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Cycling characteristics in cities with cold weather

M. Amiri*, F. Sadeghpour

Department of Civil Engineering, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada

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ABSTRACT

Transportation is one of the major contributors to the global warming due to vehicle fossil fuel consumption. Research has shown that changing travel behavior is one of the most effective methods in reducing the Greenhouse Gas (GHG) emissions in transportation. Cycling in particular, is gaining more attention as a non-automobile alternative mode of transportation. A number of studies have been conducted that examined the impact of various factors such as demographic characteristics on cycling behavior. However, cycling behavior is perceived to be dependent on weather conditions as well. This study focuses on cycling in cold weather and aims to develop an understanding of characteristics of cyclists and their cycling behavior in cold temperatures. An intercept survey is conducted among cyclist on a newly implemented bike lane under close-to-freezing temperatures in Calgary, Canada. The results of the survey provide a baseline for understanding the characteristics of winter cycling. Cross-tabulated analysis of the data identified a number of statistically significant relationships between different variables. The result of this study can help with future planning and policy making in regions with cold climate or long and cold winters.

1. Introduction

The most recent statistics on Greenhouse Gas (GHG) emissions continue to demonstrate a global increasing trend since the pre-industrial era. Between 1900 and 2008 alone, the global carbon dioxide (CO_2) emissions from fossil fuels – the main cause of global warming – have increased over 16 times (EEA, 2013; EPA, 2013; IPCC, 2007). For example Fig. 1 shows the total GHG emissions trend in Canada (1990–2010). These increasing trends led to the establishment of different policies and practices by governments to stabilize global GHG emission levels and prevent further increases (EU, 2012; Env.Canada, 2012a,b; CACPOA, 2009; OECD, 2003; PIRS, 2008; WI, 2005). However, studies show that without additional policies and a strict supervision on their implementation, it would be very difficult to meet the established targets (Hofman & Li, 2009; Hughes & Scott, 1997; IPCC, 2007; Liimatainen & Pollanen, 2010; Morrow, Sims Gallagher, Collantes, & Lee, 2010; Yang, McCollum, McCarthy, & Leighhty, 2009).

Transportation is considered one of the major contributors to the increasing trend of GHG emissions (Env.Canada, 2012a,b; Norman, MacLean, & Kennedy, 2006; Yang et al., 2009). For example in Canada, distribution of the GHG emissions by economic sector in 2010 shows that the transportation was responsible for 166 Mt of the total 692 Mt of CO_2 equivalent (CO_2 eq). This accounts for 24% of total GHG emissions in 2010. The importance of the transportation sector in stabilizing the level of GHG emissions indicates the need to increase the sustainability in this sector (Norman et al., 2006; Yang et al., 2009).

Findings from transportation studies show that changes in travel behaviors are the most effective methods for decreasing GHGs emissions in the transportation sector (Yang et al., 2009; Morrow et al., 2010). One way to achieve such changes is to reduce the role of automobiles as a primary mode of transportation and to shift toward other modes of transportation, such as cycling. Studies show that encouraging cycling, as a non-automobile alternative, can be an effective method in reducing GHG emissions, provided sufficient facilities are in place (Kim & Ulfarsson, 2008; Nazelle, Morton, Jerrett, & Crawford-Brown, 2010; Noland & Kunreuther, 1995).

As a result of such studies, cycling is receiving more attention from governments as a sustainable mode of transportation in recent years (e.g. ECF, 2013; EUT, 2012; HTD, 2004; IPSOS, 2010; NY, 2007; UBC, 2013). However, in cities with cold weather, there are still speculations and concerns on the rate of usage for cycling facilities during long winter seasons. The objective of this study is to establish a baseline for the characteristics of cyclists and cycling behavior in a typical North American city with cold weather. This baseline can be helpful in decision making regarding investing on and planning for cycling facilities in cities with cold temperatures and long winters.

* Corresponding author. Tel.: +1 403 210 6932; fax: +1 403 282 7026.
E-mail addresses: mamiri@ucalgary.ca (M. Amiri), farnaz@ucalgary.ca (F. Sadeghpour).

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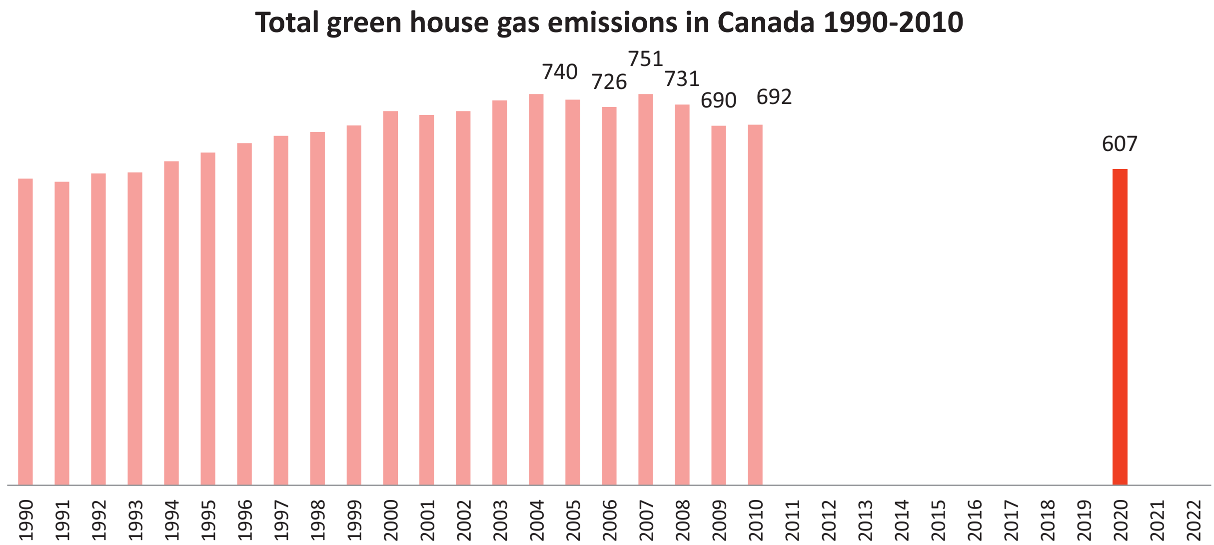

Fig. 1. Total green house gas emissions (CO_2 eq) in Canada 1990–2010 (Env.Canada, 2012a,b).

2. Literature review

Several studies have been conducted to examine the effects of different factors that influence cycling behavior and motivation. The main factors examined in literature include particular types of infrastructure (e.g. bicycle path, lane, and shared-used space), safety, gender, age, income, race, marital status and trip distance (Andrade, Jensen, & Harder, 2011; Dill, 2009; Moudon et al., 2005). These studies, along with one study by Kim and Ulfarsson (2008), have unanimously agreed that improved bicycle infrastructures increase the rate of cycling, thus encouraging more people to choose cycling as a transportation mode. Some other studies found that safety was one of the most important reasons that prevented public from cycling, and it was concluded that improving safety in cycling infrastructures can motivate more people in using them (Andrade et al., 2011; Har, 2011; Noland & Kunreuther, 1995; Trans.Canada, 2010). One study indicated that Canadians cycle more than Americans and identified developed cycling infrastructures and safer cycling trips as the main reasons for higher cycling rates in Canada (Pucher & Buehler, 2006).

Cycling was also shown to be dependent on gender and age in a study conducted in Washington State, USA. There were more male (66%) than female (34%) cyclists. Further, middle-aged and young adults (18–44 years old) tended to cycle more than older adults (Moudon et al., 2005). This study also looked into characteristics of cyclists with regards to race, marital status and income and concluded that the majority of cyclists were Caucasian and more likely to be single compared to non-cyclists. The study did not find any significant relation between the rate of income and cycling. This research also identified that the most popular purposes for cycling were recreation and exercise (Moudon et al., 2005). However, statistics in Canada indicate that cycling is also commonly used for transportation, particularly commuting to work (Trans.Canada, 2010).

Trip distance is another factor that can affect cycling motivation. Another survey conducted in Washington State, USA, investigated whether cycling was considered as a non-automobile alternative for trips shorter than 2.25 km. The study found that for trips of this length, there is a preference to walk rather than cycle due to greater safety risks associated with cycling (Kim & Ulfarsson, 2008).

Studies have also shown that cycling demand is highly dependent on weather conditions. One of the most influential factors on cycling demand is the temperature. The number of cyclists increases with higher temperatures in sunny days. Conversely, days with wind, snow and high humidity are associated with fewer cyclists. Temperature also has negative impact on cycling demand when it rises above 28 °C (Flynn, Dana, Sears, & Aultman-Hall, 2012; Miranda-Moreno & Nosal, 2011; Nankervis, 1999; Thomas, Jaarsma, & Tutert, 2013; Winters, Friesen, Koehoorn, & Teschke, 2007). The aforementioned studies demonstrate the impact of various factors on cycling. The study presented in this paper focuses specifically on cycling in cold weather, and examines the characteristics of cyclists, and factors that affect cycling demand in winter.

3. Study design and hypothesis

In this study, 11 variables of age, gender, frequency of cycling (winter and year-round), safety concerns, temperature comfort, trip purpose, trip distance, trip duration, use of intermodal transportation, and concerns with regards to infrastructure deficiencies were selected to be investigated. These variables were identified using the most important factors associated with cyclists' characteristics and cycling demand in the existing literature.

This study presents an analysis of data collected from cyclists that is related to these eleven variables. In addition, it looks into the possible effects of the first four (4) variables of age, gender and frequency of cycling in winter and year-round on the remaining seven (7) variables of safety concerns, temperature comfort, trip purpose, trip distance, trip duration, use of intermodal transportation and infrastructure concerns. Fig. 2 demonstrates the theoretical model used to examine the hypothesis of this study. For instance, age is speculated to affect all the seven (7) aforementioned variables. All the 28 possible relations between the four (4) independent and the seven (7) dependent variables were considered one by one, and 26 were selected to be examined for statistical analysis. It was not expected that the frequency of cycling, both in winter and year-round, would influence cyclists' concerns about infrastructure deficiencies, and therefore these two relationships were eliminated from the theoretical model.

4. Data collection

An intercept survey was conducted in a newly implemented bike lane at the border of the downtown core in the city of Calgary, Canada, to collect first-hand responses from the participants. A questionnaire was designed to collect data required in order to

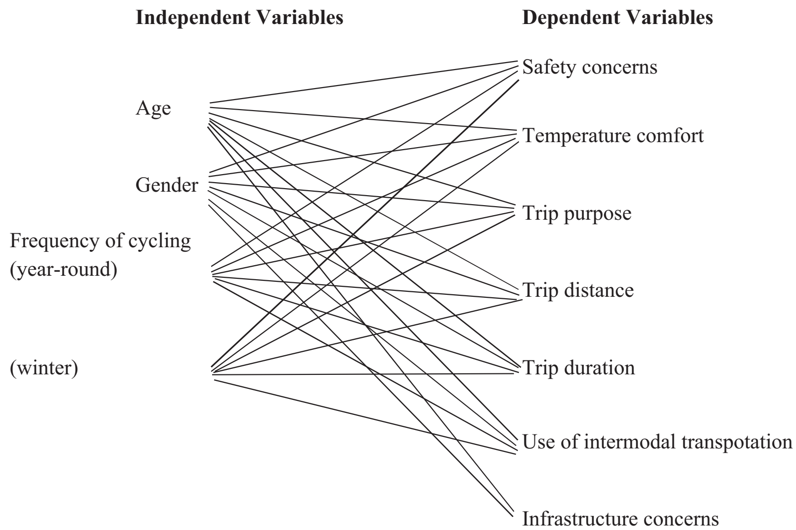

Fig. 2. Hypothesis of the study and theoretical model for statistical analysis.

examine the hypothesis of the study (see Fig. 2). In addition, a question was asked to verify if the allocation of the new bike lane resulted in bringing more cyclists to this route (q5). Table 3 shows the summary of the questionnaire.

The survey was conducted in March 2012. A total of 103 data samples were collected over nine (9) days. The temperature during survey days ranged between −14.9 °C and +14.2 °C which is typical for Calgary in this time of year. The timing of surveys (4:30–6:30 pm) was selected to be in the afternoon to take advantage of the increased number of cyclists during the rush hour. In a pilot run conducted for this survey it was observed that during the morning rush hours cyclists were often not inclined to stop as they were rushed to get to work. However, during afternoon rush hours they were more willing to participate in the survey. Table 2 shows the daily temperatures over the surveying period and the number of surveys collected per day.

5. Survey summary

Table 3 shows the summary of the survey as percentage frequency distribution for the answers. As shown in the table, almost 60% of the participants in this survey were more than 35 years old. It was interesting to observe that 33% of the participants were more than 44 years old indicating that age did not impede cycling in cold weather in this group. Cycling seemed to be extremely gender-dependent in this population: 85% of the 103 participants were male and just 15% were female, indicating a large difference between males and females in choosing cycling as a transportation mode. This difference was even more than that found in earlier research in King County, Washington in which 66% of those cycling at least once a week were male (Moudon et al., 2005).

The majority of the participants in the present study were frequent cyclists: 72% of the participants cycled 10 times or more on a weekly basis throughout the year. However, during cold weather this percentage dropped to 47%, demonstrating that the number of frequent cyclists drops by almost 1/3rd in cold weather conditions.

As the bike lane where the survey was conducted was newly implemented, it was interesting to study its impact on the frequency of cycling on that route. Roughly 25% of the participants indicated that they started to cycle on this route after the implementation of the new bike lane. This can clearly demonstrate that new infrastructure can increase the frequency of cycling (by one-third of the previous population in the case of this route). Although it was not part of the formal questionnaire, a large number of the

Table 1
Summary of the questionnaire.

Questions	Answer choices
q1. Age	<18
	18–24
	25–34
	35–44
	>44
q2. Gender	Male
	Female
q3. Frequency of cycling in winter	How many times per day, week or month
q4. Frequency of cycling year round	How many times per day, week or month
q5. Using road before bike lane construction	Yes
	No
q6a. Trip duration	<10 min
	10–20 min
	20–30 min
	>30 min
q6b. Trip distance	*X* kilometers
q7. Safety concerns	Obstacles in lane
	Cyclists riding too fast/close
	Icy road
	Pedestrians in lane
	Other, state
q8. Temperature comfort	Up to 0 °C
	Up to −10 °C
	Up to −20 °C
	Does not matter
q9. Infrastructure concerns	Lighting
	Signs
	Widths
	Road surface conditions
	Other, state
q10. Trip purpose	Work
	Exercise
	Recreation
	Home
	Shopping
	School
	Restaurant
	Other, state
q11. Use of intermodal transportation	No
	Yes
	Automobile
	Walk
	Public transit

Table 2
Temperature and number of surveys collected over data collection period.

Day #	Week day	Date (March, 2012)	# of surveys collected	Temperature (°C)		
				4:30–6:30 pm	Min	Max
1	Saturday	3	12	2.2	−6	9.4
2	Wednesday	7	6	2.4	−14.9	4.1
3	Thursday	8	23	7.4	0.7	10.1
4	Friday	9	9	9.1	0.4	14.2
5	Tuesday	13	9	0.8	−3.1	10.3
6	Wednesday	14	6	3.3	−6.4	5.2
7	Thursday	15	22	9.9	−5.8	14.1
8	Tuesday	20	2	3.4	−6.3	8.8
9	Wednesday	21	14	2.4	−4.7	5.3

participants who had been using this route before the implementation of the new bike lane expressed their satisfaction with the newly allocated bike lane upon answering this question.

The average one-way trip distance for the cyclists in this study was 7.4 km. This was an interesting observation as previous studies limited the scope of their investigations on the use of cycling to only short trips: <2.25 km (Kim & Ulfarsson, 2008) and <4.8 km (Nazelle et al., 2010). The current study suggests that cycling is also used for much longer trips (more that 7 km on average). The majority of the participants – about 72% – had trip durations between 10 and 30 min. The duration of the trip for 25% of the participants was more than 30 min. Only 3% of the participants used cycling for trips shorter than 10 min.

Participants were asked to indicate what their main safety concerns were. For this question they were asked to select as many choices as applicable. About 61% of the cyclists selected icy conditions of the bike lane as a major concern during the winter. Near 21% of the cyclists were concerned about obstacles in the bike lane such as parked cars. Proximity and higher speed of other cyclists and presence of pedestrians in the bike lane were the least

Table 3
Percentage frequency distribution.

Question	Answers: frequency for the available choices (%)							
	<18	18–24	25–34	35–44	>44			
Age	3.9	5.8	28.2	29.1	33			
	Male	Female						
Gender	84.5	15.5						
	≤2 times	2–9.9 times	10 times and up					
Frequency of cycling–winter (per week)	32	21.4	46.6					
	≤2 times	2–9.9 times	10 times and up					
Frequency of cycling-general (per week)	4.9	23.3	71.8					
	No	Yes						
Used road before bike lane	25.2	74.8						
	≤5.0 km	5.1–9.9 km	10 km and up					
Trip distance (km)	31	40.8	28.2					
	<10 min	10–20 min	20–30 min	>30 min				
Trip duration (one way)	2.9	35	36.9	25.2				
	Obstacles in lane	Cyclists riding too fast/close	Icy road	Pedestrian in lane	Other			
Safety concerns*	21.4	4.9	61.2	2.9	47.6			
	Up to 0 °c	Up to −10 °c	Up to −20 °c	Does not matter				
Temperature comfort	3.9	25.2	33	37.9				
	Lighting	Signs	Width	Road surface conditions	Other			
Infrastructure concerns*	11.7	16.5	2.9	20.4	34			
	Work	Exercise	Recreation	Home	Restaurant	Shopping	School	Other
Trip purpose*	72.8	17.5	25.2	64.1	5.8	12.6	1.9	1
	No	Yes (25.2%)						
Use of intermodal transportation	74.8	Automobile (10.3%)	Walk (31%)	Public transit (58.6%)				

* Participants were allowed to pick more than one option (percentages do not add up to 100).

Table 4
Significant relationships identified in cross-tabulated analysis; a. age, b. gender, c. frequency of cycling in *winter*, d. frequency of cycling *year-round*.

a. Significant relationships: age

Dependent variables	Independent variable: age						Chi-square result		
	Options	<18	18–24	25–34	35–44	>44	Value	df	Asymp. sig.
Safety concern-cyclists riding too fast/close	Yes	75%	16.7%	3.4%	0%	0%	47.815	4	0.000
	No	25%	83.3%	96.6%	100%	100%			
Trip purpose-work	Yes	0%	66.7%	72.4%	86.7%	76.5%	14.446	4	0.006
	No	100%	33.3%	27.6%	13.3%	23.5%			
Trip purpose-recreation	Yes	100%	50%	20.7%	16.7%	23.5%	15.336	4	0.004
	No	0%	50%	79.3%	83.3%	76.5%			
Use of intermodal transportation	Yes	25%	33.3%	41.4%	6.7%	26.5%	9.723	4	0.045
	No	75%	66.7%	58.6%	93.3%	73.5%			

b. Significant relationships: gender

Dependent variables	Independent variable: gender			Chi-square result		
	Options	Male	Female	Value	df	Asymp. sig.
Use of intermodal transportation – Yes	Walk	29.2%	100%	4.093	1	0.043
	Public transit	75%	0%	4.875	1	0.027

c. Significant relationships: frequency of cycling in *winter*

Dependent variables	Independent variable: frequency of cycling in *winter*				Chi-square result		
	Options	≤2 times/week	2–9.9 times/week	>10 times/week	Value	df	Asymp. sig.
Temperature comfort	Up to 0 °C	12.1%	0%	0%	33.809	6	0.000
	Up to −10 °C	39.4%	45.5%	6.3%			
	Up to −20 °C	33.3%	31.8%	33.3%			
	Does not matter	15.2%	22.7%	60.4%			
Trip purpose-work	Yes	48.5%	68.2%	95.8%	23.873	2	0.000
	No	51.5%	31.8%	4.2%			
Trip purpose-recreation	Yes	51.5%	13.6%	12.5%	17.771	2	0.000
	No	48.5%	86.4%	87.5%			

d. Significant relationships: frequency of cycling *year-round*

Dependent variables	Independent variable: frequency of cycling *year-round*				Chi-square result		
	Options	≤2 times/week	2–9.9 times/week	>10 times/week	Value	df	Asymp. Sig.
Trip purpose-work	Yes	60%	50%	83.8%	11.567	2	0.003
	No	40	50%	16.2%			

selected safety concerns. A large group of the participants (47%) selected "other" for this question. When asked to specify, 53% of this group identified the existence of gravel and snow on the lane, about 40% identified adjacent fast moving cars, and the remainder 7% indicated the attitude of car drivers as their largest safety concerns. Cyclists' conce rn about cars driving too close supports the findings of previous studies regarding the advantages of separated bike lanes (Andrade et al., 2011; Dill, 2009; Kim & Ulfarsson, 2008; Moudon et al., 2005). At this question, the participants commonly made a remark that the existence of the snow also reduced the width of the bike lane, preventing an effective use of the lane. They also repeatedly commented that bike lane awareness programs for automobile drivers and better lane demarcation can be used to increase cycling safety.

As for the most concerning deficiency in the bike lane, approximately 20.4% of the cyclists identified the road surface condition (e.g. cracked and rutting pavement) and about 16.5% identified lack of signs in the bike lane. The largest group of participants (other: ~34%) specified their concern to be snow and gravel removal (24.8%) and continuity of the bike lane (9.2%). Abrupt termination of the specific bike lane where the survey was conducted was brought up repeatedly as a concern in informal comments.

In terms of weather comfort, 38% of the participants said that cold weather did not influence their decision to cycle and 33% indicated that they were comfortable with cycling in temperatures up to −20 °C. It was interesting to the authors to observe such high tolerance for cold among more than 70% of the participants.

As for the trip purposes, over 70% of the participants indicated that they used cycling for commuting to work. This finding is not aligned with that from the survey conducted in Washington State in which "recreation" was identified as the main purpose for cycling (Moudon et al., 2005). The trip purpose distribution demonstrated that cyclists picked more than one purpose for their current trip, indicating that they combined different purposes in one trip. Commuting to work (73%), going home (64%), and recreation and exercise (43%) were the most selected trip purposes in this study.

Regarding using intermodal transportation, close to 75% of the participants stated that they used only cycling for that particular trip. Of the remaining 25%, 59% combined their cycling trip with public transit, 31% with walking and only 10% used cars in conjunction with cycling. It would be interesting to examine the relationship between the distance from the trip origin to the bike lane and the use of intermodal transportation in future studies.

6. Statistical analysis

Cross-tabulated analysis was conducted on the collected data to identify possible relationships between the variables. The data was analyzed using Statistical Package for Social Science (SPSS). The chi-squared test was used to examine 80 possible correlations between answer choices for each of the variables (see Table 1) as defined in the hypothesis of the study (Fig. 2).

Table 4 shows the summary of a 310-page statistical analysis generated using SPSS. Ten relationships were identified to have

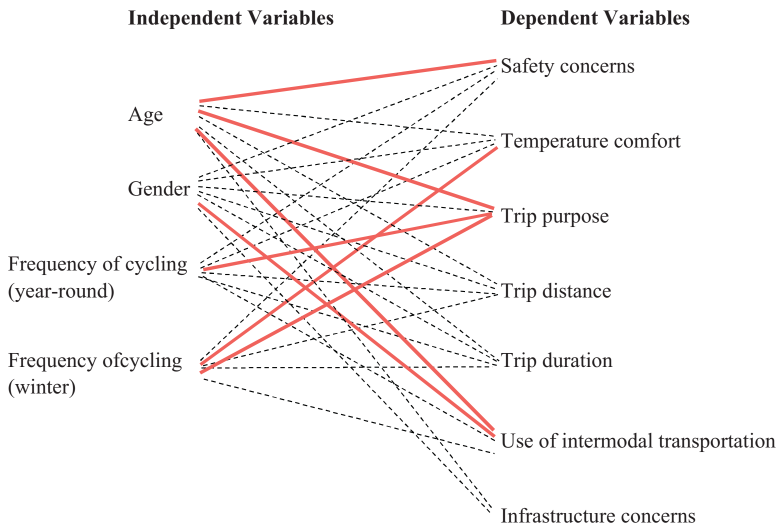

Fig. 3. Results of the statistical analysis.

statistical significance based on the cross-tabulated analysis. The correlation coefficients are indicated under the Asymptotic Significance at the far left column of Table 4. In this study, a relationship between variables was considered to be significant when the correlation coefficient was in the range of 0.00–0.05 (Afifi & Azen, 1979). In order to achieve reliable results in chi-squared test, the sample size must be greater or equal to 5 (Agresti, 1990). Therefore, any apparent significant relationships between the participants with the age group marked as "less than 18" and any dependent variable was disregarded due to the small sample size in this group (four (4) participants). The following section discusses the results with statistical significance.

6.1. Significant relationships for "age"

Age had a significant relationship with safety concerns, trip purpose, and use of intermodal transportation (Table 4a). In terms of safety concerns, apart from the "less than 18 years old" group, a strong majority of the participants in all age groups (83%, 96% and 100%) did *not* consider "cyclists riding too fast/too close" as a safety concern ($p = 0.000$).

"Commuting to work" was the main purpose for the majority in all adult age groups, especially those older than 25 years: 66% for the 18–24 age group, 72% for the 25–34 age group, 86% for the 35–44 age group, and 76% for older than 44 ($p = 0.006$). The highest frequency of the commuters to work belonged to the age group of 35–44. All the four (4) participants of the age group younger than 18 were on their cycling trip for recreational purposes ($p = 0.004$). However, while this seemed a reasonable choice for their age group, as indicated earlier, this group had too small of a sample size to enable any *statistical* confirmations.

Age was also strongly associated with using multiple modes of transportation ($p = 0.045$). About 93% of cyclists with age ranges of 35–44 years stated that they did *not* combine cycling with other modes of transportation on their trip. The percentage of those who did *not* use intermodal transportation when cycling in winter was relatively high among other adult age groups as well: 73% of those older than 44 years, 58% of those in the 25–34 age group, and 66% of those in the 18–24 age group.

6.2. Significant relationships for "gender"

This study found a strong relationship between gender and use of intermodal transportation among the participants (Table 4b). *All* the female participants stated that they combined walking with using their bicycle ($p = 0.043$). While 75% of the male participants indicated that they combined cycling with public transit on their trip ($p = 0.027$).

6.3. Significant relationships for "frequency of cycling"

About 60% of the frequent *winter* cyclists (those who cycled more than 10 times a week in winter) indicated that they cycle regardless of the temperature (Table 4c). Another 33% of frequent *winter* cyclists stated that they felt comfortable cycling in temperatures as cold as $-10\,^{\circ}$C to $-20\,^{\circ}$C. In other words, collectively, about 93% of the frequent winter cyclists felt comfortable cycling in temperatures colder than $-10\,^{\circ}$C ($p = 0.000$).

Trip purpose showed specific patterns in relation to both the "frequency of cycling *year-round*" and "frequency of cycling *in winter*". Near 96% of the participants who said that they were frequent *winter* cyclists used their bicycle for commuting to work ($p = 0.000$). Interestingly, this percentage was slightly lower (84%) among those who identified themselves as frequent *year-round* cyclists ($p = 0.003$) (Table 4d). Nonetheless, among both groups (frequent *winter* cyclists and frequent *year-round* cyclists) the most stated purpose was commuting to work. The majority of the participants (87%) who *did not* identify recreation as their trip purpose were frequent cyclists in *winter* ($p = 0.000$) (Table 4c).

Fig. 3 depicts a summary of the results of the analysis model. The solid lines reflect the hypothesized relationships that were empirically supported by the results of this study. The dashed arrows show those relationships that were hypothesized (see Fig. 2), but were not empirically supported.

7. Concluding remarks

This study provides a baseline for understanding the characteristics of winter cyclists and their motivations and concerns for cycling in cold temperatures. The results of the intercept survey showed that unlike the general perception that cycling is mostly used for recreation and exercise, a large majority of the cyclists in this study (96%) used cycling for commuting to work. An interesting finding in this survey was that most of the participants (71%) indicated that they did not mind cycling in temperatures up to $-20\,^{\circ}$C or colder. Icy roads were identified as the greatest safety concern in winter cycling. Participants' first choice for improving the facility was better snow and gravel removal. Compared to previous studies, gender distribution was more profound among cold-weather cyclists in this study, with male cyclists being 5.5 times more than female cyclists. Another unexpected observation in this study was that one third (1/3rd) of the cyclists in this study were in the oldest age category (older than 44 years).

Cross-tabulated analysis of the variables showed that cyclists from all adult age groups (18 years or older) did not identify "other cyclists riding too fast or too close" a safety concern. The trip purpose for the majority in all adult age groups was commuting to work, with highest percentage in the 35–44 years age group. The majority in all age groups used only cycling (i.e. without combining it with other modes of transportation) in their trips, with the highest majority in the 35–44 years age group. However, gender appeared to have a high impact among those who used inter-modal transportation: all female cyclists in this group combined cycling with walking, while the majority of men in this group (75%) used public transit in conjunction with cycling. The majority of frequent cyclists (both frequent *winter* cyclists and frequent *year-round* cyclists) used cycling for commuting to work. It was expected that frequent *winter* cyclist would feel comfortable with cold temperatures. However, the survey results were interesting as they identified the extent their tolerance for cold weather among this group. More than 90% of the frequent *winter* cyclist indicated that they felt comfortable to cycle in temperatures as cold as −20 °C or colder.

As cycling is emerging as a sustainable mode of transportation to reduce GHG emissions in transportation, it is expected that cities will become more involved in planning for their cycling facilities. The results of this survey can help in planning for future cycling facilities, as well as the improvement of the existing ones in cities which experience cold weather conditions. This study is just an instigation to study cycling characteristics, motivations and concerns in cold weather. Further studies including comparisons with summer surveys are required to provide a better understanding of the impact of cold weather on cycling behavior.

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