Exploring User Perspectives to Increase Winter Bicycling Mode Share in Edmonton, Canada

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ABSTRACT

Over the last decade many municipal governments in the United States and Canada have proactively invested in bicycling infrastructure, ranging from physically separated bikeways to greenways and bike-share programs. Evidence points to gradually increasing bicycle use, though this growth is small in absolute numbers, particularly in winter cities. Two interrelated issues are noteworthy: i) research shows that bicycling rates go down in cold weather, yet little is known about how those who still bicycle adapt to road conditions, and ii) while cities rely on manuals and best practices when creating bicycling policies, there is limited direct evaluation of bicycling infrastructure in severe winters.

Relying on semi-structured interviews with winter cyclists in Edmonton, Canada, this paper investigates riders' adaptation strategies. This study posits that bicycling infrastructure would be better utilized if riders' observations and experiences informed policy, thus increasing the odds of expanding winter cycling to the next most likely group. A methodological contribution of this work is using mapping voice to uncover user preferences.

In Edmonton, winter cyclists use specific corridors, both with and without bike lanes. They ride with traffic on streets or on sidewalks since bike lanes are often covered with snow windrows. Findings suggest that a group of policies including consistent snow clearing, separated bikeways, network connectivity, destination amenities, and public/driver education would make cycling more convenient and safe during the snow season.

These insights have the potential to increase winter bicycling by moving the infrastructure supply paradigm from a best practice to a best fit approach.

Keywords: Active transportation, Best practice, Bicycling, Interviews, Weather, Winter Cities

1. INTRODUCTION: BICYCLING AND WINTER CITIES

Cities in North America are focusing on improving the experience of bicycling through a wide array of investments ranging from physically separated bike paths to shared lanes and greenways (*1*). A general interest and willingness in people to engage in bicycling not just for recreation but also as a commuting mode is evident in the growth of bicycle users in the United States and Canada, though differences are evident (*2*). Growth in bicycle mode share is slow and researchers have shown that municipal policies matter (*3*,*4*,*5*). Some researchers have investigated user preferences with regard to what inhibits or facilitates bicycling behaviour and uptake (*6,7,8*), while others investigate the direct link between infrastructure and stated user preferences (*9,10*). Broadly speaking, lifestyle choices are embedded in complex social and physical systems, so affecting sustainable behaviour change often requires a holistic socio-ecological approach (*11*). Public education programs may have limited efficacy by themselves (*12*), but a concerted set of policies can nudge individuals towards certain behaviours.

Studies on bicycling have looked at many variables ranging from user attributes such as age and health to environmental factors such as topography and weather. Findings show that higher levels of rain and snow, which are common features of winter cities, reduce rates of bicycling (*13,14,15,16,17*). Pressman (*18*) outlines five elements that define a winter city, namely sub-zero temperatures, snow events, short daylight hours, long periods with the first three factors, and seasonal variation. The physiological as well as psychological impacts of severe winter on daily living are significant, including travel mode choice. Yet some individuals are yearlong bicyclists even in severe winter conditions, and their views can reveal information about barriers and facilitators for bicycling under such conditions. Insights from these user voices can either help to modulate existing bicycle-enabling policies or can help formulate concerted polices that support bicycling. This can increase the odds of expanding winter cycling to the next most likely group, opening sustainable transportation and active travel options to more individuals.

Emerging literature on winter bicycling indicates that important advances have come from revealed preference studies (*16,17,19,20,21*). Other insights into user preferences have come from directly surveying bicyclists (*13,14,15,22,23,24*). However, studies that qualitatively investigate user preferences are rare. While Pratte (*25*) looks at how winter cycling was mainstreamed in Oulu, Finland, Spencer et al. (*26*) rely on qualitative data to study how temperature, light conditions, precipitation, wind, and road conditions impact cyclist's decisions in Burlington, Vermont. The primary contribution of this paper is to delve deeper into user preferences and opinions about bicycling infrastructure through in-depth interviews (n = 33), thus unraveling connections between policies and users via emergent themes.

The following research questions inform this investigation: What strategies do bicyclists use to adapt to existing street conditions in long and harsh winters? Which specific policies are indicated from winter bicyclists' insights? This small-budget study focuses only on bicyclists who already ride in winter conditions, and learns from this group's experiences including barriers faced by these users. It is likely that bicyclists who stop riding in the winter may be impacted by other factors such as a limited budget to buy special equipment or safety concerns, and it is also possible that this non-riding group weighs barriers differently. This study leaves the exploration of opinions of comparative groups, such as cyclists who stop riding in the winter and vehicle drivers who interact with winter cyclists, for future research.

Just as the demand side is important, the supply side of bicycling is closely related to mode shares. City engineers and urban planners rely on design standard manuals (*27,28*) and best practices (*29*) when planning bike lanes. Such standards focus principally on design and say less about the management of bicycling infrastructure in locations with severe winters. Moreover, much of the demand data that is the basis for infrastructure supply is collected during the warm months, hence less is known about the impact of winter on infrastructure use. A secondary contribution of this paper is to outline how winter cities approach bicycling. Relying on phone interviews with urban planning experts in winter cities (n = 5), this paper investigates bicycle infrastructure design, planning, and maintenance for winter conditions. The following research question guides this portion of the inquiry: How do winter cities design, manage and evaluate bicycling infrastructure for snow conditions?

This study's findings indicate that winter cyclists can be classified into two groups, savvy cyclists who minimize hazards, obstacles, and risks by riding on sidewalks and other non-traditional bicycling infrastructure, and right-of-way cyclists who ride with traffic. Two-thirds of the sample is savvy cyclists, while a third is right-of-way cyclists. Major barriers to users are snow, unsafe conditions, lack of public awareness, and parked vehicles. Facilitators indicated from the emergent themes point to snow clearance, separated bike paths with network connectivity, public education, destination amenities, and a consensus that sharrows are not useful. Expert interviews suggest that evaluation of bicycling infrastructure during winter months is an important point of discussion among city planners and policy makers.

2. LITERATURE REVIEW

2.1 Factors Affecting Cycling During Winter

Researchers have looked at winter and bicycling with a focus on socio-demographics, trip characteristics, weather conditions, winter maintenance, and safety. There is emergent consensus that as age increases (~ 25 to 65 yrs.) odds of winter cycling increase up to a certain point but then start decreasing, and women bike less than men in winter (*13,14,15,17,23,24*). Winters impact leisure trips more than commute trips, weekend trips more than weekday trips, and longer trips more than shorter trips, especially trips in and around city centers (*13,15,23,24*). Generally, low temperatures, strong winds, and precipitation are all linked to lower bicycling (*13,14,15,16,17,21,23,25,26*). Specifically, precipitation directly impacts bicycling; that is, if it rains in the morning, bicycling rates go down (*16*). A counter-intuitive finding is that low temperatures (~ -10 to -20^{o}C) are not the principal deterrent for winter cyclists (*16,23*). Many researchers find that winter maintenance, particularly the presence of snow on bike lanes, is a serious deterrent to bicycling (*13,22,24,25,26*). Safety concerns, especially potential for collisions with motor vehicles, reduce the willingness to bicycle in the winter (*13,19,22,23,24*). Some scholars highlight that actual paths traversed by winter bicyclists are not studied in any detail (*15,24,30*).

2.2 Design Standards and Maintenance for Winter Conditions

The United States Federal Highway Administration recommends that walking and bicycling should be considered as equals with other transportation modes (*31*). Cities are encouraged to use flexible guidelines when designing transportation facilities for bicycling and walking (*32*). NACTO (*27*) focuses on the design aspects of bicycle infrastructure, and highlights specific interventions that take winter conditions into account such as how sinusoidal edge features and raised cycle tracks (at sidewalk level) might interact with snow removal equipment. NACTO's street guide (*33*) focuses on design features such as surface treatment for shared streets with respect to snow removal and storage.

Regarding winter maintenance, AASHTO (*28*: Section 7.2.11) outlines snow removal and storage techniques intended to minimize the impact of snow events on both cyclists and pedestrians, especially in areas often used by commuters. In reference to pedestrian paths, the Federal Highway Administration (*34*: Sections 3.2.2 and 5.6.3) lists maintenance guidelines similar to AASHTO's but highlights specific case studies. For example, Halifax, Nova Scotia in Canada has adopted performance measures for final pavement conditions and time frames for snow/ice removal, resulting in better performance. The City of Minneapolis' Bicycle Facility Design Guidelines (*29*: Chapter 8) has recommendations for winter maintenance, which include plowing trails, on-street bike lanes, and arterials soon after a snow event. Further recommendations include storing snow away from bike lanes, having property owners shovel around bike racks, defining standards for snow clearance (ice scraping, gravel/sand removal), and banning winter vehicle parking in bike lanes. Still other cities have adopted infrastructure maintenance strategies adapted to the local context. For example, Ottawa's Roads and Cycling Advisory Committee is developing the "White Route" which prioritizes some streets for higher levels of maintenance during the winter (*35*). Similarly, Edmonton completed a winter maintenance survey about the city's performance on a key bike route (*36*).

3. RESEARCH METHODOLOGY

This paper is based on interviews with adult winter bicyclists (18-60 years) and city officials in winter cities with bicycling infrastructure. Since the primary drive for this study was to understand how winter cyclists adapted to severe cold and snow conditions, cyclists were the first interviewees. Participants were recruited through the Facebook page of the Edmonton Bicycle Commuters Society, where sixty members responded to a posted recruitment request. All sixty respondents were contacted by email and thirty-three (n = 33) respondents agreed to an in-depth interview. The sample selection checked against a quota sampling strategy (*37*) to control for age and gender, but had a bias towards winter cyclists given that this group's opinions were indeed the focus of this investigation. This is a statistically non-representative sample of Edmonton's cyclists since the idea is to explore opinions, so the reader should interpret results with caution.

The researchers did not recruit more interviewees since saturation of themes was evident in the first round (*38*). The thirty-three participants were interviewed in person during the winter in March 2015. The semi-structured interview guide had open-ended questions about barriers and facilitators, including policies and infrastructure that could improve winter bicycling. The sample also reported trip frequency, trip purpose, and socio-demographic information. Participants were asked to draw their usual commuting and recreational winter cycling routes on individual street maps of Edmonton, while the researcher took notes on the commentary made during this drawing exercise (FIGURE 1). This "mapping voice" enabled collection of individual stories and experiences at a detailed geography, explaining how cyclists negotiate barriers and facilitators.

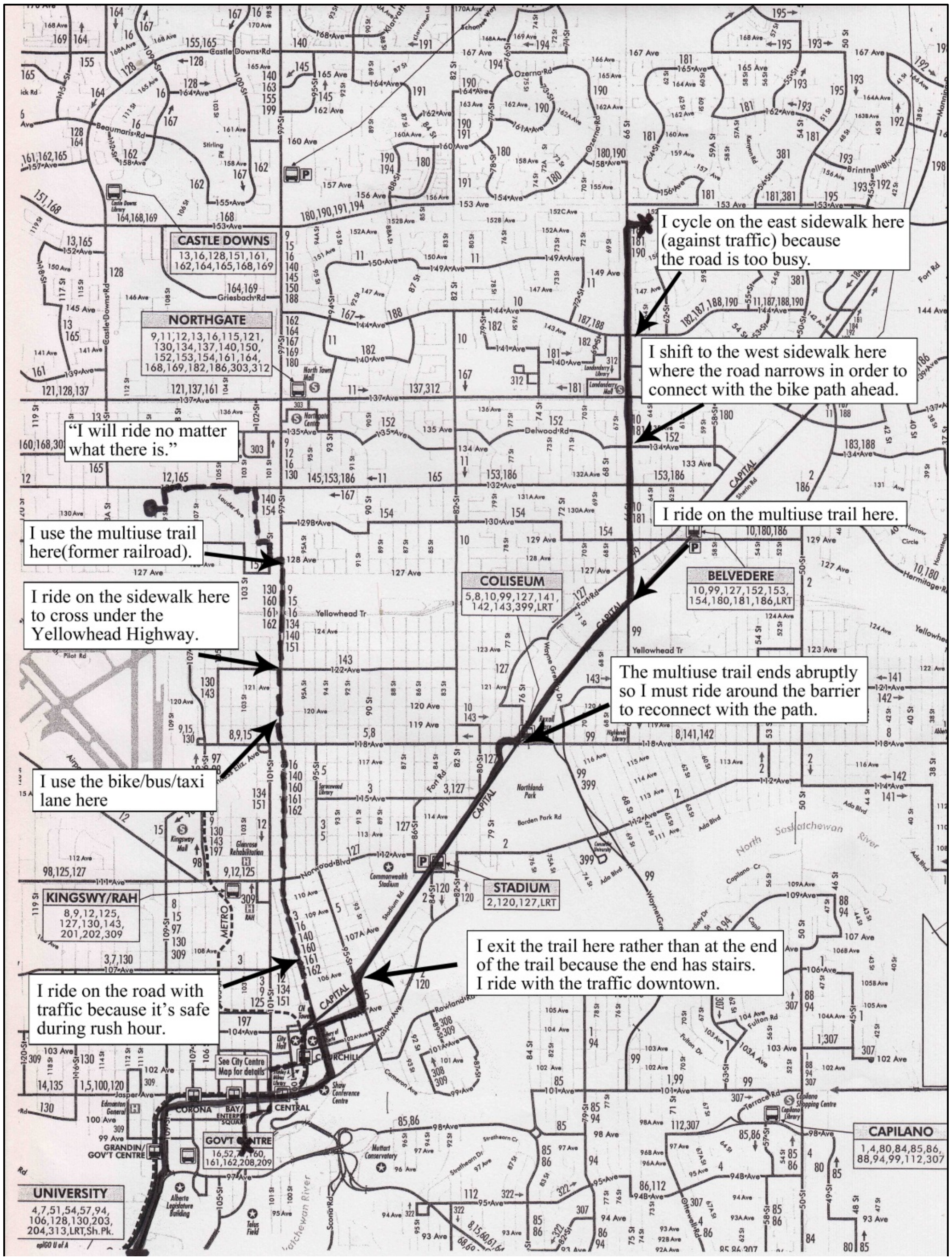

FIGURE 1 Mapping Voice (- - - Male 41-45, — Male 18-25).

The themes that emerged from the interview notes were validated through independent peer review and triangulation (*38*). Peer-review validation was achieved through the researchers independently coming up with themes from the data, and later reconciling minor differences. Triangulation was achieved by reviewing winter cycling academic literature and manuals where many of the same concepts have been discussed. Based on the emergent themes a phone interview guide was developed with questions on design and winter management / maintenance policies. Five (n = 5) experts were identified (see Section 5.1) through Internet research comprising of urban planners and transportation engineers who worked with city governments. They were contacted via email and phone to discuss how they attended to bicycle infrastructure provision and maintenance for winter conditions. Notes were taken during the phone interviews with these experts.

4. FINDINGS FROM EDMONTON'S WINTER BICYCLISTS

4.1 Sample and Reported Travel Characteristics

Of the 33 interviewees, 12% were between 18 and 25 years, 52% were between 26 and 40 years, and 36% were between 41 and 60 years. The 2014 Edmonton Municipal Census (*39*), with roughly equivalent age categories, had 13% between 20 and 24, 41% between 25 and 39, and 46% between 40 and 59 years. There was comparable gender balance, with 45% women and 55% men, while the city census had 49% women and 51% men. In the interviewee sample, 52% had been biking 5 years or less in winter conditions, 21% between 5 and 10 years, and the remaining 27% over 10 years. Most of the respondents (94%) said their trip purpose was either to work or school, with 58% making the trip each weekday and a third making between two and four cycling trips per week. 76% of the sample reported going shopping or performing errands on a bicycle during the winter, and 52% reported doing this one to four times per week. 36% of the sample reported bicycling recreationally during the winter, and 27% said they did this one to three times during a typical week.

There were some differences between men and women winter bicyclists. Men (n = 18) had an average of 7.4 years of winter bicycling experience, while women (n = 15) had 7.1 years of similar experience. The average self-reported age of men was 38.2 and that of women was 37.9 years. 17 men reported commuting to work on bike at least twice in a week, while 13 women confirmed using a bicycle for work commuting in the winter. 11 men and 14 women said they ran errands on bikes in the cold months, while 7 men and 5 women said that they bicycled in the winter for recreation.

4.2 Emergent Themes from Interviews

The interviewees were asked open-ended questions about barriers and facilitators of winter bicycling, and what they would like to have implemented in order to improve their cycling experience during winters. The responses were studied and grouped under seven major themes, namely, adaptation strategies, lack of public awareness / public education, unsafe conditions, cold / snow, design, destination amenities, and laws. TABLE 1 lists key quotes for barriers under each theme; if the interviewees recommended facilitators these are also reported. If multiple interviewees repeated an idea, the responses are only reported once in this table. These open-ended comments from both men and women were comparable across themes.

TABLE 1 User Voices Grouped by Emergent Themes

Adaptation strategies	
Barriers	“ride on sidewalk if paths not cleared”, “bike lanes are often unpassable in the winter, so ride in traffic lanes”, “take a different route in the winter than summer because of conditions”, “ ride some distance to use a good bike path; won’t ride with kids in the winter”, “look for heads in cars in case of opening doors, will swerve around the parked car, look for lights that are on then I know car might move, I watch for turning tires in parking spots”
Facilitators	N/A
Lack of public awareness / Public education	
Barriers	“verbally abused by drivers”, “drivers don’t respect bike lanes”, “people often walk on the bike lane”, “many cars don’t stop at signs”, “cars park in bike lane due to snow banks, mirrors extend into bike lanes”, “buses and taxis are very aggressive in shared lanes”, “lack of awareness of drivers about sharing the road with cyclists”
Facilitators	“education for car drivers about rules of the road and how to share the road with cyclists”
Unsafe conditions	
Barriers	“I will do what I have to do to feel safe”, “will ride on sidewalk if I sense that I’m blocking traffic”, “would sell car if cycling was more safe”, “pot holes which can throw you off and cause you to fall”, “stopped riding this year as traversing the traffic became too dangerous”, “corners are very icy and dangerous”, “parked cars are the worst”
Facilitators	“more information about the technical aspects of winter cycling”, “clear signs about yielding especially at uncontrolled intersections”
Cold / Snow	
Barriers	“cold is not an issue”, “windrows in bike lanes”, “sloppy snow is more dangerous than ice”, “(street / bike lane) would be better used if it was plowed more”, “bike lanes not cleared”, “un-cleared side roads with fresh snow so can’t be used”, “when routes are not plowed, not enough space on road”, “tire ruts are a problem”, “sanding procedures are hard to ride through where dumps of sand create ‘oatmeal’ (salt, sand, snow, ice); does not harden so can be dangerous”
Facilitators	“consistent snow clearing / cleaning / sanding”, “blading on cycle routes which removes the ice”, “have cleared arteries that I can rely on as being relatively cleared and safe”, “more snow clearing on residential streets”, “enforce sidewalk clearing of city owned sidewalks”
Design (Sharrows / Parked vehicles / Separated bike lanes / Network of bike lanes)	
Barriers	“lack of connectivity”, “bike lane abruptly ends”, “sharrows are useless/unrealistic for winter”
Facilitators	“need one meter buffer on the curb side as well as on the car side for safety”, “system of clean, connected bike paths, separate bike lanes”, “more bike infrastructure that makes sense would be positive”, “barriers between parking and bike lane”, “change lane designation in some spots, e.g., designate right lane bike and right turn lane at...”, “an East-West dedicated bike path”, “more signage so motorists know where cyclists are going”, “concrete barrier between cyclists and cars”, “lower speeds for winter months on major arterials with bikes”, “remove parking and have separate divided bike lane”, “make some roads bike corridors”, “... is a pleasant street to ride on with more pedestrians, narrower street and slower traffic”
Destination amenities	
Barriers	“Safety of bicycles at work”, “need more time going to the gym before work”
Facilitators	“better bike racks with more security”, “destination infrastructure (bike racks, lockers, showers)”
Laws (Idaho stop, Riding on sidewalks)	
Barriers	“the rules of the road were not designed for people on bikes so sometimes you have to bend them”
Facilitators	“cycling information in driver training exams”, “changing by-laws for bikes to use Idaho stops”, “advocate for leniency for riding on sidewalks in heavy traffic areas”

Under adaptation strategies for winter cycling, respondents said that they rode on sidewalks and were wary of parked cars. The cyclists reported that sometimes vehicle drivers harassed them, did not obey the traffic rules, and were generally unaware of how to share the road with cyclists. Winter bicyclists often felt unsafe about traffic and icy conditions, but reported that cold was not a primary issue. However, lack of snow clearing and snow storage in bike lanes was a major issue. There were quite a few comments on the attributes of ice, snow, slush and gravel mixing, and suggestions to clear the snow consistently on lanes (/sidewalks), and recommendations to consider key residential through-streets as connecters and clear snow from them. The winter bicyclists had a range of suggestions from a design standpoint, the most repeated one was that sharrows were not useful in the winters, while physically separated bike lanes were most suited. Other design related comments were about lane width, cleanliness, connectivity, and better signage (see TABLE 1). Respondents wanted safe places to lock up their bicycles at work and storage areas with showers. A few cyclists suggested changes in laws specifically to allow Idaho stops at some locations and riding on some sidewalks during the winter. Some cyclists also suggested more information on bicycling in the vehicle driver's license exams.

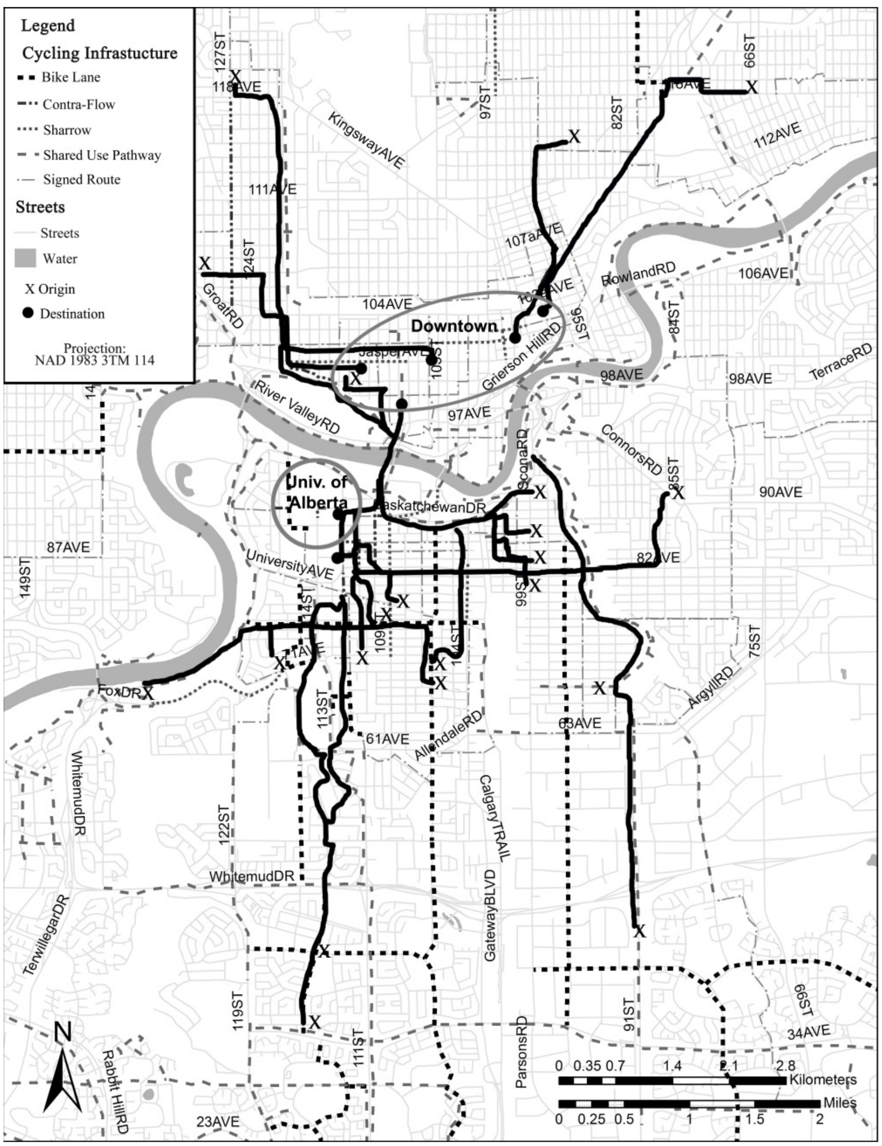

FIGURE 2 Collated Findings from Mapping Voices.

The individual mapping voices (FIGURE 1) were collated into a single image to study the routes generally followed by winter cyclists. FIGURE 2 focuses on where most of the routes were concentrated, showing that among the interview participants' usual trips, most routes ended in the downtown area or at the University of Alberta campus. The route selection suggests that trip length is within the 3-6 kilometer range, and there seems to be a preference for certain streets (or groups of streets), with sharrows remaining unused.

4.3 Bicyclist Typologies: Savvy Cyclists versus Right-of-Way Cyclists

Using the adaptation strategies and mapping voices describing how winter cyclists negotiated the environment, two typologies were discernable, namely savvy cyclists and right-of-way cyclists. *Savvy cyclists* were characterized by their avoidance of streets and cycled mainly on multiuse trails, sidewalks, side streets with minimal traffic, parking lots, and utility roads that were separated from major arterial roads. Safety concerns and snowy conditions were the main factors influencing where these cyclists rode. *Right-of-way cyclists* were characterized by their willingness to ride on roads with high traffic volumes most of the time. The mapping voices indicated that linearity to destinations was the most important factor in determining route choice for this latter group. In the interview sample, two-thirds were savvy cyclists (n = 22) and one-third were right-of-way cyclists (n = 11). Number of years of experience winter cycling did not correspond directly to willingness to cycle on main roads. Some experienced winter cyclists indicated they rode on multiuse trails and sidewalks in the winter because they were wary of the lack of space on the main roads in the winter.

Several savvy cyclists said that ineffective snow clearing left the bike lanes buried, which caused them to seek other options. Members of this group indicated that they specifically looked for sidewalks adjacent to condominiums and apartment buildings in order to take advantage of sidewalks that were cleared more promptly than sidewalks in front of other residences. A synergistic relationship between snow filled streets, decreased road space, and safety issues forced the savvy cyclists to opt for routes that circumvented busier roads. This group employed creative route selection. For example, some would take a route that included a multi-use trail that was regularly cleared, but was not connected onward to an on-street bike lane, rather than using more direct routes on roads with high traffic volumes.

While lack of snow clearing in the bike lane and icy conditions were barriers identified by both groups, potholes, uneven pavement and dumps of sand on the roads were specifically identified as barriers by right-of-way cyclists. Several of these cyclists indicated that they choose to ride on busier streets with more traffic because the side streets with less traffic often had worse pavement conditions. Some made this choice because busy arterials had slow vehicular traffic due to traffic congestion during peak hours. Some of these right-of-way cyclists indicated that they opted to ride as closely as possible to the bike lane and allowed cars to pass them on the left, while others chose to cycle with traffic and occupied a full lane on a two-lane road. Parked cars also impacted how some right-of-way bicyclists rode on streets, with several indicating that they cycled in and out of the bike lanes, if cars were parked on the right side of the bike lane. They reported doing this to avoid drivers coming out of their vehicles or if they saw that a vehicle was pulling out of a parked spot. Many right-of-way cyclists observed that there wasn't enough connectivity to enable using bike lanes on their usual trips.

5. A SURVEY OF WINTER CASE CITIES WITH BICYCLING INFRASTRUCTURE

5.1 Winter Case Cities

After understanding the demand side through winter cyclists' views of barriers and facilitators, a second related facet was to investigate the supply side through interviews with experts in some winter case cities. Following Pucher et al. (*4*) this study identified a cross-section of North American winter cities (TABLE 2). The selection criteria for cities included size, severe winters, and bicycle infrastructure investments. Cities in Canada and the United States included here have different budgets for bicycle-enabling policies and infrastructure. The aim is to explore strategies that winter cities use in different political economies. A future detailed study could compare budgets, policies, and infrastructure supplied. Since the focus was on locations with snow, cities such as Vancouver, Portland, and San Francisco were not included, but cities with winters that were well known for bicycling infrastructure such as Minneapolis were included. Very large cities such as New York were also not considered in this sample of three Canadian and two US cities.

TABLE 2 Bicycling Infrastructure Supply Statistics in Case Cities

	Chicago	Toronto	Calgary	Edmonton	Minneapolis
Population	2,718,782	2,615,060	1,096,833	812,201	400,070
Avg. Annual Snowfall (cm)	96	115	127	121	126
Average Days <= 0^oC (1981-2010)	122	101	194	180	82
On-Street Lanes (excluding sharrows) (km) (a)	269	215	31	41	155
Bike Paths (including cycle tracks) (km) (b)	30	312	803	430	132
Total Paths and Lanes (km) (a + b)	299	527	834	471	287
Bike Paths and Lanes (km) / 100,000 Population	11	20	77	58	72
Bike Parking Spaces	14,650	17,516	> 3,000	665	> 5,000
Bike Parking Spaces / 100,000 Population	539	670	275	82	1,250
Bike Share: # Stations	476	80	N/A	N/A	170
Bike Share: # Bikes	4,760	1,000	N/A	N/A	1,550

Sources: (1) Demographic data from US Census Bureau 2013 estimate and Statistics Canada 2011 national census.
(2) Environmental data from National Oceanic and Atmospheric Administration and Environment Canada.
(3) Infrastructure data from interviews with bicycling experts at each city.

Chicago is the largest city with 2.7 million and Minneapolis is the smallest with 400,000. Average annual snowfall ranges between 96 cm in Chicago to 127 cm in Calgary, while average days with temperatures below 0^oC (32^oF) range between 82 in Minneapolis and 194 days in Calgary (1981-2010 data). Bicycling infrastructure is supplied in various forms in these cities, and reported in TABLE 2 as on-street lanes (excluding sharrows) and bike paths (including cycle tracks). For each 100,000 population, Chicago has 11 km while Calgary has 77 km of bike paths and lanes. Bicycle parking for each 100,000 population ranges from 82 spaces in Edmonton to over 1,250 spaces in Minneapolis. Bike sharing exists in all of these cities except Calgary and Edmonton. Bike station numbers range from 80 in Toronto to 476 in Chicago, while shared bike numbers range from 1,000 in Toronto to 4,760 in Chicago. These statistics suggest that each of these selected winter cities is at a different stage of developing its bicycling infrastructure.

5.2 Findings from Interviews with Experts

One expert from each of these case cities was interviewed by phone using a semi-structured guide which covered questions on specific winter design features such as sinusoidal edges (*27*) and policies such as snow removal from bike lanes (*35*). Another focus was to investigate if concerted winter-centric policies including parking bans and public education were encouraged in the city, and if infrastructure evaluation was a practice, especially for winter conditions.

Manuals/Guidelines: NACTO guidelines were used by all cities in the sample, and most cities also used some version of national and state/provincial guidelines for the design and maintenance of bicycle infrastructure. The US cities relied on AASHTO guidelines whereas the Canadian cities referred to Transportation Association of Canada. Some experts said that the focus was to implement best practices.

Design Features: Minneapolis and Toronto used curved edges, and Toronto had some cycle tracks at sidewalk levels. Cities did consider how traffic-calming features, safety signs, and bollards / flex posts were placed to accommodate snowplow equipment, but also stressed adherence to engineering standards, which often governed placement. Cities did not consider how bike racks were placed in relation to nearest biking street surface. All cities used some form of color treatments and recognized that frequent application was required given winter wear. Destination amenities were considered but not implemented by the municipality, and one planner commented that this was up to building owners to provide. All five experts said that city councils / transportation commissions were aware of the importance of separated bike paths and a connected network for biking.

Snow Clearing Policies: Calgary and Toronto have a by-law requiring removal of snow from bike lanes. In Calgary, cleared snow is stored between the track and sidewalk but often moves to the sidewalk from which it is later removed, while in Toronto it is stored in cycle track buffer zones. None of the cities in this sample have a by-law to remove snow from bike racks. City by-laws for general snow removal require clearing between 13 to 72 hours after a snow event, but the experts were unsure if the by-laws were followed to the letter. Some respondents stated that there is variation in clearing based on the intensity of snow events. Cleared snow from streets is stored in a variety of locations along the right-of-way including gutters, buffers, medians, parking lanes, and in bike lanes. In general, snow is cleared from downtown areas more consistently.

Winter-centric Policies: None of the sampled cities have a parking ban to open up street capacity for bicycling, but some have a parking ban for emergency equipment. Limited resources are spent on educating the public about winter conditions, with some investments being made by Calgary and Toronto to train staff under the CanBike program. Most cities have some version of a Snow Angels program, and do encourage citizens to remove snow from their sidewalks. Chicago has a Winter Wonder Award for businesses who keep their sidewalks clear of snow. Except for Minneapolis, none of the cities have a partnership initiative with businesses to encourage snow removal or to monitor actual conditions. All cities had some version of a policy in place to evaluate bicycling infrastructure through counts, repair audits, random phone surveys, and monitoring of crash data from police records. However, none had a consistent evaluation policy that was geared to winter conditions.

6. DISCUSSION AND CONCLUSIONS

6.1 Lessons Learned

Based on emergent themes and mapping voices, two-thirds (67%) of the winter cyclists interviewed were savvy cyclists i.e., were wary of traffic, felt unsafe, and had various adaptation strategies to circumvent these barriers. Many (41%) of these savvy cyclists had been cycling in winter conditions in Edmonton for 10 years or more. In contrast, 55% of the right-of-way cyclists had 5 years or less experience bicycling in Edmonton winters. This suggests that winter bicyclists might begin with the best of intentions by using street space, but learn over time that unsafe street conditions can be avoided by riding on sidewalks or using alternative routes. If congruent policies are to be implemented so that savvy cyclists shift to more law-abiding cycling practices, then a framework is needed to organize barriers and facilitators.

TABLE 3 is a two-part matrix that segments emergent themes into barriers or facilitators. The rows represent low, medium, or high barriers and facilitators, while the columns show how the level of barriers and facilitators *impacts* the savvy or right-of-way cyclist. For example, “unsafe conditions” is a high barrier with medium impact for savvy cyclists who avoid vehicular traffic when possible, but it is a high barrier with high impact for right-of-way cyclists who ride with traffic most of the time. The classification of barriers and facilitators as low, medium, or high is based on an understanding of how often the sample repeated the idea. For example, snow clearing, as a facilitator, is a high priority for both groups and will have a high positive impact on winter cycling. However, sharrows are a low facilitator for both groups and have a low impact on winter savvy cyclists who don’t bike on the street, but a medium impact on right-of-way cyclists who do bike on streets.

TABLE 3 Emergent Themes: Impact of Barriers and Facilitators on Winter Cycling

		Impact on Winter Cycling					
		Savvy Cyclists (67%)			**Right-of-way Cyclists (33%)**		
		Low	*Medium*	*High*	*Low*	*Medium*	*High*
Barriers	*High*		Unsafe conditions	Snow		Snow	Unsafe conditions
	Medium	Parked vehicles	Lack of public awareness				Lack of public awareness , Parked vehicles
	Low		Cold			Cold	
		Low	*Medium*	*High*	*Low*	*Medium*	*High*
Facilitators	*High*		Separated bike lanes	Snow clearing		Separated bike lanes	Snow clearing
	Medium	Network of bike lanes	Public education, Idaho stop			Network of bike lanes	Public education, Idaho stop
	Low	Sharrows	Destination amenities			Sharrows, Destination amenities	

To validate this analytical framework, the authors populated the grid independently and then compared notes to reconcile minor differences. Moreover, these themes are consistently reported in much of the literature on winter cities and bicycling (Section 2.1). Another way of organizing the facilitators that the researchers employ is to think of the limited budget allocated for non-motorized transportation infrastructure in most jurisdictions, and list themes that were most demanded by winter cyclists as high facilitators. Thus, for example, separated bike lanes are a high facilitator but destination amenities are a low facilitator.

This framework offers a way to generalize from the specific findings of the interviewee sample in Edmonton. Other researchers can use this as a tool to organize emergent themes in various locations, not just limited to winter cities. Further, a group of mutually reinforcing policies can be conceptualized by using this framework. For example, public education coupled with snow clearing can be effective in the short to medium term, but investments in a network of separated bike lanes might be considered for the long term. In Edmonton, the Bicycle Transportation Plan (*40*) can benefit from this investigation.

The interviews with experts in winter cities suggest that most cities take winter conditions into account when designing some aspects of their infrastructure. However, on balance, policy makers remain hesitant to invest public dollars in more bike paths, cycle tracks, and in better connectivity. Most cities also do not have dedicated by-laws or resources to keep bicycling infrastructure consistently clear of snow and ice. The interviews suggest that cities have not developed concerted policies that might achieve efficiencies at lower costs such as educating the public and getting local communities involved in the effort to monitor pavement conditions. Evaluation of the existing infrastructure was a standard policy in the case cities; however, this was only for warm weather conditions.

6.2 Conclusions

The responses from winter cyclists, i.e., riders who have overcome the challenges of winter, suggest that most if not all barriers can be overcome through pro-cycling policies and appropriate infrastructure supply. For this group, and for others in the next most-likely group, it is possible that weather is not a serious barrier, as is often assumed. This investigation suggests that a significant increase in winter cycling could be possible through supplying a network of separated bike lanes that are regularly plowed in the winter. A secondary supporting framework of policies including lower speeds on routes which share the right-of-way with cyclists, public education campaigns, and seasonal policies such as parking bans on key routes to create storage space for snow windrows may help nudge more users to bicycling in the winter.

The insights, knowledge and expertise unearthed through interviews with winter cyclists, indicate that users can help improve bicycle infrastructure and management policies as cities increase investments in bike-friendly infrastructure. The findings suggest that infrastructure designed for summer use, such as painted bike lanes and sharrows, is not effectively operational during the winter months. The evidence from the interviews implies that if winter cities are to expand bicycling to the next most likely group during the cold season, bicycling infrastructure needs to be planned and implemented to be operational all year round.

While best practices offer general design guidance, the data that emerged from this study indicate that operational infrastructure design requires the incorporation of local knowledge as well as best practices. Indeed, local knowledge may even supersede best practices since the inherent generality of best practices may render them rigid and inflexible in some cases. The "mapping voice" methodology used in this study presents a simple but effective mechanism to uncover this knowledge. The framework presented in TABLE 3 is a tool to organize themes of barriers and facilitators, and incorporate ideas that might further inform best practices, thus helping to modulate existing policies surrounding bike-friendly infrastructure.

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