicycle. A number of studies have used assumed routes and presumed that a cyclist would use a most direct route to get from start to finish of a journey (Byrnes *et al*., 1999; Rybarczyk, 2010; Panter, 2010; Yiannakoulias, 2012). This is probably true for males commuting to work by bicycle (Byrnes *et al*., 1999), but this has not been proven for children cycling to school in Dublin. Furthermore, it has not been shown if they prefer certain road types or avoid others, or if they avoid busy roads. They might avoid or prefer routes for reasons that are not traffic related (Limbourg *et al.,* 1996). There is currently no data available about the actual distance travelled by children on the way to school by foot, bicycle or car. Furthermore, there is no data on what children perceive as dangerous, unpleasant or what they perceive to be safe or pleasant when travelling to school.

Berglund (2008) has used Maps and GIS to answer similar questions in Sweden. Aultman-Hall (1997) also made use of a GIS network database to determine the characteristics of 397 routes used by commuter cyclists in Guelph, Ontario, and compared them to the shortest path routes between each origin and destination. The analysis provides useful insight for understanding factors affecting travel behaviour such as grades, intersections, etc. The study recommends different priorities for improving conditions for existing cyclists and for attracting new cyclists to the network. Thus the question arises could a mapping and GIS analysis approach based on the work of Aultman-Hall (1997); Berglund (2008) and Children's Tracks (1998) be effectively adopted in a Dublin sub-urban location to solve some of the research issues discussed above and if so how can data originating from young children commuters be effectively used?

One study of note was in Vestfold County, Norway where a method called Children's Tracks (Children's Tracks, 2012) involved children between the ages of 8 – 13 years in the local planning process. The goal was to have children actively map the outdoor play spaces they enjoyed in their community. Local children were asked to map: where they lived; areas/ places/ playgrounds they used during the summer, winter, and year round; streets/ roads/ trails that were used; as well as any areas that they perceived as dangerous. One positive spin-off of the project was that traffic safety dramatically improved in Vestfold County The hand drawn maps created by the children were compiled digitally and informed the Vestfold County Municipal Master Plan. The final report submitted to politicians has also been circulated to the children who participated in the initial mapping.

Based on this project Berglund (2008) developed a method called Children's Maps in GIS to involve children and teachers in the urban planning process. A GIS application with a built-in questionnaire was designed to survey 10- to 12-year-old children in Sweden. Eighty-seven children and seven teachers took part in a pilot study. In this survey children drew maps of their routes to school directly on a computer and answered a number of questions about the local area from a drop down box. This survey produced accurate route data of the children's routes to school. However, the focus of this study was the children's use of the area in general, and the resulting data was of value mainly to urban planners.

While this research builds on the method used by Berglund (2008) the focus in this study is primarily on road safety and perceived danger on route to school. Previous studies have not gathered real data from children on their daily commute to school and their interaction with the local road network specifically with respect to:

1. Directness of routes of children cycling and walking to school in Dublin.
2. The actual distance travelled to school by mode of transport.
3. Preferences or adversity of children walking or cycling to school in Dublin to different road types within the local road network.
4. The ability of children to locate areas of perceived danger within the local road network.
5. If data of perceived and actual danger be used to accompany or surrogate RSA accident data.

A problem that Dublin shares with many other cities, is the low numbers of children cycling to school. As a result there are a relative low number of accidents involving children cycling. This could be incorrectly judged as a sign of safety. There is a possibly that the number of accidents may increase if the promotion of cycling to school is successful. The relative small number of recorded accidents can also be explained by the fact that these accidents are only recorded if they are so severe that they are recorded by the Gardi or result in hospitalisation. Studies by Zippel (1990) and Hautzinger (1993) have found that 90% of bicycle accidents involving children and half of all pedestrian accidents in Germany were not registered by the

Police. In Ireland, Sheridan *et al.* (2011) found that a great number of traffic accidents resulting in hospitalisation, were not recorded by the RSA. Yet, it is entirely possible that many unrecorded close calls or less severe accident experiences would have a serious negative effect on the perception of safety on route to school. Sota (2011) overcame a similar data issue in Thailand, where sufficient accident data to populate an Accident Black Spot Map was unavailable he used near accident experiences of local inhabitants. The resultant maps are populated with markers that show a location were an accident nearly happened as opposed to a recorded accident location. By following the principals of Near Miss Reporting (Manuele, 2011) a clustering of near misses can indicate locations with a high potential for the occurrence of an actual accident.

No data is available for child bicycle accidents in many parts of Dublin. This research attempts to combine the principles of Near Miss Reporting and Accident Black Spot Maps to overcome this lack of data. This innovative method, when extrapolated could establish a methodology to enable traffic planners to evaluate road networks for potentially dangerous locations for children cycling. As such data would generate potential Accident Black Spot Maps they could help to prevent the future occurrence of severe accidents.

3.0 METHODS

3.1 Methodological Framework

This research was conducted as a mixed method study relying on existing data, an area survey, a questionnaire and data from Children's Maps as outlined below in Table 5.0. This is closely related to the fact that the study subjects are children. Alternative research methods including observation, tracking, interviews and focus groups were considered (Table 5.0), however, the complications of conducting research with children rendered these methods unpractical as discussed below.

Methods Used		**Methods Not Used**	
Type	**Reason to use Method**	**Type**	**Reason not to use Method**
Analysing Existing data	To compare data with Children's Maps	Observation in the street / in traffic	Ethics
Area Survey	To confirm Road data	Observation in simulated road traffic	Practicality
Questionnaire	To compare to DTO Data	Interviews, Photo Diaries and Focus Groups	Access to children, practicality
Children's Maps	Main source of children's data	GPS tracking	Practicality

Table 5.0: Methods overview.

- Observation in the street / in traffic

Francis (1985) and Abu-Ghazzeh (1998) observed children in their local road network to learn about their use of outdoor spaces. To check the effect that mandatory helmet legislation for cyclists had on the numbers of children cycling, Macpherson and Parkin (2001) observed children cycling in an Australian suburb before and after and after legislation. Zeedyk *et al.* (2003) observed the behaviour of adults and children at light controlled pedestrian crossings. Day *et al.* (2006) used observation of children on route to school to assess the urban form on street segments in close proximity to a school.

Difficulties with associated with this methodology include that observation or tracking of children requires the consent of each parent or guardian for every single child, which is practically impossible to achieve. Additionally, the problem of validity arises with such a method as children who know that they are under investigation may differ from their normal behaviour as experienced by Borgers *et al.*, (2000). Observing children in traffic may include the possibility that children could be exposed to dangerous situations. It would be ethically improper to observe potentially dangerous behaviour in order to gain survey results.

- Observation in simulated road traffic

Extensive work has been undertaken in observing children in simulated traffic situations. Macarthur (1998) evaluated the effectiveness of bicycle training for children by observing children on a cycle training course before and after they took part in a training program. Zeedyk *et al.* (2002) created a controlled environment to video tape children's behaviour when crossing the road. Plumert (2007) used a 2x4 m video screen and a stationary bicycle to study children's behaviour and reaction times when cycling towards a road crossing. Wann *et al.* (2011) showed computer-generated images of a car approaching at different speeds to study children's reaction times.

These methods require a number of aids that were deemed impractical for this research. The technical and organisational issues in creating either a controlled traffic situation or a visual representation of traffic situations are considerable, while expected results would not have aided this research.

- Interviews, Photo Diaries and Focus Groups

A wide range of interactive techniques such as interviews, photo diaries and focus groups have been used by researchers when assessing children's and parents perceptions when engaging with their environment. When researching children's perceptions of their Neighbourhood Forni (2002) used Interviews, drawings, stories and children's photographs. Veitch (2006) used interviews to explore the perceptions of parents in Melbourne, Australia to increase understand where children their play. O'Brien, (2000); Burke (2005); Dennis Jr. (2008) and Jorgenson *et al.* (2010) used Photo Diaries to engage children in researching their environments. Children took pictures of everyday things that are important to them. Researchers will then talk with the children about the images they took to gain a better understanding of how the children viewed their surroundings.

Interviews, Photo Diaries and Focus Groups were omitted in this study on the basis that specialist knowledge would be required in the structuring of these meetings and also the interpretation of results. In addition, close contact with children is impossible without Garda vetting, this renders such a methodology highly impractical for planners and road engineers who in future may apply the methodology presented here.

- GPS tracking

The Global Positioning System (GPS) has been used in a number of studies researching the behaviour of cyclist and pedestrians. Dill (2009) used bicycle-mounted GPS units to observe the behaviour of 166 cyclists in Portland (USA). Hood *et al.* (2011) demonstrated that it is possible to use route traces from GPS units in smart phones to determine which factors influence cyclists' route choices. Dessing *et al.* (2014) asked seventy-nine children, aged 6-11 years, in six schools in the Netherlands to wear a GPS receiver for one week on route to school and found that the proportion of walking trips declined significantly at increased school trip distance, whereas the proportion of cycling trips and motorized transport increased.

GPS tracking resembles the methodology of this research very closely. However, the aim of research was that the resulting method could be easily reproduced and used in a school setting. Using GPS tracking of children by GPS receiver or Mobile Phone would make this method far more difficult to use, as it requires a high degree of technical Know How.

- Methods Used

To use available data for school travel in Dublin, road safety data and self-reported data, were considered the most appropriate data sets for this study. The self-reported element of the research encompassed a questionnaire and a map of children's routes to school to be completed as part of either a class lesson or homework. This method was chosen to allow the children work within a familiar format and also to eliminate the need for the researcher and subjects to meet, this facilitates future application of the work. Figure 7.0 outlines the methodological framework adopted including: data input, analysis and output.

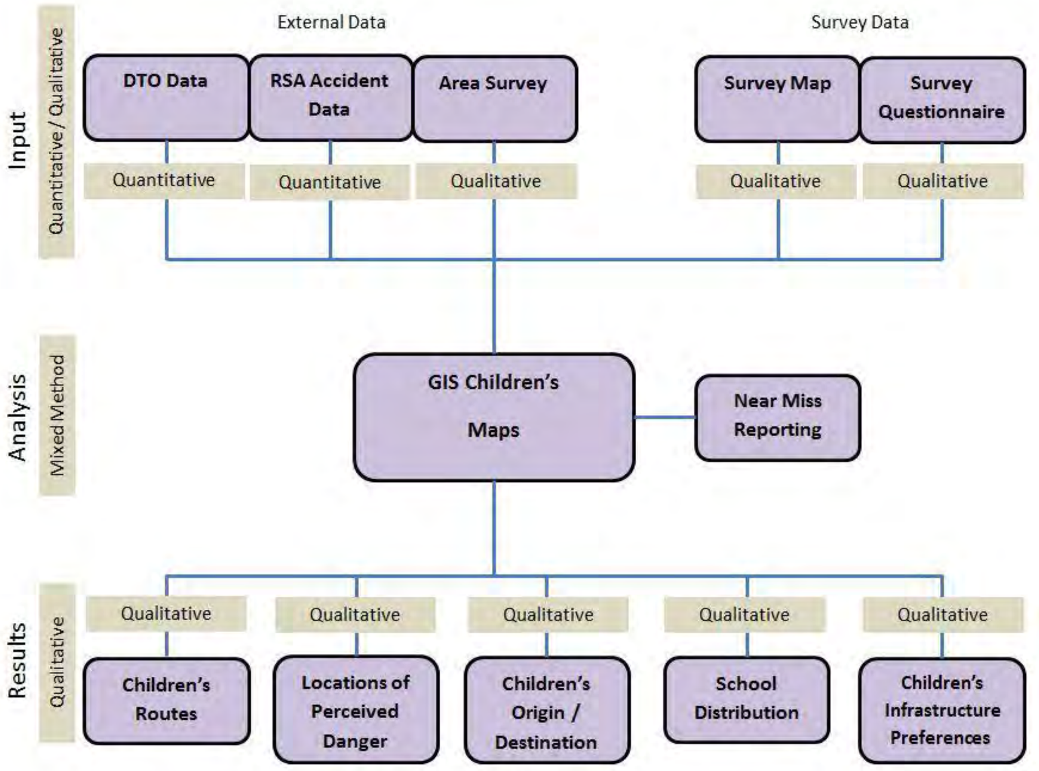


Figure 7.0: Methodology Framework.

- Existing data

Winters *et al.* (2007) compared the results of a Canadian Community Health Survey (CCHS) of Canadian cities with city-level climate data from Environment Canada records to find that bicycling patterns are associated with individual demographic characteristics and the climate of a city. Mueller *et al.* (2008) combined existing data sets of administrative areas, school locations, street network, bus and tram stops and the routes of the public transportation system of Dresden to find that school closures had an adverse affect on the numbers of children cycling and walking to school.

In this research existing (external) data from the 2006 Travel to Education Survey (DTO, 2007) was combined with RSA Accident Data for the time period from 2005 to 2009 and analysed using GIS. The existing data included also a data set of roads and road types for County Dublin.

- Area Survey

A survey of the road network surrounding the three target schools was conducted to validate an existing vector data set of the road network in the survey area.

- Questionnaire

Questionnaires have been used in a number of surveys researching mode choices when travelling to school. 10 to 12-year-olds in Australian primary schools were asked in a questionnaire about their perceptions of traffic, strangers, road safety and sporting venues in their local area (Timperio *et al*., 2004). Nelson *et al*. (2008) surveyed 15–17 year old adolescents in 61 post primary schools in Ireland. Participants self-reported distance, mode of transport to school and barriers to active commuting.

- Children's Maps

The maps that children produced were at the heart of this research. Maps have been used as a methodology in a number of projects researching children. Rissotto and Tonucci (2002) used neighborhood maps, drawn by children in Rome (Italy), to find that children travelling to school by active modes of transport have a better knowledge of the local area than children who are driven to school. In Norway, the 'Children's Tracks' project used mapping data collected by children aged between 8 and 13 to identify play-areas and tracks or paths that were important to them as well as any areas that were dangerous to them (Children's Tracks, 2012). Berglund (2007, 2008) developed this method to track children's movements in a road network using GPS.

3.1.1 Research Limitations

As with most research a certain number of limitations of the methodology adopted will apply. Three main limitations can be identified in this research and are discussed in detail here. Firstly, difficulties were encountered in having schools take part in the research as it was voluntary. In general schools would only sign up to the study if they felt that the research would benefit the school and its pupils. Many schools were approached to take part but declined. This factor and led to many delays. Eventually, due to direct support for the research from Mr Michael Byrne (DCC Road Safety Development Officer/Road Safety Services Manager) four schools in North City Dublin agreed to take part in the study. Once the schools had agreed to join the study the issue of access to pupils was dependent on the time constrains due to the school schedule. In addition, individual teachers had to be convinced to surrender their time for one lesson. The considerable difficulty in getting teachers to agree to this also resulted in many delays and the withdrawal of one school (Mount Temple Comprehensive School in Clontarf) at a later stage.

Secondly, all data from the children's questionnaire used in this research was self-reported and completed independently as homework. The problems such self-reported data present is that where possible it must be verified, this was undertaken and was a time consuming aspect of the research. The possibility that selective memory (omitting unpleasant memories) might have occurred in this study cannot be excluded. In addition, to avoid any weighting on particular negative or positive events encountered whilst cycling, it was imperative that the researcher provided clear instructions to the pupils during the class time.

Finally, as a direct consequence to the difficulties mentioned above and also due to the low number of children who actually cycle to school, the sample size of the returned schools surveys was small (a total of 292 questionnaire surveys were distributed to the target schools in the study area, with a response of 128 surveys (44%). Previous DTO Surveys (DTO, 2007) have recorded how children *usually* travel to school whereby the question posed in this survey was if a child had *ever travelled* to school by bicycle, this was considered an important change in wording to increase the number of returned surveys. The small sample size resulted in a more qualitative approach to the analysis of actual routes travelled and no emphasis was placed on transport modal shares. Extrapolation models were then used to predict problems areas in the cycle infrastructure.

3.2 School Selection Process

Target school selection was undertaken in July 2009 and based on the Final Report of the DTO 2006 Travel to Education survey (DTO, 2007). This DTO survey provides a general overview of participation and response rates, and results including the Mode of Travel to Education, Journey Time, Distance Travelled or Reasons for not Walking or Cycling (DTO, 2007). Although the DTO survey was undertaken to gather data to update and analyse the DTO Traffic Model, it also contains details with respect to age, gender, address, mode of transport and personal injuries. Thus for the purpose of this study, the DTO 2006 Travel to Education data was assessed and a list of suitable schools was selected on the basis of the following criteria:

i. The selected schools had to be located in a typically suburban setting.
ii. At least three schools should form a cluster and should be within 2 – 5 km of each other.
iii. If possible the selected schools should have a good cycling to school record.
iv. Selected schools should provide the best possible mix of age and gender.
v. Selected schools should have a record in the 2006 DTO Travel to Education Survey.

On analysing the DTO 2006 survey data in ArcGIS, thirty-two schools were identified as possible target schools in the GDA. These schools were agreed upon as target schools for this research in a meeting in July 2009 in the Dublin City Council (DCC) Planning Department with Michael Byrne (DCC Road Safety Development Officer/Road Safety Services Manager). However, on liaison with the AnTaisce National Manager Green-Schools Travel Officer, Jane Hackett, and the AnTaisce Cycling Development Officer, Ally Menary, twelve schools were omitted from the original list, resulting in a shortlist of twenty schools that had a previous working relationship with DCCand/or AnTaisce.

The twenty selected schools were contacted by letter between October 2009 and October 2010 and invited to take part in the study. However, despite significant support for the study by AnTaisce, only one school responded positively. All other schools, although verbally supportive, did not engage with the survey, reasons given included an inundation of survey requests for research purposes.

In December of 2010, through further contacts with DCC and a meeting with Michael Byrne, (DCC Road Safety Development Officer/Road Safety Services Manager) four schools in north Dublin which fulfilled the criteria outlined in Section 3.1 agreed to take part in the survey. These schools included: St Fiachras Primary School in Beaumont, Holy Faith Secondary School in Clontarf, Manor House Secondary School in Raheny and Mount Temple Comprehensive School in Clontarf. Initial contact with the schools Principals was facilitated by Michael Byrne of DCC and the research information was subsequently sent to the four selected schools and individual school visits were carried out to explain the survey procedure and obtain access to individual classes.

The school survey was conducted on three different school days in March of 2011 in St Fiachras Primary School in Beaumont, Holy Faith Secondary School in Clontarf and Manor House Secondary School in Raheny. The fourth school, Mount Temple Comprehensive School in Clontarf, was scheduled for a survey in February but due to adverse weather conditions the school was closed on the date of the survey. This school was subsequently reluctant to set a new date for a survey and after several failed attempts Mount Temple Comprehensive was deleted from the target school list in April 2011.

3.2.1 GIS based DTO Data Analysis

The DTO 2006 survey data is organized in a Personal Geodatabase containing 24 Geodatabase tables. Personal Geodatabases are one of three different types of databases supported by the Geographical Information System (GIS) ArcGIS and are known as ArcSDE Geodatabases. File databases are the other two types of databases. In Personal Geodatabases all datasets are stored within a Microsoft Access data file, which is limited in size to 2 GB.

Some of the DTO survey data is geo-referenced, whereby attribute tables, which contain information pertaining to the school, also have an Easting and Northing coordinate. These coordinate values describe a position which can be located on the Irish National Grid (ING) and thus be spatially located both locally and nationally.

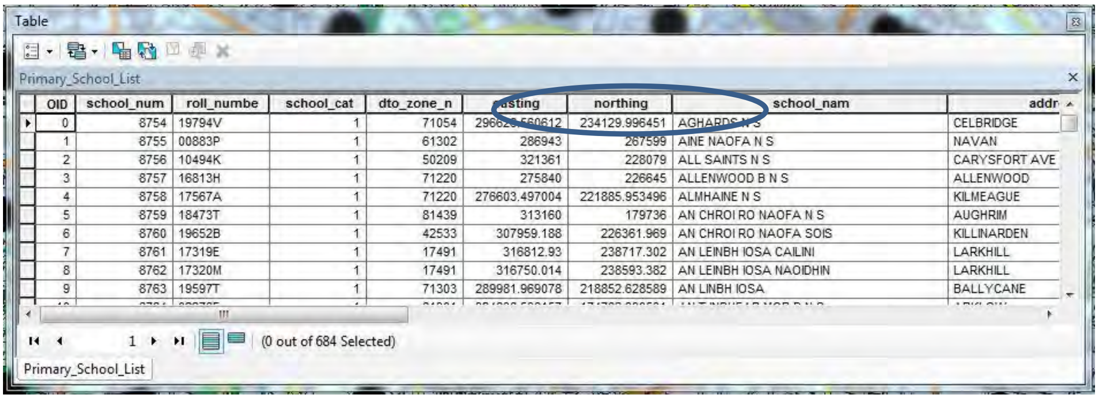
An analysis of the distance travelled to school by Dublin pupils was considered important for this study as this distance as found by Jensen (2006) is a significant factor when choosing transport modes (See Section 2.12). Previous surveys in Ireland have shown that one quarter of all primary school pupils live less than 0.5 km from their school and almost two thirds (64 %) of these pupils travel less than 2 km to school, furthermore half of all second level pupils travel 2 km or less to school (DTO, 2006). The results obtained by the DTO (2006) however do not indicate if the children travelling further than 2 km to school do so by choice or by necessity where no school is within this distance from their home. Thus a spatial analysis of the distribution of schools in Dublin enables identification of locations which have a low spatial distribution of schools and therefore highlight areas where cycling may not be a potential option. For this reason maps with the locations of primary and secondary schools were prepared to show the distribution of schools within Co. Dublin.

Although each child may live close to an appropriate school the demand and supply of school places will also influence which school a child attends. A shortage of school places in a particular area due either to a high number of local children living or because schools may be too small to accommodate demand will result in children travelling further distances. To assess the demand and availability of Primary and Secondary school places in the GDA graphically, a dot density display was used to show where children live vs. the supply of school places over the Dublin County Area

To ensure that at least 70% of the pupils of the target schools were living within the extent of the survey area data relating to the number of pupils per origin address zone of St. Fiachras Primary School and Holy Faith Secondary School, based on the 2006 Travel to Education Survey (DTO, 2007), was displayed on a survey area map. This data was not available for Manor House Secondary School as this school did not take part in the 2006 Travel to Education Survey. A 2 km buffer was drawn around each school to check that a majority of the relevant Origin Address Zones were within the survey area. Thus this data is discussed in Section 4.1.

3.2.1.1 Joining and Relating GIS Data

To view the location of all schools in the GDA the DTO *school_list* table, which contains coordinate information, (Figure 8.0) was imported into ArcGIS and a layer created on which every school was geographically located by a symbol.



Table

Primary_School_List

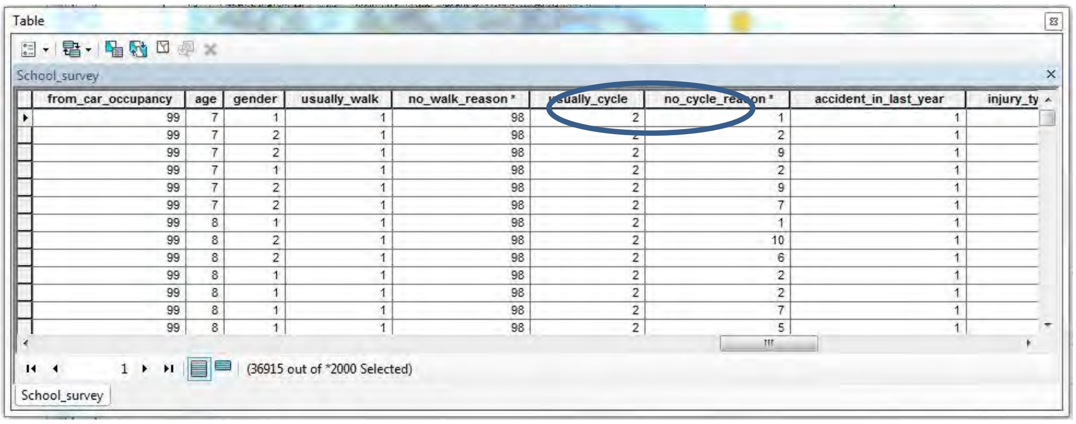
OID	school_num	roll_numbe	school_cat	dto_zone_n	[illegible]asting	northing	school_nam	addr
0	8754	19794V	1	71054	29662[illegible]560612	234129.996451	AGHARDS N S	CELBRIDGE
1	8755	00883P	1	61302	286943	267599	AINE NAOFA N S	NAVAN
2	8756	10494K	1	50209	321361	228079	ALL SAINTS N S	CARYSFORT AVE
3	8757	16813H	1	71220	275840	226645	ALLENWOOD B N S	ALLENWOOD
4	8758	17567A	1	71220	276603.497004	221885.953496	ALMHAINE N S	KILMEAGUE
5	8759	18473T	1	81439	313160	179736	AN CHROI RO NAOFA N S	AUGHRIM
6	8760	19652B	1	42533	307959.188	226361.969	AN CHROI RO NAOFA SOIS	KILLINARDEN
7	8761	17319E	1	17491	316812.93	238717.302	AN LEINBH IOSA CAILINI	LARKHILL
8	8762	17320M	1	17491	316750.014	238593.382	AN LEINBH IOSA NAOIDHIN	LARKHILL
9	8763	19597T	1	71303	289981.969078	218852.628589	AN LINBH IOSA	BALLYCANE

(0 out of 684 Selected)

Primary_School_List

Figure 8.0: School List Attribute Table (Source DTO, 2007)

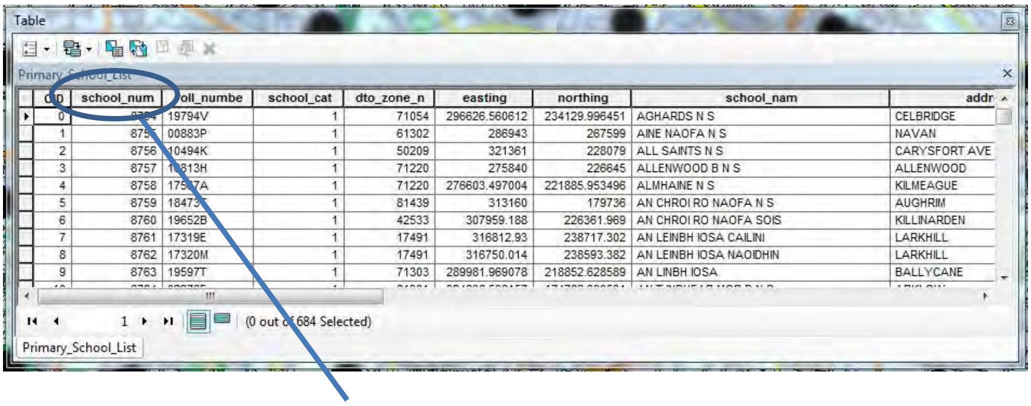
Not all Geodatabase tables are geo-referenced and the survey's entries for individual children have no coordinate information. However, every survey includes a unique identifier either in the form of an address or the schools reference number. Therefore on importing these Geodatabase tables into ArcGIS as separate attribute tables they can be linked using the unique identifiers and subsequently queried. Thus to analyse the distribution cyclists per school in the GDA on a map for example, the *school_list* Personal Geodatabase Table was imported into ArcGIS as an attribute table (see Figure 9.0) and subsequently combined with a map of Dublin with symbols representing all georeferenced schools. Tabular information relating to the georeferenced schools were shown as a single entity and linked to the *school_survey* table which contained the mode choice of children travelling to school.



from_car_occupancy	age	gender	usually_walk	no_walk_reason *	usually_cycle	no_cycle_reason *	accident_in_last_year
99	7	1	1	98	2	1	1
99	7	2	1	98	[illegible]	2	1
99	7	2	1	98	2	9	1
99	7	1	1	98	2	2	1
99	7	2	1	98	2	9	1
99	7	2	1	98	2	7	1
99	8	1	1	98	2	1	1
99	8	2	1	98	2	10	1
99	8	2	1	98	2	6	1
99	8	1	1	98	2	2	1
99	8	1	1	98	2	2	1
99	8	1	1	98	2	7	1
99	8	1	1	98	2	5	1

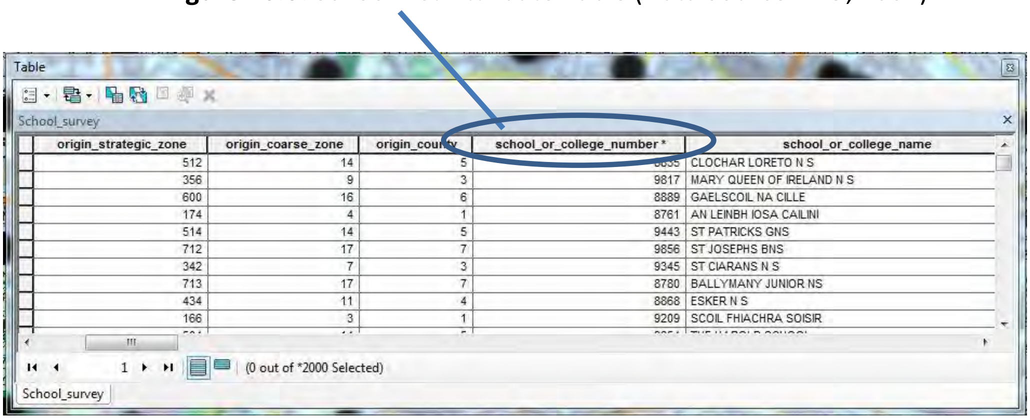
Figure 9.0: School Survey Attribute Table (Source DTO, 2007)

The relationship between these attribute tables and survey information is illustrated in Figure 10.0 and Figure 11.0. It can be seen that the unique identifiers *school_num* and *school_or_college_number** were used to link tables *school_list* and *school_survey*. In this way the seemingly disparate information was combined in a meaningful manner to allow analysis of the data on an attribute level or indeed spatially.



OID	school_num	roll_numbe	school_cat	dto_zone_n	easting	northing	school_nam	addr
0	[illegible]	19794V	1	71054	296626.560612	234129.996451	AGHARDS N S	CELBRIDGE
1	[illegible]	00883P	1	61302	286943	267599	AINE NAOFA N S	NAVAN
2	8756	10494K	1	50209	321361	228079	ALL SAINTS N S	CARYSFORT AVE
3	8757	[illegible]	1	71220	275840	226645	ALLENWOOD B N S	ALLENWOOD
4	8758	[illegible]	1	71220	276603.497004	221885.953496	ALMHAINE N S	KILMEAGUE
5	8759	[illegible]	1	81439	313160	179736	AN CHROI RO NAOFA N S	AUGHRIM
6	8760	19652B	1	42533	307959.188	226361.969	AN CHROI RO NAOFA SOIS	KILLINARDEN
7	8761	17319E	1	17491	316812.93	238717.302	AN LEINBH IOSA CAILINI	LARKHILL
8	8762	17320M	1	17491	316750.014	238593.382	AN LEINBH IOSA NAOIDHIN	LARKHILL
9	8763	19597T	1	71303	289981.969078	218852.628589	AN LINBH IOSA	BALLYCANE

Figure 10.0: School List Attribute Table (Data Source DTO, 2007)

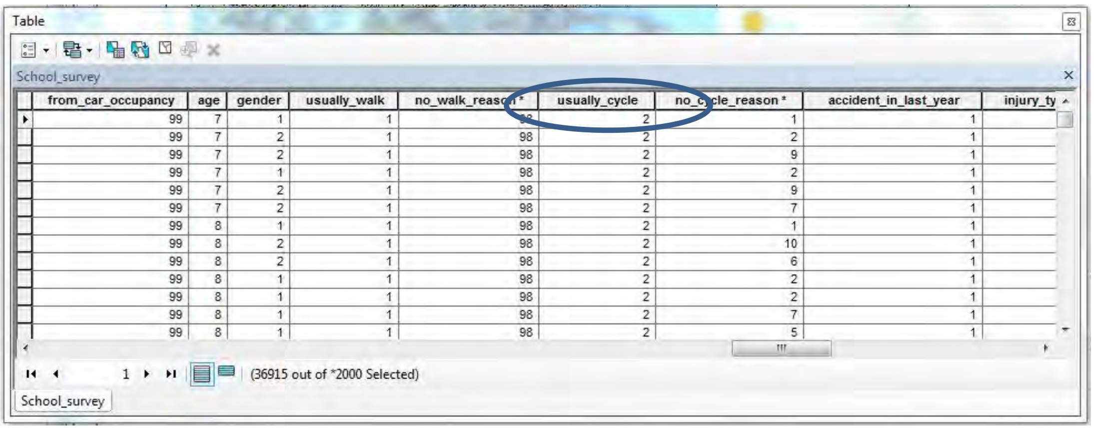


origin_strategic_zone	origin_coarse_zone	origin_county	school_or_college_number *	school_or_college_name
512	14	5	[illegible]	CLOCHAR LORETO N S
356	9	3	9817	MARY QUEEN OF IRELAND N S
600	16	6	8889	GAELSCOIL NA CILLE
174	4	1	8761	AN LEINBH IOSA CAILINI
514	14	5	9443	ST PATRICKS GNS
712	17	7	9856	ST JOSEPHS BNS
342	7	3	9345	ST CIARANS N S
713	17	7	8780	BALLYMANY JUNIOR NS
434	11	4	8868	ESKER N S
166	3	1	9209	SCOIL FHIACHRA SOISIR

Figure 11.0: School Survey Attribute Table (Data Source DTO, 2007)

3.2.1.2 Displaying GIS Data

ArcGIS allows quantities to be displayed as colours, graduated symbols, proportional symbols, dot densities or charts on a map. Graduated symbols are map symbols that are vary in size to show their relative quantitative values. This allows spatial relationships such as density, distributions or concentrations of distinct features to be spatially displayed. To display the numbers of children cycling per school on a map of Dublin, the relevant data was extracted from the associated attribute table and subsequently summarised. Data pertaining to the children's mode of travel to school is contained within the *school_survey* table as shown in Figure 12.0.



from_car_occupancy	age	gender	usually_walk	no_walk_reason *	usually_cycle	no_cycle_reason *	accident_in_last_year	injury_ty
99	7	1	1	98	2	1	1	
99	7	2	1	98	2	2	1	
99	7	2	1	98	2	9	1	
99	7	1	1	98	2	2	1	
99	7	2	1	98	2	9	1	
99	7	2	1	98	2	7	1	
99	8	1	1	98	2	1	1	
99	8	2	1	98	2	10	1	
99	8	2	1	98	2	6	1	
99	8	1	1	98	2	2	1	
99	8	1	1	98	2	2	1	
99	8	1	1	98	2	7	1	
99	8	1	1	98	2	5	1	

Figure 12.0: School Survey Attribute Table (Source DTO, 2007)

Using the ArcGIS Query Builder (Figure 13.0) all children usually cycling to school (model_mode = 2) were selected from the school_survey table. The selected data was then exported and saved as a new attribute table.

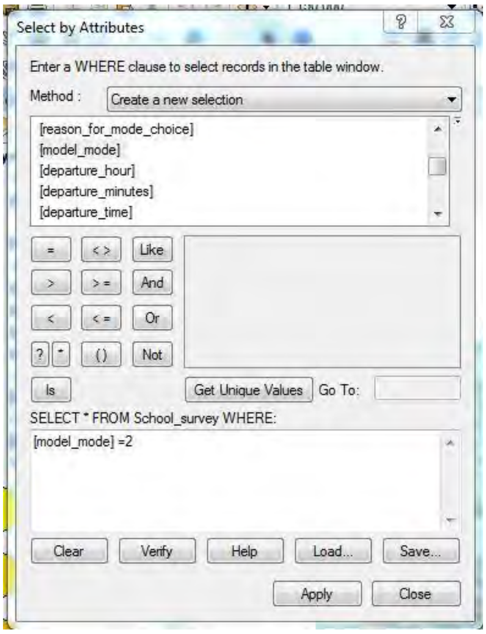


Figure 13.0: ArcGIS Query Builder (Source DTO, 2007)

This new table contained only the data pertaining to each individual child who usually cycles to school. Thereafter the cycling numbers per school is determined using the unique identifier for each school (*school_or field*) as shown in Figure 14.0.

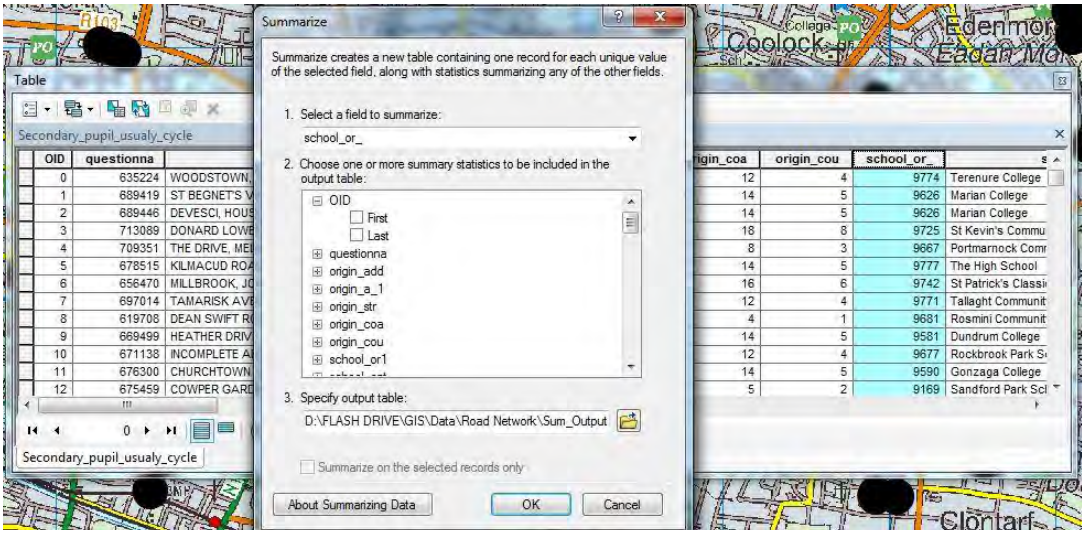


Figure 14.0: Summarising the school_or_field.

This procedure resulted in a new attribute table containing the unique school identifier (*school_or_*) and a value for how many times each school identifier had been counted, thus providing the number of children usually cycling to school for each school (Figure 15.0).

Table

Primary_Pupil_Cycle_School_Count

OID	school_or_ *	Cnt_school
0	8756	2
1	8761	1
2	8763	4
3	8764	2
4	8767	1
5	8772	1
6	8774	13
7	8776	1
8	8777	3
9	8778	1
10	8779	6
11	8780	1
12	8782	15

(0 out of 408 Selected)

Primary_Pupil_Cycle_School_Count

Figure 15.0: Summary of the *school_or_ field*.

From the above mentioned ArcGIS procedures the resulting table was then joined with the *school_list* attribute table as shown in Figure 16.0.

Table

Primary_School_List

teachers	survey_par	survey_for	survey_f_1	records_in	green_scho	OID_	Shape *	OID	school_or_ *	Count_school_or_
0	N	0	0	0	0	0	Point	<Null>	<Null>	<Null>
0	Y	323	190	140	0	0	Point	<Null>	<Null>	<Null>
0	Y	57	32	24	0	0	Point	0	8756	2
0	Y	126	74	50	0	0	Point	<Null>	<Null>	<Null>
0	Y	172	131	74	0	0	Point	<Null>	<Null>	<Null>
0	Y	148	103	55	1	0	Point	<Null>	<Null>	<Null>
0	Y	271	105	105	0	0	Point	<Null>	<Null>	<Null>
0	Y	191	117	91	0	0	Point	1	8761	1
0	Y	182	59	59	0	0	Point	<Null>	<Null>	<Null>
0	Y	522	444	252	1	0	Point	2	8763	4
0	Y	163	40	40	0	0	Point	3	8764	2
0	Y	86	19	19	0	0	Point	<Null>	<Null>	<Null>
0	Y	96	61	31	1	0	Point	<Null>	<Null>	<Null>

(1 out of 684 Selected)

Primary_School_List

Figure 16.0: *School_list* table containing unique school identifier count.

Using the ArcView *Symbology tab* feature contained in the Layer properties, the *Count_school_or_ field* values could then displayed as graduated symbols on a map of the area. The resulting map was used as a spatial method to locate schools geographically and indicate the number of children cycling to school. Figure 17.0 illustrates the resulting map of Dublin with graduated symbols representing the number of children who cycle to school as determined from the DTO (2007) survey.

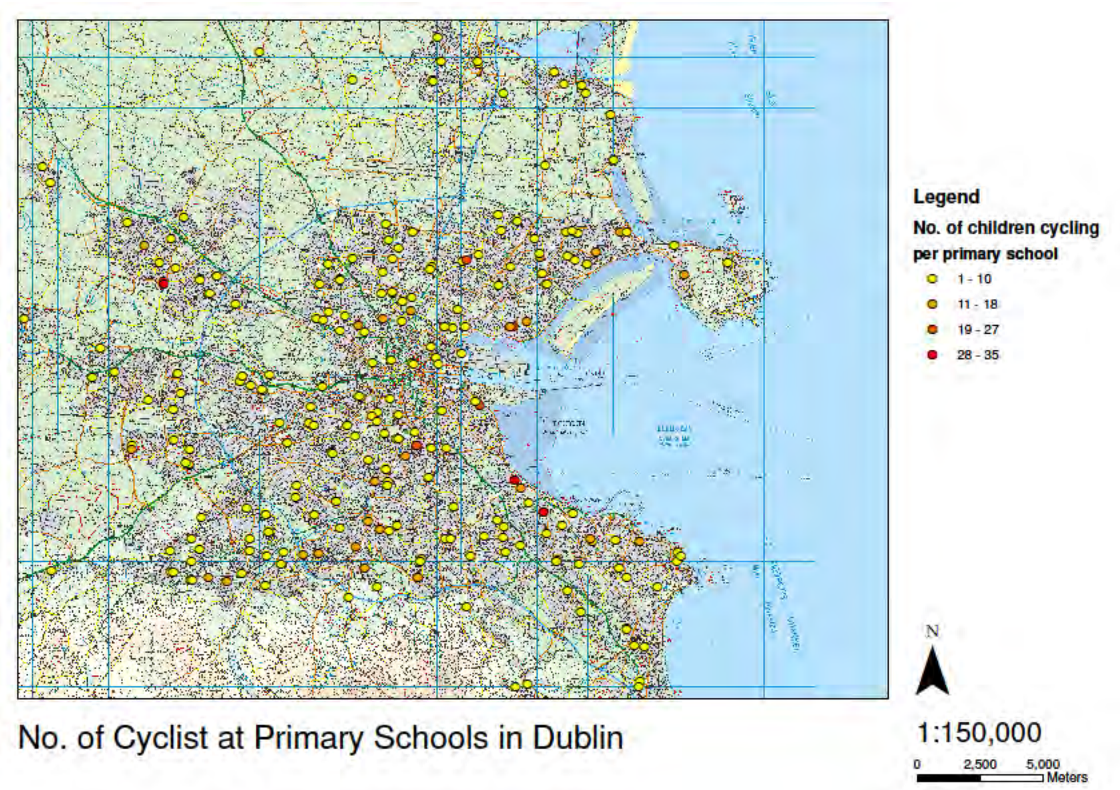


Figure 17.0: Graduated Symbols: Children Cycling to School (DTO, 2007).

A more detailed analysis enables examination of the modal split of specific areas and locations in the GDA, thus enabling direct comparisons to other cities or municipals in terms of urban and geographical features or modal split. Such analysis is beyond the scope of this research.

3.3 Analysis of the Road Safety Authority (RSA) Data

To assess the 2 km area surrounding the three selected target schools for potential locations of danger for children when walking or cycling to school prior to the area survey, road accident data collected by the Road Safety Authority (RSA) for the time period 2005 to 2009 was analysed using the RSA 'Ireland Road Collisions' map (www.rsa.ie) and ArcGIS. This analysis is outlined in more detail in the following sections.

3.3.1 RSA 'Ireland Road Collisions' Map

An Garda Síochána forwards all road traffic accidents which occur on public roads in Ireland and that involve fatalities, personal injury or material damage to the RSA.

This data details when and where road collisions occurred, who was involved, contributory actions and contributory factors and the cost of collisions to the public. This is the most extensive and accurate data available on accidents in Ireland and forms the basis of the RSA road safety statistics which are released on an annual basis in tabular form (RSA, 2012). The data are also used as the basis for the RSA 'Ireland Road Collisions' map (RSA, 2012) that can be accessed online. This map shows the pattern and locations of road collisions in recent years in Ireland where personal injury was involved are shown on national, county and local levels. The map is interactive and the user can use a zoom function to locate an area of interest, choose between three levels of severity (fatal, serious and minor) or to display all levels of severity and the type of road user that has been involved in the accident. On selecting an accident symbol on screen, further details including: Severity, Year, Vehicle, Circumstances, Day of week, Time, Speed limit and no. casualties can be displayed for the selected accident.

3.3.2 RSA Bicycle Accident Data

A total of 7,644 road traffic accidents were recorded in County Dublin between 1996 and 2007 and are maintained in a Microsoft Access format (mdb file) by the RSA. This data was analysed to provide an overview of bicycle accidents involving children in the GDA. The database of accidents was directly compatible with ArcGIS and could therefore be imported as a personal geodatabase and subsequently viewed and queried using standard ArcGIS tools.

The RSA provide a data dictionary explaining the labels and values of individual geodatabase fields as shown in Table 6.0. On querying the data dictionary all accidents involving bicycles where extracted, these included: (CLASS1 Vehicle Type 1 = 1 (Pedal cycle)). Thereafter, all accidents involving cyclists travelling to or from school were identified: (pedal cyclist trip purpose value was 2 (To/From School)

Table 6.0: RSA Data Dictionary

Class	Vehicle Type	Driver Trip	Purpose
1	Pedal Cycle	1	To/from work
2	2 Wheeled Motor Vehicle	2	To/from school
3	Private Car	3	To/from shopping
4	Van	4	To/from match
5	Taxi	5	To/from home
6	Hackney Car	6	To/from pub/hotel
7	Van	7	Other Leisure
8	Mini bus	8	Unknown
9	Goods, not over 2 tons, unladen		
10	Goods, over 2 tone, rigid		
11	Goods, rigid + trailer		
12	Goods, artic with semi trailer		
13	Artic tractor only		
14	Other		

As can be seen in Table 6.0 the data provided by the RSA does not include information pertaining to the trip purpose for pedestrians. No improvement in the pre-survey assessment of the area surrounding the three selected target schools was found by extending the RSA accident record time span to eleven years (1996-2007).

3.4 Area Survey

A survey of the area within a 2 km radius surrounding each of the three schools in the study was undertaken by bicycle to assess the local road network. The area survey, which outlined the road infrastructure and identified the three target schools, is shown in Figure 18.0.

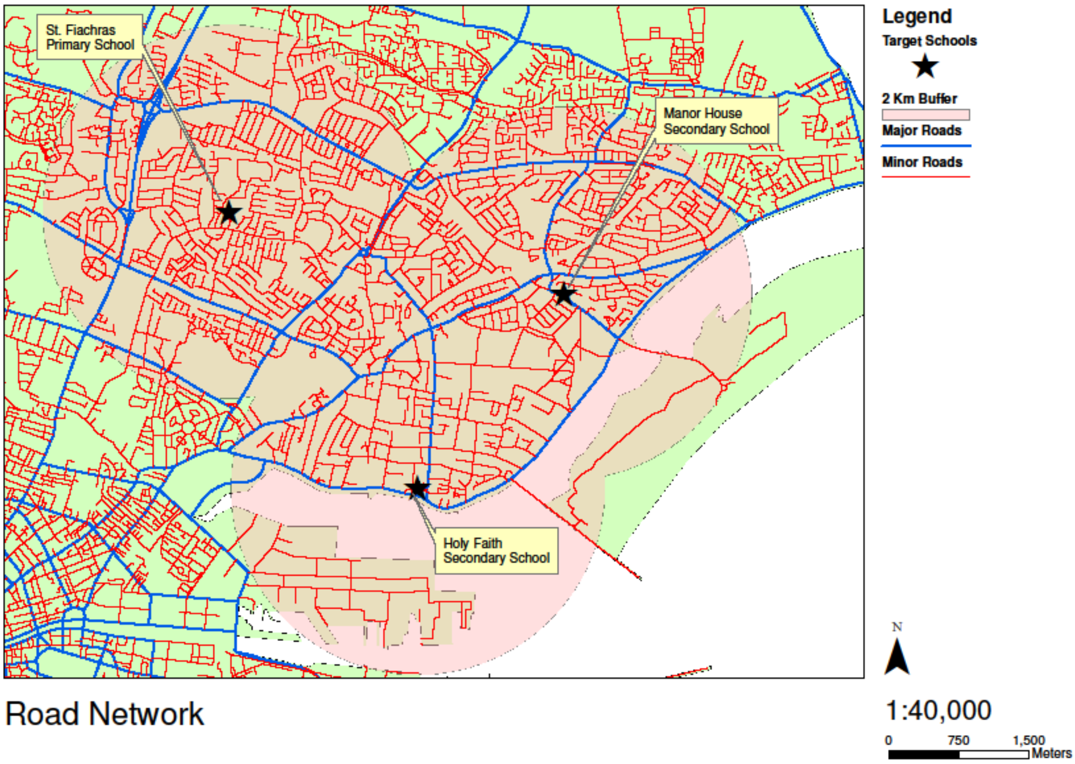


Figure 18.0: Survey Area and Existing Road Infrastructure

The fieldwork was completed during a two week period in August 2010. At the beginning of each day of fieldwork a specific area within the overall survey area was printed on an A4 sheet and the routes to be surveyed divided into preliminary sections and assigned individual codes. For the duration of the fieldwork a high visibility vest was worn at all times. Before any notes were recorded individual routes were cycled in their entirety. The sectioning of each route was checked on site and amended where required. Route sections were defined using the following criteria:

A section began or ended when:

a) A new road began or ended e.g. where a road number or road type changed.
b) A continuous road changed in its character with regard to speed limits and or road width.
c) A major crossroads was encountered e.g. where there were changes in the number of road lanes, at traffic lights or at a stop sign.

Segmentation of road sections based on infrastructure was found to be impractical, as conditions changed so rapidly that in most cases no sensible length of section could be achieved. This was in particular true for bicycle infrastructure.

The bicycle survey served a number of purposes as listed:

1. Provide perspectives of the streetscape from the child's viewpoint.
2. Provide information to help design pupils questionnaires and survey maps.
3. Provide an overview of the nature and character of the local road network.
4. To validate a vector data set of the road network in the survey area.

These four purposes will be discussed in more detail in sections 3.4.1 and 3.4.2.

3.4.1 The Road Network from a Child's Point of View

This survey method was based on 'Road User Role Play', a tool in the NRA's Road Safety Audit Process (NRA, 2007), and the 'Road Users Audit' as described in the Irish 'Traffic Management Guidelines' (Government Publications, 2003). Whereby a NRA Road Safety Audit is conducted as an evaluation of road schemes during design and construction, before the scheme is opened to traffic, to identify potential safety hazards which may affect any type of road user and to suggest measures to eliminate or mitigate those problems and applies to all National Roads and motorways schemes (NRA, 2007). It requires an Audit Team to put themself into the situation of a vunerable road user using the proposed Infrastructure.

The NRA outline a suggested working method for the Construction Stage (Stage 3) of a road safety audit as follows (NRA, 2007):

- The Audit Team visits the site during daylight;
- The Audit Team walks, drives and, where appropriate, cycles along and across the scheme;
- One team member takes notes of all the possible safety points;
- The other team member takes photographs of all the possible safety points;

- Before leaving the site a team meeting is held to ensure that the note-taker has covered all safety points;
- The Audit Team visits the site during darkness;
- One team member produces a draft Audit Report and circulates it to all present at the site visit;
- The report is edited following comments from the other team members and observers.

The area survey undertaken during this research differed from the NRA Road Safety Audit in some aspects as outlined here:

- The audit was undertaken on an existing road network.
- The audit was undertaken by a single person, the researcher.
- No photographs were taken. However, points of special interest were marked in the field on a paper map and subsequently visually inspected and analysed using Google Maps.
- No field work was undertaken during darkness.
- No audit report was written or edited.
- A spread sheet was used to assess road sections and crossroads.
- The area survey took into account all road types including paths and rail lines. It also encompassed a large road network rather than a single road scheme.
- There was no Design Stage Audit as the area survey dealt with existing roads.

3.4.1. Road Infrastructure Classification and verification in the Study Area

An Ordnance Survey Ireland (OSi) vector data set of the road network in the survey area was obtained through the Department of Spatial Information Sciences, DIT. This road network data was divided in to two general categories and 7 types of roads:

- Major Roads (Type 1 – 5)
- Minor Roads (Type 6 – 7)

The area survey formed the basis of a more detailed road type classification based on the Irish 'Traffic Management Guidelines' (Government Publications, 2003) in the survey area.

As the vector data set of the road network in the survey area was in many places not consistent with the OSi raster map of the area, the network had to be validated to establish which of the two sources (vector data versus raster data) are existent in reality. For this reason areas in which the data was conflicting were checked on site. Also, a number of paths and tracks that are not part of the raster data or the vector data where located. The vector data was edited accordingly in ArcGIS where necessary.

All roads in the survey area were divided into sections on a map and individually surveyed by bicycle. A section length was marked on the printed map and a spread sheet completed for each section with a short report written. The report was concerned with the general character of the road section. For instance, if the area was urban, suburban, residential, industrial, a possible speeding location, delivered a nice cycle experience, indicated any potential problems regarding children cycling or walking and any additional information that was deemed important (see Appendix 1).

Where possible the spread sheet was completed on site. In some situations, where access was difficult or dangerous, or where there was no clear view of a section, the section in question was later studied using online Google Maps and the missing data inserted. Section lengths were, in general, determined by Google Maps.

3.5 Children's Questionnaire Design

The questionnaire used in this research is based on the DTO Travel to Education Survey (DTO, 2007). In 2002 the DTO undertook the comprehensive Travel to Education Survey to coincide with the 2002 Census. All first, second and third level institutions in the GDA were invited to take part. The data obtained on travel-to-education patterns was considered essential to the DTO's Safe Routes to School Program.

In September 2006, the Dublin Transportation Office appointed MVA Consultancy in conjunction with Field Research Ireland (FRI) to undertake a follow up survey that would allow the DTO to update their transport model (DTO, 2007). All schools within the GDA were contacted by letter and invited to take part in the survey by MVA Consultancy. All participating schools subsequently received a survey pack from FRI, including the questionnaires, posters and collection boxes. The questionnaires were specifically designed for Primary Schools, Secondary Schools and Third Level Colleges/Universities. Once a school had collected a batch of surveys FRI visited the school and collected the surveys.

The questionnaire used in this research is based on this DTO Travel to Education Survey (DTO, 2007). The distribution and collection of the questionnaire survey in this study also closely resembled the DTO survey, with the exception that a range of lesson presentation options were provided to teachers. The presentations were designed in such a way that they could become part of the Geography Curriculum for 5th and 6th year primary school pupils and would therefore also be manageable for older children. The presentation options were prepared in Microsoft Power Point format and were designed with different age groups in mind as follows:

1. Primary School : A Safe Journey to School.
   This lesson concentrated on basic rules of the road and personal safety.
2. Primary/Secondary Schools: UNESCO Child friendly cities/Children's Participation.
   An overview of the Child friendly cities initiative and the UN Convention of the rights of the child.
3. Primary and Secondary Schools: Mapping.
   Basic mapping skills. Different types of maps, legends, Northing and Easting, Scale…
4. Secondary School -Transition Year: GIS and GPS
   An overview of the technology.

The questionnaires and maps where distributed during a one lesson period of 45 minutes given to each class. The 45 minute lesson period was delivered as follows:

1. 5 Min:

   Class settles down and introduction of the researcher by the class teacher.
2. 25 Min:

   The selected presentation made using Microsoft Power Point.
3. 10 Min:

   The survey and mapping task explained to the class.
4. 5 Min.

   Questions and answers.

The Power Point format was used to aid the oral presentation.

On completion of the lesson the survey portfolio was distributed to the class and the task of completing the map was explained in detail. The maps were subsequently completed at home in the form of homework. Primary school children in the 6th year curriculum were asked to complete the map by themselves whereas the questionnaire was to be completed with the aid of their parents, similar to the DTO survey methodology. Secondary school children were asked to complete both the map and the questionnaire by themselves. It was explained to the children that taking part in the survey (completing the homework) was entirely voluntary. Delivering the survey in the form of homework was an important part of the methodology as it overcomes a number of ethical and technical issues that arise when surveying children including:

- The children did not need to be supervised during the completion of the survey by the researcher or teacher.
- The researcher did not need to apply for Garda Vetting as there is no direct contact with the children.
- Distribution and collection of the surveys was easy to organize.
- Delivering the survey as homework could possibly result in a higher survey return rate.

The completed surveys where collected the following day by the class teacher and subsequently by the researcher. The three target schools were surveyed on five different days as shown in Table 7.0. More detailed information pertaining to the breakdown of responses are provided in Section 4.0.

Table 7.0: Target Schools Surveyed

School	Date Surveyed
Holy Faith	March 9th , 2011
	March 11th , 2011
Manor House	March 15th , 2011
Holy Faith	March 17th , 2011
	March 18th , 2011

The total number of pupils surveyed was 292 and resulted in a response rate of 42% (see Section 4.4). This was considered acceptable and forms a solid basis on which analyse the data. It should be noted here that this research focuses on a methodology to bring children's perspective to safe cycling to school. Therefore, even a relatively small sample could form the basis for improving existing survey methods.

3.5.1 Written Questionnaire

The children's questionnaire design was largely based on the DTO Travel to Education Survey, for the simple reason of comparability of results and that the resulting map could form part of a similar DTO survey in the future. All questions posed in this questionnaire were designed to be as clear, direct and unambiguous as possible.

3.5.2 Questionnaire Map Design

The mapping exercise was considered the most important part of the survey as the routes and symbols recorded on the maps were the most important information gathered. Therefore the following decisions relating to the map layout were made:

1. Map Version: Alternatives considered included:

   (a) a custom map created using CloudMade,

   (b) a custom map using the road network data in ArcGIS

   (c) the OSi Dublin City Street Map.

   The main advantages of the CloudMade option (a) was that the resulting map could be designed in such a way that the road network would be the main feature of the map. CloudMade allows the user to edit and customise maps such as Google, Bing or Yahoo Maps, which are freely available on the internet. This makes it relatively easy to ensure that all routes and paths are on the resulting map. However, CloudMade uses exclusively Creative Commons-licensed OpenStreetMap data. Thus the maps created for this survey would not be available to other users. For this reason CloudMade was not selected.

   Using the road network that was created in ArcGIS (option b) would guarantee that all roads and paths currently existing in the dataset would appear on the maps. However, editing the maps to a level that makes them easily readable in paper format proved to be a difficult task.

   Therefore option (c) the OSi Dublin City Street Map was selected as the most appropriate method as this map was available in a digital format it was possible to remove street and road names thus ensuring that road network appeared clearer. The OSi Street Map is also widely available in shops in a paper format and can be used as a reference to find street names. The main drawback of the OSi Street Map was that not all recorded tracks and paths were present on the map. For this reason the instructions to pupils in the questionnaire included a note that routes not present on the map could be marked on the map using a dotted line. Several children made use of this option.

2. Map Medium.

A decision was made in this study to use a paper map. This step is important as it differs significantly from the method used by Berglund (2008). Here children used a modified GIS program to draw routes and areas of activity directly onto a computer screen. The advantage of Berglund's system is that in contrast to the paper maps no digitisation of the routes is necessary which could lead to a faster analysis of the recorded data. However, paper maps were found to have some significant advantages.

Firstly, they could be distributed in conjunction with a DTO survey in the future. Secondly, they did not require the presence of assisting personal and could therefore be used as part of a larger survey. Thirdly, they could be completed in the school as part of a lesson or at home as part of homework. Parents' attitudes towards their children's mode of transport to school together with their perceptions of traffic, strangers, road safety are have been shown by Timperio (2003) to be significant (see Section 2.5). Thus a positive outcome of completing the survey as part of the homework would be to also gain insight into the parent's perspective. Fourthly, paper maps are easy to modify to suit specific survey locations. Finally, paper maps were more accessible to children in the classroom as they negate the need for individual computers.

3. Map Scale.

On analysis of the available *origin_address_zone* data from the RSA database and the location of the most potential journeys to school for children in the three target schools (see Section 3.2.1.2) resulted in individual maps with the relative target school in its centre at a scale of 1:25 000 which reflected the OSi Street Map scale. An issue identified with the selected scale was that some of journeys could potentially be represented by very short routes (lines). However, the use of maps at different scales was rejected to ensure the task remained simple for the children and to minimise the number of map sheets required. Map scale is closely linked to sheet size and an A3 format was chosen. This format also closely resembles the size of an opened OSi Street Map.

Each school had a unique map which contained a title, scale bar, nominal scale, north arrow and a symbol indicating the schools location. Each map also included a tick box were children could indicate which mode of transport they used on their journey. This information was simplified where possible. Appendix 2 includes the portfolio with maps provided to pupils in each of the target schools. A note for children with instructions to read all information before completing the map and an instruction to describe a journey made by bicycle if possible was also included on the map.

Part of the portfolio given to the children included an A4 sheet with all instructions to complete the map in 4 steps as follows:

Step 1: Children must find their school (marked on the map) and their home, and then trace their journey to school with their finger on the map and think about their daily journey to school.

Step 2: Children should trace this journey on the map using a black marker.

Step 3: Children should trace, using a red, green or blue line next to the black line, their journey to school and indicate what kind of infrastructure they use. Whereby red line indicates – Here I am cycling on the road, green indicates - Here I am cycling on a cycle path/way and blue indicates - Here I am not cycling on either of the above. Please make a note were you are cycling instead (footpath, Bus lane, dirt- track…)

Step 4: Children should use the seven different symbols as shown in Table 8.0 to mark incidents that have happened along the route or indicate their likes or dislikes relating to their journey to school.

These symbols can be separated into positive, negative and neutral symbols as shown in Table 8.0.

Table 8.0: Map Symbols

Symbol	Explanation	Sign
☺	I like to cycle here	Positive
☹	I don't like cycling here	Negative
☐	It's safe to cycle here	Positive
☠	It's dangerous to cycle here	Negative
◆	I had an accident here	Negative
⦿	I almost had an accident here	Negative
×	Here I'm crossing a road	Neutral

The collection of the surveys was organised in conjunction with the class teachers and the principal office of each school. Each child had three days to complete and return the survey to their class teacher. The class teachers collected all returned surveys in a provided box and after three days deposited the collection box in the principal's office. Within a week after the last survey was handed out in an individual school, the collection boxes with all returned surveys were collected. This gave the individual teachers and schools a short period grace in which late collection boxes could be returned. This method of collection worked very well apart from one case, where the class met the teacher on a weekly basis. This one collection box was returned a week later.

3.6 Digitising children's routes and symbols

The routes and symbols that children drew on their maps where subsequently digitised in ArcGIS. The routes were drawn as polylines and the symbols were added as nodes (points). This is a relatively straight forward procedure. Each individual route drawn by a child was retraced on a digital map. In a GIS a route is defined as a linear feature that stores a unique identifier and contains coordinates that locates it on a map. GIS systems also allow attributes to be added to routes and nodes that can later be queried.

In this study, apart from the unique identifier and coordinates associated which each route and node, a number of additional attributes were added manually. These included: school, gender, age, mode of transport and length for each routes and: school, gender, age, mode of transport and symbol value for each node.

4.0 RESULTS AND ANALYS

The results presented here are based on the analysis of DTO and RSA data, a survey of the area surrounding three target schools and a survey of 128 children who are pupils at these schools. Initially, the analysis of the DTO Travel to Education (DTO, 2007) data that shows the general distribution of schools in the GDA and the origin and destination of school pupils in the GDA is presented. This addresses Objective i. (see Section 1.6) of the study. Thereafter, accident data obtained from the RSA was analysed to determine if bicycle accidents were more likely on certain road types and to assess the number of recorded child road traffic accidents in the survey area. Furthermore, these records were used to identify the possibility of potential hot spots or Accident Black Spots. This is followed by the analysis of the area survey which deals with child specific problems in the survey area road network and the classification of roads and tracks in the survey area road network. The results of the written survey and the Children's Maps symbols and routes (Objective ii, iii and iv – see Section 1.6) are presented in detail. Finally, a research technique to populate accident black spot maps in lieu of existing data is examined (Objective v – see Section 1.6).

4.1 DTO Data Spatial Analysis

All primary and secondary schools in the GDA are displayed with 1 km and 2 km buffer zones in Figures 19.0 and 20.0, respectively. From these Figures it is apparent that most children in Dublin live within 1 km of a primary or secondary school, and a great number within 500 m of a school.

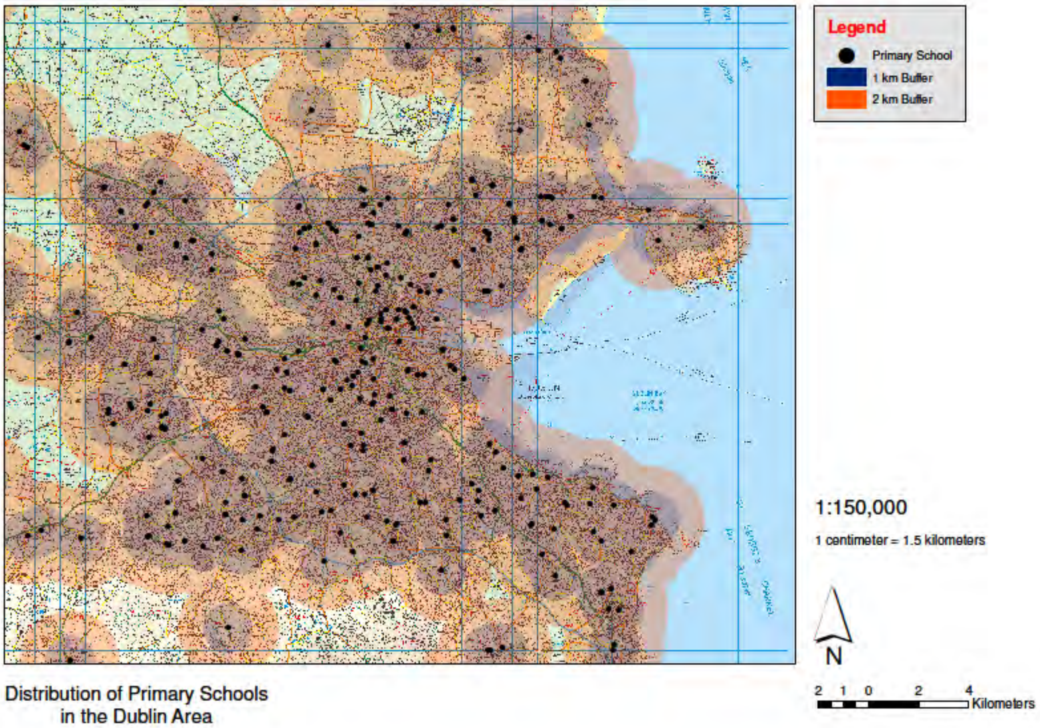


Figure 19.0: Distribution of Primary Schools in the Dublin Area

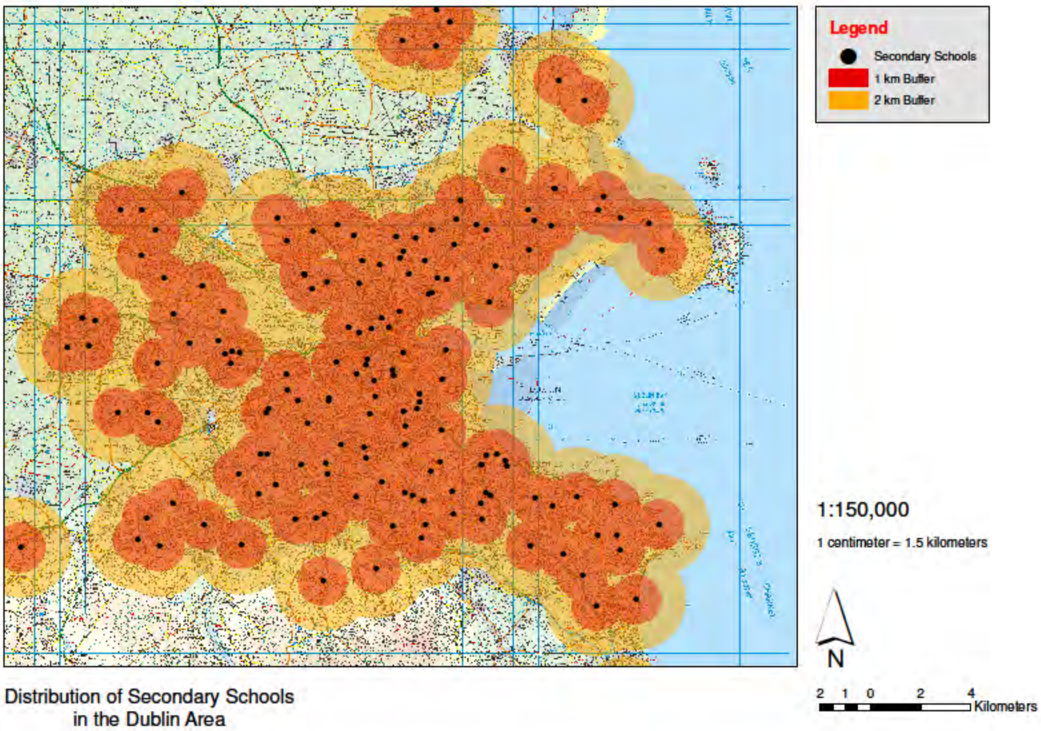


Figure 20.0: Distribution of Secondary Schools in the Dublin Area

Data from the DTO (2007) is displayed in Figures 21.0 and 22.0 to respectively illustrate the demand and supply of available Primary and Secondary School places.

From these figures it is evident that there is good match between demand and supply of school places, meaning that in principal children should be able to find a school close to where they live. This is important as it was shown in section 2.9 that living close to a school increases the likelihood of children travelling to school using an active mode of transport.

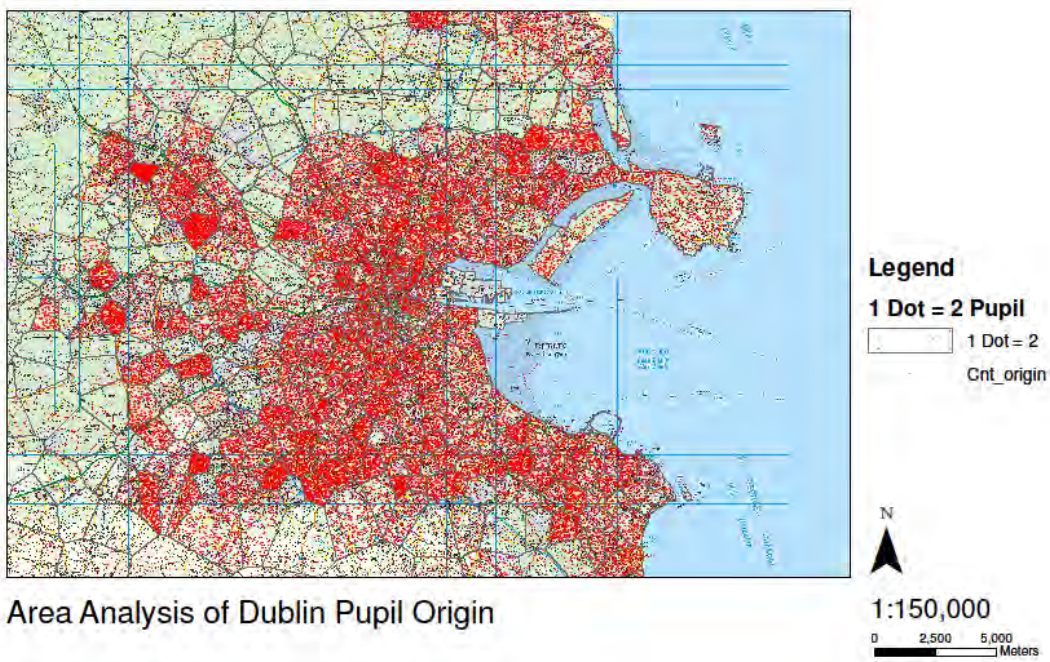


Figure 21.0: School Demand Dot Density Map (DTO, 2007)

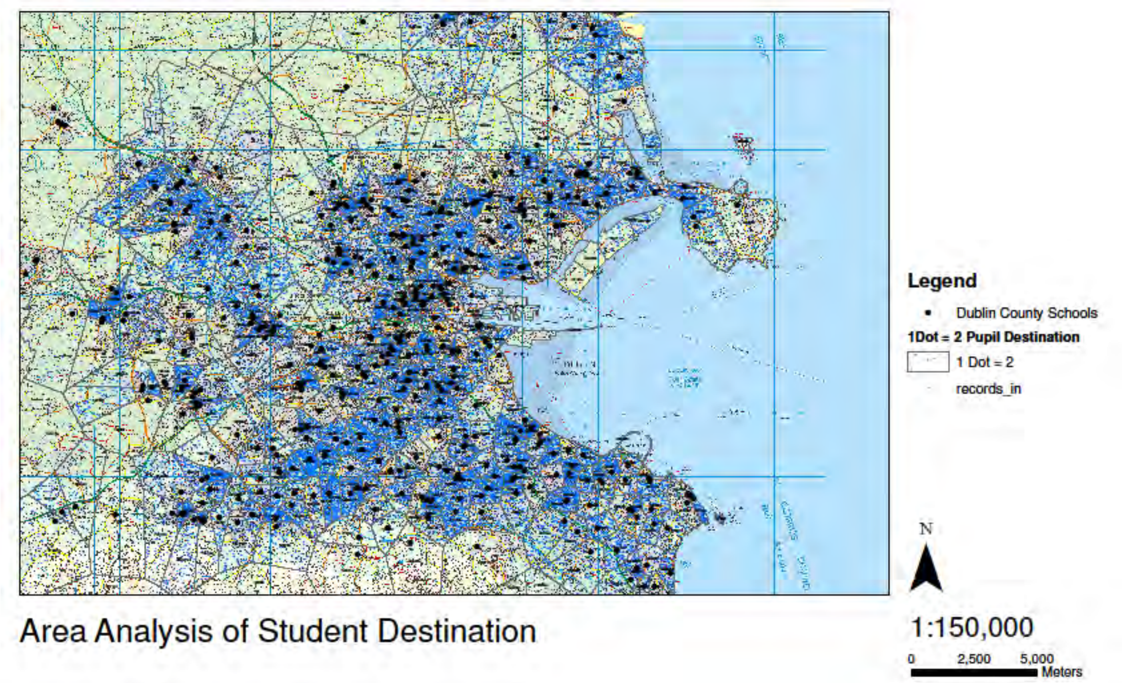


Figure 22.0: School Supply Dot Density Map (DTO, 2007)

Figures 19.0 and 20.0 illustrate that according to Jensen (2006) most children in Co. Dublin live within a comfortable cycling distance from an appropriate school. For this reason spatial distance should not be a major barrier to cycling to school in Co. Dublin. The good balance of demand and supply of school places (Figures 21.0 and 27.0) indicates that the reasons children travel to secondary schools further away than the closest school are most likely not due to school place availability.

From Figure 21.0 It can be seen that no areas in the GDA have a considerably higher or lower density of children of school going age. On analysis of the numbers of children related to an area rather than as a percentage of households, it is apparent that the number of children per area remains a relatively even throughout the city and suburban areas. In fact, as Figure 21.0 illustrates, some residential areas in the GDA such as Clontarf have a lower density of children than the City Centre.

4.2 RSA Data

The RSA data results consist of:

- Analysis of the RSA 'Ireland Road Collisions' online map (as outlined in section 3.3.1).
- Analysis of RSA road accident data analysed using GIS (as outlined in section 3.3.2).

The RSA data as presented here serves two purposes: firstly, it provides an insight into the time required to build up an accident data base for cycling in general and for children cycling in particular. Secondly, it facilitates an examination of any apparent relationship between road types that children consider either dangerous or safe to cycle on in the survey area, and the actual danger that cyclists have encountered on distinct road types in Dublin. Due to the scarcity of data in the RSA database it is impossible to determine more interesting relationships for children or to undertake any significant statistical analysis than presented here.

4.2.1 RSA 'Ireland Road Collisions' Map

In the GDA road related accident data is recorded and publically available as a Collision road map on the RSA web page (www.rsa.ie). For the purpose of this research the RSA data relating to bicycle and pedestrian accidents was obtained and analysed to determine if meaningful results for children's cycling safety could be extracted. Data extracted from the RSA database included records of all recorded bicycle accidents in Dublin between 2005 and 2009, as shown in Figure 28.0 and also all recorded pedestrian accidents during the same time period (Figure 24.0).

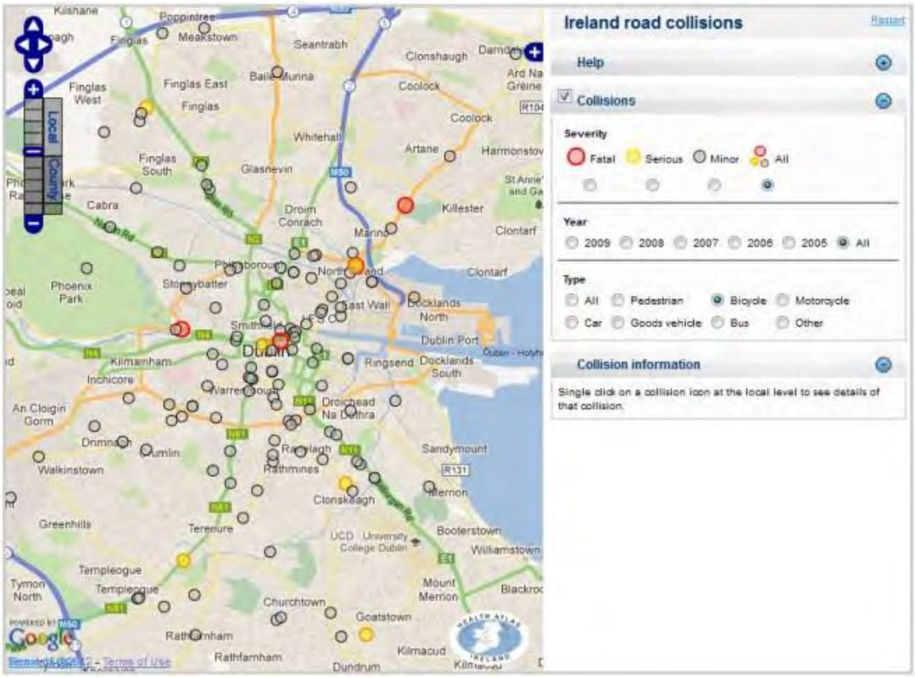


Figure 23.0: RSA 'Ireland Road Collisions' Map. Recorded bicycle accidents in Dublin between 2005 and 2009 (www.rsa.ie)

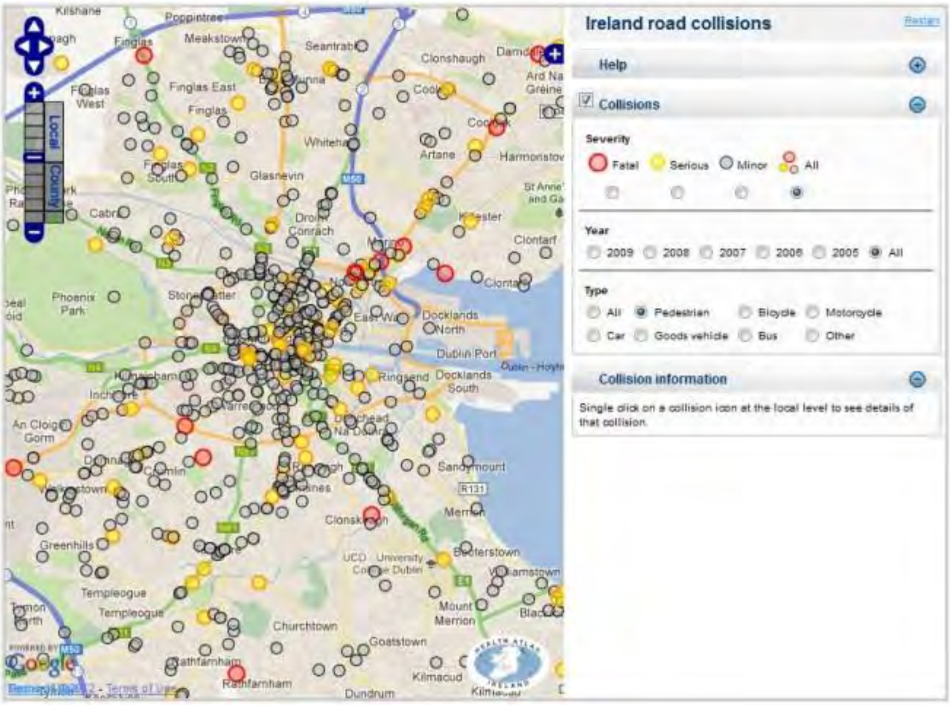


Figure 24.0: RSA 'Ireland Road Collisions' Map. Recorded pedestrian accidents in Dublin between 2005 and 2009 (www.rsa.ie)

On closer inspection of this RSA data it is evident that the accident data collected in a five year time span is sparse within the area of interest, most apparent when viewing cycle accidents (Figure 25.0) and little analysis can be based on this data. Although the spatial data representing pedestrian accidents indicated some spatial patterns (as shown in Figure 26.0), the collected data is again too sparse for use in determination of accident black spot detection in the area of the target schools used in this study.

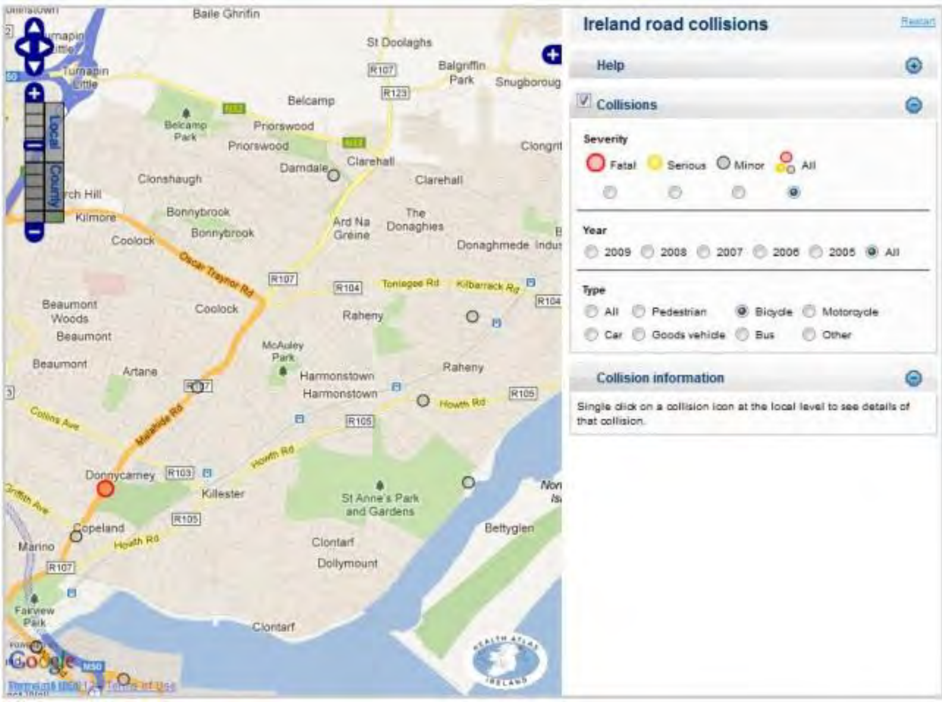


Figure 25.0: RSA 'Ireland Road Collisions' Map. Recorded Bicycle Accidents in the Study Area 2005 and 2009 (www.rsa.ie)

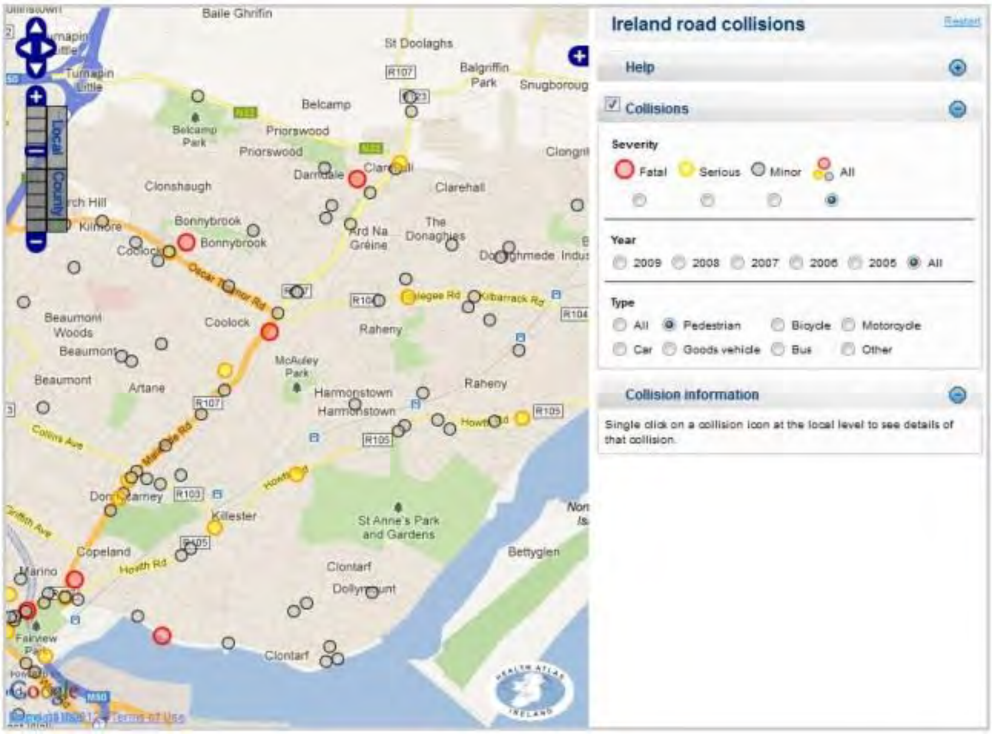


Figure 26.0: RSA 'Ireland Road Collisions' Map. Recorded Pedestrian Accidents in the Study Area 2005 and 2009 (www.rsa.ie)

It is important to note that the displayed accidents in Figures 23.0 and 24.0 include the total number of accidents recorded in the area and this data cannot be filtered to display child cyclist or child pedestrian accidents. For this reason the bicycle and pedestrian data was filtered using the Trip Purpose category 2 (to/from School) (See Section 3.3.2). This category includes trips to college and university. As a result it is impossible to determine the age of the person involved in the traffic accident. The lack of available cycling accident data for the survey area (Figure 25.0) may be due to too low cycling numbers in general and for children in particular.

4.2.2 RSA Bicycle Accident Data

A further spatial analysis using GIS of RSA cycling accident data for an extended period of time (1996 – 2007) was undertaken to determine if more useable statistical and spatial patterns could be determined. However, during this time period only 30 (0.4%) of the recorded 7,644 accidents in Dublin were directly associated with a trip to school (Figure 27.0) and only one of these accidents occurred within the survey area (Figure 28.0).

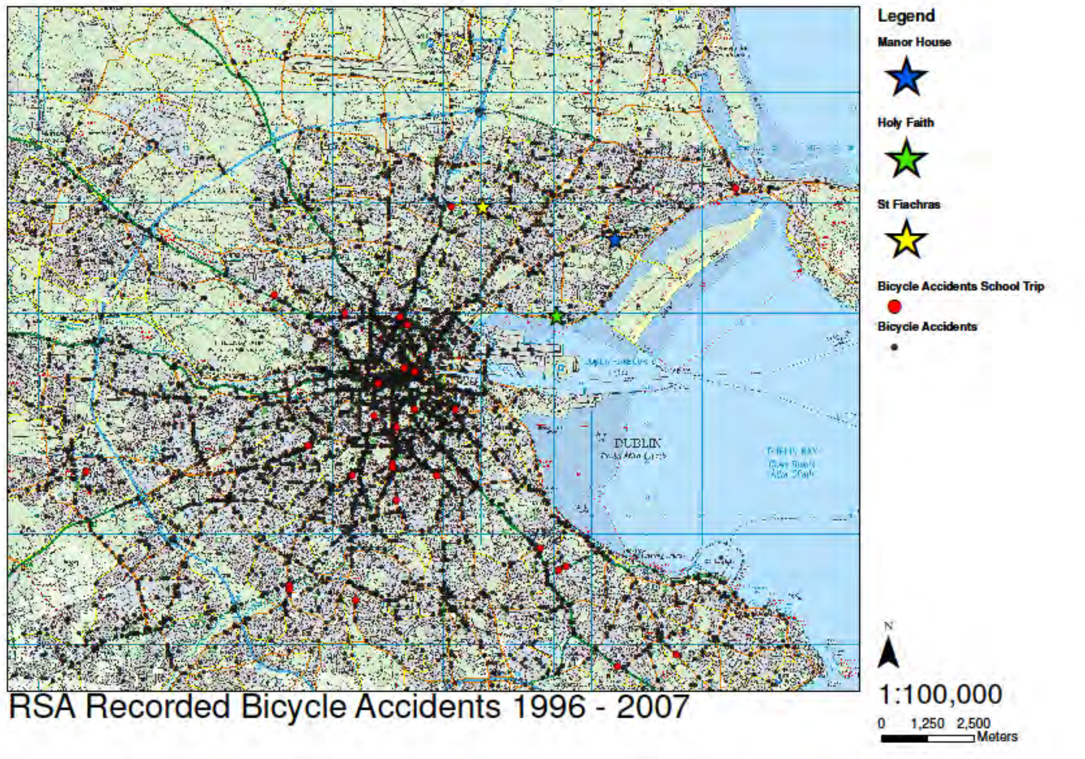


Figure 27.0: Dublin Bicycle Accidents 1996-2007.

(Source RSA, 2007)

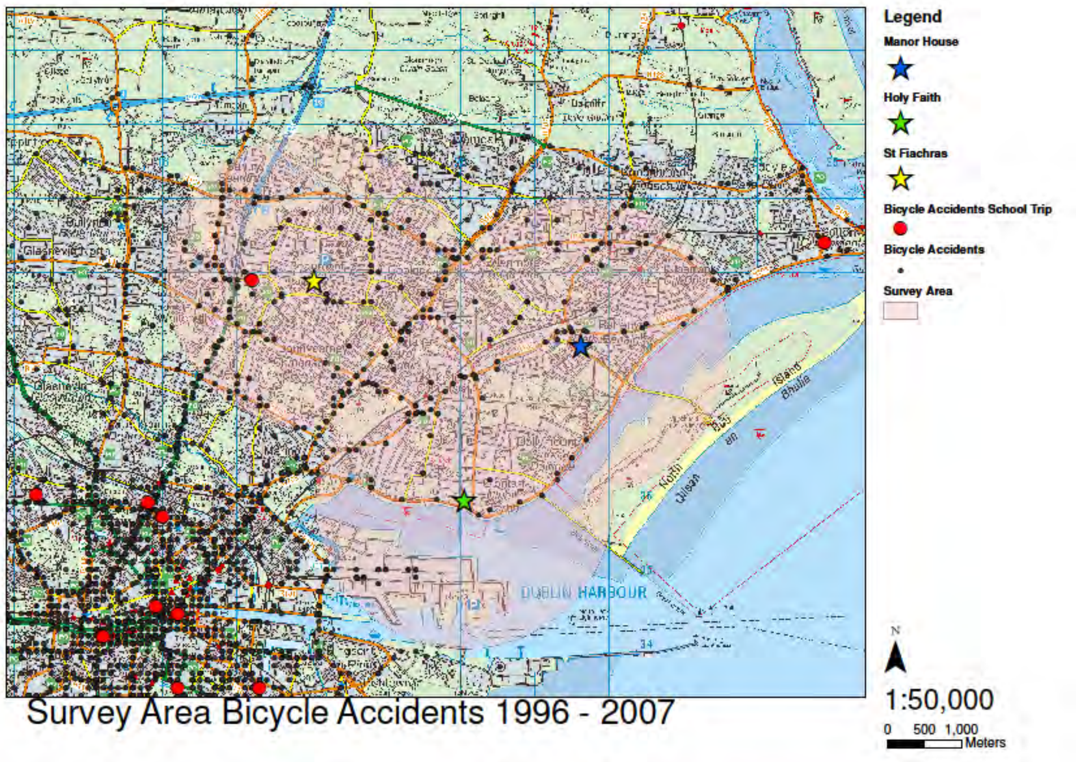


Figure 28.0: Survey Area Bicycle Accidents 1996-2007.

(Source RSA, 2007)

Of interest to this research is that a great number of cycling accidents as recorded by the RSA between 1996 and 2007 occur on major roads as shown in Figure 29.0. Road Types 5 and Type 6 in particular can be considered high risk as over 50% (3796) of all RSA recorded bicycle accidents occurred on these road types (Figure 30.0) while they make up only 27% of the Dublin City road network.

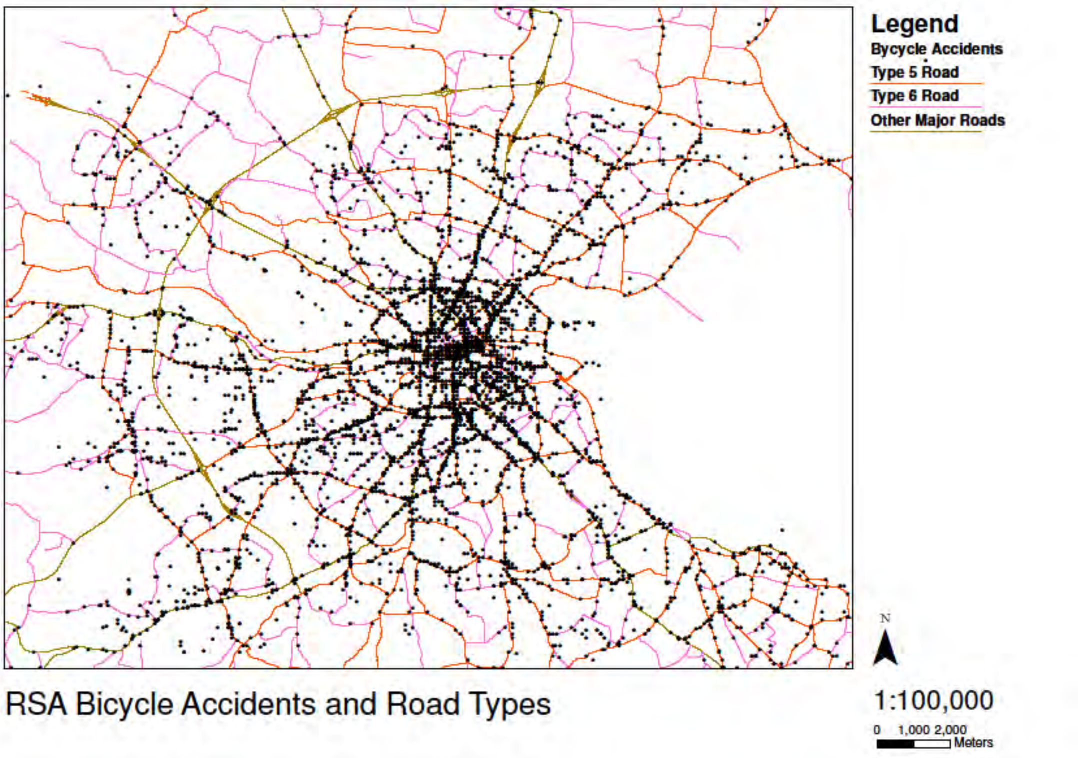


Figure 29.0: Dublin Bicycle Accidents 1996-2007 and Toad Types. (Source RSA, 2007)

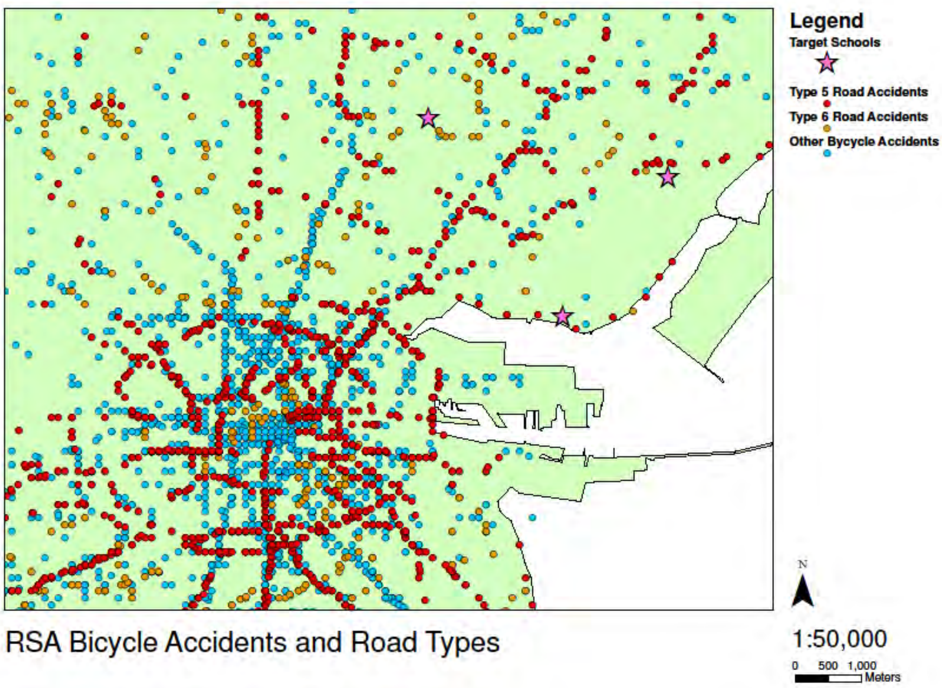


Figure 30.0: Recorded Bicycle Accidents on Road Types 5 and 6 between 1996 and 2007. (Source RSA, 2007)

Of significance to this study is that children in the survey placed a high number of negative symbols on these two road types.

4.3 Area Survey Results

The area surveyed in this study is defined by a 2 km radius surrounding each of the three schools, as shown in Figure 17.0. This area was visually assessed (see Section 3.4) in terms of both pedestrian infrastructure and cycling infrastructure, to determine if the infrastructure was sufficiently adequate to provide a safe journey to/from school for children. Results of this assessment indicated that there is sufficient pedestrian infrastructure almost everywhere with adequate pathways, pedestrian lights or pedestrian crossings enabling a safe mode of transport for children between major road intersections. However, the cycling infrastructure in the area surveyed was found to be more sporadic in terms of the nature of the infrastructure provided i.e. often changing in nature from shared bus lanes to cycling lanes and from mandatory cycle lanes to advisory cycle lanes. In addition, cycle lanes were often extremely short and narrow and segments of the cycle lanes had very poor surface quality. In places the cycle lanes competed for space with other traffic lanes and road markings and were simply worn away. Thus it can be surmised that issues relating to parents perception of child safety when cycling, as mentioned in Section 2.4.3, would have direct implication in the number of children cycling to/from school.

The great amount of variables (as shown in the Roads Data Dictionary in Appendix 1) including speed limits (and actual traffic speed), traffic volume, parking cars, signage, gradients, road surfaces or traffic calming measures make it difficult to divide roads into stretches of any meaningful length that would deliver a consistent travel experience for a child cycling along. These variables can change in a short time depending on the time of day, day of the week, weather, the season and other factors. Specific analysis of these interdependent and time variant variables in the above maps was found to be impossible for the extent of the road network surveyed and would constitute a separate body of work outside the remit of this research. However, surveying the road network in the area was extremely beneficial in assessing the issues that arise from the Childs's point of view as discussed below.

4.3.1 The Child's Point of View

During the area survey special attention was given to problems and situations that could potentially be harmless for an adult yet pose a danger to a child. As the survey was mainly conducted by bicycle, this form of transport was examined in most detail however; most of the situations found would be problematic for both cyclists and pedestrians. Children's height can result in situations where they are not able to see or be seen, while an adult would normally be sufficiently tall enough to have a clear view. This situation most often occurred on road intersections where hedges or garden fences obstructed views. Parked cars were a further source of visual obstruction, especially when parked illegally in the vicinity of road crossings or intersections. In addition, it should be noted that children might not always be able to understand all road signage or could be distracted by their surroundings and lose their concentration in traffic. Large busy intersections with multiple lane layouts, traffic islands and phased pedestrian lights could also potentially be confusing and imposing for children.

The specific problems identified during this area survey for children included cycling on narrow cycle lanes where passing busses or HGV's at high speed (aprox. 50 km/h) could seriously unsteady a child on a bike. While this experience was unsettling to an adult, especially when it occurred very suddenly, to a child it would be extremely frightening.

Other issues observed related to general problems with children's bicycles and road surface quality and obstructions. Some of the potholes and cracks in the road surface encountered in the area survey were sufficiently large to cause a considerable impact and a temporary loss of control of an adults bicycle. A child's bicycles smaller wheels would most likely increase the impact; this also applies for ramps and lower curb stones. A full sized bicycle wheel can usually clear these quite easily whereas a children's bike wheel could be unsettled by this impact.

It is important to note here that assessing the traffic situation from the perspective of the child did not entail directly observing children and their behaviour in the area as carried out in previous studies (Francis, 1985; Wurtele *et al.,* 2005). This method, although considered, was avoided for ethical and practical reasons (see Section 3.1). From an engineer's or planner's perspective it is also important to consider the road safety situation of a child and thus the limitations and challenges which define a highly complex situation such as a street which must be considered. To rank high accident concentration sections on roads the engineer, specialist or urban planner must conduct a comprehensive analysis of the road and make recommendations for road safety improvements. As this might be practical for a small section of road as described in the NRA's Road Safety Audit, it was found to be highly impractical to do this for an extensive road network as the survey area. The attempt to divide roads into sections and categorise them using a data spread-sheet led to no meaningful result, as the street is not a homogenous environment. Circumstances are constantly changing due to the time of day, day of the week, weather and numerous other factors that can potentially affect road safety. A local road which can easily accommodate a car to overtake a cyclist in a safe distance of 1.5 m can turn into a narrow lane when cars are parked on both sides. Alternatively, a section of road adjacent to an open field can be dangerous to cyclists in stormy conditions and lighting conditions at night can vary greatly due to obstructions from vegetation or other sources. Road sections change so rapidly in character and layout that the method of rating road sections is only practical for short section. This makes it difficult for engineers, specialists or urban planners to define a length of road infrastructure for which the Road Safety Inspection is valid. In a Road Safety Audit the extent of the road to which it applies is clearly defined. This definition is much more difficult to make when a Road Safety Inspection is conducted, even before taking into account traffic unrelated issues such as personal safety in regards of other children, youth or adults. For the same reason it is difficult for a child to answer questionnaires on preferred types of roads, cycling infrastructure. The written reports that accompanied the spread sheets and that give a general overview of the area and road infrastructure in each location were found to be a better source of information to rate an area.

4.3.2 Road Types and Vector Data

All three target schools (St Fiachras Primary, Holy Faith Secondary and Manor House Secondary) were located within 4 km of each other, as seen in Figure 31.0 and all are within the DCC area. Implementing a 2 km buffers around each target school resulted in an area exceeding 32 km² which extended to approximately 50% of north Dublin.

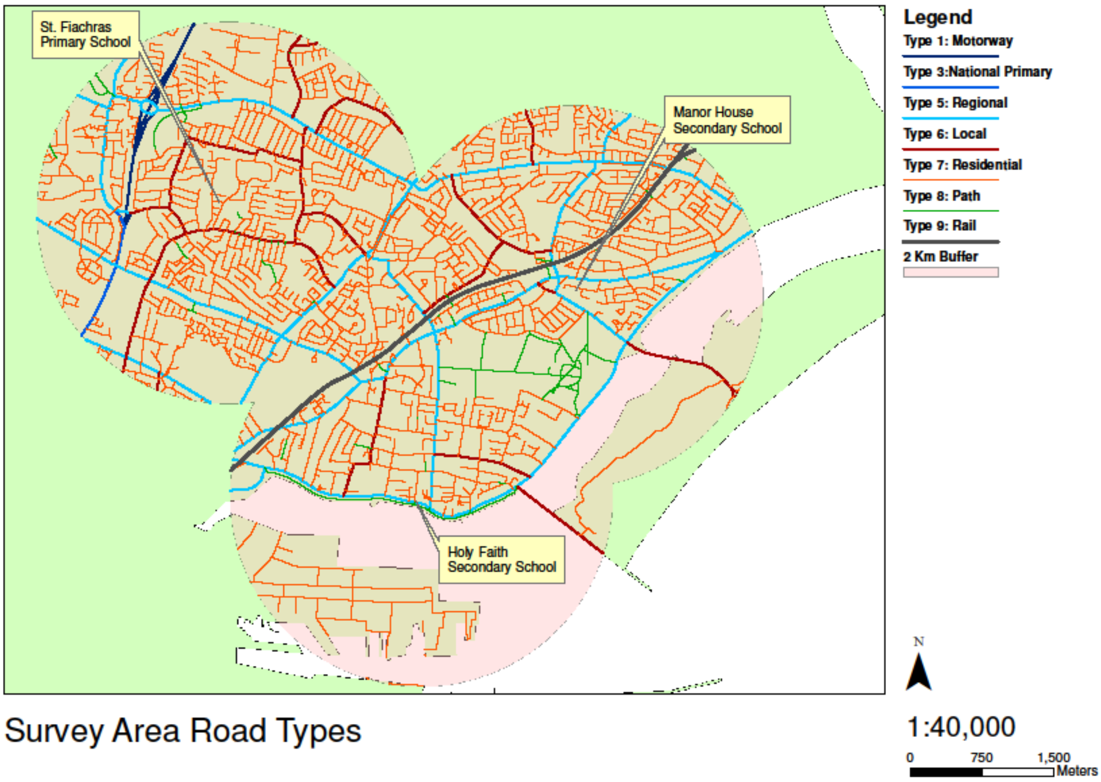


Figure 31.0: Survey Area and New Road Types

A vector database of roads in this extended area of Dublin, supplied by the Department of Spatial Information Sciences DIT (see Section 3.4.1) was divided into two distinct categories (Major roads and Minor Roads) and 7 road types. Two new road types were added to the survey area road network (Type 8 – Path and Tracks and Type 9 – Rail) resulting in nine discrete types and categories, ranging from Motorway to Rail as shown in Table 9.0. This subdivision was based on the roads classification found in the Irish 'Traffic Management Guidelines' (Government Publications, 2003) and was validated during the area survey. This classification proved very useful in this research as the different road types described offer an accurate picture of different experiences when cycling in the survey area.

Table 9.0: Result Road Categories

Road Category	Type	Length, km
Major	1 Motorway	4.42
	2 Dual Carriageway	0.0
	3 National Primary	1.44
	4 National Secondary	0.0
	5 Regional	37.10
Minor	6 Local	19.30
	7 Residential	231.74
	8 Path or Track (car Free)	14.38
	9* Rail	6.24

**Road Type 9-Rail was added to accommodate routes to school by rail services*

From Table 9.0 it can be seen that the four main road types found in the area were Type 5 – Regional Roads, Type 6 – Local Roads, Type 7 Residential Roads and Type 8 – Paths and Laneways, each of which are described in more detail here:

- **Type 5 Regional Roads –** These roads (see Fig. 31.1) provide links between local districts within urban areas. They can be up to 9m in width and often have Bus lanes and/or cycle lanes, with segregated footpath on either side. They tend to have multi-lane road intersections. They usually allow car speeds of 50 km/h. They can suffer from very heavy traffic, especially at rush hour.

Figure 31.1: Type 5 Regional Road (Google Maps).

- **Type 6 Local Roads –** These Roads (see Fig. 31.2) are the main links within the housing areas serving between 100 and 300 residential dwellings. They can be up to 8 m in width and often have bus lanes or cycle lanes, with segregated footpath on either side. They usually allow car speeds of 50 km/h.

Figure 31.2: Type 6 Local Road (Google Maps)

- **Type 7 Residential Roads –** These generally are roads up to 6 m width, and service small groups of housing (see Fig. 31.3). Car speeds are generally below 50 km/h and they generally have segregated footpaths on each side and cyclist share the road space with other road users.

Figure 31.3: Type 7 Residential Road (Google Maps).

- **Type 8 Paths or Tracks –** These are routes that free of motor traffic (see Fig. 31.4). They are provided for pedestrians and cyclists, to link various parts of a development. They often provide shortcuts in a housing estate or paths and tracks in parks.

Figure 31.4: Type 8 Paths or Tracks (Google Maps).

The area survey excluded Road Type 1 (Motorway) as no cyclists or pedestrians are permitted on these roads and Road Type 2 (Dual Carriageways) as they were absent from the survey area. On the basis of the area survey, a decision was made to treat all Road Type 7 (Residential) roads as clusters within an area, as these clusters of roads form areas that are distinct in their residential character and deliver in the vast majority a homogenous environment to cycle or walk. Road Type 7 (Residential) roads are also the most numerous roads in the survey area. They account for 77.4% of the road network in the survey area. Road Type 5 (Regional) with 12.3% and Road Type 6 (Local) with 6.4% are the next most numerous roads in the survey area.

4.4 School Survey Returns

A total of 292 questionnaire surveys were distributed to the target schools in the study area, with a response of 128 returned surveys (44% response rate) as shown in Table 10.0. This rate of response is slightly lower than the response to the 2006 Travel to Education Survey of 47% for primary schools, and slightly higher than the 43 % response rate at secondary schools (DTO, 2006). There were 17 Inconclusive returns. Returns were deemed inconclusive if the route on the map had not been drawn, could not be traced or was obviously wrong (did not match home address or followed a river). Questionnaires attached to inconclusive maps were not analysed. The lowest rate of inconclusive surveys (9.7%) was achieved at the primary school level. The highest rate of inconclusive responses (33.3%) occurred in Manor House Secondary School. Manor House Secondary School also had the lowest rate of response (36.6%) mainly due to the very poor return rate of surveys from the Transition Year (Table 11.0).

Table 10.0: Overall Survey Returns

Mode of Transport	Number	%
Distributed Surveys	292	100
Response	128	44
Walking	57	20
Cycling	24	8
Car Passenger	27	9
Other	3	1
Inconclusive	17	6

The reason for the poor return rate for Transition Year students might be due to the fact that they are saw the exercise less as a home work or school project and took full advantage of the fact that this exercise was voluntary. The 2006 DTO Travel to Education Survey showed a clear trend that response rates are dropping with an increasing age. They dropped from 47% for Primary Schools to 43% for Secondary and 26 % for Third Level Education. The percentage of inconclusive surveys is relatively low. It is a positive fact that the lowest rate of inconclusive surveys was achieved at the primary school level with 9.7%.

Table 11.0: Individual School Survey Returns

School	St Fiachras Primary	Holy Faith Secondary	Manor House Secondary
Distributed Surveys	172	79	41
Response	62	51	15
Walking	22	28	7
Cycling	18	6	0
Car Passenger	16	10	1
Other	0	1	2
Inconclusive	6	6	5

The return rates of the survey are lower than the overall figures for the 2006 Travel to Education Survey. This can be explained by the fact that completion of the questionnaires for this study was purely voluntary to comply with DIT ethical policy. If the questionnaires were delivered by a teacher as a homework assignment (as proposed in Section 3.5) then the expected returns would be considerably higher. However, a direct comparison of the survey returns in this study with the DTO 2006 Travel to Education Survey records of the three target schools revealed that the Children's Maps Survey had a considerably higher return rate at these schools than the DTO 2006 Travel to Education Survey and thus can be considered quite successful.

4.5 Questionnaire Results

The questionnaires distributed to each school included a section comprising of three questions which addressed the road safety concerns of children when travelling to school as this was identified in the literature review (Section 2.9.1) and in the DTO Travel to Education Survey (DTO, 2007) as a significant factor in the decision of children for cycling to school or not. The questions posed were:

6. What is the main reason you do not cycle to school?
7. When you are cycling what type of cycling facilities do / or would you use?
8. What do you think makes cycling less enjoyable or safe?

The tabularised results of these three questions are shown respectively in figures 32.0, 33.0 and 34.0.

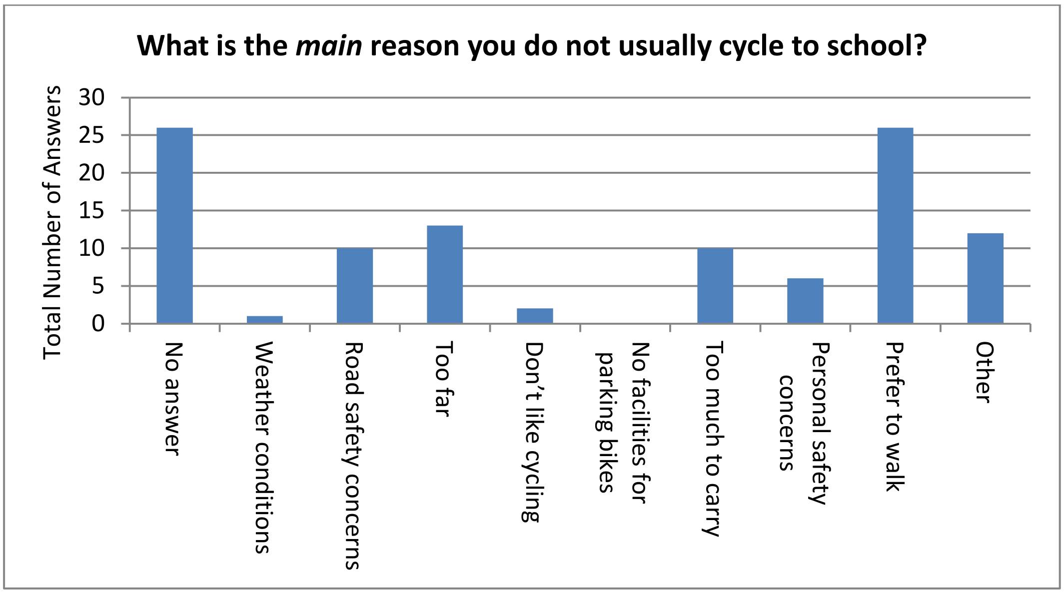


Figure 32.0: Written Questionnaire Results: Reasons for not cycling to school (Total no. of responses n=106)

From Figure 32.0 it can be seen that many children prefer to walk (26 children), while 13 children would not cycle to school because they found the distance too far. This result indicates that a lot of children live sufficiently close to school that they find walking more convenient. This correlates with Kweon *et al.* (2006); and Nelson *et al.* (2008) who found that children living close to their school preferred to walk, while children living further from school preferred to cycle. Dessing *et al.* (2014) found that walking trips to school declined with greater distance while cycling and motorised transport increased. However, road safety (10), too much to carry (10) and personal safety (6) can be identified as contributing factors.

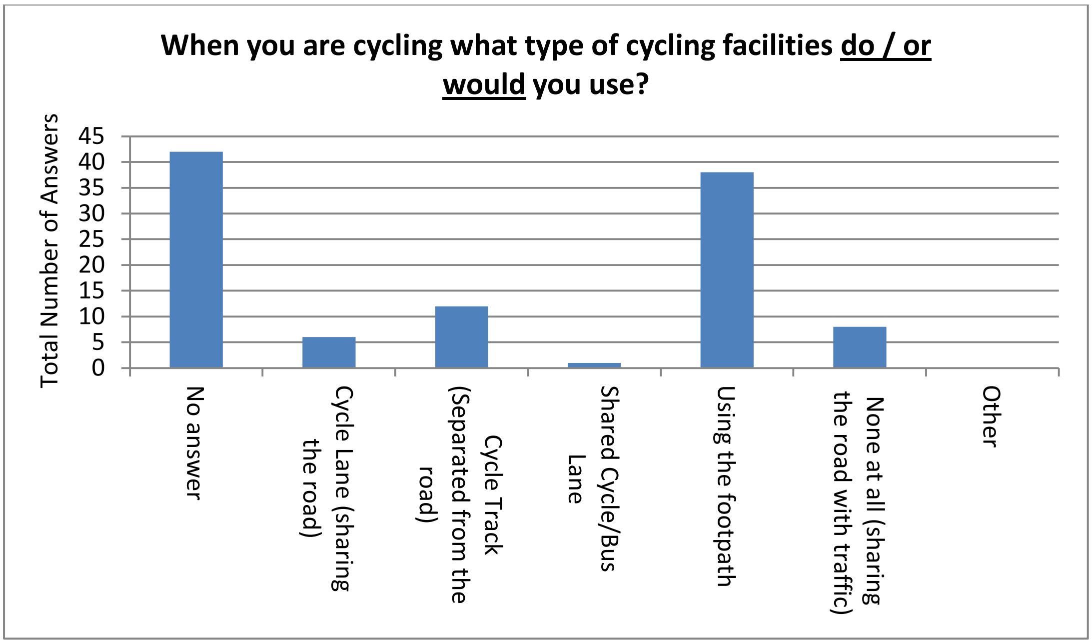


Figure 33.0: Written Questionnaire Results: Preferred Cycling Facilities (Total no. of responses n=107)

Figure 33.0 indicates that children find walking facilities safer than cycling facilities as most children use the footpath for cycling (37) while only six children state they use a cycle lane on route to school. This is a strong indication that cycle facilities in the area do not cater well for children as they prefer to cycle on walking paths.

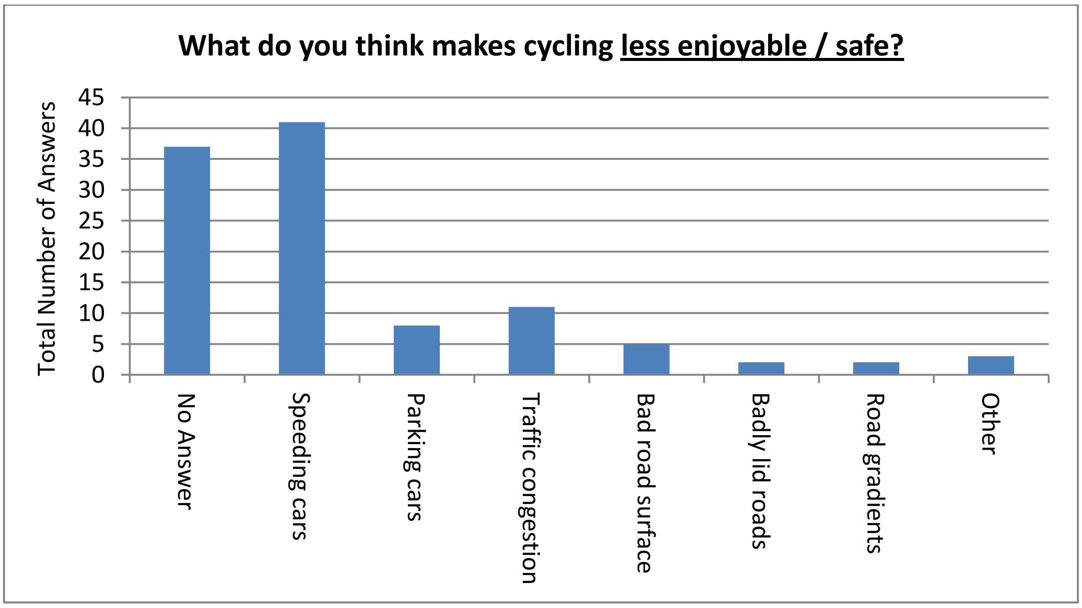


Figure 34.0: Written Questionnaire Results: Factors which influence cycling enjoyment. (Total no. of responses n=107)

Figure 34.0 indicates that speeding cars are the greatest barrier to children enjoying cycling in a safe environment. This further shows that a lot of children feel that cycle facilities do not protect them adequately from motor traffic.

4.6 Children's Map Results

Children's Map results as presented in the following sections consist of two main areas:

- Firstly, analysis of the symbols used by children to locate i. areas of accidents, ii. near misses, iii. perceived danger, iv. were they feel it is safe to cycle, v. were they like to cycle and vi. Locations were they cross the road.
- Secondly, analysis of the actual routes which children use on their journey to school.

This data is discussed with respect to School, Mode of Transport and Gender

4.6.1 Symbols Results

It has been shown in Section 4.2.1 that there is an almost complete lack of geo-referenced bicycle accident data in the survey area. For this reason the results of the children's symbols could not be compared to locations of actual Accident Black Spots. However, although only a few bicycle accidents were recorded in the survey, the RSA data shows four bicycle accident locations in close proximity to the 'Hot Spot' the children identified.

The surveyed children had to choose from seven different symbols, as identified in Section 3.5.2 to mark and rate locations of specific interest along their route to school. Subsequently these symbols can were separated into positive, negative and neutral symbols, as shown in Table 8.0, and are discussed in more detail in the following sections.

4.6.1.1 Negative Symbols

Negative symbols, as outlined in Section 3.5.2 indicate specific locations where children had a serious incident or perceived a difficulty on their route to school. The frequency of each negative symbol was analysed and the results are presented here in order of severity:

- '◆*I had an accident here*'

This was the most severe of all four negative symbols and was only employed once in this survey (Table 12.0). The symbol was used by a second year secondary school girl, walking to school, as shown in the extracted GIS map in Figure 35.0.

The accident location was situated on a Type 7 (Residential) road (Mount Prospect Road, Figure 36.0). The character of the road more closely resembles a Type 6 (Local) road due to its cross-sectional dimension which is relatively wide and the fact that it has a straight longitudinal section, thus allowing faster car speeds than normally found on a type 7 Residential Road. This road is often also used as a shortcut between Clontarf Road and Vernon Avenue to avoid Clontarf Village which increases the level of traffic. As only one accident location was identified in this survey the implication is that accidents occur relatively seldom.

Figure 35.0: Accident Location from Survey Data

Figure 36.0: Mount Prospect Road (Google Maps)

- ⦿ *'I almost had an accident here'*

The second most severe negative symbol was where a child in the population sample identified a near miss or accident. The ⦿ *'I almost had an accident here'* symbol was used eight times (Table 12.0) by children from St. Fiachras and Manor House School, as shown in Figure 37.0. This symbol was placed three times on Type 5 (Regional) and four times on Type 6 (Local) Roads. One symbol was placed on a Type 7 (Residential Road). The chance of a near miss increased from recordings of an actual accident in the study area by eight fold.

Figure 37.0: I almost had an Accident here Locations from Survey Data

- ☠ *'It's dangerous to cycle here'*

The third negative symbol ☠ *'It's dangerous to cycle here'* is quite similar to the second negative symbol with a slightly lower degree of severity. This symbol was used twelve times (Table 12.0). Four times on Type 5 (Regional) and eight times on Type 6 (Local) Roads as shown in Figure 38.0.

Figure 38.0: It's dangerous to cycle here Locations from Survey Data

- ☹ *'I do not like cycling here'*

The final negative symbol ☹ '*I do not like cycling here'* is the least severe symbol. This symbol was employed nine times (Table 12.0), twice on Type 5 (Regional), four times on Type 6 (Local) roads, and also three times on Type 7 Local roads (Figure 39.0).

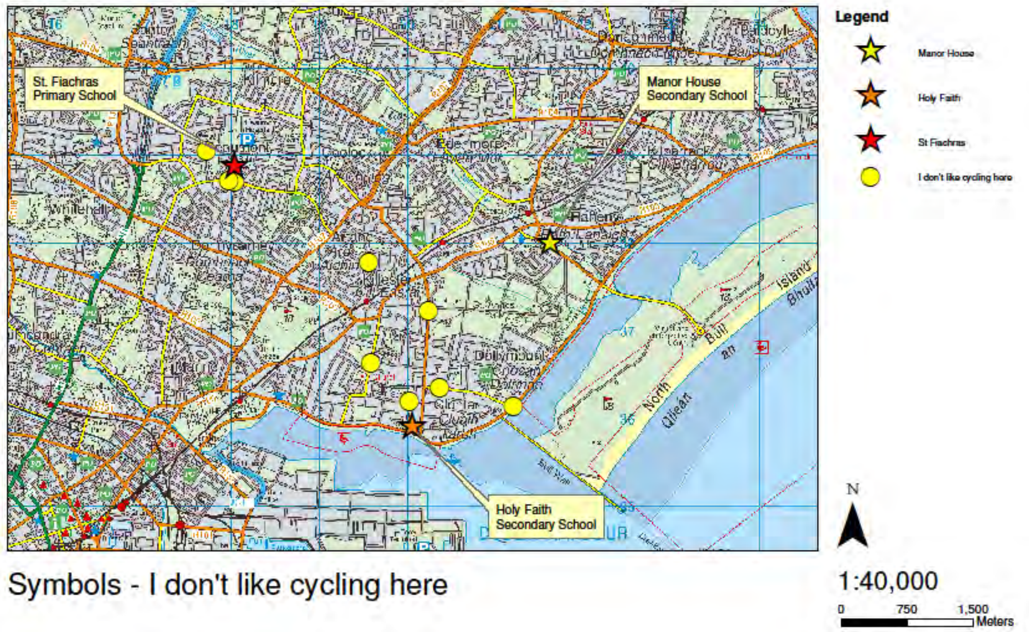


Figure 39.0: I don't like to cycle here Locations from Survey Data

The results of the symbol locations as presented in the Figures 35.0 – 39.0 differ from school to school. The negative symbol locations for Holy Faith School and Manor House School were mainly located along Type 5 and Type 6 roads, they were also evenly distributed within the survey area, as illustrated in Figure 40.0. While the negative markers for St Fiachras are also mainly located on a Type 6 (Local) road, here in contrast, the negative symbols were concentrated in a relative small area or Hot Spot.

Surprisingly, on appraising this 'Hot Spot 'area during a site visit it appeared well served with dedicated pedestrian/cycling infrastructure (Figure 40.1). There is a controlled pedestrian crossings and a lollypop lady crossing for school children in the location where most negative markers were placed. The entire length of the road section has a cycle lane and a separated footpath on both sides of the road. However, children's comments on the maps and in the accompanying survey indicate that children feel unsafe here due to traffic speed and volume.

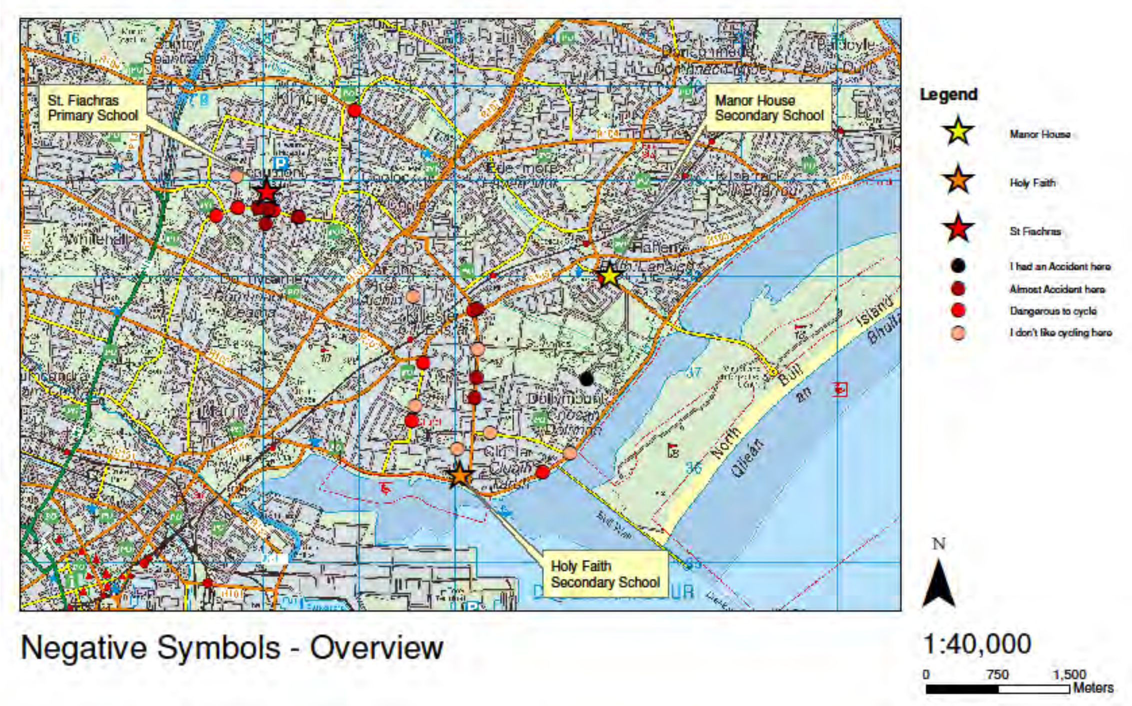


Figure 40.0: Spatial Distribution of Negative Symbols from Survey Data

Figure 40.1: St Fiachra Hot Spot.

Table 12 lists the number of times each negative symbol has been used by boys and girls from the individual schools. Boys and girls show no difference in the frequency they used negative symbols (24.1% and 25%), while Holy Faith pupil used negative symbols at a higher rate (35%) than pupil from St. Fiachras (26.8%) and Manor House, were only one negative symbol was used.

Table 12.0: Overview of Negative Symbols Ratings.

Symbol	Male	Female	St. Fiachra	Manor house	Holy Faith	Total
Accident location	0	1	0	0	1	1
Almost Acc. Location	4	3	5	0	3	8
Danger location	3	7	7	1	4	12
Not like it location	0	8	3	0	6	9
Total	**7(24.1%)**	**19(25%)**	**15(26.8%)**	**1(11.1%)**	**14(35%)**	**30**

Table 13 illustrates the use of negative symbols by mode of transport. This table shows a clear difference in the use of negative symbols between the active modes of transport and the car passengers. This indicates that children feel much safer when they are driven to school. It is interesting to note that children who walk to school used more negative markers (17%) than children who cycle (12%). In Figure 32 the main reason given for not cycling to school was 'Prefer to Walk'. This result indicates that this is mainly due to convenience rather than a higher sense of safety.

Table 13.0: Negative Symbols by Mode of Transport.

Symbol	Walking	Cycling	Car
Accident location	1	0	0
Almost Acc. Location	3	5	0
Danger location	7	4	1
Not like it location	6	3	0
Total	**17(16.2%)**	**12(11.4%)**	**1(1%)**

Table 14 illustrates the frequency negative symbols have been placed on the different road types. It becomes very obvious that most negative symbols (25) where used on the bigger Roads Types 5 and 6 that usually carry more motorised traffic and allow higher speeds than on the residential Road Type 7 and paths / tracks Road Type 8 (5). It is interesting to note that Road Type 5 and 6 would be the only roads in the survey area that carry bicycle infrastructure, yet children feel that the quieter residential roads are safer to use.

Table 14.0: Negative Symbols by Road Type.

Symbol	Road Type 5	Road Type 6	Road Type 7	Road Type 8
Accident location	0	0	1	0
Almost Acc. Location	3	4	1	0
Danger location	4	8	0	0
Not like it location	2	4	3	0
Total	**9**	**16**	**5**	**0**

In the case of Manor House School and Holy Faith School the prevalence of negative markers on the road types 5 (Regional) and 6 (Local) indicate that children in general feel less safe on the bigger road types in the area (Figure 40.0). This may be a result of the general road design in the area, resulting in generally higher traffic speeds. Also, heavier traffic in the vicinity of Holy Faith School and Manor House School could contribute to problems along these routes.

A common method to define an accident black spot is by locating a site were the rate or frequency of accidents exceed what is normal for such a site (Hauer, 1996). Thus it can be argued that in the case of Manor House School and Holy Faith School the prevalence of negative markers on the road types 5 (Regional) and 6 (Local) indicate that children in general feel less safe on the bigger road types in the area. This is an obvious reaction as children dislike high traffic volume and speeding cars. The volume of negative symbols in one area around St. Fiachras (see Figure 40.0) is quite alarming and indicates a potential accident black spot. In general, negative symbols would be expected along the bigger road types here however, they are concentrated in one area signifying a location where the perception of danger exceeds what is considered normal for such an area.

The difference in the spatial distribution of negative markers between the three schools also validates the assumption that the massing of symbols in one place is most likely due to a specific problem in this location (in this case at St. Fiachras) and is not caused by the higher concentration of routes in this area. This assumption is further validated by the distinct differences in the distribution of positive and negative symbols used by St. Fiachras pupil. Contrary to the negative symbols the positive symbols are distributed evenly over the survey area.

Table 12.0 indicates a relationship between the severity and frequency of traffic incidents. In absolute numbers, the figures resemble the Heinrich Pyramid (Manuele, 2011) which assumes that the number of accidents in a workplace is inversely proportional to the severity of those accidents (Section 2.15).

The common cause hypothesis (the hypothesis that accidents and near misses in the same area actually have the same root cause) has been found to be true in road traffic incidents and railway accidents (Roberts *et al.*, 2004; Wright *et al.*, 2004). The overall figures in Table 12.0 indicate a similar relationship.

The Negative Symbols (Table 14.0) indicate a direct relationship between the danger of road types as experienced by school children in the area and their perceived danger of differing road types. The locations of ◆ *'I had an accident here'* and ⊙ *'I almost had an accident here'* symbols which represent real events that children have experienced and these negative experiences happened in random locations on their journey to and from school. The locations of the ☠ *'It's dangerous to cycle here'* and ☹ *'I don't like to cycle here'* symbols are different in that they are based on the children's perception of safety or danger on their route to and from school. However, the symbols for actual dangerous locations: ◆ and ⊙ and the symbols of perceived danger: ☠ and ☹, can be seen to be mainly located on the same road types (road types 5 and 6). Specifically in the case of the St. Fiachras, results of the pupil survey indicate a spatial relationship between both of these sets of symbols, as they have been placed in close proximity to each other (Figure 40.0).

The common cause hypothesis is further supported by analysing the RSA accident map (Figure 30.0). Here it is apparent that cyclists in general face the highest risk of an accident on road types that resemble road type 5 (Regional) and 6 (Local) in the survey area. These road types have attracted 18 out of 21 symbols of perceived danger. This result supports previous research carried out by Møller *et al.,* (2008) who found indicators for accordance between the perceived and actual risk of cyclists using roundabouts.

4.6.1.2 Positive Symbols

The positive symbols employed in this study were designed for children to identify where they felt safe and their preferred route to travel to school. These symbols included ☐ '*It's safe to cycle here*' and ☺ *'I like to cycle here'*. It is interesting to note the difference in the total amount of these positive symbols used by the children in this survey. The symbol ☐ '*It's safe to cycle here'* was used 11 times

(Table 15.0), while the less specific symbol ☺ '*I like to cycle here*' was used 29 times (Table 15.0). Each category of Positive Symbol will be presented here in tabular format and discussed in more detail.

Table 15.0: Overview of Positive Symbols Ratings.

Symbol	Male	Female	St. Fiachra	Manor House	Holy Faith	Total
It's safe to cycle here	0	11	1	0	10	11
I like to cycle here	7	20	9	0	20	29
Total	**7(24.1%)**	**31(39.2%)**	**10(17.9%)**	**0(0%)**	**30(75%)**	**40**

Table 15.0 illustrates that the positive symbols were used more often by girls than boys.

Table 16.0: Positive Symbols by Mode of Transport.

Symbol	Walking	Cycling	Car
It's safe to cycle here	8	3	0
I like to cycle here	17	12	0
Total	**25(23.8%)**	**15(14.3%)**	**0(0%)**

Table 16 illustrates the difference of positive symbols used by mode of transport. Walking routes attracted more positive symbols (23.8%) than cycling routes (14.3%).

- ☐ '*It's safe to cycle here*'

Road type 7 has been chosen seven out of a possible eleven times (Table 17.0) to place this symbol (Figure 41.0), whereas the bigger road types 5 and 6 were only selected on four occasions (Table 17.0). This correlates with the results presented in Figure 40.0, where almost all negative symbols were located on the bigger road types 5 and 6.

Figure 41.0: It's safe to cycle here locations from Survey Data

- ☺ *'I like to cycle here'*

Road type 7 has been chosen twenty-five out of a possible thirty times (Table 17.0) as shown in Figure 42.0. Again road types 5 and 6 were selected to a much lesser extent three out of a possible 30 times (Table 17.0). Seventy-five percent of the comments for this symbol were placed by Holy Faith Pupils (Table 15.0). Figure 42.0 shows that this symbol is evenly distributed in the residential areas surrounding St Fiachras and Holy Faith School, with a small cluster of symbols close to the entrance of Holy Faith School.

Figure 42.0: I like to cycle here locations from Survey Data

On analysis of the spatial distribution of the positive symbols an even spread of markers across the area is evident (Figure 43.0). This spatial distribution differs to that of the negative markers as illustrated previously in Figure 40.0. As evidenced from Figures 40.0 and Figure 41.0 children appear to rate an area as safe or nice to cycle whereas they rate stretches of a particular roads or distinct locations as unsafe or not nice to cycle.

Figure 43.0: Spatial Distribution of Positive Symbols from Survey Data

Table 17.0: Positive Symbols by Road Type.

	Road Type 5	**Road Type 6**	**Road Type 7**	**Road Type 8**
It's safe to cycle here	3	1	7	0
I like to cycle here	1	2	25	1
Total	**4**	**3**	**32**	**1**

Table 17 illustrates that the there is a clear division between major road types 5 and 6 and the minor road type 7. Children placed 32 out of 40 positive symbols on road type 7.

4.6.1.3 Neutral Symbol

The symbol for × *'Here I'm crossing the road'* can best be described as a neutral symbol and with 58 locations identified by children in the study area it is the most frequently used symbol (Table 18.0). This symbol does not imply any preference or aversion when used by a child. It is however interesting to note that St Fiachra's pupils placed a cluster of × *'Here I'm crossing the road'* symbols in the same area as a cluster of negative symbols (Figure 40.0), whilst in the vicinity of the Holy Cross School this symbol is more evenly spread (Figure 43.0). This neutral symbol was used equally on small type 7 roads (29 times out of 58) and on type 6 and type 5 roads (29 times out of 58).

Figure 44.0: Here I'm crossing the road locations from Survey Data.

Table 18.0: Overview of Neutral Symbols Ratings.

Symbol	Male	Female	St. Fiachra	Manor House	Holy Faith	Total
Here I'm crossing the road	14(48.3%)	42(53.2%)	31(55.4%)	2(22%)	24(60%)	57

Table 19.0: Neutral Symbols by Mode of Transport.

Symbol	Walking	Cycling	Car
Here I'm crossing the road	41(39%)	16(15%)	0(0%)

Table 20.0: Neutral Symbols by Road Type.

Symbol	Road Type 5	Road Type 6	Road Type 7	Road Type 8
Here I'm crossing the road	11	18	29	0

Although almost every child has to cross at least one road on their route to school, not all children have used this neutral symbol. Indeed it can be seen that some children, travelling relatively long distances to school, have used this symbol sparsely and then only in at very specific locations. This indicates that children do not consider crossing the road in some locations as remarkable, whereas other locations where they cross the road have more significance in terms of perceived danger. Many perceived dangerous road crossings, identified using the negative symbols, are situated on bigger roads thus explaining the levels of awareness the pupils have of danger when crossing such a road.

4.6.1.4 Analysis of Symbols by School

The positive location symbols as mention in Section 4.6.1.2 have been used to a high degree (75%) by the pupils of Holy Faith School. These symbols are mainly located on Type 7 roads in an area to the east of the school (Figure 43.0). As the pupils of Holy Faith School only employed negative location symbols in 35% of locations identified, and these symbols were mostly a good distance away from the school it can be interpreted that Holy Faith pupils in general feel safe on the roads in the immediate vicinity of their school (Figure 43.0).

St. Fiachra's School pupils have employed far less positive symbols (17.9%) than Holy Faith pupils. Although these pupils also used a lower percentage of negative symbols (26.8%) the accumulation of these negative symbols in one distinct location indicates a perception of danger in close proximity to the school. This effect is very apparent when the attribute information collected during the school survey is spatially analysed, as can be seen in Figure 40.0. This highlights the advantages of using geographical mapping tools such as GIS to interpret spatial data.

4.6.1.5 Analysis of Symbols by Mode of Transport.

An analysis of the modes of transport employed by pupils with respect to the symbols used indicated a high level of disparity between road safety awareness that pupils have when travelling to school on foot, by bicycle or by car. These disparities are evident in Tables 13.0, 16.0 and 19.0 where it can be see that of 23 Car Routes only one (Route ID 49) employed a single symbol. All other symbols have been used either by children who walk or cycle to school. Negative Symbols were used most by Pedestrians (seventeen out of forty). Cyclists used twelve out of forty negative symbols (Table 13.0). Pedestrians also used more positive symbols (twenty-five out of forty, Table 16.0) than cyclists (15 out of forty) and pedestrians used more neutral symbols with 41 times (Table 19.0) while cyclists used neutral symbols sixteen times out of fifty-seven (Table 19.0).

4.6.1.6 Analysis of Symbols by Gender.

No gender differences were evidenced in the use of negative markers (Male 24.1%, Female 25%) in this study. However, females used slightly more positive symbols (39.2%) than males (24.1%). This can be attributed to the fact that Holy Faith School, which has used a lot of positive symbols, is a girl's school.

4.6.2 Routes Results

Children were asked to trace their route to school on a map that was supplied with the Survey as outlined in Section 3.5.2. The resulting routes where analysed with respect to length of route, route choice and the directness of route from home to school. These attributes where subsequently examined comparing the target schools, mode of transport, gender and different road types. Furthermore four individual routes where selected and examined in more detail with respect to route choice. Each of these parameters are now discussed.

4.6.2.1 Analysis of Routes by School

Analysis of the distance that children travel to school is summarised in Table 21.0 which highlights a number of differences between schools. Holy Faith pupils travel, on average, the furthest distance to school irrespective of the mode of transport. St. Fiachras pupils and Manor House pupils travel approximately the same mean distance when travelling on foot or by car (see Table 21.0). Holy Faith pupils on average walk approximately 30 % further than St. Fiachras pupils and Manor House pupils. Holy Faith pupils also travel 40% further by car than St Fiachras pupils. Only one car route was recorded for Manor House School measuring 2,297 m in distance.

Table 21.0: Summary of Distances Travelled by School and Mode of Transport

St Fiachra

Mode	No. of Routes	Min. Distance (m)	Max. Distance (m)	Ave. Distance (m)
Walking	22	233	3053	1014
Cycling	18	869	2931	1508
Car	16	2343	5656	2670

Manor House

Mode	No. of Routes	Min. Distance (m)	Max. Distance (m)	Ave. Distance (m)
Walking	7	229	2104	979
Car	1	2297	2297	2297
Bus	2	1870	7188	4529

Holy Faith Routes

Mode	No. of Routes	Min. Distance (m)	Max. Distance (m)	Ave. Distance (m)
Walking	28	232	2871	1425
Cycling	6	1576	4085	2463
Car	10	1924	9047	4557
Rail	1	14515	14515	14515

4.6.2.2 Analysis of Routes by Mode of Transport

From the evidence presented here there is a clear difference between the routes of children who are driven to school and those who use active modes of transport. While car routes vary greatly between direct routes and detours along Type 5 and type 6 roads, active mode of travel routes prefer direct routes.

A total of 57 walking routes were collected and are with 54.3% the most numerous mode of transport used (Figure 45.0). The mean length of walking routes was with 1,139m the shortest of all modes of transport.

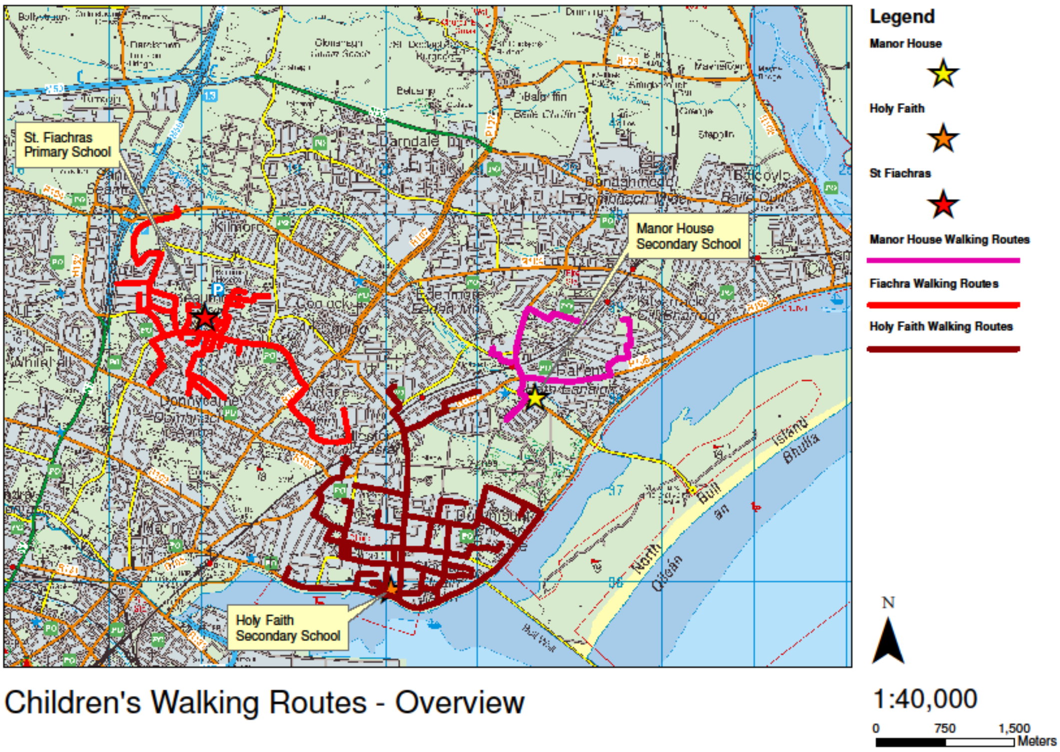


Figure 45.0: Children's Walking Routes from Survey Data.

Cycling routes (Figure 46.0) are the next the most numerous mode of transport used with a total of 24 routes, representing 22.9% of all routes. The mean length of cycling routes was with 1,985m the second shortest of all modes of transport.

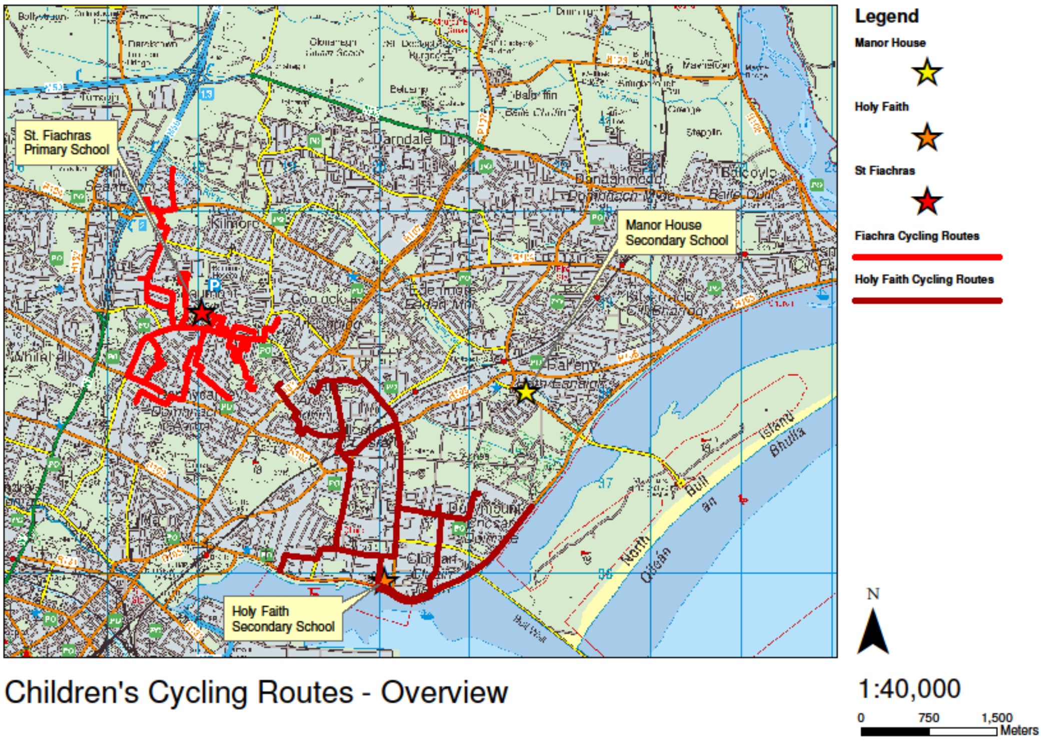


Figure 46.0: Children’s Cycling Routes from Survey Data.

Car routes (Figure 47.0) accounted for a total of 21 routes, representing 20.0% of all routes. The mean length of a car routes was 3,174m.

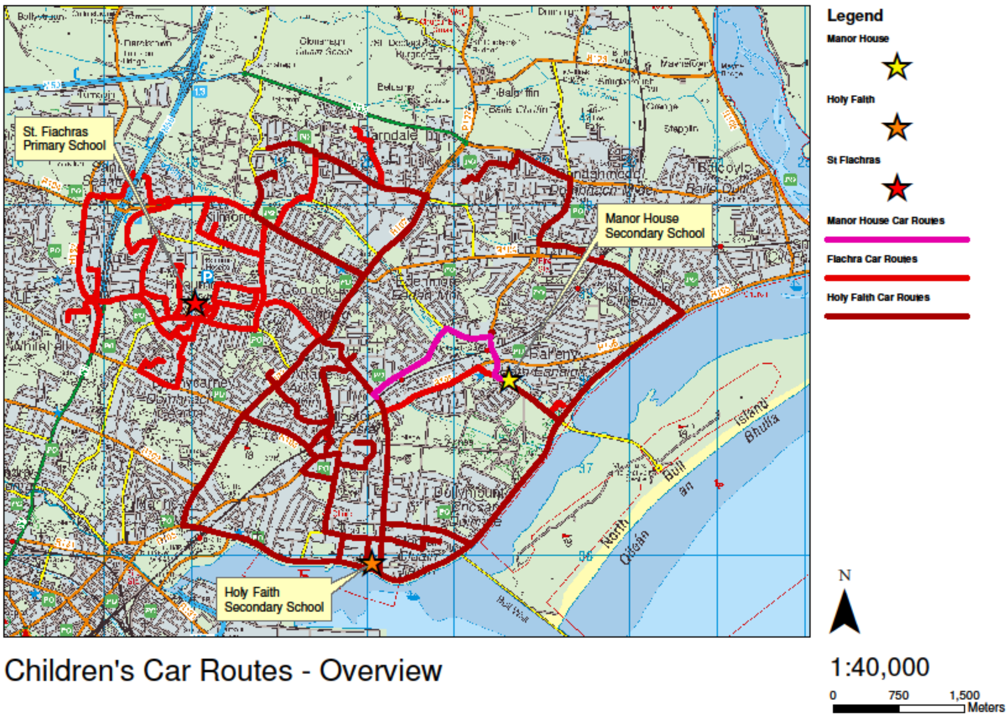


Figure 47.0: Children’s Car Routes from Survey Data.

The second longest mean route is the bus route (Figure 48.0) with 4,529m and the longest route is the rail route (Figure 49.0) with 14 515m. However, these two modes of transport have only been used twice for the bus and once for the rail.

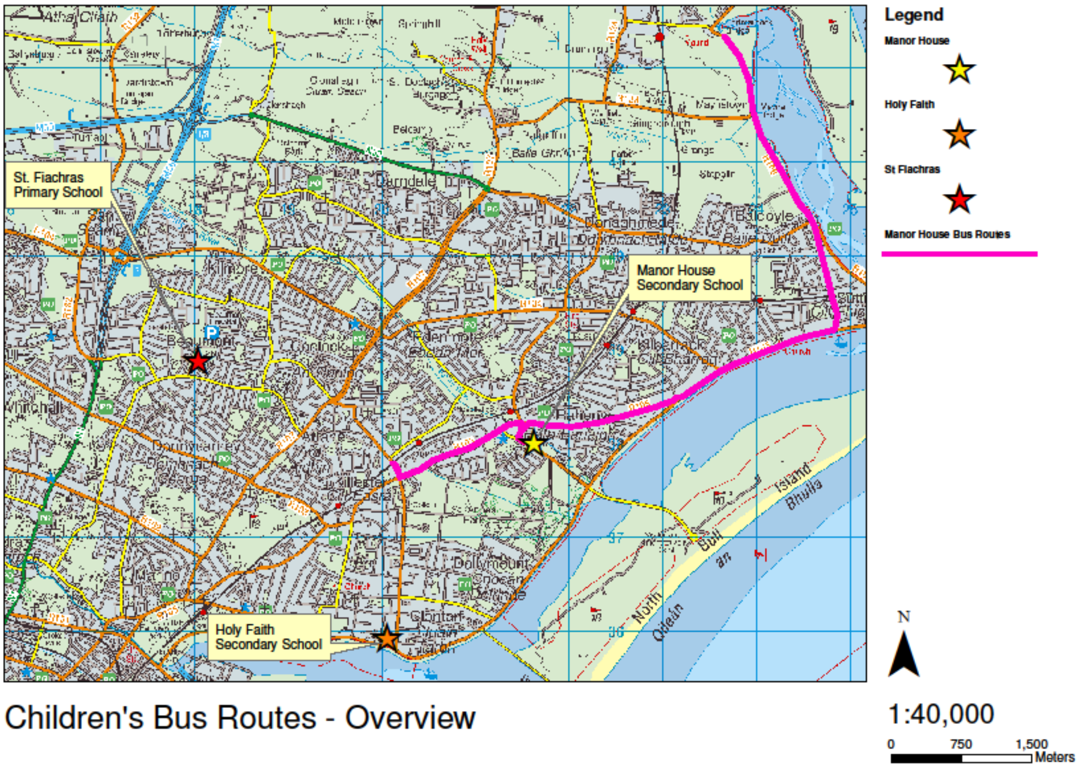


Figure 48.0: Children's Bus Routes from Survey Data.

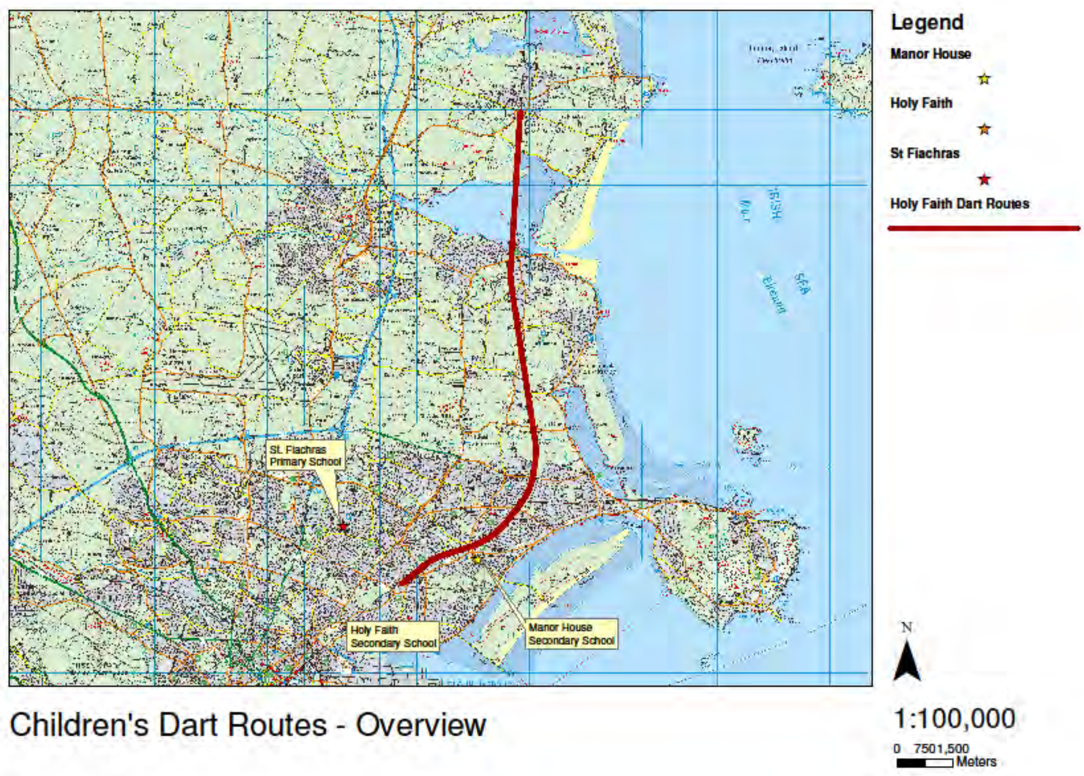


Figure 49.0: Children's Rail Routes from Survey Data.

4.6.2.3 Analysis of Route by Gender.

Analysis of the mean distance travelled by male and female pupils was also undertaken. However in this case only the routes of St. Fiachras pupils were used as both Manor House School and Holy Faith School are single sex girls schools. From the data provided by the pupils in St. Fiachras school (Table 22.0) it can be seen that the girls on average travel longer distances to and from school in each of the three modes of transport – Walking, Cycling, Car.

Out of 22 walking routes in St Fiachra (Table 22.0) eight were drawn by boys and 14 by girls. Girls walked on average 365m further than boys (Figure 50.0).

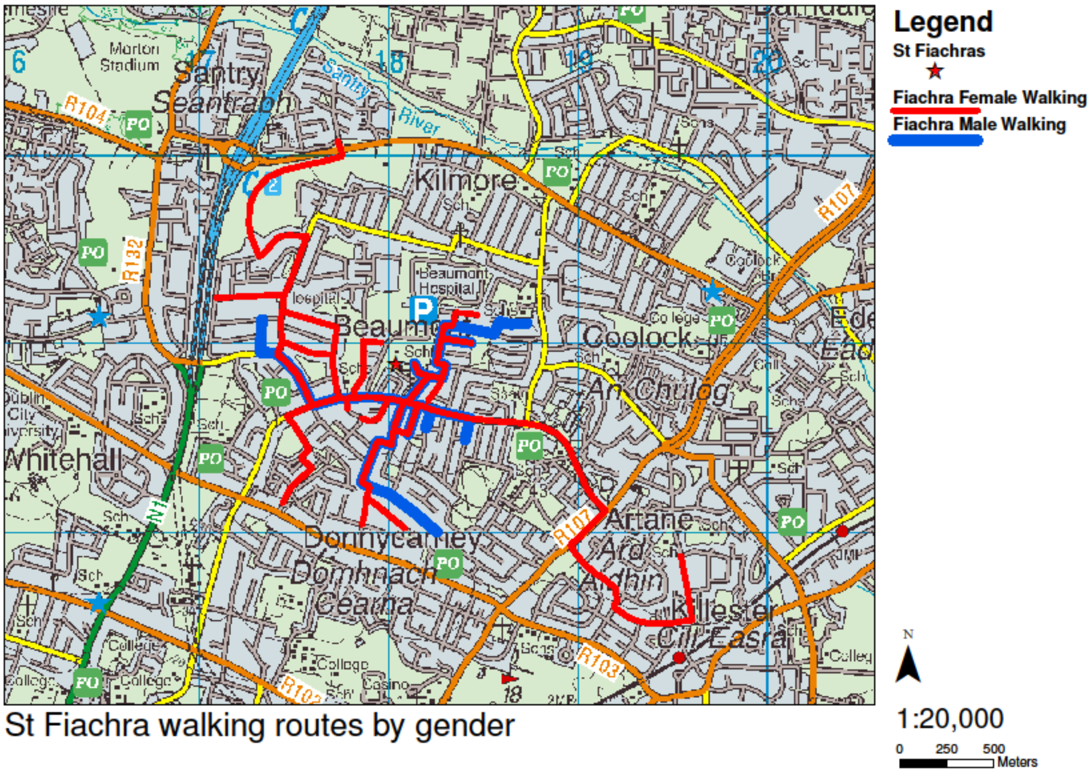


Figure 50.0: St Fiachra Walking Routes by Gender from Survey Data.

Sixteen cycling routes were recorded in St Fiachra (Table 22.0), twelve from boys and four from girls. Although boys cycled more, girls cycled further on average (Table 22.0). Girls cycled 1,728m and boys 1,307m on average. Girls cycled on average 421m further than boys (Figure 50.0).

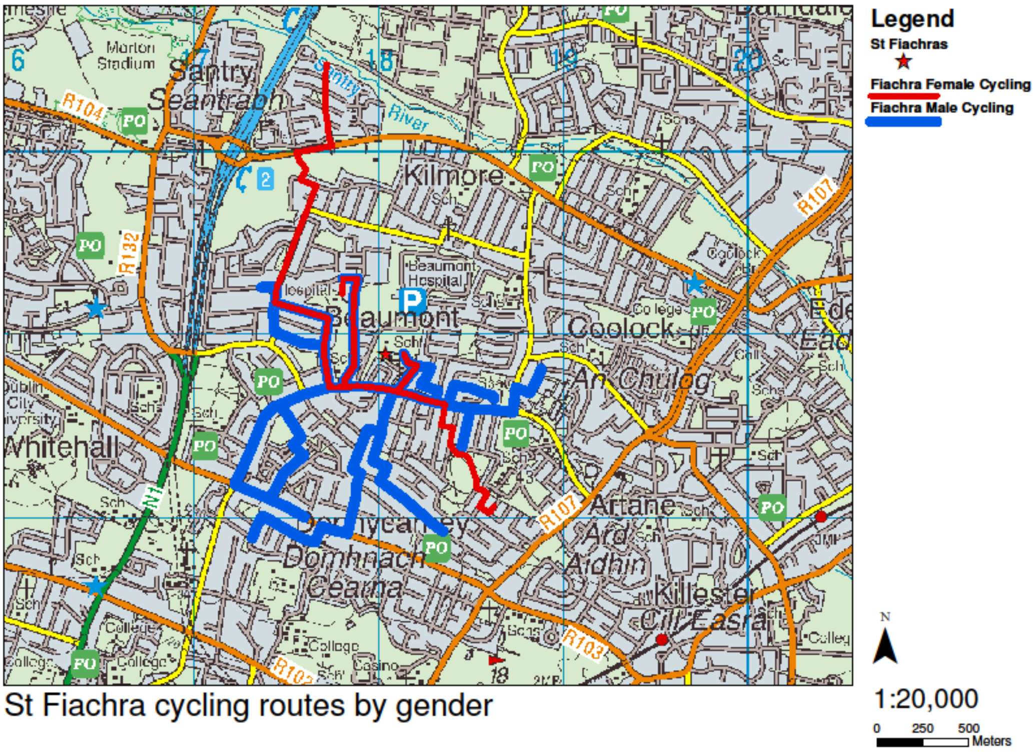


Figure 51.0: St Fiachra Cycling Routes by Gender from Survey Data.

A total of 21 car routes in St Fiachra (Table 22.0) were divided into fourteen routes from boys and seven from girls. Girls travelled by car further than boys (Table 22.0). Girls were driven 2,725 m to school on average and boys 2,013 m. Girls were driven to school on average 712 m further than boys (Figure 51.0).

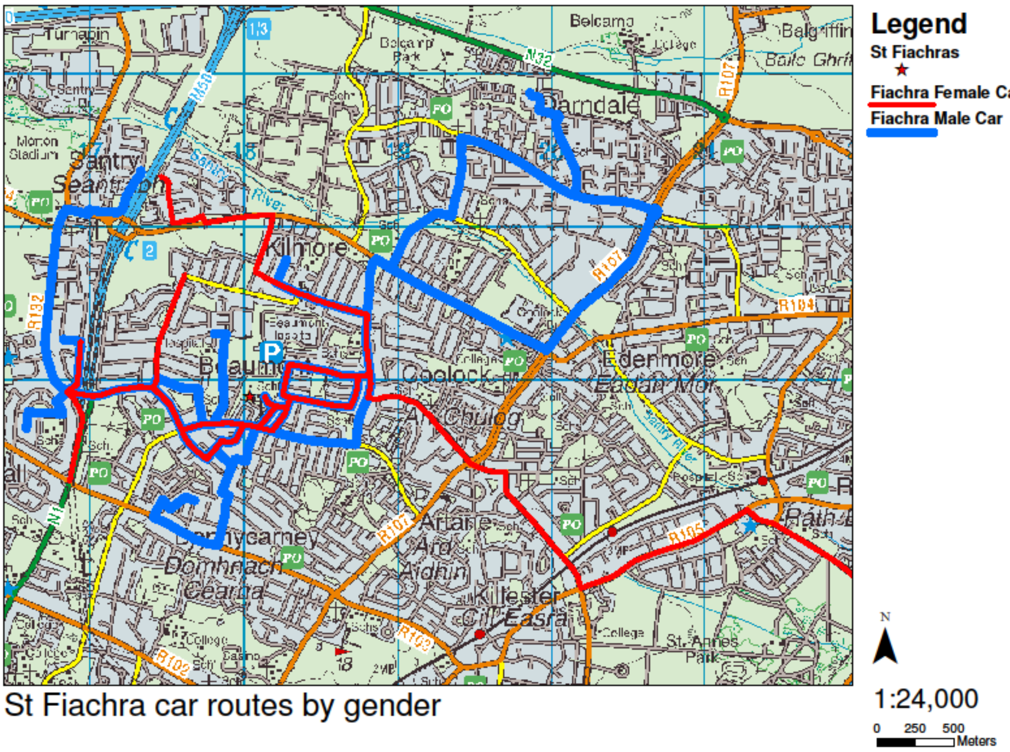


Figure 52.0: St Fiachra Car Routes by Gender from Survey Data.

Table 22.0: Route distance by Gender (St. Fiachras School)

Male/Female	No. of routes	Mean Distance, m
Walking	8 / 14	782 / 1147
Cycling	12 / 4	1307 / 1728
Car	14 / 7	2013 / 2725

4.7 Route Choices

The majority of children travelling by foot or bicycle selected the shortest route to school (Figure 45.0 and 46.0). For a number of the walking and cycling routes this involved climbing over obstacles such as fences and ditches, and cutting through green field sites.

Although children using active modes of transport to school were able to clearly identify locations and road types that they found less safe or enjoyable to travel on, they do not seem to try and avoid these locations and road types. The main criteria for children’s choice of routes to school appear to be the directness of the route. The only route where a child seems to take a detour for good infrastructure is Route ID 67 (Figure 53.0). This child could clearly use a more direct route using Type 5 and Type 6 roads, but chooses a longer route to be able to travel on a Type 7 road and a segregated cycle path.

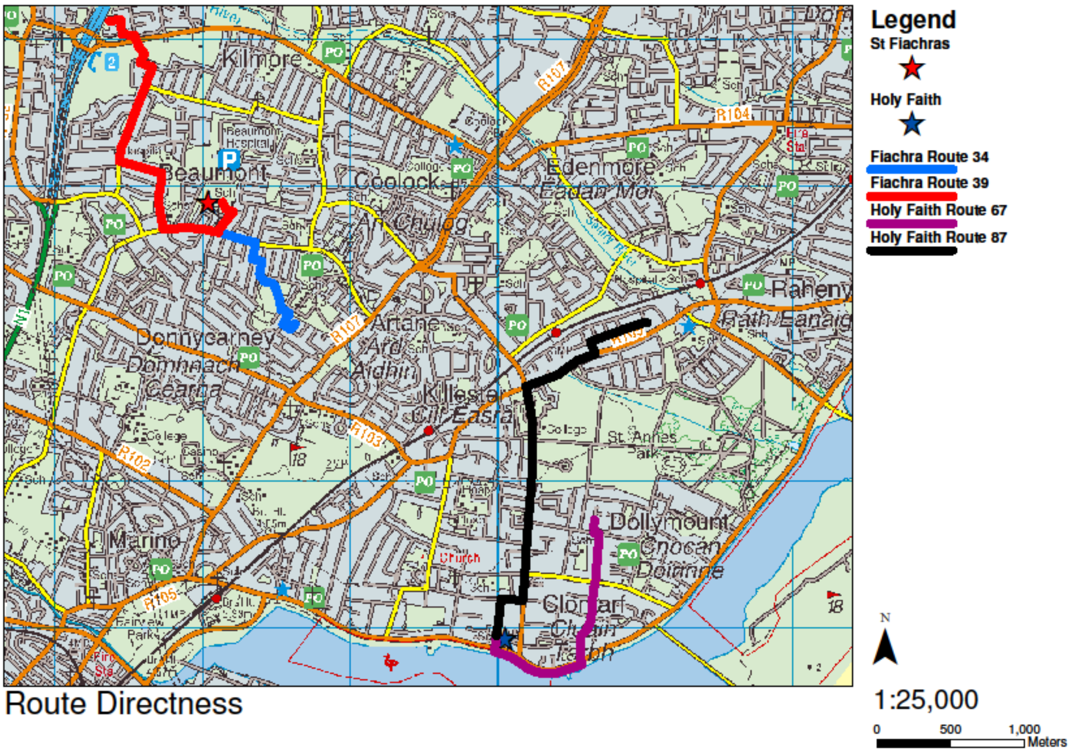


Figure 53.0: Selected Routes from Survey Data.

The search for the most direct route includes the use of paths and tracks. It is interesting to compare Route ID 87 to Route ID 39 and Route ID 34 (Figure 53.0). Route ID 87 (walking) could use the paths of St Anne’s Park and Type 7 Roads in the area with a route distance of 3.2km, but instead used mainly Type 5 Roads indicating ‘*I don’t like cycling here*’ and ‘*I almost had an accident here’* to have a route distance of 2.87km. That is a saving of 300m between the two routes.

Contrary to this, Route ID 39 (Figure 53.0) used some tracks to cycle to school. However this time using the track (2575m) resulted in a more direct route, when compared to using the road network (3700m). This is a saving of 1100m. Even small savings in distance seem to matter. Route ID 34 (Figure 53.0) is using a short cut through a park and is saving 100m distance compared to using the road network.

Also remarkable is the fact that the path Route ID 87 which could be described as perfect for walking 55.0) was not selected and the path that Route ID 34 chooses to cycle on could be described as very poor for cycling (Figure 56.0). St Anne's Park is a beautiful park and widely used for recreation.

Figure 54.0: St Anne's Park (Google Maps)

The track that Route ID 39 uses is a path through a derelict site (Figure 56.0 and 57.0). The path itself is only partly built up with tarmac and mostly just a dirt track. At one location of this route the child even has to climb with the bike over a bend down fence.

Figure 55.0: Derelict Site (Google Maps)

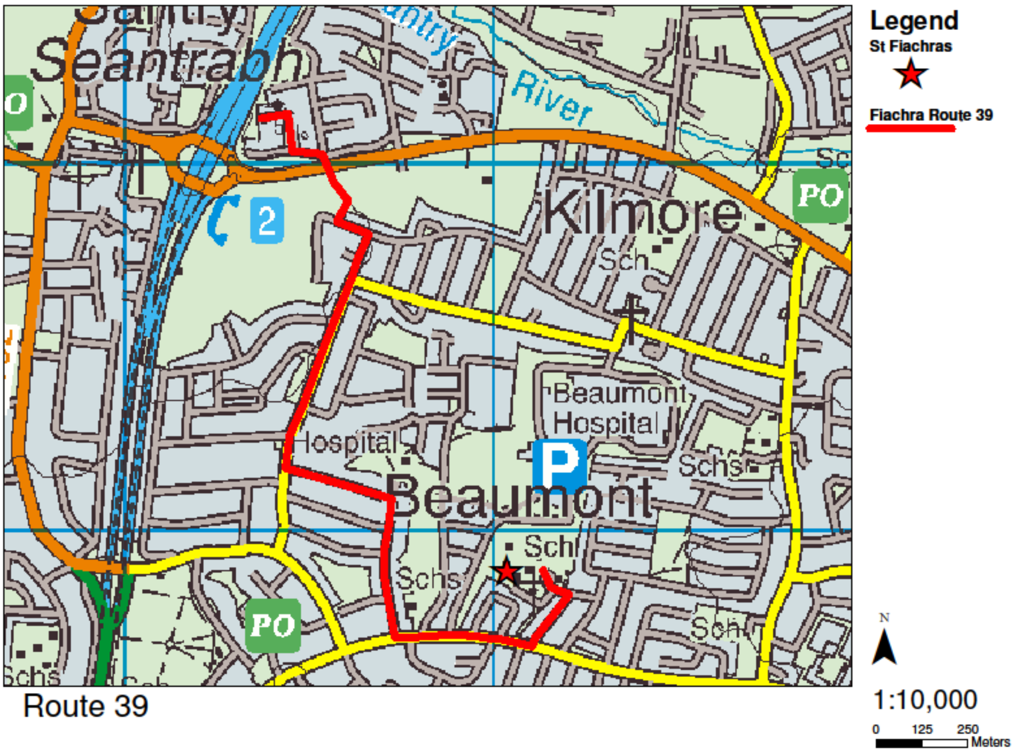


Figure 56.0: Route 39 from Survey Data.

4.8 Summary of Results

This study has shown that most Dublin children live within 1km of a primary or secondary school. This is important as distance is a major factor in deciding on whether or not to cycle or walk to school, and thus the majority of Dublin children are within a suitable cycling or walking distance to school.

Road safety is another important factor. To find potential areas of danger to children in the Dublin road network RSA accident data for a time period from 1996 to 2007 was analysed. In this time period only 30 (0.4%) of the recorded 7,644 accidents in Dublin were directly associated with a trip to school (Figure 27.0) and only one of these accidents occurred within the survey area (Figure 28.0).

A survey of the area surrounding the three target schools found nine discrete road types as shown in Table 9.0. This classification proved very useful in this research as the different road types described offered an accurate picture of different experiences when cycling in the survey area.

The written survey showed that many children prefer to walk or found the distance too far when they were asked why they do not cycle to school. Speeding cars were found to be the greatest barrier to a safe cycling environment for children. This indicates that a lot of children feel that the exisiting cycle facilities do not protect them adequately from motor traffic.

Using a predefined set of symbols children identified two distinct road types (Road Type 5 and 6 – see Section 3.4.1) as potentially dangerous for them. This correlates with analysis of RSA data which found that these particular road types attract a high proportion of bicycle accidents. Conversely children identified Road Type 7 (see Section 3.4.1) as roads that were safe to cycle. In addition, a cluster of symbols in one location indicates that children encounter a specific problem in this location.

The analysis of the Children's Routes to school indicates that distance is an important factor when children choose their mode of transport to school. They prefer to walk short distances up to about 1km, use the bicycle for journeys between 1km and 2km of length and use motorised modes of transport for distances in excess of approximately 2km. They also prefer to travel the shortest distance from origin to destination irrespective of the potential for danger and in general do not make de-tours for the purpose of a safer route.

The results of this research will be discussed in chapter 5.0 with respect to the objectives stated in Section 1.3.

5.0 DISCUSSION

This chapter presents a discussion of the results from Section 4 in the context of the research objectives as defined in Section 1.6. Each objective is outlined separately.

5.1 Objective i: Spatially analyse the potential for cycling to school in Dublin

The first objective of this study was to determine if Dublin as a city had potential for children to cycle to school. It has been previously shown by many studies that distance is a significant factor in children’s mode choice when travelling to school (DTO, 2006; Parkin, 2007; Muller, 2008; Nelson, 2008; Wen, 2008). To asses if this factor is prohibitive to cycling to school in Dublin a number of data sources from the RSA and DTO were spatially analysed using ArcGIS. On imposing 1km and 2km buffer around schools in the GDA using ArcGIS it was evident that the GDA is well served in terms of quantity and location of the primary and secondary schools. The spatial distribution of schools in Dublin evident in Figures 19.0 and 20.0 is such that the vast majority of children live within an eminently suitable walking or cycling distance from school. Furthermore, analysis of children’s domicile and the availability of school places indicated a high correlation between these two variables. Thus no child should have to travel distances greater than 2km to school. These results support the findings of the 2006 DTO Travel to Education Survey (DTO, 2007) which found that 25% of primary school pupils live less than 0.5 km from their school, while almost two thirds (64%) travel less than 2 km to school and half of all second level pupils travel 2km to school. The question remains why this good modal share for walking to school in Dublin cannot be replicated for cycling to school.

One of the main reasons for not cycling to school cited in the 2006 Travel to Education Survey (DTO, 2007) was ‘Road safety concerns’, this accounted for 25% of all primary school children responses and 7% of all secondary school children. The research carried out in this study found that ‘Road safety concerns’ prevented 10% of children from cycling to school. Thus it can be said that a considerable number of children perceive their journey to school by bicycle to be dangerous and therefore the perception of road danger on route to school should be considered a barrier to cycling to school in Dublin.

5.2 Objective ii: Collect children's travel to school route data for a local road network.

The second objective in this study was to compile information how children travel to school and the routes they choose. This was considered a necessary step if the implementation of road safety improvements is to be effective for children. Collection of data from children poses a number of methodological and ethical problems as outlined in section 2.13 and highlighted by Borgers (2000). A significant problem in this regard is access to children which is by necessity restricted. The methodology employed in this study overcame this problem by using a class-room setting with the teacher present. During the lesson period the survey requirements was introduced at a level cognisant with children's development and their curricula, and subsequently completed as homework. The school setting is ideal as it provides access to a considerable number of children in specific geographical locations and facilitates surveys with respect to age and/or gender. Most importantly there is no requirement for unsupervised contact between researcher and children, and therefore no need for Garda vetting. The survey methodology adopted is also an easily replicated system which can be employed nationally if desired.

An important finding from this research is that, with the exception of 4 children, all children cycling or walking to school travel on the most direct route from their home to school, while children who are driven to school take considerable detours. Existing data on route directness for active modes of transport is only available for adults. The directness of the active mode of transport routes to school described in this study suggest that children commute in a similar manner to male adults. Dill (2009) found that utilitarian bicyclists in Portland (USA) '*want to minimize their travel time,* yet: *women appear more likely to go out of their way to bicycle on low-traffic streets and bicycle boulevards, and slightly less likely to go out of their way to* *use streets with bike lanes'*. The children of both sexes travelling by foot or bicycle in this study selected the most direct route regardless of the infrastructure and the negative safety ratings they attributed to these routes. Thus children cycling to school appear unwilling to make detours to ensure a safer route to school and may choose a different mode of transport to avoid dangerous location.

The analysis of the children's routes has shown that the mean length of walking routes is with 1,139m the shortest of all modes of transport. The mean length of cycling routes is 1,985m and the second shortest of all modes of transport. The mean length of a car routes is 3,174m. This validates the findings of Nelson *et al*., (2008) who showed that in Ireland the majority of walkers lived within 2.4km and cyclists within 4.0km of their school.

5.3 Objective iii: Locate areas of perceived danger for child cyclists and pedestrians in a local road network

The third objective of this study was to locate areas of perceived and actual danger in the local road network. To achieve this objective, children used a set of defined symbols placed on a map of the local road network.

The children used the available symbols in a manner that suggests that they are very capable of connecting memories and experiences to locations on a local map. The use of symbols was consistent in that smaller road types (Type 7 and Type 8) which attracted more positive symbols. Bigger road types (Type 5 and Type 6) attracted a higher percentage of negative symbols. Of significance was that children at St. Fiachras School were able to identify a 'Hot Spot' of negative symbols.

Analysing RSA bicycle accident data revealed that the road types that attracted the highest percentage of negative symbols from the children also reflects a proportionally higher number of bicycle accidents, thus proving the validity and accuracy of childrens perceptions of dangerous road sections.

5.4 Objective iv: Assess the viability of the use of children's incident reporting to locate areas of perceived danger on routes to school in Dublin.

Analysis of the RSA bicycle accident data revealed that Road Types 5 and 6 attract more accidents than other road types. These road types have a share of over 50% (3796) of all RSA recorded bicycle accidents and yet only account for 27% of the Dublin City road network. These road types also include the majority of bicycle infrastructure in Dublin (Section 4.3.2).

Children in this study placed 83% of negative markers on road types 5 and 6 (Section 4.61.1). This indicates that children are aware of the danger these roads can pose to cyclists and used their symbols accordingly. The relationship between perceived and actual danger for cyclists has been documented before by Møller *et al*., (2008) who found a correlation between perceived risk and actual risk based on accident statistics for cyclist using roundabouts in Denmark.

Another indication that the children used the symbols in a meaningful way can be found when the results of the symbols are compared to the 'Iceberg Model' (Section 2.15). This model works on the basis that the frequency of an occurrence raises from accidents to incidents. Thus as incidents are more numerous than accidents they are more suitable for statistical analysis. This effect is used as a safety tool in a number of fields were accidents are a rare occurrence but can be catastrophic when they happen as in Aviation, Marine or Hospital Safety (Davies *et al.*, 1998; Van der Schaaf *et al.*, 1991; Williams, 2001; Wright *et al.,* 2004). The results of this study show a clear correlation between the number of symbols used by children and their severity, resembling the Iceberg Model.

It can therefore be argued that children who took part in this research were able to judge road traffic dangers correctly and are capable of locating areas of potential danger to child cyclists on a map. Thus data produced by children is valuable and can be used when identifying problem locations within the existing cycle infrastructure.

5.5 Objective v: Identify an appropriate research technique to populate accident black spot maps in lieu of existing data.

Accident Black Spot Maps are a proven tool in local road traffic safety in a number of European countries (Sørensen, 2007). In Ireland, the RSA offers an interactive online version of an Accident Black Spot Map based on An Garda Síochána recorded accident data (RSA, 2012). However, the absence of available data on child bicycle accidents in Dublin prevents the use of this tool for children's cycle safety. A further issue with Accident Black Spot Maps is that they are dependent on accidents happening rather than preventing their occurrence. Thus the theory of Near Miss Reporting (Section 2.11) was considered more appropriate in this study. Near Miss Reporting derives from industrial safety and states that for every accident there is a number of near misses and incidents. As most of the accidents and incidents are considered to have the same root-cause, it is possible to avoid accidents from happening by curing the cause of near misses (Wright *et al.,* 2004). Applying this theory to children's bicycle accidents is a new technique and has a number of important advantages over collecting accident data, including the following:

- Identifying these near misses and incidents has the potential of preventing accidents before they happen.
- Data of a specific type of road user can be collected.
- Sufficient data can be collected from small sample groups.
- The collected data is based on children's own perceptions and experiences.
- It is a participatory tool.
- The results are easy to access by planners and engineers.

6.0 CONCLUSIONS

Currently, there is a distinct lack of evidence on how infrastructure and road safety measures designed for adults, affect the traffic safety of children when using active modes of transport travelling to school. The perception of road traffic danger remains a significant barrier to cycling to school this fact coupled with the low numbers of children cycling to school in Dublin indicates that children do not feel safe using the existing cycling infrastructure. Road Engineers and Urban Planners therefore face a dilemma as low cycling numbers make it difficult to promote higher budgetary percentages on cycling infrastructure and their associated road safety measures.

Improvement of cycling safety in an existing road network is a complex and difficult undertaking as the volume of road network involved can be extensive. Currently there is no facility to predict locations in the existing road network which may be dangerous or perceived dangerous to children, information emanating from children is not currently used in transport planning in Ireland. This research addresses these knowledge deficiencies and presents a new ethically sound methodology for Road Engineers and Urban Planners to locate areas of danger or perceived danger to children in an existing road network which is based on children's experiences and knowledge.

The two existing road safety tools currently used in Ireland, the RSA Accident Black Spot Map and the NRA Road Safety Audit, were found to be inadequate for this study in providing a useful tool to locate areas of perceived road danger to children. In the case of the RSA Accident data, it is apparent that the existing accident data is not sufficiently extensive or detailed to assess a relatively small area around a school. In addition, this data is dependent on accidents happening and is therefore not preventive or progressive. The NRA Road Safety Audit is designed to assess a newly built road segment and is particularly aimed at improving the road safety of 'vulnerable' road users. While this tool may be effective when surveying a small road sections, in this study it was found to be impractical for surveying a more extensive area such as a school catchment. Neither of these existing road safety tools provides any information on how children interact with the cycle infrastructure on route to school.

To overcome these issues this study proposes a new method to enable Road Engineers and Urban Planners locate areas of danger or perceived danger to children in an existing road network. As this method can be delivered as part of a homework assignment there is no contact between engineers/planners and children and thus surveys can be delivered without many of the difficulties such studies can present. The Children's Maps method will enhance data that is currently collected through written questionnaires by generating exact route distances and helping stakeholders to understand how children use a local road network. The analytical power of map-based methods have been proven effective in both road traffic safety and children's participation, as they are easy for children to understand, and were therefore adopted as a medium for this study. In the method adopted, the lack of availability of children's cycling and accident data was overcome by using locations of accident near misses and perceived danger rather than actual accident locations. This had the beneficial effect of ensuring the method was preventive and proactive in terms of road safety as children's experiences and perceptions were recorded rather than observations of potentially dangerous situations. The resulting map of actual and perceived dangerous locations does not require any interpretation by third parties qualified to interact with children and can be used in a similar manner to an Accident Black Spot Map.

The proposed survey methodology of using Children's maps to locate areas of perceived danger presented here has many advantages. Firstly, by conducting the data collection through schools, target groups can be easily identified and the resulting cost of conducting the survey minimized. Secondly, a small sample group can produce results that highlight problem areas in a local road network. This is significant as the numbers of children cycling to school in Dublin are currently very low and thus more difficult to analyse. Finally, data necessary to produce meaningful results can be collected more quickly than accident data and the resulting data is proactive rather than reactive as accidents do not need to happen before an analysis can take place

This research has demonstrated that children are capable of differentiating between locations in the road network surrounding their school where they feel safe or they preferred to locations which are perceived as unsafe or they disliked. By adopting the markers on a map as presented here it is possible to build up a picture that resembles an Accident Black Spot map. Although the marked locations do not show actual accident sites it can be argued that applying the Heinrich Law, these markers indicate the existence of a root-cause that might cause an accident to happen in this location.

It should be noted here that a prior survey of the road network surrounding the St. Fiachras School did not identify the specific location as highlighted by the children to be particularly risky, as it is relatively well served with pedestrian and cycling infrastructure. However, dangerous road traffic situations may arise from a large array of variables and a single site visit may not enough to asses such a location. Thus to properly assess the potential danger of a specific location, the knowledge and experience of travelling the route on a regular basis is needed and the information collected from children provides access to this knowledge.

One of the most important aspects of the proposed method is that the map gives children the opportunity to participate - express their perceptions, their knowledge and experience of routes and areas that they know well. For them, the road network is not just a means to get from A to B. The road is a place where they play and where they live. How this road network is designed and built has a great impact on their lives and they have a right to have a voice in all matters that directly affect them. They are the experts in their own world.

The National Cycle Manual offers engineers and planners a document that could help make Dublin a more cycle friendly city. However, implementations of the recommendations made in this document are not currently considered achievable

(Fallon, 2012). The proposed method could enable planners and traffic engineers to implement measures that can help to realise the full potential of Dublin for cycling to school.

Using children's maps to locate areas of perceived and actual danger is based on accident black spot maps, a proven tool in road safety management. Using this method in conjunction with 'Near Miss' reporting data directly collected from children makes this preventive information readily available to planners and engineers. The use of this preventive method in a GIS stetting facilitates and an expanding data set that is easy to query and can be used in combination with other data sets by various users for spatial analysis. Ethical issues associated with working with children can be overcome on adoption of the approach suggested here whereby the data is collected through schools and in the form of homework. Of significance is the fact that the collected data reflects the views and experiences of children, the stakeholders of interest, and can form the basis of children's participation in traffic planning.

Participation as a concept is well established and some of the benefits of participation in urban planning that can be expected from this method include:

- Increased quality of the functions performed and services provided by public agencies: As this information should lead to better, evidence based decisions.
- Revitalization of democratic practice in general: As it teaches children that their views matter.
- Maintaining the stability of society. When people are directly involved in the decision-making process, they become more aware of the possible problems and are more willing to live with the consequences than they are when decisions are imposed from outside. They become more aware of problems and tend less towards explosive situations or conflicts:

The implementation of road safety measures can lead to opposition from particular groups of road users. The implementation of a general 30km/h speed limit in Dublin City centre for instance triggered a lot of opposition from the public and lobby groups in 2011. Basing road safety measures in local areas on the needs of local children could help to build support for such measures.

6.1 Recommendations

This section provides a number of recommendations for further research in a number of different areas. These include recommendations on how research can refine the findings of this study and suggestions on how the method presented here could be applied to benefit other areas of research.

1. How do children in the target schools, their teachers and parents and other stake holders view the results?

Further research should focus on the perception of the results of this research in the target schools. Do the children / parents and teachers think this method can help to make active travel to school safer? This could be achived by a follow up survey and interviews of the children / parents and teachers in the target schools.

2. Use this method to help understand how other road users travel within a road network and how they perceive a local road network.

The perception of road networks by other target groups would also be of interest as children represent only one of a number of groups that are currently underrepresented in cycling (Pucher and Dijkstra, 2003; Murphy, 2011). Road safety effects all cyclists and it has been shown that such concerns deter more women than men from cycling (Hajinikitas, 2001), as women are more risk averse than men and tend to use safer routes while men use more direct routes when commuting to work (Byrnes *et al*., 1999). It would be interesting to use this method to see how distinct demographic groups such as the elderly or disabled people use the road network when they are actively commuting.

3. Use the method to study other areas such as inner city streets or a rural road network.

This research has shown that Children's Maps can provide an important insight of how children use a local road network when actively commuting to school. It would be interesting to see if the findings of this study could be replicated in a road network that is different in character, since the rates of road traffic accidents vary considerably between urban and rural areas (de Hartog, 2010).

4. Use accurate route data to improve models that that rely on estimated or assumed route data.

A number of studies use either self-reported estimated distances (Nelson *et al.,* 2008), on presumed route data, obtained using existing origin/destination data (Yiannakoulias, 2012) or demographic data (Rybarczyk, 2010) to build models that can answer questions relating to cycling and walking in a road network and that depend on travel distances. Further research could identify if the method of obtaining accurate route data could help calibrate these models to give more accurate results, especially as the results showed that some walking and cycling routes are not confined to the local road network, but use tracks and short cuts that can often only be found using local knowledge.

5. Use this method to enhance hospital accident data.

In Ireland, Sheridan *et al.* (2011) found that a great number of traffic accidents resulting in hospitalisation, were not recorded by the RSA. The accidents recorded by the hospitals are therefore an important source of data. However, the accidents that are recorded by the hospitals miss an important attribute, as they do not geo-reference were the accident occurred. Adding this information using a map where the injured party marks the accident location could add valuable information to the hospital data and could subsequently add to the existing RSA data.

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APPENDICES

Appendix 1

This annex contains:

1. Original Area Survey Roads Spreadsheet.
2. Roads Spreadsheet Data Dictionary.

Sheet 1

Sheet 2

Sheet 3

Roads Spreadsheet Data Dictionary

Name	Data Type	Description
Sec Code	**Numeric**	**Code for Road Section**
Sec Dis	**Numeric**	**Length of Road Section**
Sec Wid	**Numeric**	**Width of Road Section (m)**
Categ	**Numeric**	**Road Category**
	Value	***Label***
	1	Major Road
	2	Local Road
	3	Minor Road
	4	Car free Track / Lane
Lanes	**Numeric**	**Number of Lanes**
	Value	***Label***
	1	Single Lane
	2	Multi Lane
One Way	**Yes/No**	
Cycle Inf	**Numeric**	**Bicycle Infrastructure**
	Value	***Label***
	1	Cycle Lane Mandatory
	2	Cycle Lane Advisory
	3	Cycle Track (Separated)
	4	Shared Bus Lane
	5	None

Time Cyc	**Yes / No**	**Time rest Cycle Infrastructure**
Cycle Sur	**Numeric**	**Cycle Infrastructure Surface**
	Value	***Label***
	1	Good
	2	Sufficient
	3	Bad
	4	Dangerous
Cycle Wid	**Numeric**	**Cycle Infrastructure Width (m)**
Ped Inf	**Yes/No**	**Pedestrian Infrastructure**
Ped Sur	**Numeric**	**Ped. Infrastructure Surface**
	Value	***Label***
	1	Good
	2	Sufficient
	3	Bad
	4	Dangerous
Ped Wid	**Numeric**	**Ped. Infrastructure Width (m)**
Road Sur	**Numeric**	**Road Surface**
	Value	***Label***
	1	Good
	2	Sufficient
	3	Bad
	4	Dangerous
Ramp	**Yes / No**	**Speed Ramps**
Sign	**Yes / No**	**Road Signs**
Rd Mark	**Yes / No**	**Road Markings**

Sur Var	**Yes / No**	**Surface Variations**
Ref Isl	**Yes / No**	**Refuge Islands**
Rd Stud	**Yes / No**	**Road studs**
Min Round	**Yes / No**	**Mini Roundabout**
Grad	**Numeric**	**Road Gradient**
	Value	***Label***
	1	Severe
	2	Considerable
	3	Light
	4	None
Light	**Yes / No**	**Road Light**
So Prob	**Numeric**	**Social Problems**
	1	Severe
	2	Considerable
	3	Light
	4	None
Park	**Numeric**	**Car Parking**
	Value	***Label***
	1	Problematic
	2	Unproblematic
	3	None
Tra Con	**Numeric**	**Traffic Congestion**
	Value	***Label***
	1	Mostly
	2	At Peak Times

	3	Occasionally
	4	Rarely / Never
Speed	**Numeric**	**Speed Limit**
	Value	***Label***
	1	30 km/h
	2	50km/h
	3	80km/h
	4	More than 80km/h
Cyclebi	**Numeric**	**Perceived Cyclebility**
	Value	***Label***
	1	Good
	2	Sufficient
	3	Bad
	4	Dangerous
Cycl Pot	**Numeric**	**Cycle Route Potential**
	Value	***Label***
	1	Good
	2	Sufficient
	3	Bad

Appendix 2

This annex contains:

1. Original Children's Maps Survey.

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Appendix 3

This annex contains:

1. Published Conference Paper.