Modelling Rates of Bicycle Ownership

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Abstract

Bicycle ownership is an often overlooked aspect of transport modelling, and transport planning in general. While many, if not most, strategic transport models have well established sub-models to estimate access to private cars, there is an implicit assumption that all trip makers can consider cycling if the network is of a suitable quality. To state the obvious, an individual must have access to a working bicycle that fits them to undertake trips by cycling. Given the relatively high price of new bicycles, and the lack of access to cycle to work schemes for large segment of the population, such assumptions may be failing to capture an important factor in the promotion of cycling as a sustainable transport mode. To get a better understanding of the distribution of bicycles throughout the Irish population, this study uses a sample of 8,698 individual responses from the nationally representative Irish National Household Travel Survey of 2022 to estimate levels of bicycle ownership within the Irish population via a binary logistic regression model. The modelling accounts for factors such as age, sex, shared bicycle scheme membership, access to a car, and the area type in which the respondent resides. Results indicate that while roughly half of the Irish population owns a working bicycle, there is considerable variance in bicycle ownership by both age and sex, but not with respect to area type. The model also reveals that individuals with access to cars and shared bicycle schemes are more likely to own bicycles, which suggests that these may be complementary modes of transport, rather than alternatives. The modelling adopts a hold-out sample validation approach, to provide insights into the predictive power of the model and its ability to be used as a forecasting tool, and demonstrates that the model provides acceptable predictions at sub-population level

Introduction

Cycling is often prompting as a means of active and sustainable travel, and a method of replacing car trips over shorter distances. Typically, when strategic transport models include cycling there is an implied assumption that all trip makers have access to bicycles. This is inconsistent with the approach to other forms of private vehicular transport (cars) within such models [1], where significant levels of effort have been invested to either car ownership or trip level car availability.

To undertake a cycling trip an individual must have a bicycle that is in working order, and also fits them, or at least isn't prohibitively large or small for them. When modelling assumes the presence of universal access to bicycles, this does not reflect the reality of life, where new entry level bicycles can often cost €500, presenting a considerable barrier to cycling for individuals on lower incomes. To support active travel policies and to provide citizens with access to bicycles, tax incentives such as Ireland's Cycle to Work scheme, public shared bikes such as Dublin Bikes and An Rothar Nua, as well as private operators such as Bolt and Bleeper Bikes have been implemented. However, such schemes are still somewhat limited, with tax incentives favouring higher income earners and shared bikes scheme largely being limited to the urban core of cities and large towns.

Historically bicycle ownership data have not been collected in a consistent manner in Ireland, but it is possible to use comparative data from the 2021 National Household Survey for England. These data reveal high levels of bicycle ownership and access in children followed by a sharp decline after the age of 16 and a slight rebound for people in their 40's and 50's. [2]. A review study by Oke et al [3] of international levels of bicycle ownership identified levels of ownership ranging from roughly 4% in Armenia over 80% in Burkina Fuso, and reporting that 42% of households globally own at least one bike.

This research sets out to utilise the latest iteration of Ireland's National Household Travel Survey to estimate levels of bicycle ownership, at an individual rather than household level, and assess how it varies with regard to the characteristics of the respondents.

Methodology

This study uses data collected as part of the Irish National Household Travel Survey (NHTS), undertaken in November 2022 [4]. The NHTS is a national level trip diary based travel survey that is now undertaken annually in Ireland for the purposes of transport statistics collection, transport model calibration, and sustainable transport mode share and trend monitoring. The survey collects both daily travel diary data, as well as a survey characteristics of the trip makers. The survey contains data from nearly ten thousand individuals across six thousand households, and is designed to be a nationally representative sample of Irish trip makers. This study utilizes the individual level data to examine the factors that relate to observed levels of bicycle ownership. Table 1 presents the characteristics of the final sample used to estimate the model. It should be noted that the original full sample contained 9,238 individuals, however this was reduced to 8,698 once individuals with partially complete responses were removed.

Table 1: Sample Characteristics

Gender		Area Type	
Male	48.50%	City	25.59%
Female	49.61%	Large Town	27.77%
Other	0.09%	Small Town	17.39%
Prefer Not to Say	0.25%	Rural	29.25%
NA	1.54%		
		Shared Bikes	
Age		Member	2.12%
U10	6.97	Non Member	97.13%
Teens	14.59%	NA	0.76%
20s	9.94%		
30s	11.38%	Driver's License	
40s	16.87%	Full	67.39%
50s	17.04%	Provisional	7.22%
60s	14.19%	No	24.42%
70s	7.47%	NA	0.97%
80+	1.54%		
Cars (Inc. U17s)			
Car Non Available	41.88%		
Car Available	58.12%		

For the purposes of this study, bicycle ownership is treated as a binary variable, as respondents were asked to state whether or not they had a working (push) bicycle, and the presence of multiple bicycles was not considered. Data on electric bikes and scooters are treated in other questions, and are beyond the scope of this paper (although the survey indicates their uptake is still very low with respect to bicycle ownership). Due to the binary nature of the dependent variable, bicycle ownership is modelled via a binary logit regression model, taking the form:

$$P_b = \frac{e^{k_i X_i + C}}{1 + e^{k_i X_i + C}}$$

Where:

Pb= The probability of owning a bicycle

Xi = Independent socio-economic variables

Ki = Estimated parameters

C = Intercept constant

Inversely, the probability of not owning a bicycle P_{nb} is defined as:

$$P_{nb} = \frac{1}{1 + e^{k_i X_i + C}}$$

Due to both the relatively large sample size available from the NHTS, and the requirement for strategic transport models to be used as forecasting tools, an estimation and validation approach was utilized for this study. Specifically, the logit model was estimated for roughly 80% of the sample, with the remaining 20% of survey responses being held back for the purposes of model validation. This approach provides an intuitive estimate of goodness-of-fit that would otherwise be lacking for such logit models. Observations were assigned to either the estimation or validation samples based upon a random number generated by the RAND function Stata 17.

Results

This section provides an overview of the breakdown of bicycle ownership by a number of demographic characteristics. Table 2 provides an overview of the total number of individuals who stated that they owned a working bicycle, with slightly less than half of respondents possessing one.

Table 2: Bicycle Ownership

	Total	Percentage
No	4,661	53.6%
Yes	4,037	46.4%

Table 3 presents that breakdown of bicycle ownership by sex, with the male and female accounting for the vast majority of responses. Levels of bicycle ownership is considerably higher among males, at 51.9%, than females, at 40%.

Table 3: Bicycle Ownership by Sex

	Total	No Bike	Bike
Male	4,218	48.1%	51.9%
Female	4,315	60.0%	40%
Other	4	50%	50%
Prefer not to Say	22	54.5%	45.5%
N/A	134	53.73%	46.27%

Figure 1 presents a visualization of the percentage of respondents within each age band that possessed a working bicycle. It is evident that highest rates are for those under the age of ten and teenagers, with the rate of bicycle ownership declining rapidly for those in their 20's before rebounding somewhat for people aged between 40 and 60, before again falling off as age increases.

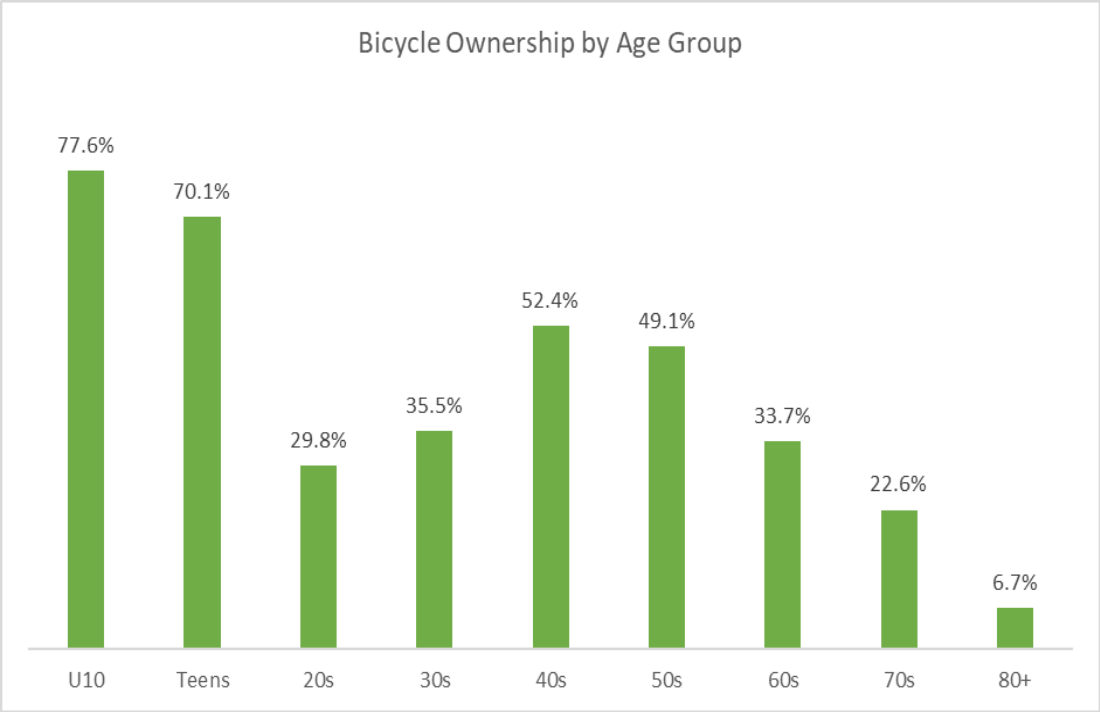

Figure 1: Bicycle Ownership by Age

Table 4 presents the breakdown in bicycle ownership by broad area type, with the highest levels of bicycle ownership actually being observed in rural area. However the differences between the area types are not large, all displaying averages in the 40%'s, and with no area type displaying a majority bike owning population.

Table 4: Bicycle Ownership by Area

	Total	No Bike	Bike
City	2,226	53.9%	46.1%
Large Town	2,415	56.9%	43.1%
Small Town	1,513	53.9%	46.1%
Rural	2,544	50.1%	49.9%

While descriptive statistics may provide information regarding trends within the data, the power of a model is the ability to control for variables and to provide predictions of bicycle ownership, based on the values of the respective independent variables and controlling for the co-variants. As the variable of interest (bicycle ownership) is binary in nature, a binary logistic regression was selected as the most appropriate model. As all of the independent variables are categorical in nature, parameters are presented in terms of odds ratios for ease of interpretation. Results should be interpreted with respect to the reference category for each variable (taking a value of 1). Confidence intervals in this presentation method are centred on 1, rather than 0 when co-efficients are normally presented.

As expected, the model results reflect what is seen in the descriptive statistics. With respect to age, under 10s are taken as the reference group, with all other groups (apart from teens/10-20 year olds) displaying much lower odds of owning a working bicycle. Lower odds of bicycle ownership are seen in people 60+ or 70+, which may be somewhat expected as mobility (at least at population level) decreases. The results show that there are also very low levels of bicycle ownership for people in their 20s and 30s. The model produces the same trend as in the descriptive statistics with males being much more likely to own bicycles than females. Model estimates for other genders were not statistically significant, but that is likely due to the very small number of such individuals within the sample.

Membership of a shared bicycle scheme is highly correlated with bicycle ownership, with those who are members of such schemes being much more likely to own a bicycle, suggesting that such schemes are not replacements for bicycle ownership. Additionally, people who have cars available to make trips are also more likely to own bicycles than those who don't, suggesting that the main driver of bicycle ownership is not to provide an alternative to cars. Finally no significant differences were estimated in bicycled ownership by area type.

Table 5: Binary Logit Bicycle Model

Variable	Odds ratio	P>z	95% Lower CI	95% Upper CI
Age				
Under 10s	1.00	Ref.	Ref.	Ref.
Teens	0.80	0.10	0.61	1.05
20s	0.11	0.00	0.08	0.15
30s	0.13	0.00	0.10	0.18
40s	0.26	0.00	0.20	0.35
50s	0.23	0.00	0.17	0.30
60s	0.11	0.00	0.08	0.15
70s	0.07	0.00	0.05	0.09
80+	0.02	0.00	0.01	0.04

Gender				
Male	1.00	Ref.	Ref.	Ref.
Female	0.63	0.00	0.56	0.70
Other	1.38	0.75	0.19	10.34
PNTS	1.04	0.94	0.36	3.06
NA	0.88	0.59	0.55	1.41
Shared Bike Member				
Yes	1.00	Ref.	Ref.	Ref.
No	0.28	0.00	0.18	0.42
NA	0.86	0.71	0.40	1.87
Car Available				
No	1.00	Ref.	Ref.	Ref.
Yes	1.31	0.00	1.13	1.52
Area Type				
City	1.00	Ref.	Ref.	Ref.
Large Town	0.88	0.11	0.75	1.03
Small Town	0.96	0.64	0.80	1.14
Rural	1.07	0.40	0.92	1.25
Constant	14.81	0.00	9.15	23.98
Number of obs.				6,932
Wald chi2(18)				744.81
Prob > chi2				0
Pseudo R2				0.13
Log pseudo likelihood				-4196.03

For the purposes of model validation and to understand the model fit, 1765 (~20% of the sample) survey respondents were held back from the original models estimation and used as a validation set. As the predicted values produced by logit models are non-binary/continuous, and therefore do not match the observations used for model validation, it is not possible to compare the model fit at a person level. One solution is to compare the predicted number of bicycles owned with a given category with the observed number for that same category in the validation dataset and to repeat for different sub-samples. Table 6 provides a number of comparisons across various different sample segment methods. Figure 2 provides a graphical representation of the data within the table. While the segmentation of the data is essentially arbitrary (as different segments could have been selected), it hopefully still provides an overview for the performance of the model.

Table 6: Model Validation

Validation Sample Size		1765
	Observed Bikes in Category	Estimated Bikes in Category
Total	813	808.7
U10	86	81.4
Teens	177	193.5
20s	43	47.1
30s	80	74.0
40s	159	164.4
50s	144	138.3
60s	91	80.9
70s	31	27.2
80+	2	1.8
Male	448	438.3
Female	353	355.2
Other	0	0.6
PNTS	1	2.5
NA	11	12.1
City No Car	529	547.9
City Car	498	471.2
Large Town No Car	469	486.0
Large Town Car	572	536.0
Small Town No Car	343	333.7
Small Town Car	355	360.0
Rural No Car	588	561.8
Rural Car	683	680.6

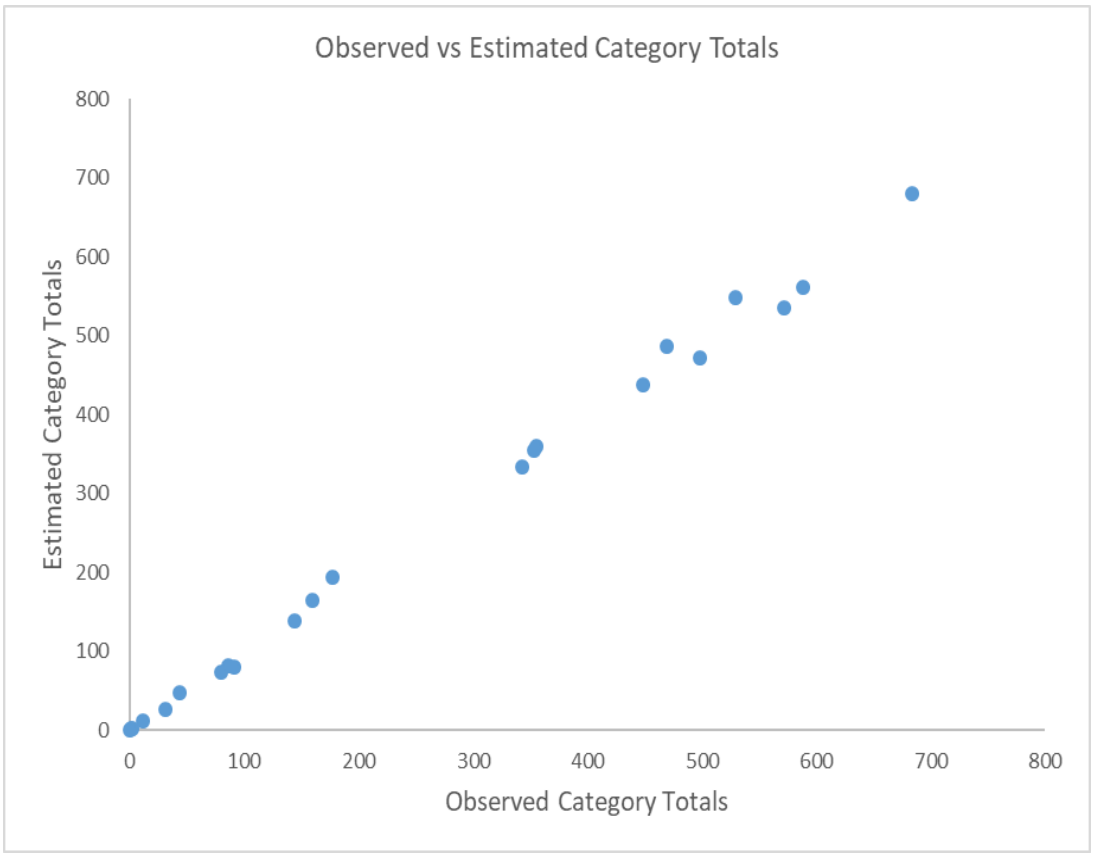

Figure 2: Validation Fit

Discussion

This paper presents the results of a study undertaken to understand levels of bicycle ownership in Ireland, accounting for demographic variables and area type. While transport models traditionally have included models that account for access to cars, such as car ownership and car availability models, bicycle ownership has traditionally been overlooked. Given that owning a bicycle (or at least having access to one) is a prerequisite for making cycling trips, and that the purchase price of bicycles is a non-trivial factor with prices often starting close to €500, it is important to understand levels of bicycle ownership the current available pool of cyclists.

Results suggest that rough half of the population own a working bicycle, however levels of bicycle ownership vary greatly with regard to age, with the highest levels of bicycle ownership being observed for children and teenagers. When accounting for the impact of bicycle ownership within the population of children (where bicycles may to some extent be considered to be toys), results show that less than half of the Irish adult population currently owns a working bike with rates of bicycle ownership are also found to be significantly higher for males compared to females.

While cycling is often promoted as a means of replacing car trips, especially for short distances, less than half of those over the age of 20 own a working bicycle. While bicycle sharing within a household may be possible, unlike cars, bicycles are size specific and there is no guarantee a single bike can be used by multiple residents. Area type does not appear to be a strong predictor of bicycle ownership. The availability of a car for trip making is found to be positively correlated with bicycle ownership, suggesting that bicycles are not purchased as alternatives to cars, rather to complement them, or as recreational vehicles.

References

1. Jong, G. D., Fox, J., Daly, A., Pieters, M., & Smit, R. (2004). Comparison of car ownership models. Transport Reviews, 24(4), 379–408. https://doi.org/10.1080/0144164032000138733
2. National Travel Survey 2021: Active travel, Department for Transport, 2022, available at: https://www.gov.uk/government/statistics/national-travel-survey-2021/national-travel-survey-2021-active-travel
3. Oke, Olufolajimi, Bhalla, Kavi, Love, David C., and Siddiqui, Saulh. 2015. Tracking global bicycle ownership patterns. Journal of Transport and Health, Vol. 2 p490-501
4. National Transport Authority, 2023. National Household Travel Survey 2022 Final Report, available at: https://www.nationaltransport.ie/wp-content/uploads/2023/08/NTA_NHTS2022_IpsosReport_28July2023.pdf