THE SAFETY CHALLENGE OF INCREASED CYCLING

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Abstract

Many countries have recently set out policy frameworks to support the growth of cycling. However, increased cycling can mean more collisions, injuries and even fatalities. This paper discusses the role of safety in cycling policy in the particular case of Ireland, which is one of the countries that has a government-endorsed policy to increase cycling. It examines available information on cycling, including police-reported accident data over the last fifteen years and more recent hospital accident data. Comparisons are made for injuries between the two sources and data matching and capture-recapture methods used to estimate injuries. The deficiencies in data are analysed and suggestions for improvements made. It is argued that gaps in available data have led to accident risks being poorly understood. The paper discusses how a convergence in cycling and safety policy can be achieved and suggests additional measures including a cycling safety target, increased communication on cycling safety, lower urban speeds and compulsory wearing of helmets for children.

1. Background: Road Safety and Cycling in Ireland

Road safety

Ireland has had a highly successful decade in reducing road traffic fatalities and has jumped up the international safety league tables (International Transport Forum(IRTAD), 2011). Not previously known as a country with a particularly good road safety record, the achievements, especially in the latter half of the past decade have attracted a lot of attention from international bodies and from countries keen to understand the reasons for the improvements. With a fatality rate of less than 50 per million people, Ireland, in 2010, joined the elite group of around ten countries achieving this level (IRTAD, 2011). In terms of fatalities per vehicle kilometre, arguably a more correct measure, Ireland was rated fourth behind Iceland, Sweden and Great Britain, recording fewer than 5 deaths per billion vehicle kilometres. Cyclist fatalities have also fallen significantly and at 5 in 2010 were among the lowest (absolutely and per capita) in the OECD (IRTAD, 2011).

Cycling

Between 1986 and 2002, cycling in Ireland declined dramatically as can be seen from Table 1. The number of people cycling to work almost halved and, because the number at work grew, the modal share by bike fell from 5.6% to below 2% (CSO 2011(a)). The decline in cycling to school or college was even more striking. Between 1986 and 2006, the number of children between 5 and 12 years of age cycling to school fell by 83%. The number of 13-18 year olds cycling to school fell even more, by 85% and the number of girls of this age cycling to school fell by 98%. In 2011, there were as many people in this age group driving a car to school or college as there were cycling. (CSO, 2011 (a)).

The decline halted between 2002 and 2006 and cycling started to grow again. Supported by policy, including a successful scheme to subsidise bicycle purchase through tax-free loans (Caulfield and Leahy, 2011), the creation of cycleways and, probably also since 2008, by the severe downturn, there has been a significant increase in cycling, especially in Dublin, which introduced a city bicycle rental scheme, Dublin Bike, in September 2009. Since it began the scheme has accounted for over 5 million trips and cycling in the capital is now believed to account for 5% of city centre trips. (Caulfield et al, 2012). The Dublin Bikes scheme consists of 950 bicycles that can be rented from any one of 58 stations in Dublin City Centre (Dublin Bikes, 2014).

The growth of cycling has been reported in many studies (Busch-Geertsema and Lanzendorf, 2012; Caulfield, 2013; Pucher et al, 2011a, and Pucher et al, 2011b). This growth has been supported by national policy in many countries (ECMT 2004; ITF 2013). While many authors have examined the health and environmental benefits of a growth in cycling numbers, fewer have analysed what this increase means for road safety. In Ireland, while the number of cycling fatalities has been reduced significantly, the number of collisions and injuries has not declined and has even increased in recent years. International data (ITF, 2013. Figure 3.6) show that there are quite a few countries where, between 2000 and 2009, cycling collisions either increased (Germany, Switzerland , Belgium) or decreased at a slower rate than for other road users (US, Portugal, Canada, UK, Japan, Austria, France, Netherlands, Greece). Thus, managing safety in the context of a growth in cycling is a challenge in many countries.

2. Data and Methods.

2.1 Cycling data

Like many other countries, Ireland has limited data on the amount of cycling. The absence of such exposure data implies that there are no indicators on accident rates (per kilometre, per hour or per cyclist). As a consequence the absolute figures - the total number of fatalities or injuries- are those that are known and, therefore, most relevant for policy.

There are some data, however. The Census has collected information on cycling to work or school since 1986 (CSO, 2011(a)) and the first National Travel Survey in 2009 provides estimates on cycling by those over 18 (CSO 2011(b)).

These sources were combined to estimate the total amount of cycling in Ireland. The calculations are set out in Annex 1 and give an estimate of around 235 million bicycle kilometres per annum. Based on this estimate and the figure of 25 fatalities in the three years 2008-2010, one can derive a figure for Ireland of about 3.5 deaths per 100 million km cycled. This puts Ireland well behind leading cycling countries like Denmark and the Netherlands, somewhat behind France and Germany but close to the UK and US (Pucher and Buehler, 2012; ITF, 2013). Comparing this calculation with a similar one for motorised vehicles, we see that cycling fatality risk per kilometre in Ireland is about 8 times that of vehicle users.

2.2 Cyclist Accident data

There are two main sources of information on cyclist accidents. These are, as in many countries, police reported collisions and hospital discharge data. There are other potential sources, like Accident and Emergency Units, Ambulance services, Injuries Board or Insurance data. But none of these has national data and the paper therefore focuses on the two principal sources.

Police data

The information which follows is derived from the Irish Road Safety Authority (RSA) database, which contains all police reported collisions from 1996 to 2010. There are over 102,000 collisions in the data base, of which over 6,000 involve a cyclist (Road Safety Authority, Road Collision Facts, various years). These are the official data on cycling accidents, as well as being the most widely known and the base for policy analysis.

The database is an invaluable source of information on collisions, and potentially an indispensible tool in helping to understand the reasons they occur and in taking action to avoid them. However, the database has a number of problems in relation to the quality of the data collected. Relevant data fields are poorly or ambiguously answered. There are no specific questions on cyclists' equipment e.g. whether a light was used or a helmet or high visibility clothing was worn and the details of the collision and the factors that contributed to it are limited. Given the increased policy importance being attached to cycling, it will be beneficial if an effort is made to improve the amount and quality of the information collected on cycling collisions. There are a number of steps in this regard that could be taken, including tidying up coding ambiguities and adding some questions on cyclists.

A particular problem, common to many countries (ITF 2012), is in the definition and measurement of a serious injury. The police in Ireland define a serious injury to include all those admitted to hospital as well as a set of other injuries[1]. This is the same definition as UK and New Zealand, but, as will be shown is not applied in practice, is unreliable as a measure of severity and is not consistent over time .

Hospital data

Hospital discharge data contains valuable information on the type of accident as well as being the only source for clinical data on the injuries. The hospital record dataset, known as the Hospital In-Patient Enquiry (HIPE) is collected from Ireland's acute hospitals and is managed by the Economic and Social Research Centre for the Health Service Executive. It covers admissions to all acute public hospitals in Ireland, where virtually all the emergency admissions go (HIPE , 2011).

1. The definition of "serious injury" is.. ''an injury for which the person is detained in hospital as an 'in-patient', or any of the following injuries whether or not detained in hospital: fractures, concussion, internal injuries, crushings, severe cuts and lacerations, severe general shock requiring medical treatment."

The information includes details on the type of transport accident and clinical coding for injuries using the International Classification of Diseases (ICD) (WHO, ICD, 10^{th} edition 1990, Australian modification) and comparable information is available since 2005. The hospital data covers episodes of care and because there are no unique personal identifiers it is not possible to combine episodes into a personal record. If an injured person is transferred to another hospital, this will show as a second episode of care. This means that using episodes of care overstates the number of people involved. Estimates of return visits to hospital for the same injury can be made only in statistical terms. When this is done and matches made for age, sex, residence, principal diagnosis and type of accident, about 5% are seen to be repeat visits. Relaxing these conditions obviously increases the proportion but even with weak criteria the figure does not go above 10%. Therefore, while the results shown in this paper are subject to error due to duplicate episodes of care, the error is unlikely to be greater than 10%.

A second statistical issue concerns the nature of the accident. The ICD coding makes a distinction between a traffic accident and a non-traffic accident. A traffic accident is one that occurs on the public highway and that therefore could appear in the police reported data. For example, accidents on mountain bike routes or falls or collisions that occur in parks or driveways are not counted as road accidents by the Police. The ICD classification tries to reflect this idea in its coding. However, in Ireland almost two thirds of cyclist hospitalisations are categorised as non-traffic accidents. This is far higher than UK (Ministry of Transport UK, 2012) and an examination of the codes concerned leaves room for doubt on the accuracy of the coding. Take for example, the ICD codes V180 to V182. V180 is the code for cycle riders in non- traffic accidents, V181 for cycle passengers in non- traffic accidents and V182 is for unspecified cyclists in non- traffic accidents. Code V182 has over 1500 cases and it seems strange that coders are unsure whether the person was a cyclist or a passenger but were sure that it was not a traffic accident. Since the ICD coding instructions indicate that the default option is a traffic accident, this issue could merit a coding review at hospital level. Because of this, distinctions between traffic and non-traffic accidents are made where needed.

2.3 Analytic Methods used

The main analysis relies on statistical tabulations and comparisons from the police and hospital data bases to highlight the main trends and key points. In addition, binary logistic analysis , data matching and capture –recapture estimation were used to provide further insights into the data.

Binary logistic models

Logistic regression is the most important model for categorical response data and is used in a wide variety of applications . (Agresti, 2013) The models here are used to try to increase understanding of the factors influencing accident severity. The models take the following form:

$$\text{logit(p)} = \log \frac{p}{1-p} \equiv a + \beta I + e \qquad (1)$$

where p is the probability of a severe accident, *I* is the set of variables associated with the accident, the β are coefficients and e is a random error term. The benefit from modelling is that the models provide more explicit indications on the nature and strengths of the relationships between severity and the factor concerned. The β coefficients in the logit model indicate the change in the log odds ratio for a unit change in the independent variable. The values of Exp β give the odds ratios and are usually used, as they are easier to interpret.

Data matching

Comparing police and hospital data provides insights into the structure and composition of the two data sets. But it does not tell us whether they contain the same people or not. To do this the technique known as record linkage or record matching is used. The technique is increasingly used in public health and epidemiology and allows analyses that would otherwise be impossible or extremely expensive. It combines ideas from statistics, computer systems and operations research and has been greatly facilitated by high speed computing though it began earlier. A comprehensive overview is provided by Clark (2004) and there is an extensive literature review in ITF (2012).

Its use in road safety research is relatively recent. It has been used to make estimates of underreporting of particular kinds of accidents or injuries, as in the Rhone region in France by Amoros et al (2007). It has allowed comparison of information on the medical consequences of accidents using the established ICD injury codes for hospital data combined with the on the spot assessment by the police. It is being used to estimate costs, to identify associated factors in collisions and to estimate the number of severe casualties. For example, the UK now uses the method to recalculate the social costs of crashes (Department for Transport, UK, 2012) and New Zealand uses it as a benchmark for the police as well as in the calculation of social costs. The International Transport Forum (ITF 2012) cites 16 countries where the technique has been used in road safety. Despite its limitations, it can contribute to a better understanding of the injury problem. In addition, the combination of information from police and hospitals is a valuable research resource on crashes and their consequences.

The terms “deterministic”, “fuzzy” or “probabilistic” are used to describe the different kinds of record linkage or data matching. Deterministic matching is where matches can be found directly by examination of the records using unique identifiers. Fuzzy matching is where scores are assigned for matches on different variables and the scores totalled to give a matching score. Probabilistic matching uses the mathematical theory developed by Felligi and Sunter (1969) to assign pairs as matched or unmatched or undecided. A mixture of fuzzy and probabilistic matching is used here. Neither the police nor hospital data in Ireland have any personal identifiers and matching is done on the basis of five variables, date of crash and hospital admission, age, sex, mode and County. In international terms, the data available for matching in Ireland are weaker than in those countries with unique identifiers like Denmark, Finland, Sweden and Switzerland, but also than those which have good crash localisation and hospital information like Japan, Netherlands, the UK and Spain. Ireland has strong data privacy and patient protection laws and the data available for matching seem more similar to countries like Austria and Germany (ITF 2012). This means that matching will inevitably be less accurate than in countries with more precise matching variables. Before the data matching can be carried out there is a significant amount of data preparation to be undertaken as well as decisions on the weightings and methods to be used to be used. They are set out in more detail in the literature, for example in Amoros et al (2007), and in this case, in Short (2013).

Capture – Recapture

The capture–recapture method has been used mainly in animal zoology, in order to estimate a population size. This has led to an extensive literature with increasingly sophisticated statistical methodologies. These are well summarised in a handbook edited by Amstrup and others (Amstrup, 2005). Capture -recapture is increasingly being used in other fields, including demography and health, in the estimation of the prevalence of medical conditions and the size of hidden populations like drug users.

It has been applied more recently to road traffic injury, usually focusing on subgroups, such as children or teenagers, cyclists or truck drivers. ITF(2012) has a bibliography. Specific examples of the use of the method in road safety are Razzak (1998), Jarvis (2000), Morrison and Stone(2000) and Amoros (2007).

The easiest case is when there are two "captures" or, for human populations, lists or registrations or data sets. Here the basic principle is elegantly simple. If, the two lists A and B, contain N_A and N_B individuals with n common to both lists, an estimator (known as the Lincoln-Petersen estimator) of the true population size N is given by $N_A N_B/n$. The reasoning is that the proportion recaptured in the second sample is representative of the entire population and so $N_A/N = n/N_{B.}$

This estimator is unbiased with other desirable statistical properties under specific conditions. The relevant ones here are, (see Hook and Regal (1999) exact identification of subjects common to both registrations, independence between the registrations and homogeneity of capture by a given registration. None of these are fully met for police and hospital data and the results should at this stage be seen as indicative. Further work to improve the estimates requires more precise matching variables, a deeper understanding of the associations between the data sets, and indications from other sources like Accident and Emergency.

3 Analysis of data

3.1 Police reported cycle accidents

This section of the paper uses information from the road safety database to provide a broad picture of cycling collisions in Ireland. Much of the information is contained in Tables A1 and A2 in the Annex.

From these data we would like to focus on two main points. The first concerns the relative frequency of cycling collisions compared to all traffic collisions. The data show the circumstances where there is a higher share of cyclist collisions than general collisions. These include weekdays, the summer months, fine weather and peak traffic times. These findings are similar to those in other countries (ITF, 2013; De Geus, et al, 2012; Knowles, et al, 2009). The higher accident frequencies under these circumstances are likely to be linked to the higher volumes of cycling traffic under these conditions. In the same way, three quarters of the casualties are men but this too reflects the fact that around three times as many kilometres are cycled by men. There is one clear exception and it is the proportion of cyclist collisions that occur at junctions. A half of cyclist collisions occur there, obviously greater than the share of kilometres or time spent at them. This finding is also confirmed in the literature referenced above and is a particular concern for cycling policy.

Secondly, the data underline and quantify the vulnerability of cyclists. In collisions involving cyclists, it is the cyclist that is killed or injured in 97.5% of the cases. This equates to the cyclists being 40 times more likely to be killed or injured in a collision than the occupants of the other vehicle. In addition, the risk per kilometre of being involved in a fatal collision is 8 times higher for cyclists (see Annex 1 for the calculation). The higher risk of being in an accident and the much higher risk of injury or death in a collision, are central to considering the safety of cyclists.

3.1.1. Analysis of police data on severity

Defining and measuring accident severity is problematic and different definitions can give quite different results (ITF, 2012). The one used officially in Ireland is the police assessment on the spot. Table A3 in the Annex shows how collision severity, as assessed by the police, varies under different circumstances. The table shows how serious accidents occur under all the identified circumstances. However, it also shows how some particular circumstances are associated with significantly higher serious injury rates. These are dark roads at night, collisions that are not at junctions, being unfamiliar with the location, higher speed limits and being under 14 or over 65 years of age. In fact, cyclist age and accident severity are related in a U curve with peaks at the youngest and oldest ages.

Speed and severity are linked in a strikingly clear way with accident severity increasing rapidly with speed, as a glance at Table A2 will confirm. That only 5% of collisions are severe in 30 km/hour zones contrasts with the growing figure as the speed limit increases and especially with the figure of 37% for the 100 km speed limit.

An important conclusion for policy concerns the fact that severe accidents happen under all circumstances. From this it can be inferred that, while specific measures targeted at particular circumstances could reduce severity, doing so across all conditions requires more general measures, which would apply universally. And, from the evidence presented in Tables A2 and A3, speed is a key factor influencing collision severity and is therefore a main policy variable on which to act.

Logit Regression Analysis

The cycling accident data above, with records of over 6000 collisions from 1996 to 2010 was analysed to see if further insights could be obtained on the relationships between police - recorded severity and possible explanatory factors. For this **a** series of logit regression models were estimated. As before, possible explanatory factors were classified into two groups, personal and trip factors and road and conditions factors. In the first group were age and sex as well as time of day, day of the week and month of collision, trip purpose and whether the person was familiar with the location. In the second, the factors were light(whether in daylight or at night), the weather, road surface conditions road type characteristics and markings, junction type and type of collision. Other studies have used this approach to analyse the severity of cyclist accidents for example Moore et al, (2011), Kim et al (2011).

The variables included in the model selected are described in Annex Table A4 while Table 4 summarises the results. As suggested in the descriptive analysis above, several of the variables examined had no significant influence on the severity of the collision; and this was confirmed by the non-significance of the β values for these variables.

For police-recorded serious crashes, and considering first the group of variables concerned with person and trip factors, there was no difference in severity by gender, nor by when the collision occurred or trip purpose. However, as shown also in Table A3, age is an important exception and severity was higher for the oldest and youngest age groups. The Exp β coefficients indicate that the severity odds ratio almost doubles for cyclists aged under 14 and those over 55. A significant β coefficient was found also for young male drivers of the motorised vehicle involved in the collision.

In the road and conditions factors, there was no difference in the severity in different weather conditions or in different road surface conditions. The factors that made a difference were unlit roads at night and speed. For dark roads at night, the odds ratio increases by a factor of over 2. For speed, the figure of 1.033 for the odds ratio indicates a 3% increase in the odds of being seriously injured for every km/hour increase in speed. This finding accords well with the literature and in particular with what is known as Nilssons power law (Nilsson, 2004).

In summary, the logit analysis confirms the significance of the factors shown in Table A3. In addition, it provides estimates of how the odds of a serious injury change as the explanatory factors change.

While these insights are interesting and that on speed is highly relevant for policy, it is important to note that the logit models are not good predictors of serious collisions. This is mainly because the majority of collisions occur in “normal” conditions and the variables associated with higher risk in the model occur relatively infrequently. It is also because variables that might better explain severity are not available. Such variables are used in other cycling studies e.g. Kim and Moore already cited, and include speed at impact, point of impact, whether the cyclist or driver had been drinking and whether the cyclist had a light or wore a helmet or high visibility clothing.

3.2. Hospital In-patient data

The following summary is based mainly on the material in Tables 3 and 4 and Tables A5 to A7 in the Annex.

In the period 2005 to 2011, hospitals recorded 6,565 emergency in-patient episodes of care for cyclists. Of these 2,304 (35%) were recorded as traffic injuries. The remaining 65% were mainly falls and were recorded as non-traffic accidents or were unspecified. Less than 10% of the episodes were coded as traffic accidents involving a collision with a vehicle. The share of episodes classified as traffic or transport is stable over time.

Over this period, cyclist injuries accounted for over 19,000 days in hospital. The trend is increasing and the number of days spent by cyclists in hospital is a growing share of the total days spent in hospital by transport casualties. In 2011, cyclists accounted for 13.9% of the days spent in hospital from transport injuries- up from 8.3% in 2005, as shown in Table3.

Almost three quarters of the episodes concern males (73% to 27%). This differs slightly for traffic accidents, which has 76% males. This proportion varies by age group with males accounting for 85% of the episodes in the 15-24 age group. Importantly, 55% of those admitted are under 15 years of age. Head injuries account for almost 40% of hospital admissions, well ahead of arm and elbow injuries, which account for about 20%.

One measure of severity is length of stay in hospital. The data show that 22% of in-patients are released on the same day and 62% stay one day or less. Stays of four days or more accounted for 956 (15%) episodes and of six days or more for 584 (9%). The average length of stay is around 3 days and the median is 1 day. Work is underway to apply clinically based classifications like the Abbreviated Injury Scale (AIS) to Irish Hospital data but they are not available for this analysis.

3.3. Comparison of Police and Hospital data sets

The two data sets are compiled for different purposes and in different ways. Both are subsets of those injured in bicycle accidents, with one limited to cases where the police were called and the other to emergency in-patient episodes in hospital. The next section compares the two data sets directly.

3.3.1. Direct comparisons

Table 4 summarises the police and hospital data for the years from 2005 to 2011. Police recorded 2,133 cycling injuries, 2,000 minor and 133 serious ones. Hospitals had 6,565 episodes of care for cyclists. So hospital data shows roughly three times as many incidents involving cyclists as the police data even allowing for repeat care episodes. However, the coding of the hospital episodes indicates that only that 2,304 (35%) were traffic accidents.

The remaining 65% of accidents coded as non- traffic or transport accidents are mainly falls of which there are around 4,000.

The figure of 2,304 traffic accident episodes from the hospital data is at first sight comparable with the 2,133 police collisions. But, though the numbers are similar the people involved are not necessarily the same. For example, hospitals record 589 episodes involving a collision with a vehicle (car, van, truck and coded V12-V16 in the ICD). The police recorded 1,845 injuries involving a collision with a car and 187 with a truck. So police data show over three times as many collision related injuries as the hospital data.

Both datasets show a predominance of males in the accident figures. The police data show that 76% of those injured were males and the hospital data shows 73% of the episodes involved males.

In contrast, the age structure of the data sets is strikingly different. Over 55% of those admitted to hospital were under 15. And for hospitalised females, the figure is 63%. The share of police recorded cyclist injuries that are under 15 is only 14%.

The cyclist data from both sources show a picture that is at odds with the broader data on road accidents. Neither police recorded injuries nor days spent in hospital by cyclists are declining as they are for all other modes. As a result, the share of total road traffic injuries accounted for by cyclists is increasing. In 2011, cyclists accounted for 14% of the days spent in hospital in all transport accidents, far in excess of the 0.6% of vehicle kilometres that cyclists account for (CSO,2011(a) and (b), also Appendix1).

The police data indicate a large decline in the share of injuries that are serious from 11% in 2005 to 4% in 2011. This decline can be an accurate gauge of a real reduction in accident severity or can also reflect administrative and other factors. The police assessment is obviously not a clinical assessment and can be influenced by, among other things, the work police have to carry out if an injury is judged to be serious.

Different measures of severity can also be obtained from the hospital data. Clinical coding of the injuries has not yet been translated into the recognised classifications like AIS or ICISS. Ireland has committed to moving to MAIS but the coding work has not yet been undertaken. Here, length of stay (LOS) has been used as a proxy for seriousness of injuries. While it is an imperfect measure, being subject to administrative or supply side influences it does give useful indications. The data show that LOS for cyclists is relatively stable with an average of 3 days and a median of 1 day. Length of stay for collisions with another vehicle shows higher averages and variances. On this measure, hospital data does not indicate a decline in the severity of cycle accidents.

The data in Table 4 updates and expands on the work of Bedford et al (2011). Bedford (2011) argued that the comparison of hospital and police data showed how police data understated the number of serious injuries. For cyclists, this understatement was greater than for other modes. The analysis here confirms that the number of hospitalised cyclists far exceeds –by a factor of almost 50- the number of cyclists reported as seriously injured by the police. The findings here compare also police- reported minor injuries with hospital data and show that, unlike other modes, the number of hospitalised cyclists exceeds also the police reported number of minor injuries (Short (2013)). Moreover, the data confirm that the police frequently misclassify a serious injury as a minor one (by definition, any person admitted to hospital as an in-patient is seriously injured). This shows that the police do not apply their own definition of serious injury and further, the evidence suggests that the police classification of a serious injury has changed over time. In conclusion, the data here show that the cyclist collision problem is both greater and more complicated than thought previously.

3.3.2. Matching Police and Hospital data

The matching was carried out for the police file of 2,133 injuries and a hospital file with 3,158 care episodes, including all the traffic accidents as well as some of the other cases where there is uncertainty on whether the episode related to a traffic accident or not.
Matching was carried out with different thresholds and scoring systems and levels of posterior probability. Using a posterior probability (the probability of a true match given agreement on matching variables) of .85 the number of matches was 571, 18% of the hospital records and 27% of the police file. These figures can be used, on certain assumptions, to make estimates of the total number of cycling injuries in traffic accidents using what is known as the capture - recapture method. This is done in the next section.

To summarise, the matching shows that about half the police reported seriously injured cyclists were matched with hospital records. Of the police reported seriously injured cyclists that were matched, 30% remained in hospital for a day or less. On the other hand, around 10% of the matched cyclists with minor injuries remained in hospital for more than four days. When matches are found for police reported serious injuries there is a tendency for them to be longer stay patients. But police reported serious injuries are also found among short stay patients and about half do not seem to get to hospital at all. This underlines the obvious point that police recorded serious injury is not a reliable indicator of severity but more significantly, emphasises that the two groups do not overlap to a large extent. This leads then to the following attempt to estimate the true number of injured cyclists.

3.3.3 Capture-recapture estimates

As mentioned in section2, capture recapture can be used to estimate population size based on a number of samples or registrations. With two samples, the Lincoln-Petersen estimator is unbiased if there is independence between the samples, perfect identification of the common individuals and homogeneity of the probabilities of being in each data set. These conditions are not met for these data and the estimate is indicative only.

Using the Lincoln_Petersen estimator, the number of cyclist traffic injuries would be 2133*3158/571=11,796, which is six times the police reported number and twice the total number hospitalised.
While the calculation is approximative, it can safely be concluded that the cyclist injury problem is both much greater and different in structure than the official figures indicate. The final section of the paper examines the implications for policy of these findings.

4. Can Safety and Cycling Policy converge?

The data presented above for Ireland seem to conform to the situation in many countries, with limited exposure data, under reporting of collisions, and poor or missing collision information (ITF, 2013). From the evidence presented above, the official data on cycling safety do not correctly reflect the risks or vulnerabilities of cyclists. Per kilometre travelled cyclists are 8 times more likely to have a fatal collision, and 40 times more likely to be injured or killed in a collision. Moreover many injuries are not included in official statistics and neither police nor hospital data fully captures the extent of the accident problem in cycling.

The evidence above points to some clear directions for policy as it attempts to reconcile the broadly environmental aims of cycling policy with the safety objective to make cycling a low risk transport option.

Safer pro-cycling policies will start with a more careful collection and organisation of the crash data. There is a need for a better understanding of the real extent of the cyclist crash problem. This requires both better collision data and improved exposure measures. Police data needs to include more and better information on cyclist accidents. Hospital data, not widely used up to now, should become a regular source of information, to complement and verify police data and also for clinical data for analysis on injuries. Both sources are relevant for transport and health policy and provide different perspectives on the problem. The national travel survey needs larger samples to provide more reliable exposure data for cyclists. The large number of non-collision accidents, mainly falls, many involving children, frequently have serious consequences and little is known of them. Finally, it is essential to learn from cycling collisions through detailed study of crashes. This information should be available for research.

The data since 2005 shows an increase in reported collisions and in the number of hospitalisations. Cycling is growing but because the data on this are not precise it is not possible to say if collision and injury rates are declining. There is a developing literature on "safety in numbers" which tries to identify a mechanism that might explain declining accident rates as traffic grows (Johanssen, 2003; Elvik, 2009; Wegman, 2012 and ITF, 2013). It will be useful to begin such analysis in Ireland. But as exposure data are not available for cycling and as all other categories of road traffic casualties are declining in absolute terms, it cannot be claimed that the cycling policy is a success. Cycling is about 8 times more risky than car driving per kilometre. As a result, encouraging people out of cars (or public transport) on to bicycles increases the risks and, other things equal, will lead to an increase in the number of collisions. The stated aim to increase cycling by a factor of four by around 2020 will therefore see a large increase in the number of accidents unless there is a commensurate reduction in per kilometre risk. Even if cycling grows at a lower rate (which seems more plausible), a reduction in risk per kilometre of the same order would be required to maintain a stable number of accidents. It does seem reasonable that, in the absence of more precise exposure measures, an objective that the number of cyclist casualties would not increase, would be agreed to accompany the cycling volume target. And the measurement should be based on all sources – not just police reported data.

In addition, the severe asymmetry in collision consequences needs to be more central to policy. The chances of minor injury, serious injury or death in a collision are 40 times higher for a cyclist. This justifies additional measures both to avoid the likelihood of collisions and to minimise their consequences. For each, the most important factor is vehicle speed.

Urban speed limits are generally set at 50 km/hour. Moreover, the 50 km/hour speed limits are those where respect of the limits is least. Surveys show that 59% of cars on urban roads are speeding (RSA, 2012). If this infrastructure is to be shared with cyclists this is too fast. Since 2010, there has been an increase in the number of roads with 30 km/hour limits. Based on the crash data, there is a strong case to extend this network significantly. Reductions in speed will reduce crash severity much more than proportionately. And the same argument applies also in rural areas where many of the serious collisions occur. Since speeding is so prevalent, the strengthening of speed enforcement seems also to be a rather obvious response.

Wearing helmets is not compulsory for cyclists in Ireland. This reflects long standing practice as well the views of many cycling organisations and supporters. The perception that the success of the Dublin Bike scheme is partially at least due to the fact that helmets are not compulsory is also a factor. However, the evidence above that a very large share of hospitalisations, especially among children, involve head injuries provides evidence that the compulsory wearing of helmets, initially by children, could have important health benefits.

Cycling advocates argue that putting too much accent on safety undermines the aim to encourage cycling and risks to put people off. On the other hand, the risks are real, have been understated and should not be ignored. And while cyclists are the losers in collisions, they also have responsibilities. The police data indicate that cyclists were at least partially responsible in about half the collisions. There is therefore scope to improve cyclist behaviour. For this, more information on risks, and practical advice and training on dealing with dangerous situations can contribute.

Finally, the data above and surveys of cyclists, for example (Lawson et al, 2012) show there is still a significant effort needed to improve cycling infrastructure, to increase separation from other vehicles, deal with cyclist safety at junctions and reduce risks in rural areas and at night.

Conclusions

Cycling is growing and is being supported by public policy. The evidence here shows that cycling is less safe than official figures show and that cycling is not becoming safer as other modes are. If cycling policy is to be successful, safety needs to be more at its centre. In the absence of exposure data safety targets could be set on the basis of no increase in the absolute numbers of victims. Better integration of cycling and safety policies requires additional efforts to improve the understanding of the safety problem for cyclists. Here both police and hospital data should be used and both need to be improved. The extreme vulnerability of cyclists in collisions justifies additional measures to protect them including more 30km /hour speeds, and the wearing of helmets, at least by children.

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Annex 1

Estimate of Total Distance Cycled in Ireland

Two sources are used, the national travel survey (CSO, 2011), carried out for the first time in 2009, and Census data (CSO various years), since 1986.

The national travel survey estimates are that the total number of cycling kilometres undertaken in the reference week was 3.36 million kilometres. This is calculated for all persons 18 years and over, on the basis of an average of 17 trips per person per week, an average trip distance of 5km and an estimate of the share of trips by bicycle at 1%. The population 18 years and over in 2009 is estimated to be 3.3 million. Putting these together gives the estimated total distance of 3.36 million kilometres above. Multiplying this by 52 is likely to give an underestimate of the total kilometres cycled as the week in question was in November and was exceptionally cold. On the other hand, there is no obvious adjustment factor to apply. The number of collisions in November is not much lower than other months and no particular reasons have been identified to indicate more risky behaviour in November. On balance, it has been decided to not adjust the weekly estimate. This gives a figure of 174.7 million kilometres per annum.

Census data (CSO,2011 (a)) provides estimates on travel to school and college by those under 18, information not collected in the National Travel Survey. . There were 6,252 students in the age range 5-12 cycling an average daily distance of 8 kms. Multiplying by 200 gives 10 million kms. Similarly for the 6,592 students aged 13-18 cycling 16 kms a day a total of 19.8 million kms is obtained. This gives a total of 29.8 million kilometres as the distance travelled to school. No information is available on other cycling activities by children. As a guess, this figure is doubled, giving an estimate of about 60 million kilometres cycled by children. Adding the figures from the two sources gives 235 million kilometres as an estimate of the total distance cycled annually in Ireland.

To calculate accident rates, total vehicle kilometres travelled in 2010 were 42,409 million kms (Road Traffic volumes data, Central Statistics Office, 2013) and the cycling share is therefore 235/42409=0.6%.

TABLES

Tables for text.

Annex Tables.

Tables and Figures to Include in Text

Table 2. Cycling to work, Ireland 1986-2011.

Year	Number Cycling to Work (000)	Total at Work(000)	% Cycling
1986	60.8	1,084	5.6
1991	50.3	1,137	4.4
1996	46.5	1,294,	3.6
2002	34.3	1,610,	2.1
2006	36.3	1,8923	1.9
2011	39.8	1,695	2.3

Table 2. Logistic Regression Results.

Variables in the Equation		β	S.E.	Wald	df	Sig.	Exp(β)
Serious Collisions	Speed	.032	.002	268.542	1	.000	1.033
	Dark Roads	.798	.191	17.531	1	.000	2.222
	Older Cyclists	.632	.124	25.784	1	.000	1.881
	Young Cyclists	.556	.101	30.178	1	.000	1.743
	Young Driver	.385	.120	10.250	1	.001	1.470
	Constant	-4.156	.131	999.374	1	.000	.016

Table 3. **Hospitalisation for Transport and Cycling injuries; 2005-2011.**

Year	Hospital Days		Cyclist Share
	All Transport	Cyclists	
2005	34,028	2,818	8.3
2006	34,988	2,764	7.9
2007	32,159	2,651	8.2
2008	33.544	2,710	8.1
2009	27,694	2,820	10.2
2010	24,318	2,558	10.5
2011	20,105	2,794	13.9

Source: HIPE data, ESRI

Table 4. Comparisons of Hospital and Police Injury data.

Source	Type	2005	2006	2007	2008	2009	2010	2011	Total
Police	Serious	24	18	19	27	21	13	16	133
	Minor	177	190	236	305	339	378	375	2000
Hospitalised (traffic accidents)	Total	318	333	344	272	301	371	365	2304
	Over one day	136	120	155	121	124	166	164	986
	Over 4 days	60	61	62	62	51	74	76	446
	Over 6 days	44	37	35	41	34	42	50	283
Hospitalised (All accidents)	Total	948	886	933	823	934	1032	1009	6565
	Over 1 day	372	312	396	313	332	384	393	2492
	Over 4 days	145	124	127	130	128	149	153	956
	Over 6 days	94	75	75	77	84	79	100	584

Figure 1. Cyclist Collisions 1996-2010.

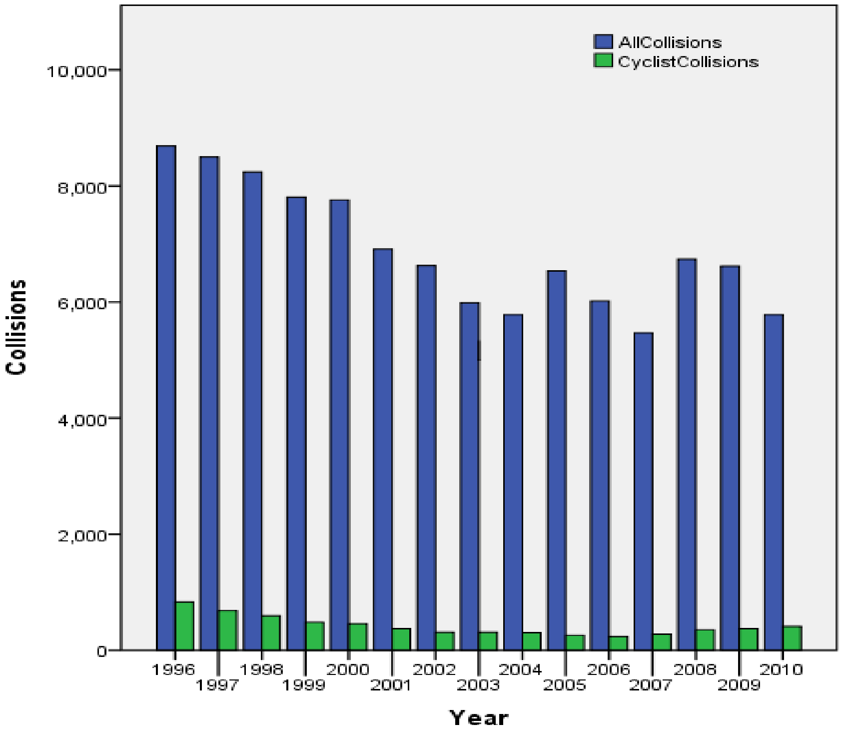
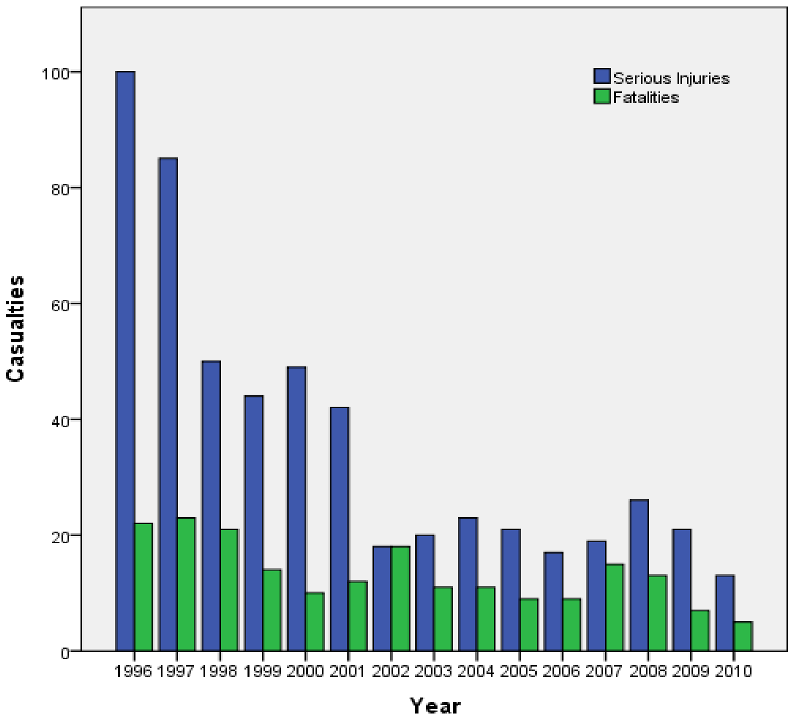


Figure 2. Cyclist Casualties 1996-2010.



Tables to Include in Annex (Numbered A1 to A7)

Table A1. Trends in total and cyclist collisions - 1996-2010.

Year	All Collisions				Cyclist Collisions			
	Total	**Fatal**	**Serious**	**Minor**	**Total**	**Fatal**	**Serious**	**Minor**
1996	8686 *100%*	415 *5%*	1651 *19%*	6620 *76%*	833 *100%*	24 *3%*	104 *12%*	705 *85%*
1997	8496 *100%*	424 *5%*	1544 *18%*	6528 *77%*	683 *100%*	26 *4%*	90 *13%*	567 *83%*
1998	8239 *100%*	408 *5%*	1345 *16%*	6486 *79%*	596 *100%*	21 *4%*	52 *9%*	523 *88%*
1999	7807 *100%*	374 *5%*	1302 *17%*	6131 *79%*	481 *100%*	14 *3%*	46 *10%*	421 *88%*
2000	7757 *100%*	362 *5%*	1189 *15%*	6206 *80%*	455 *100%*	10 *2%*	50 *11%*	395 *87%*
2001	6909 *100%*	360 *5%*	1034 *15%*	5515 *80%*	374 *100%*	12 *3%*	43 *11%*	319 *85%*
2002	6625 *100%*	346 *5%*	827 *12%*	5452 *82%*	306 *100%*	19 *6%*	19 *6%*	268 *88%*

2003	5985 *100%*	301 *5%*	796 *13%*	4888 *82%*	307 *100%*	11 *4%*	21 *7%*	275 *90%*
2004	5781 *100%*	334 *6%*	662 *11%*	4785 *83%*	301 *100%*	11 *4%*	23 *8%*	267 *89%*
2005	6533 *100%*	360 *6%*	787 *12%*	5386 *82%*	256 *100%*	10 *4%*	24 *9%*	222 *87%*
2006	6018 *100%*	321 *5%*	653 *11%*	5044 *84%*	232 *100%*	9 *4%*	18 *8%*	205 *88%*
2007	5467 *100%*	309 *6%*	618 *11%*	4540 *83%*	277 *100%*	15 *5%*	22 *8%*	240 *87%*
2008	6736 *100%*	254 *4%*	613 *9%*	5869 *87%*	351 *100%*	13 *4%*	29 *8%*	309 *88%*
2009	6615 *100%*	220 *3%*	463 *7%*	5932 *90%*	374 *100%*	7 *2%*	21 *6%*	346 *93%*
2010	5780 *100%*	185 *3%*	409 *7%*	5186 *90%*	408 *100%*	5 *1%*	15 *4%*	388 *95%*
Total	**103434** *100%*	**4797** *5%*	**13568** *13%*	**83568** *81%*	**6234** *100%*	**207** *3%*	**577** *9%*	**5450** *87%*

Table A2. All Collisions and Collisions Involving Cyclists, 1996–2010

Collisions		Cycling		All Collisions		Cycling Share (%)
		No.	%	No.	%	
All		6,234	100	103,434	100	6.0
of which:						
	Fatal	207	3.3	4,973	4.8	4.2
	Serious	577	9.3	13,893	13.4	4.1
	Minor	5,450	87.4	84,568	81.8	6.4
Road and Environment						
	Dry	4,909	79.8	73,385	71.5	6.7
	Good visibility	4,366	70.4	60,171	58.4	7.3
	Straight	4,189	70.0	62,593	62.2	6.7
	2-lane	4,454	83.5	81,534	87.4	5.5
	At Junction	3,213	51.5	36,671	35.5	8.8
Personal and Trip factors						
Trip Purpose:	Work	913	25.3	31,930	29.4	2.9
	School	240	6.6	830	0.8	28.9
	Leisure	2328	64.5	65,716	65.3	3.5
Season:	Winter	1,299	20.8	24,426	23.6	5.3
	Spring	1,487	23.9	25,283	24.4	5.8
	Summer	1,753	28.1	26,405	25.5	6.6
	Autumn	1,696	27.3	27,320	26.4	6.2
Day:	Weekend	1,155	18.5	30,829	29.8	3.7
	Weekday	5,076	81.5	72,605	70.2	7.0
Time:	Morning Peak	1378	22.2	16,968	16.5	8.1
	Day	1720	27.8	27,479	26.7	6.3
	Evening Peak	2419	39.0	33,973	33.0	7.1
	Night	674	10.9	24,426	23.8	2.8
Knows location		4265	83.4	69,126	87.6	6.2

Table A3. Cycle Collision Severity.

Broad factors	Specific	Cyclist Collisions		
		Total	Serious	Share%
All		6234	784	12.6
Road and Environmental factors	Dry	4909	658	13.4
	Not Dry	901	97	10.8
	Daylight	4366	552	12.6
	Dark-no lighting	150	64	42.7*
	At Junction	3213	312	9.7
	Not at Junction	3021	472	15.6*
	at X road	788	85	10.8
	at Y junction	143	19	13.3
	at T Junctions	1787	169	9.4
	at Roundabout	328	19	5.8
	Complex Junctions	167	20	12.0
	2 Lane Road	4454	632	14.2
	One Way	597	45	7.5
	Straight	3822	632	14.2
	Bend	552	45	7.5
	Familiar with location	3824	541	14.1
	Unfamiliar with Location	143	41	28.7*
	30Km/hr	72	4	5.3
	50Km/hr	4431	422	8.7
	60Km/hr	269	35	11.5
	80Km/hr	189	53	21.9*
	100Km/hr	429	251	36.5**
Personal and Trip Factors	Weekday	5079	588	11.6
	Weekend	1155	196	17.0
	Night time	674	95	14.1
	Morning Peak	1378	127	9.2
	Day	1720	236	13.7
	Evening Peak	2419	322	13.3
	Under14	985	184	18.7*
	15-24	1302	155	11.9
	25-34	1178	105	8.9
	35-44	632	64	10.1
	45-54	440	62	14.1
	55-64	315	62	19.7
	65and over	216	56	25.9**
	With Car	5073	517	12.8
	With Truck / bus	545	141	13.1
	Male	4418	566	12.8
	Female	1336	175	13.1

(1) Percentages that are significantly different statistically from the population means (12.6 on the first line above) are shown with an * if the difference is significant at the 5% level, and with ** if it is significant at the 1% level. The test statistic used was $(p-p_0)\, n^{1/2}/(pq)^{1/2}$ where **p** and p_0 are the observed and population percentages, **q=1-p** and **n** is the observed number of collisions in the category concerned.

Table A4. Logistic Regression; Definition of Variables included

Variable	Type	Definition	Values	Other values
Speed	Discrete Values, Independent	Road Speed limit	30,50,60,80,100,120	none
Dark Roads	Dichotomous, Independent	Collision occurred on unlit road after dark	1	0
Older Cyclists	Dichotomous, Independent	Age 55 or over	1	0
Young Cyclists	Dichotomous, Independent	Age less than 15	1	0
Young Driver (crash opponent)	Dichotomous, Independent	Male Driver under 25 years	1	0
Serious Injury	Dichotomous, Dependent	Police recorded serious injury	1	0

Table A5. Hospitalised Cyclists by type of accident and whether traffic or not 2005-2011

Type of Collision	Traffic Accident	Non-traffic accident or unspecified	Total
Pedestrian, cyclist or motor cycle	59	95	154
Vehicle	589	122	711
Object	53	151	204
Non Collision (falls)	944	3167	4111
Other/NS	659	722	1385
Total	**2304**	**4261**	**6565**

Source: HIPE data, ESRI.

Table A6. Length of Stay for Cyclists by type of accident, 2005-2011.

Type of Injury		Length of Stay				Total
		One day or less	2 to 3 days	4 to 5 days	6 days or more	
Non -traffic Injury or not specified	2005	394	151	35	50	630
	2006	361	129	25	38	553
	2007	348	176	25	40	589
	2008	359	124	32	36	551
	2009	425	131	27	50	633
	2010	443	143	38	37	661
	2011	425	142	27	50	644
	Total	**2755**	**996**	**209**	**301**	**4261**
Traffic Injury	2005	182	76	16	44	318
	2006	213	59	24	37	333
	2007	189	93	27	35	344
	2008	151	59	21	41	272
	2009	177	73	17	34	301
	2010	205	92	32	42	371
	2011	201	88	26	50	365
	Total	**1318**	**540**	**163**	**283**	**2304**
Total	2005	576	227	51	94	948
	2006	574	188	49	75	886
	2007	537	269	52	75	933
	2008	510	183	53	77	823
	2009	602	204	44	84	934
	2010	648	235	70	79	1032
	2011	626	230	53	100	1009
	Total	**4073**	**1536**	**372**	**584**	**6565**

Source: HIPE data, ESRI.

Table A7. Hospitalised Cyclists by Sex Age and Type of Injury 2005-2011.

Type of Injury			**Sex**		**Total**
			Male	**Female**	
Non -traffic Injury or not specified	Age Group	0-14	1,765	824	2,589
		15-24	376	77	453
		25-34	276	83	359
		35-44	214	43	257
		45-54	188	67	255
		55-64	132	55	187
		65 and over	120	41	161
	Total		3,071	1190	4,261
Traffic Injury	Age Group	0-14	695	304	999
		15-24	273	39	312
		25-34	210	81	291
		35-44	197	41	238
		45-54	140	56	196
		55-64	95	55	150
		65 and over	90	28	118
	Total		1,700	604	2,304
Total	Age Group	0-14	2,460	1,128	3,588
		15-24	649	116	765
		25-34	486	164	650
		35-44	411	84	495
		45-54	328	123	451
		55-64	227	110	337
		65 and over	210	69	279
	Total		4,771	1,794	6,565