Leadership in Sustainable Infrastructure

Leadership en Infrastructures Durables

Vancouver, Canada

May 31 – June 3, 2017/ *Mai 31 – Juin 3, 2017*

DECISION MAKING FOR THE CONSTRUCTION OF CYCLING INFRASTRUCTURE THROUGH PREDICTING USAGE

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Abstract: Cycling has gained an increasing attention among both researchers and municipalities in the last two decades as a sustainable alternative to car-based transportation. However, when it comes to decision making, there is a debate on whether investing on cycling infrastructure would be cost beneficial. This debate is particularly pronounced in cities with cold climate such as most Canadian cities since it is assumed that the cycling infrastructure will remain unused for the main part of the year. Furthermore, when deciding to build or extend cycling infrastructure, the question of where to build to get the most usage rises. This paper presents a portion of a larger study the overall goal of which is to predict usage for a proposed cycling infrastructure in cities with cold climate. Studies have shown that several factors such as Cyclists' Demographics, Attitudes toward Cycling, Built Environment, Infrastructure Quality and Weather Condition affect cycling frequency. This paper focuses on a subset of variables from the first factor, referred to as Cyclist Demographics, on cycling frequency. The objective of this paper is to identify the characteristics that impact the frequency of cycling and infrastructure usage, and to determine the magnitude of their impact. An intercept survey with a purposive sample of winter cyclists in Calgary is used. A regression model is developed to identify the characteristics with statistically significant impact for cycling frequency prediction. Eventually, it is examined to what extent the examined Cyclist Characteristics are accountable for predicting cycling frequency. The findings of the study presented in this paper will be used in developing a complete model that incorporates all variables affecting cycling frequency. When developed, the complete model can help planners and decision makers in municipalities to identify the best locations for constructing and expanding on cycling infrastructure within a city with cold climate.

1. INTRODUCTION

Cycling as a sustainable means of transportation provides both social and individual benefits for societies and individuals. Nowadays, populated cities suffer from congested streets. Besides, emissions from car-based transportation have serious impacts on the environment. Cycling as a sustainable mode of transportation can help societies with the above-mentioned difficulties since it has no emissions. Also, increase in usage of this type of transportation leads to a decrease in car-based demand for congested streets. Furthermore, cycling can help individuals with lack of physical activity as it provides physical activity for users. Therefore, cycling has received increasing attention in the last two decades. Several studies have shown that cycling rate has a positive association with infrastructure expansion (Buehler and Pucher 2012, Dill and Carr 2003). Thus, infrastructure expansion is needed for increasing usage of this type of transportation. However, there is a debate on whether it is cost beneficial to build new infrastructure as it is assumed that the infrastructure might remain unused or will have very low usage during winter months. To answer this debate, it is essential to quantify to what extent new infrastructures will be used, especially in cities with cold climate. This paper is a section of a larger study with the overall goal of predicting usage for specific cycling infrastructure in cities with cold climate. The result of the overall study can be used for evaluating cycling infrastructure usage and decision making for the construction of new cycling infrastructure. With conducting inferential tests on available data, this paper evaluates the association of available variables with cycling frequency. Also, this paper examines to what extent these variables predict cycling frequency.

2. LITERATURE REVIEW

Studies have shown that several variables affect cycling. In this study, these variables are categorized into five groups: Cyclist Demographics, Attitude toward Cycling, Built Environment, Infrastructure Quality and Weather Condition. Table 1 provides a summery of various studies, examining the effect of variables from the five defined groups on cycling.

Table 1: Literature review on factors affecting cycling frequency

Article	Cyclist Demographics	Attitude toward Cycling	Infrastructure Quality	Weather Condition	Built Environment
Titze et al. 2008	✓		✓		✓
Vandenbulcke et al. 2009	✓				
Wegman et al. 2012	✓				
Moritz 1997	✓		✓		
Buehler 2012			✓	✓	
Garrard et al. 2008	✓				
Dickinson et al. 2003	✓		✓		
Walker 2007	✓				
Larsen and El-Geneidy 2011	✓		✓		
Flynn et al. 2012	✓			✓	
Twaddle et al. 2011	✓		✓		
Plaut 2005	✓				
Gatersleben and Appleton 2007		✓			
Heinen et al. 2011		✓			
Gatersleben and Haddad 2010		✓			
Bergstrom and Magnusson 2003		✓	✓		
Daley and Rissel 2011		✓			
Dill 2009			✓		
Caulfield et al. 2012			✓		✓
Parkin and Meyers 2010			✓		
Krizek and Roland 2005			✓		
Li et al. 2012			✓		✓
Bernhoft and Carstensen 2008			✓		✓
Saneinejad et al. 2012				✓	
Spencer et al. 2013				✓	
Nankervis 1999				✓	

2.1 Cyclists' Demographics

Cyclists Demographics includes variables describing individuals' characteristics such as gender, age, education, trip duration, trip length and annual income. A number of studies found that women cycle less compared to men (Garrard et al. 2008, Fuller et al. 2011, Buehler 2012, Flynn et al. 2012). A case study from UK conducted on commuters of three companies in Hertfordshire, showed that women cycle shorter distances compared to men. The study showed that women's mean travel distance was equal to 8.3 miles, while men mean travel distance was 12.5 miles. Since the mean travel time for both genders were approximately equal, it can be concluded that women cycle with lower speed (Dickinson et al. 2003). Age is also one of the important variables that affect cycling. Several articles investigated the effect of this variable on cycling frequency (Vandenbulcke et al. 2009, Moritz 1997). A case study in Belgium Indicated that as the percentage of people less than 25 years of age increases in urban population, bicycle usage also increases (Vandenbulcke et al. 2009). However, another study using a survey with respondents from United States and Canada showed that majority of cyclists were between 26 and 45 years old (Moritz 1997). Other variables associated with cycling are travel distance and travel time. Studies have shown that travel distance has an inverse association with cycling frequency. As travel distance increases cycling frequency decreases (Vandenbulcke et al. 2009, Larsen and El-Geneidy 2011). Other studies focus on travel time showed that cyclists prefer to have shorter trips compared to longer trips (Caulfield et al. 2012).

2.2 Attitudes toward Cycling

The effect of attitudes toward cycling has been discussed by (Gatersleben and Appleton 2007, Heinen et al. 2011, Gatersleben and Haddad 2010, Bergstrom and Magnusson 2003, Daley and Rissel 2011). Attitude toward cycling plays an important role in individuals' decision to cycle. Regular cyclists believe cycling to be an efficient, cheap and environmentally friendly mode of transportation. On the other hand, one of the main reasons that prevents non-cyclists (especially women) from cycling is individual's concerns about the dangers of this type of transportation (Daley and Rissel 2011). Other studies found that non-cyclists believe that cycling is not a comfortable type of transportation while cyclists believe that cycling is both mentally and physically relaxing and a cheap type of transportation (Heinen et al. 2011).

2.3 Weather Condition

The effect of weather condition on cycling has been discussed by (Spencer et al. 2013, Buehler 2012). A case study in Vermont found that people cycle less during cold weather and rainy days. Between the weather factors, rain was found to have the largest effect on cycling. Days without rain have odd ratio equal to 1.91 compared to rainy days (Flynn et al. 2012). Temperature is another variable affect cycling. Cycling rate has a positive association with temperature. As temperature decreases cycling rate decreases as well (Saneinejad et al. 2012).

2.4 Infrastructure Quality

Cycling Infrastructure is one of the principal factors affecting cyclists' decision for choosing a road to cycle on. Study from the Oregon metropolitan area in Portland showed that although roads with bicycle facilities account for only 8 percent of total road network, they account for 49 percent of total bike usage (Dill 2009). Other articles discussed about the effect of infrastructure type on usage. Off-road paths tend to have more usage compared to other types of facilities followed by green lanes and on-road lanes. Streets without any facilities for cycling were the least favoured route choices for cyclists (Caulfield et al. 2012). Another study argued about the effect of infrastructure condition on cyclists' choice. Slippery road surface and roads without clearing from snow were found as two most important road conditions that affect cyclists' mode choice (Bergstrom and Magnusson 2003).

2.5 Built Environment

A number of studies argued about effect of built environment on cycling. Their findings indicate that cyclists prefer more connected network of cycling track and network connectivity is positively associated with cycling frequency (Osama et al. 2017, Titze et al. 2008, Caulfield et al. 2012). A study from city of Graz in Austria found that highly connected networks has nearly double odd ratio compared to low connected networks in term of cyclists' usage (Titze et al. 2008). Another study showed that cyclists have high preference for roads with lower number of intersections (Caulfield et al. 2012). Details of variables and their grouping can be seen in Table 2.

Table 2: Factor groups affecting cycling discussed in literature

Demographics	Attitude toward Cycling	Infrastructure	Weather Condition	Built Environment
Age	Belief in benefits	Infrastructure type	Temperature	Neighbourhood
Gender	*Environment benefit*	*Off-road pathways*	Humidity	*Residential*
Education	*Fitness and exercise*	*On-road Sep. physically*	Wind	*Commercial*
Annual income	*Enjoyment*	*On-road Sep. by lane*	Precipitation	*Industrial*
Body mass index	*Being outside*	*Without cycling facilities*	*Rain*	*Parks*
Own a car	*Flexibility*	Cycling road Width	*Hail*	Network connectivity
Own a bicycle	*Cost saving*	Road condition	*Snow*	Number of intersections
Having children	Habit	*Surface snow clearance*		Bus stop, parking
Time of day	Subjective norm	*Slippery*		Traffic speed
Peak/regular	Perceived behavioural	*Occurrence of grit/debris*		Destination facilities
Day/night	Culture	*Surface cracks*		*Bike parking*
Trip distance	Safety concerns	Road Slope		*Showers*
Trip duration		Traffic on the road		*Lockers*
Trip purpose				*Free car parking*

While these studies shed a light on the effect of various factors on regular cycling, there are few studies investigating the effect of factors on winter cycling. The effect of factors on winter cycling could be different from regular cycling. In cities with cold climate like most Canadian cities, winter cycling is more important because of cold weather during main part of the year. It is important to get a better understanding of who winter cyclists are and what factors affect their cycling and how they affect it.

3. DATA SOURCES

The source of data for this study is taken from an intercept survey conducted in February and March of 2013 in Calgary. The intercept survey ensures that respondents were actual winter cyclists since the survey was conducted while they were on bikes waiting at intersections. 1877 cyclists participated in survey, however 121 of them did not completely fill the questionnaire; hence they were excluded. Also 18 respondents used bicycle as part of their work. The goal of this study was to determine impact of different factors on cycling frequency for non-professional cyclists which refers to people who cycle without any income from their cycling. Hence, authors decided to eliminate those respondents from data which provided a usable sample of 1738 participants for data analysis. Respondents received a hardcopy of a questionnaire which included 14 questions, requested information about their personal characteristics such as gender, age, their cycling frequencies in winter and summer, their cold temperature resistance, their trip length, their trip duration, their nature of trip, their biggest concern on the route while cycling and their preferences for bike path improvements. Out of 1738 respondents, 75.4% of them were male and 24.6% were female. 75.4% of the respondents were commuters while other 24.6% had other destinations. 33.3% of the respondents indicated that they would cycle in any cold temperature and 31.8% of them indicated that they would cycle only in days with positive temperatures. Details of respondents' characteristics can be seen in Table 3.

Table 3: Winter cyclists' characteristics, Calgary, 2013

	N (1738)	Percentage
Gender		
Male	1310	75.4
Female	428	24.6
Age		
18-24	171	9.8
25-34	512	29.5
35-44	546	31.4
45-54	344	19.8
More than 54	165	9.5
Car ownership		
Yes	1408	81.0
No	330	19.0
Bike with Children on route		
Yes	225	14.7
No	1483	85.3
What temperature is too cold for cycling?		
None	579	33.3
Less than -20 °C	401	23.1
Less than -10 °C	206	11.9
Less than 0 °C	552	31.8
Trip purpose		
Work	1311	75.4
Other	427	24.6

4. DATA ANALYSIS AND MODEL DEVELOPMENT

In this part of the paper, authors were interested in two subjects. The first one was to find the variables with significant association with cycling frequency. Second subject was to determine which combination of variables can predict cycling frequency most precisely. The following sections describe the two subjects respectively.

4.1 Identification variables with significant association

For the first part of analysis, authors were interested to find the variables with statistically significant association with cycling frequency. Identifying those variables would be valuable and could be used as a guide for future procedures aiming to increase cycling frequency by improving the situations related to each variable. Several quantitative analysis procedures were used to identify variables with statistically significant association with cycling frequency. SPSS software was used for carrying out statistical analysis during this study. Inferential tests were used to evaluate the association of different measurements of data with cycling frequency. The inferential tests used for this section were T-test, ANOVA and correlation. T-test used on characteristics of respondents with binary answers questions such as gender. ANOVA used for characteristics with multiple choice answers such as age and temperature resistance. Pearson Correlation used to determine association of variables with continuous values on cycling frequency such as trip length. Table 4 shows the result of inferential tests conducted to verify the association of cyclists' demographics with cycling frequency.

Table 4: Inferential analyses results

Cyclists Demographics	Inferential Test	Observed P-value
Age	ANOVA	0.001**
Temperature resistance	ANOVA	0.000**
Trip duration	ANOVA	0.315
Biggest concern	ANOVA	0.941
Gender	T-test	0.001**
Car ownership	T-test	0.896
Bike with children	T-test	0.009**
Trip purpose-work	T-test	0.000**
Trip length	Pearson correlation	0.755

* indicate Coefficient is significant at the 0.05 level, two-tailed.
** indicate Coefficient is significant at the 0.01 level, two-tailed.

It can be seen from Table 4 that age, temperature resistance, gender, bike with children and work as trip purpose have significant association with cycling frequency. ANOVA analysis on different age groups indicates statistically significant differences in cycling frequency between participants aged 18-25 and 35-44, 18-25 and 45-54, 25-34 and 45-54. Also, ANOVA analysis conducted on different temperature resistance groups indicates statistically significant differences in cycling frequency between all groups. However, trip duration, car ownership and trip length do not show a significant association with cycling frequency. Comparison of monthly mean cycling frequency of different groups can be seen in Figures 1 to 3.

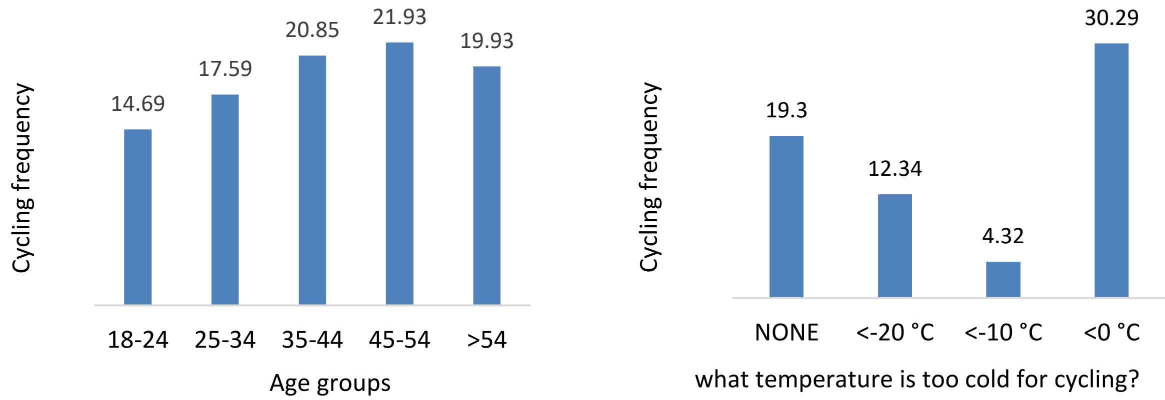

Figure 1. Cycling frequency comparison by age and temperature resistance

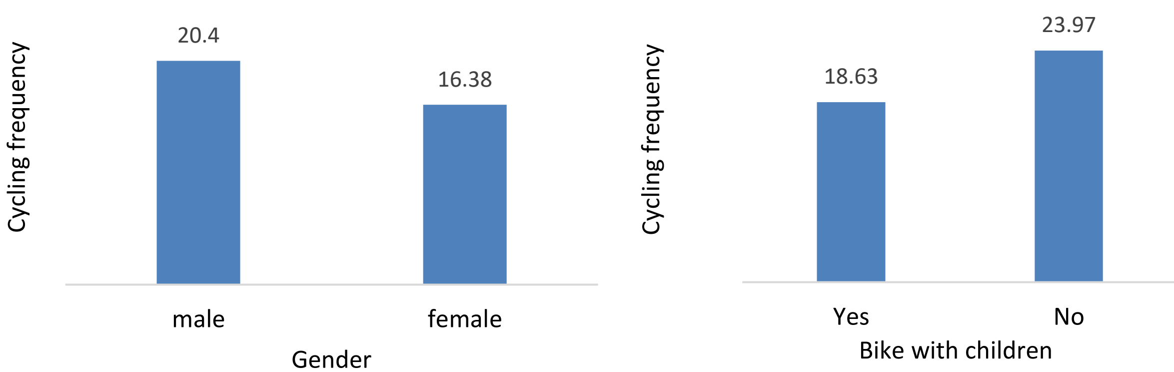

Figure 2. Cycling frequency comparison by gender and cycling with children

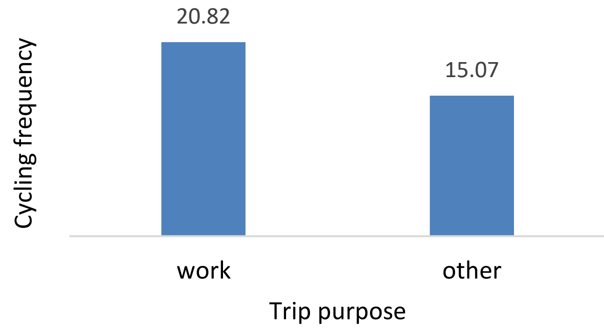

Figure 3. Cycling frequency comparison by trip purpose

4.2 Prediction model

For the second part of analysis, authors were interested to find the best combination of variables that can predict cycling frequency. The prediction model could be used to predict cycling frequency for a proposed road based on users' demographics. A multiple linear regression was calculated to predict cycling frequency based on Cyclists' Demographics. Several regression models developed with different combination of variables to find the best model with highest goodness of fit. A significant regression equation was found $F(6, 1731) = 19.977$, $p < .05$, $R^2 = .065$. Six characteristics were identified as significantly related for predicting cycling frequency including gender, age, bike with children, temperature resistance, trip duration and work as trip purpose. These six predictors were able to account for 6.5 % of the variance of cyclists cycling frequency. Although ANOVA analysis indicates that trip duration does not have a significant association with cycling frequency, multiple regression result indicates that trip duration has significant effect for predicting cycling frequency. Difference between the result of two tests is attributed to two reasons. First, ANOVA deals with trip duration as a categorical variable, while multiple regression deals with trip duration as an ordinal variable. Second, ANOVA examines only the effect of trip duration on cycling frequency, however multiple regression examines the effect of trip duration amongst with other variables on cycling frequency. It can be concluded that even though trip duration does not have a significant association with cycling frequency itself, it could be used amongst other variables to predict cycling frequency. Table 5 provide details about variables assigned values used for data analysis. Table 6 represents the result of regression model.

Table 5: Detailed information about cyclists' characteristics assigned values

	Assigned Values used for data analysis				
	1	2	3	4	5
Gender	Male	Female			
Age (years)	18-24	25-34	35-44	45-54	>54
Bike with children	Yes	No			
What temperature is too cold for cycling	None	< -20 °C	< -10 °C	< 0 °C	
Trip duration (minutes)	< 10	10-20	20-30	> 30	
Trip purpose-work	Yes	No			

Table 6: Summary of multiple regression analysis

Predicting variable	Coefficient	Standardized coefficient
Constant	10.485**	
Gender	-2.806*	-0.055
Age	1.306*	0.067
Bike with children	4.495*	0.073
What temperature is too cold for cycling?	3.217**	0.184
Trip duration	-1.274*	-0.055
Trip purpose-work	4.924**	0.097

* indicate Coefficient is significant at the 0.05 level, two-tailed.
** indicate Coefficient is significant at the 0.01 level, two-tailed.

The results of multiple regression indicate that gender and trip duration have negative coefficients with cycling frequency. These negative coefficients indicate that male cyclists would cycle more compare to female cyclists and as trip duration increases cycling rate decreases. People who cycle without children would cycle more compared to people who cycle with children. Cyclists who can cycle in colder weather cycle less compare to cyclists who can cycle in warmer weathers. As age increases cycling frequency increases which means older cyclists tend to cycle more compared to younger cyclists. Commuter cyclists cycle more compared to cyclists with other destinations. The standardized coefficients show that within these factors temperature resistance, work as trip purpose and bike with children have biggest impact on cycling frequency.

5. DISCUSSION AND CONCLUSIONS

This study looked into the effect of different variables on cycling with an extensive literature review and grouped them into five groups. The association of different variables from the first group referred to as Cyclists' Demographics with cycling frequency was examined. Moreover, cycling frequency was predicted based on variables with significant impact for predicting cycling frequency. The result of this paper indicates that biking with children has a negative association with cycling frequency. The reason that cyclists who cycle with children cycle less, could be attributed to difficulties of cycling with children and concerns about children's safety. Safety and issues about dangers of cycling are believed to be important factors preventing individuals from cycling (Daley and Rissel 2011). The majority of cyclists in this study were between 25 and 44 years old which is similar to (Moritz 1997) respondents. Both studies have respondents from North America which can be the reason for this similarity. Regression analysis shows that age has a positive coefficient with cycling frequency, indicates that older cyclists cycle more. However, the small coefficient indicates that between winter cyclists, age is not going to make a drastic change in predicting cycling frequency. Related studies support the finding of this study about cycling frequency difference between different genders. Men would cycle more compare to women (Fuller et al. 2011, Buehler 2012). Another variable examined in this paper was the association of temperature resistance with cycling frequency. Multiple regression analysis indicates that cyclists with higher temperature resistance, cycle less compared to cyclists with lower temperature resistance. In this study, cyclists were categorized into four groups in terms of temperature resistance. ANOVA analysis shows that cyclists with lowest temperature resistance have the maximum cycling frequency followed by cyclists with highest temperature resistance, followed by the other two groups. This distribution of cycling frequency for temperature resistance groups is one of the reasons for a reduced R square in the regression model. Regression analysis also finds a negative coefficient for trip duration, indicating that cyclists prefer short trips, which is in line with findings of other studies (Vandenbulcke 2009). One of the main reasons for this preference in winter cyclists could be due to cold weather. For longer trips cyclists are exposed to cold weather for longer periods. This issue emphasizes the importance of the effect of temperature on cycling. This paper also found that cyclists who were commuters cycle more compared to other types of cyclists. In conclusion, to get a complete understanding of the effect of different factors on winter cycling, adding more variables from other groups to the model would be useful and will help to improve model accuracy. Further, variables with significant association could address the future actions trying to increase cycling frequency. Future studies can be conducted on those variables with large effect on cycling frequency, such as biking with children to determine the main reason preventing cyclists from cycling. With determining the reasons, planners and decision makers would be able to work on this basis and try to increase cycling frequency by reducing the obstacles.

6. REFERENCES

Bergstrom, A. and Magnusson, R. 2003. Potential of transferring car trips to bicycle during winter. *Transportation Research Part A*, **37**(8): 649-666.

Bernhoft, I.M. and Carstensen, G. 2008. Preferences and behaviour of pedestrians and cyclists by age and gender. *Transportation Research Part F*, **11**(2): 83-95.

Buehler, R. 2012. Determinants of bicycle commuting in the Washington, DC region: The role of bicycle parking, cyclist showers, and free car parking at work. *Transportation Research Part D*, **17**(7): 525-531.

Buehler, R. and Pucher, J. 2012. Cycling to work in 90 large American cities: New evidence on the role of bike paths and lanes. *Transportation*, **39**(2): 409-432.

Caulfield, B. Brick, E. and McCarthy, O.T. 2012. Determining bicycle infrastructure preferences - A case study of Dublin. *Transportation Research Part D*, **17**(5): 413-417.

Daley, M. and Rissel, C. 2011. Perspectives and images of cycling as a barrier or facilitator of cycling. *Transport Policy*, **18**(1): 211-216.

Dickinson, J.E. Kingham, S. Copsey, S. and Pearlman, D.J. 2003. Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK ?. *Transportation Research Part D,* **8**(1): 53-67.

Dill, J. 2009. Bicycling for Transportation and Health: The Role of Infrastructure. *Journal of Public Health Policy*, **30**(1): 95-110.

Dill, J. and Carr, T. 2003. Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them. *Transportation Research Record*, **1828**(1): 116-123.

Flynn, B.S. Dana, G.S. Sears, J. and Aultman-Hall, L. 2012. Weather factor impacts on commuting to work by bicycle. *Preventive Medicine*, **54**(2): 122-124.

Fuller, D. Gauvin, L. Kestens, Y. Daniel, M. Fournier, M. Morency, P. and Drouin, L. 2011. Use of a new public bicycle share program in Montreal, Canada. *American Journal of Preventive Medicine*, **41**(1): 80-83.

Garrard, J. Rose, G. and Lo, S.K. 2008. Promoting transportation cycling for women: The role of bicycle infrastructure. *Preventive Medicine*, **46**(1): 55-59.

Gatersleben, B. and Appleton, K.M. 2007. Contemplating cycling to work: Attitudes and perceptions in different stages of change. *Transportation Research Part A*, **41**(4): 302-312.

Gatersleben, B. and Haddad, H. 2010. Who is the typical bicyclist?. *Transportation Research Part F*, **13**(1): 41-48.

Heinen, E. Maat, K. and Van Wee, B. 2011. The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances. *Transportation Research Part D*, **16**(2): 102-109.

Krizek, K.J. and Roland, R.W. 2005. What is at the end of the road? Understanding discontinuities of on-street bicycle lanes in urban settings. *Transportation Research Part D*, **10**(1): 55-68.

Larsen, J. and El-Geneidy, A. 2011. A travel behavior analysis of urban cycling facilities in Montr??al, Canada. *Transportation Research Part D*, **16**(2): 172-177.

Li, Z. Wang, W. Liu, P. and Ragland, D.R. 2012. Physical environments influencing bicyclists' perception of comfort on separated and on-street bicycle facilities. *Transportation Research Part D*, **17**(3): 256-261.

Moritz, W. 1997. Survey of North American Bicycle Commuters: Design and Aggregate Results. *Transportation Research Record*, **1578**(1): 91-101.

Nankervis, M. 1999. The effect of weather and climate on bicycle commuting. *Transportation Research Part A*, **33**(6): 417-431.

Osama, A. Sayed, T. and Bigazzi, A.Y. 2017. Models for estimating zone-level bike kilometers traveled using bike network, land use, and road facility variables. *Transportation Research Part A*, **96**, 14-28.

Parkin, J. and Meyers, C. 2010. The effect of cycle lanes on the proximity between motor traffic and cycle traffic. *Accident Analysis and Prevention*, **42**(1): 159-165.

Plaut, P. O. 2005. Non-motorized commuting in the US. *Transportation Research Part D*, **10**(5): 347-356.

Saneinejad, S. Roorda, M.J. and Kennedy, C. 2012. Modelling the impact of weather conditions on active transportation travel behaviour. *Transportation Research Part D*, **17**(2): 129-137.

Spencer, P. Watts, R. Vivanco, L. and Flynn, B. 2013. The effect of environmental factors on bicycle commuters in Vermont: Influences of a northern climate. *Journal of Transport Geography*, **31**, 11-17.

Titze, S. Stronegger, W.J. Janschitz, S. and Oja, P. 2008. Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers. *Preventive Medicine*, **47**(3): 252-259.

Twaddle, H. Hall, F. and Bracic, B. 2011. Latent Bicycle Commuting Demand and Effects of Gender on Commuter Cycling and Accident Rates. *Transportation Research Record: Journal of the Transportation Research Board*, **2190**(1): 28-36.

Vandenbulcke, G. Thomas, I. de Geus, B. Degraeuwe, B. Torfs, R. Meeusen, R. and Int Panis, L. 2009. Mapping bicycle use and the risk of accidents for commuters who cycle to work in Belgium. *Transport Policy*, **16**(2): 77-87.

Walker, I. 2007. Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis and Prevention*, **39**(2): 417-425.

Wegman, F. Zhang, F. and Dijkstra, A. 2012. How to make more cycling good for road safety?. *Accident Analysis and Prevention*, **44**(1): 19-29.