# The role of bicycle-sharing in the city: analysis of the Irish experience

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## Abstract

**Bicycle-sharing schemes have become an important piece of infrastructure in many cities across the world over the last decade. However, existing research investigating the role and impact of these schemes in cities is sparse. This research analyses the impact of a recently implemented scheme in Dublin, Ireland. Using evidence from 360 questionnaires, the paper examines four associated with the scheme: (1) the socio-economic characteristics of the users; (2) its impact on modal choice; (3) its peak and off-peak functionality; and (4) its impact on driver awareness of cyclists. Results show the scheme is used predominantly by higher-income individuals, it has a different functionality during the peak and off-peak and has been indirectly successful at improving driver awareness towards cyclists.**

## INTRODUCTION

The role of cycling in the city transportation system has gained increasing attention in recent years due, at least in part, to its rise in popularity as an alternative mode of transport in many European cities. This rise in popularity is related to numerous factors in individual countries some of which are policy-related while others are related to changing cultural and socio-economic contexts (see DeMaio, 2009; Midgley, 2011). There is little

doubt though that it is due, at least in part, to the fact that awareness of the bicycle as an environmentally-friendly and healthy alternative to motorised transportation has been raised. In addition, the move in some cities towards transport policies that are more facilitative of cycling as a mode of transport such as fiscal incentives (Caulfield and Leahy, 2011), improved infrastructure and enhanced safety have undoubtedly increased the appeal of cycling as a mainstream mode of transport not only for commuting but for non-work trips also (Horton et al, 2007).



Chief among policies implemented to promote cycling has been the implementation of bicycling-sharing schemes in many cities around the world - the vast majority being in European cities (DeMaio, 2004; 2009). Bicycle-sharing is important because it has the potential to increase the modal share of cycling, better meet the demands of increasingly mobile populations, and lessen the environmental impacts of motorised transportation systems (Midgley, 2011). These are important goals for transport policy-makers that also complement the 'green' political agenda that has emerged over the last decade or so. The basic underlying premise of the bicycle-sharing concept is more sustainable transportation and in particular more sustainable public transportation via the use of the bicycle. The ultimate goal is to expand cycling as a mode of transport and integrate it into the wider transport system (Shaheen, 2010).

The first experiments with bicycle-sharing schemes date back to the first known scheme in Amsterdam in 1965 (DeMaio, 2009). Thereafter 2$^{nd}$ generation schemes were initiated in Denmark in 1991 and 1995 with 3$^{rd}$ generation schemes appearing soonafter in

England (1996) and Rennes (1998) (DeMaio, 2009). The schemes have evolved significantly since the 1960s and 3rd generation systems are now characterised by such technological improvements as electronic locking, smartcard (RFID) technology, GPS tracking of bicycles, mobile phone applications and real-time information. Over the last ten years in particular, there has been a surge in take-up of the schemes throughout the world mainly as a result of the success and promotion of the large-scale Parisian 'Vélib' scheme which was initiated in 2007. In fact, ten years ago there were only five schemes operating in European countries (Denmark, France, Germany, Italy and Portugal); today 'there is an estimated 375 bicycle-sharing schemes operating in 33 countries in almost every region of the world using around 236,000 bicycles' (Midgley, 2011, 1).



Under the scheme bicycles are available for short-term rental throughout the city whereby they can be picked up and returned at self-service bicycle stations. Bicycles are used on an 'as-needed' basis without the costs (e.g. capital cost, depreciation, maintenance etc.) and responsibilities (e.g. theft prevention, parking etc) associated with traditional bicycle ownership and use. Usually, they are accessed through a combination of a small annual subscription fee which provides users with smartcard swipe access to bicycles at rental stations[1]. Thereafter, most systems offer the first 30 minutes free of charge with prices increasing exponentially after each additional 30 minutes to encourage short-term usage and bicycle availability throughout the system. Thus, the intention of the scheme is for bicycles to be used for relatively short trips and to provide the missing link between existing points of public transportation and desired destinations. The scheme also offers a

[1] Occasional users can also get short-term access using a credit card.

different form of mobility in cities which has the potential to complement and enhance the existing public transportation network (Nair et al, 2013). In terms of operationalisation, various agencies may be responsible for providing bicycle-sharing schemes including governments, quasi-governmental transport agencies, universities and advertising companies, the latter of which appears to be the most popular (DeMaio, 2004; 2009).



While there is a plethora of literature investigating various aspects of cycling as a mode of transport in cities, De Maio and Gifford (2004, 4) have pointed out that there is remarkably little research available on bicycle-sharing schemes. In particular, there has been little analysis of their role within the broader city transport system, their function and impact as well as their effectiveness and uptake. Indeed, Midgley (2011, 16) asserts that 'there is very little meaningful data on the benefits or impacts of bicycle-sharing schemes' and also that 'there is limited data available on changes in mode of travel before and after the introduction of bicycle-sharing'. These issues are examined in this paper.

Within this context, the current research contributes to literature in this area by investigating four specific aspects of a recently implemented bicycle-sharing scheme in Dublin, Ireland. Specifically, our objectives were: first, to identify the socio-economic characteristics of the users of the scheme; second, to investigate the impact of the scheme on the modal choice of users; third, to examine whether the role and functionality of the scheme between the peak and off-peak periods in terms of trip-type characteristics; and

finally, to examine the impact of the scheme on improving driver awareness of cyclists. While some of these issues have been investigated in the broader cycling literature, they have received relatively little examination within the context of the emergence of bicycle-sharing schemes and its user-base. Accordingly, the contribution of this paper lies in assessing the aforementioned issues within a bicycle-sharing context.



**Relevant Literature**

Quite a significant amount of literature has emerged in the last decade or so in relation to cycling, socio-economic issues, public health and safety among other issues. In the case of socio-economics and cycling, the majority of studies conducted found that males cycle much more frequently than their female counterparts (Pucher and Diijkstra, 2003; Moudon et al, 2005). Dickinson et al. (2003) have suggested that women cycle less because they often trip-chain undertaking activities such as shopping, transporting children to school together with commuting to work; this type of trip pattern is facilitated to a greater extent by the private car than by public transport or cycling although this trend is not obvious in high cycling countries. In addition, women tend to be much more conscious of the safety risks associated with cycling while they also tend to be more aware of their appearance when going to work (Garrard et al., 2008). However, exceptions do indeed exist, and some research has suggested that in countries with very high levels of cycling such as the Netherlands, as many women cycle as men, while in countries with much lower cycling levels, men tend to cycle at least twice as much as women (Horton et al., 2007). This assertion is supported by Garrard (2003) who points out that in countries with high cycling levels, women tend to cycle even more frequently

than men. The implication here is that gender imbalances are less likely to occur where cycling is recognised as a main mode of transport.

Evidence from the United States suggests that the modal share of cycling declines rapidly with age (Moudon et al, 2005; Pucher et al, 1999) but only slightly in Europe (Pucher and Dijkstra, 2000). Moudon et al. (2005) found cycling levels to be highest among 25–45 year olds with a significant drop off in commuting and utilitarian cycling occurring beyond 55 years old. Indeed, Parkin (2004) found that a greater number of people cycle to work in areas with a higher proportion of workers aged 34 and under. This is related to numerous factors including the physical nature of cycling; a lower level of car ownership among younger age cohorts and the fact that individuals in those age cohorts tend to live in more central locations (Horton et al, 2007).

In the literature, the association between cycling and income level is somewhat ambiguous. Horton et al (2007, 6) assert that it can be confusing with the literature offering conflicting views on its significance. Commins and Nolan (2008) found that those in the top three socio-economic groups are significantly less likely to cycle to work. Indeed, Horton et al (2007, 6) point out that 'if, in some places, cycling is understood as a practice of the poor, in others it is increasingly a practice of the rich'. However, Pucher et al. (1999) stress that this is not always the case. In countries such as Denmark, Netherlands and Germany there are high bicycle modal shares among all socio-economic groups. Moreover, in assessing cycling levels in the Netherlands, Germany and the UK, Pucher and Buehler (2006) found that low-income groups cycle only slightly more than

high-income groups. Moreover, because cycling is affordable by a broad spectrum of the public, it is considered to be among the most equitable of all transport modes. Guo et al (2007) purport that a combination of low income, a high number of bicycles and a low number of cars per household are linked to a tendency to use non-motorised transport modes. Whilst cycling levels are assumed to be higher among people without cars (Wardman et al., 2007; Parkin et al, 2008), research carried out by Parkin et al (2007) in the UK suggests that car-owning households are more likely to generate cycling trips than households without cars. Indeed, Zacharias (2005) concludes that the levels of cycling are more susceptible to locality, with income having little or no significant effect.

Given the foregoing discussion, there does not appear to be a definite association between socio-economic factors and cycling although some strong trends do indeed emerge from the literature. The influence of gender appears to fluctuate with males dominating cycling numbers in countries where cycling is not mainstream and a gender balance occurring in countries with high cycling levels. The evidence based on income levels is conflicting and it is likely to be the case that country-specific issues affect the outcome considerably.

Su et al (2010) argue that cycling promotion should be geared towards the next generation of cyclists; people who would be willing to start cycling if they considered the circumstances to be correct. In this regard, the promotion of bicycle-sharing schemes serve to increase general bicycle ridership by virtue of introducing the bicycle as a means of everyday travel to a new group of travellers (Martens, 2007). Similar views have also been expressed by DeMaio (2009) who contends that bicycle-sharing has had profound

effects not only on increasing the level of cycling but also increasing transit use, decreasing greenhouse gases, and improving public health more generally within the context of active transport solutions (see Sallis et al, 2004). DeMaio (2009) argues that bicycle-sharing contributes to an increase of 1.0–1.5% in bicycle mode share in cities with pre-existing low levels of cycling. Indeed, this argument is supported by evidence from the 'Velib' bicycle-sharing scheme in Paris and the 'Bicing' system in Barcelona (Nadal, 2007). However, it is worth noting also that cycle infrastructure improvements were also made in both cities during these time periods making it difficult to assess the exact impact of bicycle-sharing on changing modal choice over the period.

Moreover, quite aside from the perceived benefits of cycling in terms of health, reducing congestion and reducing harmful environmental emissions (see Rojas-Rueda et al, 2011), bicycle-sharing is relatively inexpensive (at least in terms of initial capital investment) compared to other transport schemes; depending on the method of procurement, it often requires little financial investment from the local administrative authority than other transport services and it promotes greater transit use through modal integration (Britton, 2009). Coming from the Dutch experience of bike-and-ride, Martens (2007, 331) is a strong advocate of bicycle-sharing or what he refers to as the 'public transport–bicycle' (PT-bicycle). In the Netherlands, the bicycle-sharing system is integrated into the wider public transport network and it has led to a considerable increase in bicycle use for egress trips; not only replacing egress trips made by bus, tram and metro but also those made by car and taxi. Martens (2007) concludes that the high share of business trips suggests that the combined use of the train and bicycle-sharing can compete with the private car in

terms of comfort and travel time. In fact, he (2007, 337) found that bicycle-sharing is 'the only measure that has some chance of succeeding in other cities and countries'. Despite the benefits of bicycle-sharing schemes, Vidalis et al. (2010) have pointed out the importance of analysing in detail the specific costs associated with the implementation of a successful system because overall costs may be more significant than they initially appear. Indeed, Midgley (2011) has pointed out that the capital costs of bicycle-sharing systems can range from $3000–4500 per bicycle while annual operating costs can range from $1200–1700 per bicycle.



## Study Area And Methodology

### Cycling And The Dublin Bike Scheme

Dublin is a relatively favourable city for cycling with a relatively flat terrain, mild year-round temperatures and surprisingly few wet days when compared to other successful cycling cities (such as Amsterdam). Despite this, between 1997 and 2004, the general cycling trend in Dublin city had been on the decline (see Figure 1). However, since 2004 the general trend has been increasing with a 60.5% increase recorded between 2004 and 2009. This has been due to a number of reasons including improved cycling infrastructure and safety, more publicity, rising fuel prices and fiscal incentives for bicycle ownership (see Caulfield and Leahy, 2011). It is not yet known what impact the Dublin bicycle-sharing scheme has had on usage statistics but if evidence from other countries (see DeMaio, 2009) plays out in Dublin, it is likely to be positive.

Dublinbikes is a 3rd generation bicycle-sharing scheme that officially opened in September 2009. At that time, the scheme had 450 bicycles installed at 40 stations throughout the city centre. It currently has 550 bicycles at 44 stations, a radius of c. 300 metres in the central area. The scheme is modelled on the Parisian 'Velib' scheme and like its counterpart is operated as a public private partnership (PPP). It is operated and maintained almost entirely by advertising company JC Decaux who do so in exchange for the use of 72 advertising spaces (valued at €54.36 million) in the Dublin City Council area for a period of fifteen years (www.dublincity.ie).



The scheme has been hugely popular; it currently has in excess of 58,000 subscribers (up from 38,000 in July 2010) with an average of c.5,000 trips being made daily (www.dublinbikes.ie). On the 14th of August 2010 (after 11 months) the scheme reached its one millionth trip after only eleven months in operation; nine months later (12th May 2011), the scheme reached its two millionth journey and only seven months after that (on December 22nd 2011) the three millionth journey was undertaken highlighting its increasing popularity. In a recent survey conducted by Dublin City Council, 95% of respondents felt the scheme had either a positive or very positive impact on the city (www.dublinbikes.ie). Such is the popularity of the scheme that plans are already in place for a major five-year expansion from 2011–2016. This includes a considerable extension of existing geographic distribution of the network, increasing the number of stations to 300 and the number of bikes to 5000 (Kelly, 2010; Dublin City Council, 2011).

**Site Selection And Sampling Strategy**

Bearing the research focus in mind, the study sought to gather quantitative data from users of the bicycle-sharing scheme to assist with answering the research questions. The overall strategy involved (1) selection of stations; (2) survey design; (3) sampling strategy; and (4) data analysis. More details are now provided on each aspect.

The dublinbike station network consists of 44 stations. At the time the research was undertaken it consisted of only 40 stations. Given the objectives outlined already, six bicycle stations (15% of the total number of stations) were chosen in order to gather data from respondents (Figure 2); we felt that six stations were necessary in order to acquire a representative number of sites throughout the dublinbike study area. The stations were selected at random (using a random number generator) to avoid bias entering the data given that the stations vary considerably in terms of their proximity to the local rail system (Dart and Luas), bus routes, primary employment centres and various tourist attractions which influence the socio-economic make-up of respondents and the usage patterns at each of the stations. By selecting sites at random we aimed to acquire a representative sample of stations that would minimise the weighted impact of any of those factors in the findings that could be attributed to bias in researcher site selection. Figure 2 shows the location of stations in the study area while the sites randomly selected for analysis are circled in yellow.

A questionnaire survey was designed which had a series of open and closed questions focussing on key issues of interest to the study including the socio-economic profile of respondents, primary usage functions during each of the travel periods as well

as rates of usage, the role of the scheme in promoting cycling, potential for modal shift, the role of the scheme for assisting public transport trip interchange and integration and the role of the scheme in raising driver awareness of cyclists. In total, twenty questions were asked. The survey was designed to be relatively short and convenient so that: (1) users of the bike scheme could self-administer and complete it within a short timeframe (c.7–10 minutes); and (2) the response rate would be high.



The sampling strategy focussed on attaining 60 responses at each of the selected stations: 30 responses each for the morning peak and evening off-peak period. In line with the recommendation of the Automobile Association of Ireland, we took the morning peak and evening off-peak periods to range from 07:30–10:00 and 19:00–21:30 respectively. Respondents were randomly selected (in order to achieve a representative sample of the user population) at each of the stations and surveys were self-administered. A sample size of 30 was chosen because it is the minimum sample size recommended for undertaking inference testing (see Blalock, 1979). The analysis involved the use chi-square tests for analysing relationships between certain variables as well as descriptive statistics. Chi-Square tests are non-parametric statistical tests that are useful for testing associations between categorical variables (Blalock, 1979). Overall, a total of 360 responses were attained representing c. 7.2% of total average daily trips. The response rate was high but varied slightly at each station ranging from 81–92%.

## RESULTS

### Gender, Age And Income

Cervero (2003) asserts that whilst different regions and cultures can have a multitude of differing socio-economic features, those that exhibit the strongest correlation in modal choice studies are gender, income and age. Thus, the extent to which the use of the bike scheme is differentiated on those grounds was investigated. The results demonstrate that the vast majority of Dublin Bikes users were male (78%); only 22% were female. This correlates closely with research in this area focusing on the general cycling user base (see Pucher and Diijkstra, 2003; Moudon et al, 2005). Reasons outlined in the academic literature for the considerable gender imbalance in the use of the bicycle relate to the fact that females tend to be more reluctant to cycle because of the associated safety risks; another is that females tend to have more complex trip patterns than males (for example, trip chaining on the way to and from work to drop kids to school, undertake shopping, other errands etc.) and also that females tend to be more cognisant of their appearance at work than males and thus do not like to arrive at work in a dishevelled manner (Dickinson et al., 2003; Garrard et al, 2008). This is particularly an issue for workplaces without shower facilities with evidence suggesting that the provision of such facilities within workplaces tends to increase the rate of cycling to work (see Wardman et al, 2007; Hunt and Abraham, 2007) although given that the trips undertaken on the dublinbikes system are short, this is likely to be less of an issue. Whatever the exact case, the results show that the dublinbike scheme has a predominantly male-oriented user-base. In policy terms this indicates significant potential for policies that target the female population and address their concerns over cycling in the city including improving the safety of cycling and promoting the introduction of shower facilities at workplaces. Such policies would

also involve more specific research as to the relative lack of take-up of the scheme among females in the case of Dublin.

Turning to the profile of the respondents by age, the results show that the majority of respondents (58.8%) are between the ages of 25–36 with 22.6% falling into the 37–48 cohort and only 4.8% in the 48+ cohort. These results conform to the work of Moudon et al. (2005) who suggest a similar trend in the age profile of general bicycle users. There is little doubt that the decline in the proportional usage of the scheme beyond this age cohort is likely to be due to the physical demands exerted by cycling. Thus, the tendency for proportional usage to drop off with age is quite strong despite the fact that Dublin is a relatively flat city with gradient conditions that are particularly suitable for older age cohorts.

Perhaps one of the most interesting results to emerge from the socio-economic characteristics of the dublinbike user-base was with respect to income levels. Figure 3 shows the profile of the income distribution of the bike user-base. The results show that 57.3% of respondents earn a salary of more than €40,000 while only 17.2% earned less than €30,000 annually[2]. This indicates that the dublinbikes scheme has a relatively affluent user profile i.e. middle and higher income earners. This suggests that there may be barriers to entry for lower-income groups such as the requirement to access the internet and provide credit card details or direct debit information in order to hold a long term hire card. The restrictions are even more severe for short term cards (3-day)

[2] The average industrial wage in Ireland was c.€35500 in 2011 (see www.cso.ie).

including the need to provide a €150 euro guarantee deposit via debit/credit card in the event that the bicycle is not returned to a station. From a policy perspective, it is worth investigating the extent of the barriers for entry to the scheme for lower income groups. In financial terms, alternative arrangements should be explored to allow those groups easier access to the scheme.

It is also worth noting that the results may simply reflect changing social norms among higher income earners. It has now become quite trendy for high income young males (the 'early adopters') to cycle and it may be the case that older age cohorts, females and lower-income cohorts will follow these trends in the near future as a result of changing social norms rather than targeted promotional efforts. There is a need for further research in this area to better understand barriers to entry for these schemes and attitudes towards cycling among different income groups more generally and specifically within the context of bicycle-sharing schemes.

**Modal Choice**

As stated already one of the core objectives of the research was to determine the extent to which dublinbikes had an influence on the modal choice of respondents. Respondents were initially asked whether or not they used a bicycle for their current trip prior to the initiation of the dublinbikes scheme. Interestingly, an overwhelming 68.4% of respondents claimed not to have cycled for their current trip prior to the launch of the dublinbikes scheme. In fact, 63.4% of respondents who own their own private bicycle said they purchased it as a result of using the dublinbike scheme. These results imply a

considerable modal shift to the bicycle for the respondents surveyed and suggests that the scheme has been successful at promoting the bicycle as a mode of transport beyond the scheme. In order to investigate this trend further, respondents were asked what particular mode they were using dublinbikes as a substitute for.

The results (Figure 4) show that 45.6% of respondents use the scheme as a substitute for walking. Given that the scheme is city centre-based and is primarily facilitative of short trips this is somewhat unsurprising. Nevertheless the magnitude of the figure is quite large and suggests that the potential health benefits of the scheme may be limited given the significant modal shift from walking to the scheme. Moreover, a further 34.6% of respondents use the scheme as a substitute for public transportation modes while 19.8% use it as a substitute for the car. This implies that the scheme is being used primarily (80.2%) as a substitute for other sustainable modes of transport (walking, bus and rail) and in particular as a substitute for the most sustainable mode - walking.

We also investigated whether a relationship existed between income status and modal shift for the scheme. It was expected that modal shift from car to the bicycle would be greater than expected for higher income earners because they would be more likely to be able to afford a car and vice versa; we also expected that modal shift from the bus to the bicycle would be less than expected for higher income earners and vice versa and that modal shift for rail users would be higher than expected mainly due to the fact that higher income earners tend to live closer to good transport links such as the rail because they can afford to do so while less live in areas where they are forced to use an inferior public

bus system. Thus, a chi-square test was conducted to investigate these relationships and the results are presented in Table 1. They show that a statistically significant relationship does exist between income status and modal shift for the scheme ($p=0.016$). Moreover, the hypothesised relationships between observed and expected values did indeed emerge indicating that modal shift among higher income earners is most likely to be from car to bicycle or from rail to bicycle while for lower income groups modal shift to the bicycle is more likely to occur from bus to bicycle or from walking to the bicycle most likely for the reasons alluded to already.

Another trend to emerge from the results was the fact that 39.0% of respondents use dublinbikes in conjunction with another mode to complete their trip (Figure 5). The results in Figure 5 show that the scheme is primarily used in conjunction with public transport modes: 56.3% of respondents use it with rail while the corresponding figure for bus is 35.2%. To a large degree, this trend can be explained by the close proximity of the bicycle station to rail stations as well as the fact that the scheme is city-centre based and is in close proximity to where many bus routes converge. From a transportation planning perspective, the results are particularly interesting. They imply that a major role of the bike scheme is to provide intermodal connectivity between the two main public transport modes - namely bus and rail, which are largely segregated within the wider Dublin transport network (Murphy, 2009). Moreover, they also imply that the bike scheme operates as a feeder service for trip origins and destinations within the central area. Rather interestingly, these findings correlate closely with those of Martens (2007) who

suggests that bike-sharing schemes are beneficial in providing an egress solution for infrequent, non-recurrent trips.

**Peak And Off-Peak Trip Characteristics**

Another objective of the research was to determine the extent to which the functionality of the bike scheme changed between the peak and off-peak periods specifically in terms of the type of the trips undertaken during the two periods. Figure 6 outlines these results demonstrating that a change in trip-type characteristics does indeed occur between the two travel periods. More specifically, the results show that the peak period is dominated by commuting trips with 85.6% of respondents using the scheme for this purpose with only marginal uses for other trip purposes during this period. However, for the off-peak period the most dominant trip purpose is for leisure/recreation trips (48.3%) indicating that the scheme has a significantly different role and functionality between the two journey periods. Moreover, 11% of respondents use the scheme for shopping trips in the off-peak period suggesting that it serves to facilitate retailing in the central area to a considerable degree. Rather interestingly though is the fact that even for the off-peak period work-related trips continue to be important as a trip purpose (28.9%) indicating that the scheme is used for commuting in the off-peak period. It also suggests that the scheme is useful for the business community in that it is used by workers not only for commuting but might also be used for other work-related trips (i.e. meetings) during the off-peak period. Overall, the results demonstrate that the scheme is used primarily for commuting purposes during the peak period but for non-work trips in the off-peak. This highlights the dual functionality of the scheme in providing a mode that caters quite well

for the diversity of peak and off-peak travel patterns and particularly for short trips in the central area.

Given the foregoing differences in peak and off-peak trip use characteristics, the relationship between travel period and trip purpose was investigated; the results using a chi-square test are shown in Table 2. They demonstrate that a statistically significant relationship ($p=0.000$) exists between trip purpose during the peak and off-peak periods. In particular, more respondents than expected use the scheme in the off-peak for education, shopping and leisure trips and vice versa for the peak period. Moreover, more respondents than might be expected use it for work trips during the peak and much less than might be expected use it for off-peak work-related trips demonstrating that there are indeed significant difference in the role and functionality of the scheme during the two travel periods in terms of the trip characteristics it serves.

A chi-square test was also conducted to determine whether a significant difference existed between the income level of the user base between the peak and off-peak periods. Given that off-peak usage is predominantly for non-work trips we hypothesised that there may be lower numbers of lower income users during the off-peak period. This was not the case; there was no significant difference between the income levels of users during the peak and off-peak periods ($p=0.24$). The same test also showed that there was no significant difference in the age profile of the user base during the peak and off-peak periods ($p=0.12$).

In summary, it is clear that the Dublin Bikes scheme is used primarily as a formal mode of transport for commuting to work but it is used widely during the off-peak period for work-related trip making also. Nevertheless, a significant difference does exist between trip purpose usage characteristics during the peak and off-peak periods where commuting dominates the former period and non-work trips dominate the latter. Perhaps most importantly, the results demonstrate that, as a public transport service, the scheme is playing a useful role in serving a wide range of trip choices for daily trip-making.



**Bicycle-Sharing And Driver Awareness**

A further objective of the research was to examine the impact of the bicycle-sharing scheme on improving driver awareness of cyclists. In particular, we were interested in respondents who owned a car and whether or not the use of the dublinbike scheme had influenced their awareness of cyclists on the road when driving. The results revealed that 80.5% of survey respondents were also car drivers. Most interesting is the fact that 93.8% of respondents (who were also car drivers) said that using the dublinbikes scheme had raised their awareness of cyclists on the road while driving. This is an interesting result and suggests that one of the major positive implications of the dublinbikes scheme has been to raise drivers' awareness of road cyclists when driving which might be expected to contribute, at least partially, to improved road safety for cyclists. Moreover, the fact that the scheme is raising the average volume of cyclists on the roads (Dublin City Council, 2011) implies in itself that safety might be raised for cyclists. This is related to the literature on the 'safety in numbers' concept which suggests that the more cyclists there

are on the road the more safe it becomes and vice versa in urban areas (see Jacobsen, 2003; Robinson, 2005; Elvik, 2009)[3].

## DISCUSSION AND CONCLUSION

In the academic literature, there is conflicting evidence related to the socio-economic profile of cyclists; however, there is little available evidence specifically related to bicycle-sharing schemes in this regard. The results of our analysis of Dublin's scheme demonstrate that the users of the scheme are male from a relatively young demographic (which conforms to similar generic studies in the literature) and come overwhelmingly from middle and upper middle-income backgrounds. This suggests that there are equity issues with regard to accessing the scheme and indicates also that impediments may exist which prevent people from lower income cohorts from using the scheme. In addition, there is significant scope to encourage greater female use of the bike scheme and to raise the age profile of the user base somewhat. Given that a significant expansion of the scheme is planned (Dublin City Council, 2011) these issues should be targeted to diversify the user base of the scheme.

In terms of modal choice our results show that the scheme has indeed been responsible for considerable modal shift. However, the prevailing trend showed a large modal shift away from other sustainable modes of travel to the bicycle including movement from bus and rail but particularly from walking. It is important to note that the scheme has been much less successful at achieving modal shift from the private car to the

[3] It should be noted that Bhatia and Weir (2011) have raised some concerns about this causal relationship

bicycle which is perhaps unsurprising given the relatively compact space in which the scheme operates (see Figure 2). It seems then that the scheme is encouraging a shift between 'sustainable' modes of transport but is responsible for much less of a shift from the most 'unsustainable' mode. Despite this, a 20% modal shift from the car to the bicycle is not at all insignificant given the restricted operational area of the scheme and given the traditional difficulties in achieving modal switch away from the private car (Murphy and Killen, 2011). In broader transport policy terms, implementing such schemes may provide a useful incentive for people to switch from cars to the bicycle, particularly for short trips.

Moreover, the modal shift results have particularly notable implications from a health perspective as well as from a sustainable transport perspective. Much of the rhetoric surrounding the implementation of bicycle-sharing schemes relates to their ability to promote increased physical activity and consequently better health outcomes (see DeMaio, 2009; Midgley, 2011; Dublin City Council, 2011). Yet our results suggest that the health benefits are likely to be minimal given the significant modal shift from walking. Thus, there should be a considerable degree of caution when espousing the health benefits of these schemes and/or implementing them on the basis of potential health benefits alone. Despite this, the scheme may have potential to form part of a broader policy to encourage active transport solutions to encourage public health benefits (Sallis et al, 2004; Rosenberg et al, 2006)

The results show also that the scheme is playing a very important role in trip chaining between the various forms of public transport within the city. In effect, the scheme appears to be acting as a key link between origins and destinations for public transport trips. In broad terms, this suggested that the scheme is highly functional as a integration mode for various mechanical public transport options. In a Dublin context, it suggests that the scheme should be encouraged by placing more stations and providing more bicycle units within close proximity to public transport stops and particularly at rail stations where the use of the scheme is particularly important.

There are significant differences in the way the scheme is used in the peak and off-peak period in terms of trip purpose. Generally, the scheme is used for commuting purposes during the peak period but for predominantly non-work trips during the off-peak period. This is likely related to the significant demarcation between peak and off-peak trip-making characteristics in Dublin (see Murphy, 2012) but it does show that the scheme is successful at facilitating retailing and leisure trips in the off-peak as well as also facilitating work-related trips during this period. Thus, the scheme would appear to providing considerable assistance to the local business community in a variety of ways.

Perhaps one of the most interesting conclusions to be drawn from the results relates to the potential for the scheme to raise awareness of cyclists among car drivers. The research shows that individuals who use the scheme and are drivers feel that their awareness of cyclists on the road has been increased when they return to driving. This implies that one of the indirect impacts of the dublinbike scheme has been to improve driver behaviour

towards cyclists in terms of improving their awareness and tolerance of cyclists as road users. While self-reported increases in awareness cannot necessarily be associated with objective increases in road safety for cyclists, it might be expected that improved awareness among drivers would contribute to improved safety. In addition, the modal transfer (c. 20%) from the car to the scheme may also have contributed to improved safety given the non-linearity of risk concept which suggests that 'the more people walk or cycle, the safer walking or cycling becomes' (Elvik, 2009, 852–4). Given that one of the main goals of the *National Cycle Policy Framework* (Department of Transport, 2009) is to improve the safety of roads for cyclists, our research suggests that the scheme has the potential to contribute, at least in part, to this goal.

Finally, the research has broader implications which should be borne in mind by policymakers. In particular, the expansion of the scheme beyond the central area may impact significantly upon modal shift from the car to cycling. Indeed, if similar modal shift outcomes from car to cycling were to be achieved on expansion of the scheme (c.20%), it would be considered hugely successful as a policy measure. At present it is heavily reliant for modal shift on shorter trips which are less likely to be car based anyway; if the scheme was expanded to include the possibility of longer trips, greater levels of movement from the car to the bicycle might be witnessed, particularly for commuting trips. This has implications for other nations considering implementing similar schemes.



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Table 1. The relationship between income status and modal shift

| | | Use scheme as a substitute for: | | | | Total |
|---|---|---|---|---|---|---|
| | | Car | Bus | Rail | Walking | |
| 0-20k | Observed | 1 | 6 | 2 | 5 | 14 |
| | Expected | 2.9 | 3.4 | 1.2 | 6.4 | 14.0 |
| 21-30k | Observed | 7 | 11 | 0 | 22 | 40 |
| | Expected | 8.3 | 9.8 | 3.5 | 18.4 | 40.0 |
| 31-40k | Observed | 10 | 22 | 5 | 42 | 79 |
| | Expected | 16.5 | 19.3 | 6.9 | 36.3 | 79.0 |
| 41-50k | Observed | 20 | 25 | 11 | 41 | 97 |
| | Expected | 20.2 | 23.7 | 8.5 | 44.6 | 97.0 |
| 50k+ | Observed | 26 | 11 | 9 | 31 | 77 |
| | Expected | 16.1 | 18.8 | 6.8 | 35.4 | 77.0 |
| Total | Observed | 64 | 75 | 27 | 141 | 307 |
| | Expected | 64.0 | 75.0 | 27.0 | 141.0 | 307.0 |

Table 2. Relationship between travel period and trip purpose

| | | Purpose of current trip | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Work | Education | Shopping | Leisure | Tourism | Other | |
| Peak | Observed | 154 | 1 | 4 | 12 | 7 | 2 | 180 |
| | Expected | 103.0 | 1.5 | 12.0 | 49.5 | 5.5 | 8.5 | 180.0 |
| OP | Observed | 52 | 2 | 20 | 87 | 4 | 15 | 180 |
| | Expected | 103.0 | 1.5 | 12.0 | 49.5 | 5.5 | 8.5 | 180.0 |
| Total | Observed | 206 | 3 | 24 | 99 | 11 | 17 | 360 |
| | Expected | 206.0 | 3.0 | 24.0 | 99.0 | 11.0 | 17.0 | 360.0 |

Figure 1. Inbound Canal Cordon (city centre) traffic between 07:00–10:00, 1997–2009

Source: Data taken from Dublin City Council (2011).

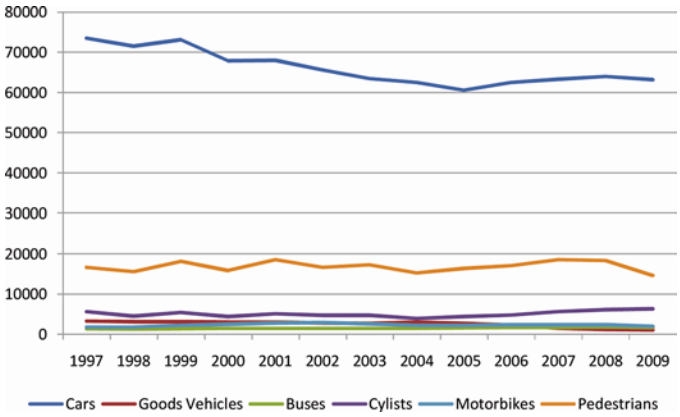
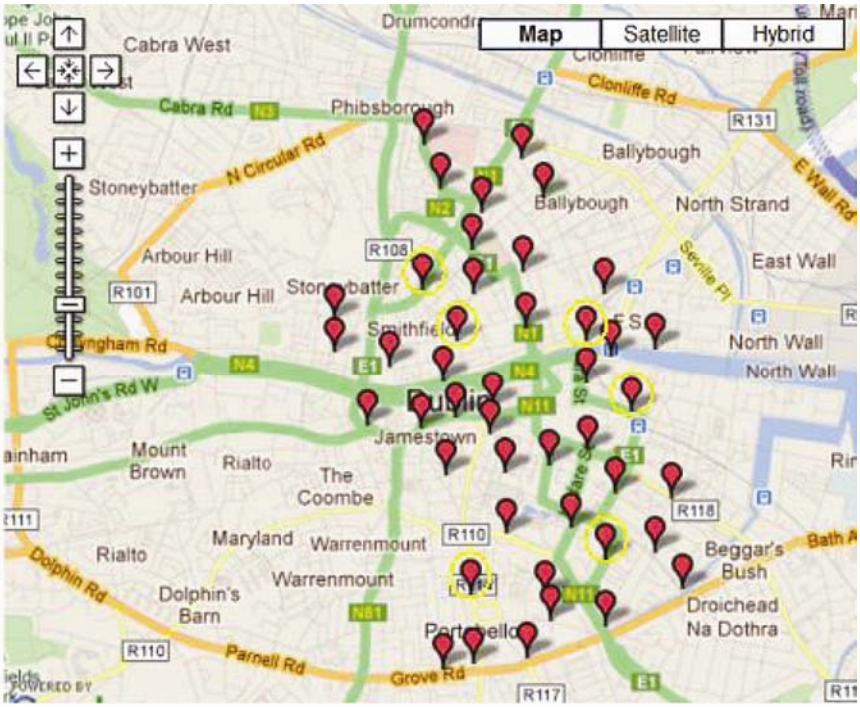


Figure 2. Questionnaire survey sampling sites.




Source: Google Maps; www.dublinbikes.ie

Figure 3. Income level of respondents.

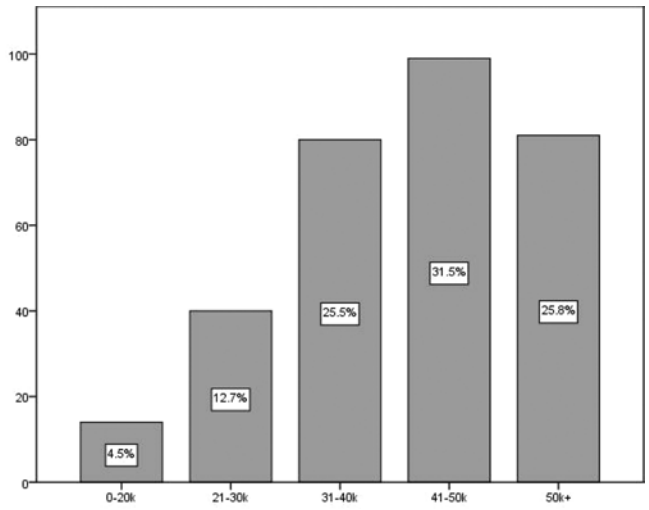


Figure 4. Mode of transport used prior to using the dublinbike scheme.

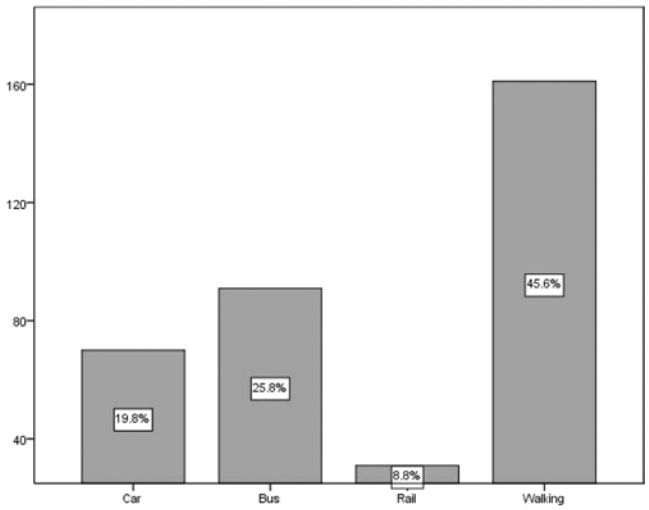


Figure 5. Modal breakdown for respondents using an additional mode in conjunction with the dublinbike scheme.

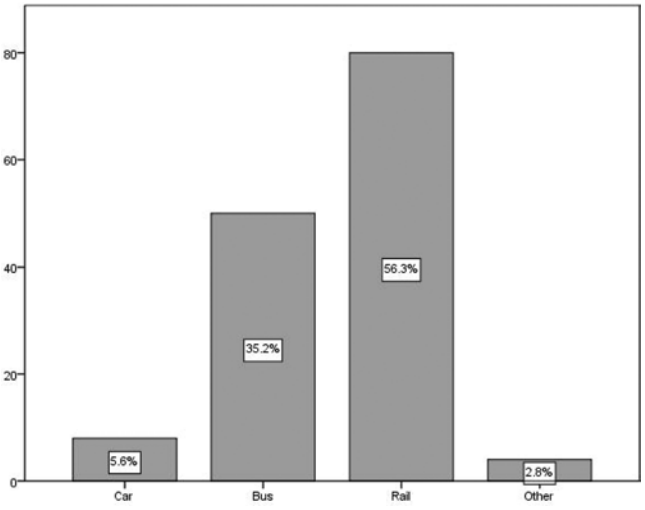


Figure 6. Peak and off-peak trip usage characteristics.