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Analysing Seasonality of Londoner's Cycling Patterns and Behaviour

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Abstract

The aim of this paper is to analyse the characteristics of Londoners' cycle trips and develop models to identify the factors affecting the number of cycling trips in the summer and in the winter. Data from the London Travel Demand Survey (2010-2013) is used to evaluate the differences between summer and winter cyclists and what may influence higher frequency cycling. The sample consists of 12,900 individuals. Cycling frequencies vary greatly between the two seasons with an average of 7.3 days per month dropping off significantly to just 1.7 days in the winter. Model estimation results showed that young cyclists are the most impacted by seasonal effects, cycling significantly more in the summer than the winter. The results further demonstrated that White British people cycle less than those from other ethnic groups in the summer, but are less impacted by the different conditions in the winter. This outlines a lot of potential for increasing cycling through better targeting promotional policies. It further shows promising results if the younger generation can retain their cycling habits and become less sensitive to seasonal variations.

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Keywords: Bicycles; Cycling; Number of trips; Seasonality; London; Poison regression; Sustainable mobility

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1. Introduction

Against a backdrop of increasing environmental pressures and a less healthy population in many developed countries, private motorized modes of transport remain the dominant way of travel for most trips. This trend causes further detrimental effects to the environment and society, such as pollution, congestion, and traffic accidents. Additionally, serious health problems such as obesity come as a result of low levels of physical activity accompanying modern urban lifestyles (WHO, 2010). Including active transport in people's daily routine has the potential to reverse many of these negative health trends ensuring higher activity levels, while also alleviating climate change, congestion, and noise and air pollution in urban areas.

A large proportion of trips conducted are considered to be within cycling distance and as many as half could be cycled within 20 minutes, yielding an opportunity to transfer many trips to bicycle (ATFA, 2009). As such there has been a growing interest in cycling from both policy makers and researchers; however, cycling rates remain low in many large cities. There are significant differences between cycling levels across different countries: as high as 31% cycling in the Netherlands, while just 2% in the UK (European Commission, 2011). Nevertheless, recent reports suggest that the future of active transportation is promising, especially in urban areas (Davis et al., 2012).

In order to address the differences between cities and countries, there is a growing body of research into cycling determinants and how to best convince travellers to take up cycling. There has been a large scale-up of investment in cycle related facilities, such as bike paths or bike share schemes introduced globally. Research indicates that if the facilities are provided, people will use them. However, cycling also appears to be determined, at least in part, by the characteristics of cities: the climate, size, topography, as well as population, demographic and culture (Rietveld and Daniel, 2004; Pucher and Buehler, 2010). Improving cycling infrastructure is important; but to achieve a significant positive shift, a change in culture and mentality is needed.

The current research focuses on factors contributing to cycling demand, but rarely takes into account the direct impact of seasonality on all-year figures. Given the high energy expended on motorized transport, as well as lower active transportation during winter months, there is an opportunity to achieve meaningful change based on seasonal trends. As such, the aim of this paper is two-fold. First we analyse the characteristics of cycling trips in London by providing various descriptive statistics. Then, in order to quantify the factors affecting cycling frequency and compare cycling behaviour between the summer and winter, we estimate two Poisson regression models, one for the number of cycling trips conducted during each season for the same individuals. This paper looks at data from the London Travel Demand Survey (LTDS) between 2010 and 2013, focusing on individuals' seasonal cycling habits. The sample under consideration includes 12,900 cyclists (who have cycled in the 12 months prior to the interview). Through better understanding London's cyclists, policy can be adapted to achieve higher year-round cycling rates in the city and change the transport culture.

The remainder of this paper is as follows: Section 2 reviews the existing literature. Section 3 describes the sample under observation and presents the descriptive statistics. Section 4 outlines the model specification before showing the estimation results. Finally, section 5 concludes the paper, summarising the findings and implications, as well as suggestions for further research.

2. Literature review

As GDP/Capita rises globally, car ownership levels and vehicle kilometres travelled by motorised transport modes are increasing, especially in urban areas (Santos et al., 2013). High motorised transport levels have had numerous negative consequences on the environment and society: higher energy consumption, congestion, noise and air pollution, and accident rates (Mohan, 2002; Steg and Gifford, 2005). In order to reverse some of these trends, a lot of effort has been placed on making sustainable transport methods, especially active ones such as cycling, more prominent. Cycling has the potential to contribute to quality of life improvements for society, achieving large reductions in CO_2 emissions, improving road safety and enforcing a more active, physical lifestyle while also making travel more enjoyable (Bassett et al., 2008; De Hartog et al., 2010; Pucher and Buehler, 2010; Massink et al., 2011; Saunders et al., 2013; Woodcock et al., 2014).

As such, there has been a growing body of research looking to determine how best to increase the modal share of cycling in urban environments. Previous literature generally uses stated preference (SP) data to discuss a wide range of determinants that may influence people's choice to cycle or not. Some studies identify the importance of policies improving bicycle facilities, such as cycle paths or parking facilities, traffic calming, cycle training programmes, as well as promotional and safety campaigns, while others focus on land use and city make up, socio-economic characteristics of cities, inhabitants' travel culture, and the importance of changes to society (Nelson and Allen, 1997; Rietveld and Daniel, 2004; Pucher and Buehler, 2006; Wardman et al., 2007; Buehler and Pucher, 2011; Pooley et al., 2011; Tight et al., 2011; Santos et al., 2013; Aldred and Jungnickel, 2014; Pistoll and Goodman, 2014; Kamargianni, 2015).

Weather conditions are commonly quoted as playing a role in people's choice to cycle, with certain adverse weather conditions significantly reducing the distances and frequency of cycling. However, few studies focus directly on weather effects on cycling. For example, Dill and Carr (2003) find that adverse weather such as extreme temperatures or precipitation harm cycling levels using a census supplement. However, they determine that investment in cycle paths and infrastructure is most important in increasing cycling. Similarly, based on a multiple regression analysis of Dutch municipalities, Rietveld and Daniel (2004) identify wind and rain as harmful to cyclists, but focus on land-use, culture and infrastructure as the more important determinants of cycling demand. Winters et al. (2007), using data from 53 Canadian cities, find that freezing temperatures and precipitation reduced cycling levels. However, they conclude that this could be offset by better infrastructure and maintenance services. Pucher and Buehler (2006) compared cycling in the USA and Canada using census data and discover that extreme weather conditions (temperature and rain) discourage cycling. However, Canada had weather conditions less conducive to cycling yet still had higher cycling rates than the USA, indicating that other factors such as land use, infrastructure and psychological issues are more important for encouraging active transport. Further outlining the need for direct analysis of weather's impact on travel, Buehler and Pucher (2011), in a cross-sectional analysis of 90 American cities, could not find any significant correlation between weather factors and cycling demand.

On top of census results, various studies use stated preference data to identify how different weather conditions impact cycling. Indicatively, Lawson et al. (2013) on the basis of a survey of Dublin's cyclists found that certain weather conditions would cause a shift away from cycling: 79.8% in icy conditions, 55.6% in heavy rain (while light rain was insignificant) and 30.3% with freezing temperatures. They further found that perceptions of a lack of safety may be harming the bicycles share of travellers. Nankervis (1999) used SP data from students in Melbourne to show that 40% of cyclists would not cycle in rain and 66% in snow and ice. In an analysis of commuters in Sweden, Bergström and Magnusson (2003) find that in winter months, distance of travel becomes more significant when selecting mode of transport. Temperature is identified as the most important weather factor, while darkness is not really considered to be an issue. The research further finds that through improving maintenance levels and having better infrastructure, people would be more willing to cycle. Ortúzar et al. (2000) used SP data in Santiago to develop a mode choice model between cars and bicycles and found very hot weather conditions could reduce cycling trips by as much as 46.6% when compared to mild conditions. The mode choice model further found that trip length is a fundamental variable when choosing to cycle. A web based SP survey helps Stinson and Bhat (2004) to show that travel time was the most important variable when choosing route options. The analysis also demonstrates that unpleasant weather conditions (rain, temperature, daylight) are a significant deterrent to cycling. Kamargianni and Polydoropoulou (2014), include sunny and rainy weather conditions in an analysis of travel to school in different type of cities to find that in urban areas sunny weather positively affects cycling. However, despite bad conditions in rural areas, the study found that there were still high cycling rates as it is the only area in their analysis with an extensive cycling network.

Traffic count data as well as travel diary data has also been used by some research to gain insights into the role of weather in cycling forecasts. For example, Sears et al. (2012) use trip diary data recorded for a week in each season to understand how specific weather effects may impact travel. The regression illustrated that a 1°F (0.56°C) increase in morning temperature could raise cycling by 3%, whereas a 1mph wind speed increase could reduce cycling by 5%. The study also finds that daylight does not play a significant role in determining cycling levels, while rain in the morning could halve cycle levels. Distance of journey was found increasingly important to travellers' choice of mode. Dell'Olio et al. (2014) used travel diary data from Santander to compare three travel modes in a mixed logit model, indicating that nice weather (temperature and precipitation) is a strong predictor of cycling and would amplify effects of infrastructure put in place to incentivise active transport. Thomas et al. (2012) use counts and weather data in the Netherlands to show that temperature impacted cycling the most, followed by sunshine, precipitation and wind. Using bikesharing data from Washington, Daito and Chen (2013) confirms previous findings that temperature has the most significant effect on cycling levels, while rain was also considered important. They found snow to be statistically insignificant. This confirms a previous study by Niemeier (1996) that found temperature to be the main factor affecting cycling in Seattle and Washington. Hankey et al. (2012) use data from 259 locations in Minneapolis to create a binomial regression between cycling and non-cycling, finding a significant negative correlation between bad weather and lower cycling rates. Table 1 presents a review of the samples and methodologies used in various surveys of cycling transport including weather effects.

Despite this range of research looking at how certain weather conditions can affect cycling behaviour, there is still a lack of analysis examining the seasonality of cycling, in particular the differences between summer and winter. In addition, although London is a city with an extensive transport system, only recently cycling has become a high-priority issue for policy makers, while research work on London cycling is limited. Identifying and quantifying the factors that affect cycling frequency between summer and winter in London could provide insights to policy makers and transport planners to design targeted policies and campaigns. In doing so, this paper seeks to investigate the same individuals' cycle frequencies in the two periods (winter and summer) to determine the differences between the two and use the model estimation results to determine how best to increase cycling throughout the year.

Table 1. Literature review findings

Reference	**Sample**	**Weather effects examined**	**Methodology**
Dill and Carr, 2003	N=700,000; 64 US cities; census supplement (aggregate data)	Rain	Logistic Regression Model
Rietveld and Daniel, 2004	103 municipalities Netherlands (aggregate data)	Wind; rain	Multiple regression analysis – semi-log regression model and ordinary least squares
Winters et al., 2007	N=59,899; 53 Canadian cities (aggregate data)	Temperature; rain	Multi-level logistic regression
Pucher and Buehler, 2006	59 states and provinces: census data (aggregate data)	Temperature; rain	Multiple regression; bivariate analysis
Buehler and Pucher, 2011	American Community Survey: 90 large cities (aggregate data)	Precipitation; rain	Multiple regression; OLS; Binary Logit Proportions model
Lawson et al., 2013	N=1732; Dublin (disaggregate data)	Ice and snow; rain; temperature	Principal component analysis; Ordered logistic regression
Nankervis, 1999	Count; N=64; Melbourne (aggregate data)	Temperature; rain; wind; humidity; season	(Not mentioned)
Bergström and Magnusson, 2003	N=1998; Lulea + Linkoping (SP; disaggregate data)	Temperature; rain; light; maintenance	Hybrid choice model
Ortúzar et al., 2000	N=357; Santiago (SP; disaggregate data)	Temperature; rain	Multinomial mode-choice model
Stinson and Bhat, 2004	N=3500; online survey: US (SP; disaggregate data)	Pleasant/unpleasant conditions	Ordered response model
Kamargianni, 2015	N=9544; cities in Greece + Cyprus (SP; disaggregate data)	Sunny/rainy days	Mixed Logit model
Sears et al., 2012	N=185; Vermont (RP; disaggregate)	Season; temperature; rain; wind; snow; sunlight	Longitudinal study: generalised linear model
Dell'Olio et al., 2014	N=1987; Santander (RP; disaggregate)	Temperature; rain	Mixed logit model
Thomas et al., 2012	16 cycle paths in Gouda + 8 in Ede (Netherlands) (RP count; disaggregate)	Temperature; precipitation, wind; cloud cover; visibility; humidity	Linear multiple regression
Daito and Chen, 2013	bicycle sharing trip/day data; Washington Capital Bikeshare (RP count; disaggregate)	Temperature; rain; snow	Time-series model
Niemeier, 1996	Greater Seattle + Washington (RP count data; disaggregate)	Temperature; precipitation	Poisson model
Hankey et al., 2012	2007-2010; 259 Minneapolis locations (RP count data; disaggregate)	Temperature; precipitation	OLS and negative binomial regression

3. Case study

3.1 Data: London Travel Demand Survey

For the purposes of this paper we use data from the London Travel Demand Survey (LTDS). LTDS is a cross-sectional survey conducted by TfL (Transport for London) (2015) across all London boroughs and the City of London every year. The survey has been running since the financial year 2005/2006 and captures a wide range of information about London residents' travel habits, preferences and trips they conduct. It has an annual sample of roughly 8,000 households per year and generally has a response rate of around 50% (TfL, 2011). LTDS provides a unique look into the travel behaviour of London residents only, not capturing travel by those who are outside the Greater London region and thus does not present a complete analysis of all transport in the city. However, the results are considered robust enough to analyse travel behaviour of Inner and Outer London residents (TfL, 2015).

The survey is conducted in the form of three separate questionnaires for the household, household members (completed by all household members above the age of 5), and a trip diary for each household member. The results from the questionnaires provide detailed demographic information about household income, location, size, and vehicle ownership. The personal interviews yield details about individuals' gender, age, ethnicity, and work status and travel behaviour. Since 2010, LTDS has also included a section of the questionnaire dedicated to cycling. This section reveals those who cycle and their preferences for cycling, additional information regarding their travel behaviour as well as data for the cycling investments within London (such as the cycle sharing scheme). Through combining the demographic information with preferences for cycling in the summer and the winter in London an analysis of travel habits is performed in this paper.

3.2 Sample and Cycling Trips' Characteristics

As LTDS has included data about cycling since 2010, we used the sample from 2010 to 2013 yielding to a dataset of 70,491 individuals. In order to analyse the differences between summer and winter cyclists, we narrow down the data to the individuals who have reported cycling in the past 12 months. In doing so our dataset consists of 12,900 individuals.

The details of the sample are presented in Table 2 below. 41% are female, and the average age of the sample is 31.2 years old, ranging between 5 and 88. When cyclists are split into age categories, 31% are under 18, 11% between 18 and 25, 34% between 26 and 44, 18% between 45 and 59, and 7% are above 60. Among the sample 43% are in full time employment, 9% are employed part time, 27% are at school, 9% in higher education and 12% not working or in education. The sample contains households with 1 to 11 residents, owning up to 9 vehicles. Cyclists live across the whole of Greater London and are distributed across the different TfL fare zones. Cycling frequencies vary greatly between the two seasons with an average of 7.3 days per month dropping off significantly to just 1.7 days in the winter.

When comparing to the zones of where the sample live, more trips were conducted in zones close to the centre, further demonstrating that shorter distances are better for cycling. As can be found in many other studies, the distance of most trips was under 5km (85%). 92% of the trips were conducted just by bicycle, indicating that it is difficult or unpopular for cyclists to change to other modes of transport in London. Additionally, just four of the trips were completed using the city's cycle hire scheme, indicating that the more regular cyclists prefer to use their own equipment.

Table 2. Sample's statistics

Personal Characteristics		
Gender	Male	59%
	Female	41%
Age (years)	Mean (SD)	31.2 (17.8)
Ethnicity	White - British & Irish	65%
	White - Other	12%
	Mixed or Multiple Ethnic Groups	3%
	Asian or Asian British	10%
	Black or Black British	8%
	Other	2%
Working Status	Full-time employment	52%
	Education	36%
	Not working	12%
Income	< £15,000	16%
	£15,000-£24,999	14%
	£25,000-£34,999	12%
	£35,000-£49,999	17%
	£50,000-£74,999	19%
	£75,000-£99,999	10%
	£100,000 +	12%
Household Characteristics		
Household size	Mean (SD)	3.4 (1.5)
Vehicle ownership	Mean (SD)	1.3 (1)
Zone	1	2%
	2	18%
	3	17%
	4	18%
	5	16%
	6	18%
	Outside zone 6	12%
Trip Characteristics		
Summer Trips	Mean days per month (SD)	7.3 (6.5)
Winter Trips	Mean days per month (SD)	1.7 (3.7)
Distance (km)	Mean (SD)	3.38 (5.9)
Duration (mins)	Mean (SD)	25.1 (25.7)
Purpose	Return home	46.4%
	Work	9.6%
	Education	3.2%
	Leisure and Shopping	40.5%
Zone	1 (Central London)	1.4%
	2	24.3%
	3	18.7%
	4	17.2%
	5	14.9%
	6	14.7%
	Outside zone 6	8.8%

4 Model specification and estimation results

4.1 Model Specification

In order to assess the differences between summer and winter cycling, we estimate two Poison regression models, one for each season. In each model, the Poisson regression represents the number of days including cycling per month. Due to the fact that the dependent variable (number of trips): i) can only take non-negative values, ii) virtually all the values are restricted to single digits, and iii) the mean number of events is quite low, classical linear regression models are not appropriate for the analysis of data of this nature. As each trip occurs independently through time, Poisson analysis satisfies our requirements and is the preferred method for this paper.

The model assumes that the number of trips any individual makes in a given time period is independent and has a constant rate of occurrence. It is given by:

$$P(T) = \begin{cases} \frac{e^{-\boldsymbol{\lambda}_i}(\boldsymbol{\lambda}_i)^{T_i}}{(T_i)!}, \; for\ \boldsymbol{\lambda}_i > 0\ and\ T = 0,1,\ldots \\ 0, otherwise \end{cases} \qquad (1)$$

Where T_i is the number of trips, λ_i is the mean number of trips made by person *i*.
The mean number of trips for each individual *i* is an exponential-linear function of the explanatory variables:

$$\boldsymbol{\lambda}_i = e^{\alpha + X_i \beta_i} \qquad (2)$$

Where α is the constant, β depicts the impact of X_i explanatory variables on the mean number of trips.

The dependent variable under consideration is the number of days with cycle travel per month measure from a sample of 12,900 individuals based on the data obtained from the LTDS, as outlined above. We assume X_n independent explanatory variables affecting the frequency of cycle travel. Using a Poisson regression model (Kamargianni and Polydoropoulou, 2014), we can assess the impact of these explanatory variables on the frequency of cycling. The modelling framework is presented in Figure 1.

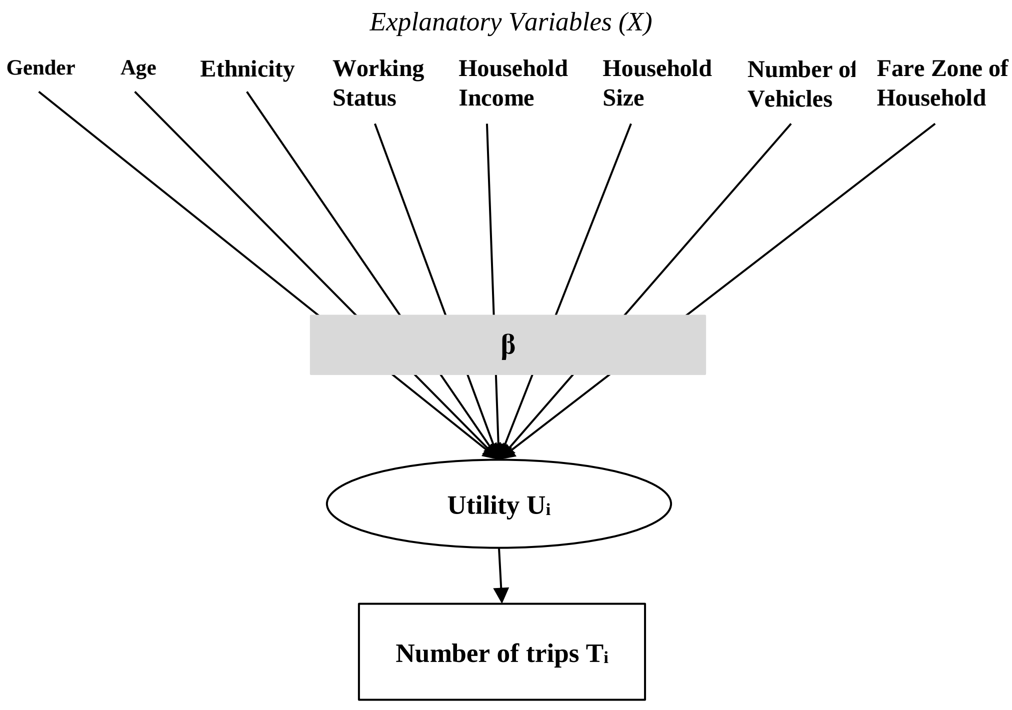

Fig. 1. Modelling framework

4.2 Model Estimation Results

This section presents and discusses the estimation results of the Poisson Regression Models. The models were estimated using Latent Gold 5.0 software by Statistical Innovations Inc. Table 3 presents the results of the Poison regression models.

The models outline some variables which could be considered general predictors of cycling demand year-round, which are further amplified by seasonality effects (such as gender, income, household residents, vehicle ownership and location) but also presents some that vary with season illustrating that some people react differently to weather conditions.

For both seasons, there is a difference between genders showing that females cycle less. The winter result is even more significant than for summer, indicating that the difference between genders is even more pronounced then. Seasonal difference impacts female cyclists more than they do male, perhaps coming down to increased safety risks. This result is consistent with the detailed research that has been conducted regarding cycling differences among genders (Garrard et al., 2008; Pucher et al., 2011; Steinbach et al., 2011; Aldred et al., 2015).

When looking at the age variable, we notice that among our sample, the youngest group (5-17 years old) conducts the most trips by bike during the summer. This could be down to more free time (a higher proportion of this age group's trips is for leisure and shopping purposes than the other groups) and is in line with other findings that show young people are becoming more interested in active transport and especially when weather conditions are good (Davis et al., 2012; Kamargianni, 2015). However, when it comes to the winter, this age group shifts away from using bicycles significantly. Reduced safety levels as well as less enjoyable cycle conditions would be responsible for discouraging winter cycling. Further looking at the age variable, the results for the 18-25 group initially present a surprising finding when looking at other researches. This demographic is often seen as one of the key drivers of cycle demand in cities, many arguing that students and youths are important factors of high cycling rates (Gatersleben and Uzzell, 2007; Pucher et al., 2011; Santos et al., 2013). Nevertheless, we can accept this sign for London, since this age group includes many students; students are new to London and may not yet be established and had enough time to settle into cycling. Further, London boasts a comprehensive public transport system that is easy to use and may discourage this group from swapping to bicycle for some of their journeys. Additionally, many may choose instead to walk if the distances are short. Individuals between the ages of 26 and 44 have a statistically significant positive sign, while the next age group (45-59 years old) up does not show any statistically significant results. The results from the two models do not change greatly for ages above 18, indicating that their reasons for choosing to cycle are not outweighed by the change of circumstances from seasonality.

Table 3. Models Estimation Results

	Summer		**Winter**	
Variable	**coef.**	**t-stat**	**coef.**	**t-stat**
β	1.91	74.40	0.37	6.79
Gender (Female)	-0.17	-24.68	-0.40	-26.70
Age (5-17)	0.10	6.59	-0.23	-7.05
Age (18-25)	-0.05	-2.84	-0.16	-4.69
Age (26-44)	0.08	4.98	0.05	1.65
Age (45-59)	0.02	1.33	0.06	1.85
Ethnicity (White British)	-0.02	-1.58	0.15	4.87
Ethnicity (White Other)	0.04	2.14	0.01	0.21
Ethnicity (Asian)	-0.11	-6.28	-0.46	-11.15
Ethnicity (Black)	0.00	0.07	-0.22	-5.62
Household income (<15,000)	0.19	14.12	0.19	6.65
Household income (15,000-24,999)	0.14	10.49	0.13	4.69
Household income (25,000-34,999)	0.10	7.39	0.10	3.51
Household income (35,000-59,999)	0.07	5.16	0.12	4.36
Household income (60,000-74,999)	0.09	7.06	0.13	4.95
Household income (75,000-99,999)	-0.00	-0.30	-0.09	-2.88
Household residents (1)	0.08	6.55	0.12	5.52
Household residents (2)	-0.01	-1.04	-0.05	-2.92
Household vehicles (0)	0.12	13.43	0.25	13.62

Household vehicles (2+)	-0.10	-11.82	-0.23	-12.47
Working status (Full-time employed)	-0.03	-2.75	0.01	0.25
Working status (Part-time employed)	0.02	1.50	0.14	4.92
Zone (1)	0.09	3.55	0.39	8.29
Zone (2)	0.15	11.01	0.55	19.88
Zone (3)	0.06	4.32	0.31	11.03
Zone (4)	-0.01	-1.13	0.02	0.61
Zone (5)	-0.03	-2.37	-0.06	-1.85
Zone (6+)	-0.04	-3.20	-0.16	-5.40
R-squared		0.523		0.342
LL		-57,259		-35,823

Various studies have outlined the importance of a 'cycling culture' for attaining high rates (as in the Netherlands), as well as the lack of such culture in Britain (Rietveld and Daniel, 2004; Aldred and Jungnickel, 2014). Thus the results for ethnicity in the summer should come as no surprise: White British individuals being less likely to cycle and other White cycle more. Asian or Asian British people in the study cycle less frequently, while Black ethnicities do not yield any significant results. Curiously, when comparing the two models, it appears that White British people are less sensitive to weather changes when deciding how much to cycle than the other groups.

The overall household characteristics of income, number of residents and vehicle ownership all seem to be general predictors of cycling, yielding similar results for both seasons. Among those in the sample, those on lower incomes cycle more in both periods. As household income rises, the frequency of cycling decreases in summer months. In the winter, the highest income categories choose to cycle significantly less; however, it is interesting to note that the other categories seem to even out and predict a similar degree. Single households are the most likely to cycle more, while 2 person households do not cycle much. Additionally, the presence of children increases the cycling frequency for summer but not for winter, in line with results attained for age. As can be expected, households with access to no vehicles at all will cycle more than those with more vehicles in both seasons. The results become more pronounced in winter.

When looking at the working status of people in the sample. Those in full-time employment will cycle less when compared to others. This is interesting given the result for the 26-44 age group, demonstrating that the higher cycle levels come from those either in part-time employment or not working (this is in line with the lower income levels cycling more as well). The interrelation of the different variables' results leads us to accept these signs. The results for people in part-time employment are not significant in the summer. The winter results for part-time employees demonstrate they are more likely to cycle more, even in the winter months, showing that the price of alternatives may play an important role to people with a lower income when choosing how frequently to cycle.

Finally, the location of where people live proves important to cycling levels. The results for all zones except 4 are statistically significant. The more central zones have higher cycling levels in both periods, which can be expected due to trip distances being shorter for these zones. However, the difference between zones is less pronounced in the winter (with the exception of zone 4). This may be due to more leisure trips being completed in the summer in the areas located further from the centre of the city. As can be seen previous research the distances travelled become even more important to travellers choosing whether or not to cycle in the winter months (Bergström and Magnusson, 2003; Winters et al., 2010; Sears et al., 2012).

5 Conclusion

The aim of this paper was two-fold: to analyse the characteristics of London residents' cycle trips before investigating the factors that affect cycling frequency between summer and winter. Through reviewing the factors affecting cycling frequency and behavioural differences between the summer and the winter, there is an opportunity to determine how best to address low rates of cycling in both seasons, as well as what to focus on when trying to balance out the levels all year round.

In order to address these aims, data from the London Travel Demand Survey between the years of 2010 and 2013 was used. The sample is made up of 12,900 individuals over the age of 5 who had cycled in the 12 months prior to the interview. First, descriptive statistics were drawn to analyse the cycle trip characteristics of the sample. Next, Poisson regression models were estimated for both seasons under consideration to investigate socio-economic characteristics impacting the frequency of cycling in the two periods.

The trip characteristics show that among this sample, a large proportion of cycle trips were conducted for leisure and shopping purposes. Under 13% of the trips were commuting journeys, indicating that cycling is not yet seen as a conventional means of transport as part of the daily routine. Further the trips are primarily single-mode trips, with just 8% using other means of travel in the overall trip, indicating that intermodality is unpopular or difficult to do with the current transportation system of London. Similarly to other cities, the normal cycling distance is under 5km (with 85% of trips being under this distance). Through influencing the travel culture of people in London and ensuring better infrastructure to improve safety and reduce travel times, some changes could be developed to make cycling more common.

The results from the model estimation show certain factors that influence cycle frequency similarly in both seasons, while others outline differences within the demographic cycling more in either period. Gender and general household characteristics (income, vehicle ownership, size) as well as working status have similar results between both seasons and are simply amplified by seasonal differences in predicting cycle frequency. On the other hand, age and ethnicity show different results between the two periods. The particularly interesting result is that in the summer the youngest category (under 18 years old) is most likely to cycle more, providing a promising change to cycling culture in London. If the behaviour could be retained through to adulthood, there would be a new generation that enjoys higher cycling modal share (Kamargianni and Polydoropoulou, 2013). Foreign, white individuals are most likely to cycle during the summer, with the local white population not having high cycling levels. However, this is different in the winter months when White British people are most likely to cycle. Since this is the largest share of the demographic (65%), this is a key target market for promotion and shift of culture with the potential to increase year-round cycling rates and keep the winter levels. Additionally, most of the trips are completed by those living in central zones, with better infrastructure. The zones further out typically have longer travel distances and an improvement in facilities for intermodality could raise cycling levels there.

This research illustrates some promising figures regarding cycling levels in London, such as high levels among the youngest age group. Furthermore, it demonstrates key sections of the demographic that could be targeted to have the greatest effect on year-round cycling. Building on the success of the Olympics (Grous, 2012) in motivating people to take up cycling, promotional campaigns would make cycling more widespread. In order to achieve higher levels of activity and provide a shift away from motorized transport modes, cycling needs to be seen as a normal mode of transport, rather than solely a leisure activity. Employers should help to make cycling more widespread by providing shower and bike parking facilities which are obstacles to commuting by bike. Training courses for employees would also make cycling in the city safer and increase rates. Training programmes about cycling and walking safety should be included in the school curriculum to ensure safety levels, as well as give the new generation confidence. Training programmes could also help boost winter levels by reassuring parents and children of the possibility to cycle all year round and helping them deal with the more difficult road conditions. As has been outlined by previous research (Bergstrom and Magnusson, 2003), ensuring better maintenance levels of infrastructure in London would be further beneficial, removing a major obstacle for the winter. Policy makers' investment in infrastructure, such as cycle lanes or bike sharing facilities, in the outer zones of London would help raise the profile of the mode of transport across the city. Additionally, London's cycle sharing facility (viewed by many as too expensive for everyday transport needs and yielding low levels of participation compared to other cities) should be reformed so that it can be used more by local residents. This would incentivise intermodality through enticing commuters to include cycling as part of their daily travel habits and make London transport patterns more varied.

In order to better analyse the potential of policies, a Stated Preference survey of those less likely to cycle frequently in both periods would demonstrate how best to change cycling behaviour. A more detailed understanding, from interviews and other qualitative studies, of the reasons behind lower cycling rates in the winter would also prove beneficial to understanding the reasons between the significantly lower cycling levels in the winter.

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