Evaluating the Need for Secured Bicycle Parking Across Cyclist Typologies

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Abstract

Concerns about bicycle theft can act as a barrier to cycling uptake. A promising solution to prevent theft is secured bicycle parking, which offers more protection than regular on-street bicycle racks through secured access, or the presence of an attendant. As cities begin to invest in this infrastructure, practitioners must make difficult decisions about which types of facilities to install, where to install them, and how much to charge for their use. Therefore, this study draws on a large-scale cycling survey (n = 1,806) distributed in Montréal, Canada to explore how secured bicycle parking needs vary across different cyclist typologies. To do so, factor-cluster analysis was conducted to generate cyclist typologies. Then the behaviors and secured bicycle parking needs of these different cyclists were established. Four distinct cyclist types emerged: Leisure Cyclists, Summer Cyclists, Occasional Cyclists, and Dedicated Cyclists. Dedicated cyclists were most interested in secured bicycle parking, while occasional cyclists were the least. Leisure cyclists, on the other hand, are willing to pay and walk the most for secured bicycle parking. Across typologies, the top three most important characteristics of secured bicycle parking are (1) being free or low cost, (2) having secured access, and (3) being close to their destination. Respondents are most interested in secured bicycle parking near their work and metro stations. The results from this study can inform practitioners and researchers about the secured bicycle parking needs of different types of cyclists, and in doing so help in the planning for such facilities.

Keywords: Bicycle; Theft; Secured Bicycle Parking; Cyclist Typologies; Factor-Cluster Analysis

Introduction

Climate change, population health concerns, and congestion problems have made cycling an increasingly popular mode of travel in many places. Indeed, participation in urban cycling is on the rise in many cities, including Montréal, Canada, the setting of this study (*1*). In the past year alone, the COVID-19 pandemic has accelerated this increased bicycle use, a trend researchers hope will continue (*2*). To capitalize on the current bicycle boom generated by COVID-19, cities should adapt to meet cyclists' needs. One such need is bicycle parking, an integral component of cycling infrastructure.

Though research on cycling infrastructure has grown exponentially in recent years, few studies consider bicycle parking (*3*). This research gap is significant because bicycle parking supply and quality are a determinant of bicycle use amongst both current and potential cyclists (*4*). Bicycle theft is also a common issue in many urban centers, in fact, in a study set in Montréal, half of the survey respondents had had their bicycle stolen at least once in the past (*5*). Of the many different types of policies and infrastructure that may help prevent bicycle theft, this paper focuses on secured bicycle parking. There is no standard definition of what secured bicycle parking is, however, bicycle parking that is considered secured generally includes a few common elements. First, unlike regular on-street bicycle racks, secured bicycle parking offers more protection from theft, vandalism, and the weather by being in a partially or fully enclosed area (*6*). Second, while on-street bicycle racks tend to be free of cost, secured bicycle parking generally charges a fee for usage (e.g., pay per use or long-term rentals), but is exclusively used by the paying cyclist (*6*). Finally, while on-street parking relies on "eyes on the street" surveillance, secured bicycle parking includes often additional supervision such as cameras or even security guards (5).

How best to install this new infrastructure is not yet clear. There are many ways one can design secured bicycle parking, and different cyclists likely have different parking needs. Given this, the objective of this paper is to analyze users' preferences relating to secured bicycle parking. Specifically, in this study we evaluate across different cyclist typologies: (1) the need for secured bicycle parking (overall and at different locations), (2) the importance of the many potential secured bicycle parking characteristics, and (3) how far people are willing to walk and the amount they are willing to pay for secured bicycle parking. To do so, a survey assessing the travel choices and preferences of cyclists in Montréal is analyzed. A factor-cluster analysis is conducted to create a typology of cyclists. Then, the secured bicycle parking preferences of respondents are analyzed across the different types of cyclists. To conclude, we elaborate recommendations on what type of secured bicycle parking should be implemented, and with what elements, depending on user needs.

Literature Review

Little research directly examines bicycle parking. However, parking has emerged as a factor that influences cycling in past research investigating motivators and deterrents to cycling. For instance, in a Vancouver-based study, 15 factors that could influence cycling habits were identified, including bicycle parking (*7*). Although availability of bicycle parking was found to have only a moderate impact on likelihood of cycling, it was still found as a motivator when bicycle parking infrastructure were available at destinations. Furthermore, fear of bicycle theft was found to be a significant deterrent to cycling, both in this study, and in many others (*4; 8-10*). For instance, a study conducted in Denver, Colorado found that concern about security and comfort, which included "fear of bike theft", lowered the odds ratio of commuting by bicycle by

0.37 (*10*). Research in Montréal has also found that concerns about bicycle theft is a motivator to use bike-share programs (*9*). In another study, students who fear bicycle theft were found to cycle less than students who do not (*11*). Even in places where cycling is a main mode of transport, concerns about bicycle theft persist. For instance, the lack of bicycle racks can result in cyclists parking their bicycles on street furniture or other alternatives to bicycle racks, which makes bicycle theft much more likely (*12*). Taken together, bicycle parking has been established as a determinant of bicycle use in several studies. This finding motivates the following research.

Research examining bicycle parking directly has found that not all bicycle parking is equal: their design characteristics affect their use. For instance, a Danish study found that different types of bicycle parking may impact cycling behavior. For instance, the chance of cycling from transit stations was almost three times greater when covered bicycle racks (which protect bicycles of theft and weather damage) were present (*13*). This may be due to the higher protection provided by secured parking. Indeed, van Lierop, Grimsrud and El-Geneidy (*5)* found that secured bicycle lockers were ranked highest for bicycle security. This research also found that people with more expensive bicycles ($500 or more) are willing to pay more for secured bicycle parking. Amongst the general population of cyclists, van Lierop, Lee and El-Geneidy (*14)* found the highest daily amount people are willing to pay for secured bicycle parking is $15.00. However, 43% were willing to pay at least $0.50/day. On the other hand, other research has found that charging for parking facilities can reduce the chances of them being used (*9*). In one study, cyclists were more inclined to park their bicycles at higher quality (e.g., sheltered and secure) bicycle parking than parking of lower quality, however, charging for parking also reduced the likelihood of using a facility (*4*). Further, a Dutch study found that cyclists were more satisfied with their bicycle

parking when it was free than when it was paid (*12*). Given that quality and cost seem to be important factors in bicycle parking design, this paper considers users' preferences when it comes to various design characteristics.

Finally, a review of bicycle parking argues that it is necessary to consider who is parking their bicycle, the bicycle itself, as well as where, when, and for how long they are parking before implanting new bicycle parking infrastructure (*15*). Theoretically, one might anticipate that people are less concerned about safely locking their bicycles when they make a quick errand than when they park their bicycle at home overnight. It is also possible that different types of cyclists have different parking needs, as previous research has found that different types of cyclists have different infrastructural preferences. This body of work examines how cyclists can be categorized into different types of groups based on several factors, such as enthusiasm for cycling, fear of cycling, and different needs of different cyclists. In 2006, Geller (*16)* developed a seminal cyclist typology which categorized cyclists as either the Strong and Fearless, Enthused and the Confident, Interested but Concerned, or No Way No How. Dill and McNeil (*17)* put this theory to the test by examining whether Geller's four types of cyclists were represented in a large survey conducted in Portland, Oregon, and found that almost all responses fit into one of the categories, bolstering Geller's claim. Examining whether cyclists fit into this typology has also been done at a national scale in the US, with results again supporting Geller's typologies (*18*). Other research has utilized more inductive and data-driven approaches to categorize cyclists. For instance, Damant-Sirois, Grimsrud and El-Geneidy (*19)* examined 2,004 survey responses about cycling in Montréal to classify cyclists through factor-cluster analysis. This resulted in four new, distinct typologies: Dedicated Cyclists, Path-Using Cyclists, Fairweather Utilitarians, and

Leisure Cyclists. Francke et al. (*20)* also used this type of analysis in Germany and found four other groups of cyclists: Ambitious, Functional, Pragmatic, and Passionate. While Geller's (*16*) groups mostly differ in terms of levels of fear of cycling, Damant-Sirois, Grimsrud and El-Geneidy (*19)*'s typology highlights how distinct policies impact cycling behaviors differently across types of cyclists. Francke et al.'s (*20*) groups, on the other hand, looked more at how cyclists could be grouped together based on their identity or purpose. Egan, Mark Dowling and Caulfield (*21)*'s recent study is the only one to date to center parking in their development of a cyclist typology. Specifically, they identify five clusters (informal parking, open parking, any parking, accessible parking, and secure parking), each with their own demographic, cycle behavior, and parking perceptions profiles – all of which have unique bicycle planning solutions. We add to this recent paper by focusing on how different typologies engage with secured bicycle parking. To do so, this study builds on the inductive conceptual approach to cyclist typologies by exploring whether secure bicycle parking preferences vary across different types of cyclists.

Data and Methodology

A bilingual (French and English) cycling survey was developed in collaboration with the Agence de Mobilité Durable of Montreal and following the recruitment approach recommended by Dillman (*22*) for online surveys. Participants were recruited through multiple avenues, including a mailing list of 3,000 cyclists who had completed cycling surveys for the Transportation Research at McGill (TRAM) research group in the past, and via paid and unpaid advertisements on Facebook, LinkedIn, and Twitter. The survey was active between June 17th and July 11th, 2021.

The survey consisted of 95 closed questions and five open-ended questions soliciting comments on cycling in Montreal. These questions were organized into six sections: general information, cycling behaviour before and during COVID-19, bicycle ownership and theft, bicycle parking, dangerous areas for cyclists, and personal profile. In the section on bicycle parking, special consideration was given to parking needs specific to secured bicycle parking (including locations where this infrastructure is needed, willingness to pay, and distance willing to walk). Both non-cyclists and cyclists were invited to complete the survey. However, non-cyclists only responded to socioeconomic characteristics and reasons for not cycling questions.

A total of 1,806 complete responses were collected. Responses that were not logical (e.g., if the person indicated they completed more trips by bicycle than total trips (all modes) to a specific destination earlier in the survey) were removed for unreliability. Non-cyclists' responses were omitted from this analysis. The final sample size used in this analysis is 1,408 respondents. The socio-economic characteristics of the sample can be found in Table 2.

An exploratory factor analysis is then used to identify groups of related responses to certain cycling attitudes or preferences. This approach offers a reduction in the number of questions and helps in interpreting patterns that can be seen among survey respondents, rather than evaluating the results of each question in isolation. The latent factors that were used for the analysis were inspired by past research on cyclist typologies (*19*) and built using variables from questions of the survey. Multiple variables from the survey were tested to find meaningful latent factors. Only the variables, that helped explain the factors and that allowed the creation of groups with high intra-cluster differences and low inter-cluster differences were kept. Factor extraction was completed in SPSS Version 24, using an Unweighted Least Squares method with an oblique rotation (Normalized Promax) to accommodate ordinal data and allow for some correlation

among factors (*23*). The scree plot was observed and only factors with eigen values above one were included in the final factor. The factors are then used to identify types of cyclists through a k-means cluster test. This approach is common in the transport research realm and has been used in the past to identify types of cyclists (*19*).

Once the cyclist typologies were generated, an analysis of these cyclists' behaviors, and secured bicycle parking needs was conducted. The cyclist behaviors were drawn from the survey, where cyclists were asked how many bicycle trips they made in the previous week. With this information an average number of weekly bicycle trips per group was calculated. We were also able to determine the proportion of those trips that were for utilitarian purposes (i.e., going to work, shopping, etc.) and for recreational purposes (i.e., bicycle ride in a scenic area). Respondents were also asked how many bicycles they personally own, the value of the bicycle they use most frequently for utilitarian purposes, and if they have ever had a bicycle stolen. Summary statistics for these behaviors were generated across all typologies.

In the Bicycle Parking section of the survey, respondents were asked to share their opinions on secured bicycle parking. Specifically, they were shown pictures of secured bicycle parking that emphasized the different designs that exist. Then they were asked whether they would like to see secured bicycle parking in Montréal. Then, they were asked how important they think it is to have secured bicycle parking next to key locations, namely at metro (subway) stations, train stations, their home, and their work location. If they indicated that the presence of secured bicycle parking was important at a location, they were also asked to rank the following eight aspects of secured bicycle parking from most to least important: being free or low cost, weather protection, secured access, proximity to the location, how long the bicycle is parked, attendance, individual locker, and inside a building. Finally, respondents were asked to enter the

maximum amount they would be willing to pay per day for secured bicycle parking and how long (in minutes) they would be willing to walk from the bicycle parking to their destination. As was the case for questions on cycling behavior, summary statistics for these secured bicycle parking responses were generated across the cyclist typologies.

Results

Survey questions about cycling behavior, preferences, and deterrents were used to cluster the respondents into four types of cyclists. Following Dent et al. (*23)*, a rotational matrix was created to see significant correlation coefficients. Five factors were obtained by grouping variables based on their level of correlation; in this case the 5 factors are: efficiency, weather, identity, health, and effort (Table 1).

The first factor, efficiency, groups variables on speed, predictability, and flexibility. The second factor, weather, combines weather-related variables including cycling in the snow, cold, and rain (*24*). The identity factor includes two variables, the perception of cycling being fun and cycling as part of self-identity/culture. The health factor has only one variable, "I cycle for health reasons". Finally, the effort factor examined the combined impact of trip distance and steepness of the ride on cycling.

Table 1 - Factors, variables and loadings used for the cluster analysis

Factors	Variables		Loadings
Efficiency	I cycle because	It is the fastest way to get from point A to point B	0.695
		Of the predictability of the travel time	0.735
		Of the flexibility for multiple trips	0.802

		Of the flexibility of the departure time	0.864
Weather	I cycle when	It's raining	0.505
		It snows	0.842
		It's cold	0.854
Identity	Cycling	Is part of my identity/culture	0.530
		Is fun	0.831
Health	I cycle	For health reasons	0.997
Effort	I cycle	When my destination is far	0.497
		When the route is steep	0.732

Cyclist Typologies

Four cyclist typologies emerged from the data: Leisure Cyclists, Summer Cyclists, Occasional Cyclists, and Dedicated Cyclists (Figure 1).

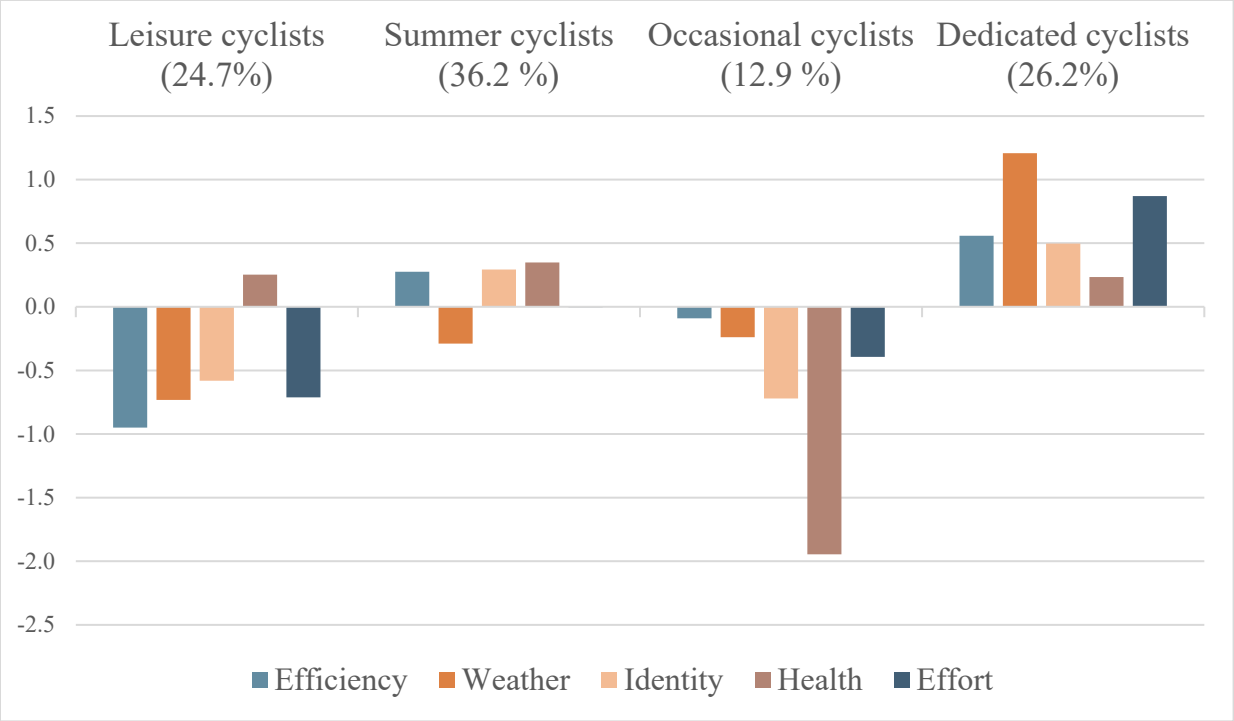

Figure 1 - Types of cyclists identified by factor analysis

Leisure Cyclists comprised 24.7% of the sample. These cyclists do not bicycle because they find it efficient, rather they tend to cycle for pleasure, as a hobby, or as a family activity. One of the main motivators for cycling is its health benefits. They do not cycle in bad weather, and they rarely cycle for utilitarian purposes. According to Table 2, Leisure Cyclists have the highest average household income: $95,000 per year which is $5,000 more to the average of all groups. They are also the oldest group with an average age of 47 years and have the highest proportion of retired respondents (13%). Finally, these cyclists have the highest proportion of respondents who have a driver's license and the lowest average household size (2.38 pers/household).

Summer Cyclists (36.2% of the sample), on the other hand, only cycle in good weather. They do not cycle when it rains or snows or when the weather gets too cold. Cycling, however, is important to them and is a part of their identity. Efficiency and health benefits of cycling also encourage them to use their bicycle for both utilitarian and recreational purposes. The demographic analysis in Table 2 shows that 82% of Summer Cyclists are employed (full time and part time) and their household income is close to that of all groups combined ($91,500). Their average age is 45 years old and most (91.1%) have a driver's license.

Occasional Cyclists were the least common cyclist typology: they make up 12.9% of the sample. These cyclists only cycle when the conditions are right (efficiency, weather, etc.). For instance, they only cycle if the weather is good, if the route is not too steep, and if the destination is not too far. Cycling is not part of their identity and they do not cycle for health reasons. The Occasional Cyclists group has the youngest mean age (39 years old), the lowest household income (on average $79,750 per year), and the lowest driver's license-ship rates. Factors that could explain this are the high proportion of students in the group (17%) and the low proportion of full time employed respondents (61%).

The final cyclist typology is the Dedicated Cyclists (26.2% of the sample). As their name suggests, their decision to cycle does not depend on the weather or the effort that is required for the trip. These cyclists will use their bicycle to reach their destination under all circumstances, even in bad weather (snow, rain or cold) or if the ride is long and steep. One of the main reasons why they cycle is for efficiency. Speed, predictability, and flexibility motivate these cyclists. In addition, health benefits also influence them. Finally, cycling is part of their identity, and they consider it fun. Though men were more present in all cyclist typologies, the gender gap was greatest amongst Dedicated Cyclists where 62.1% of the group identified as male. This group is also characterized by the highest percentage of employed respondents (84%). These cyclists have the largest households' size with an average of 2.69 persons and an average household income of around $91,500.

The characteristic of our sample is comparable to the general cycling population in Montréal when compared to the cyclists in the Montréal 2018 Origin Destination (OD) survey (*25*) (Table 2). The OD is conducted every five years and collects travel behaviour information from 5% of the residents in the Montréal metropolitan region. Our sample has a higher representation of women (40% compared to 35.6% in the OD). The average age of our sample is 44 years old while the average age of cyclists in the OD was 42 years old. On average, our sample has smaller household size (2.40 persons) compared to the OD (2.65 persons). As for income, we could only compare the average income as we used different income brackets in our survey than the ones collected from the OD. Respondent to our survey had an average household income of $90,908 compared to $90,343 in the OD.

It is important to note that we expect that our survey has a higher representation of dedicated cyclists. The survey was conducted with no incentives and the messaging used in the recruitment

concentrated on requesting help to shape the cycling system in Montréal. Such messaging is expected to attract more dedicated and regular cyclists than occasional and recreational ones, which can explain to some extent the differences noticed between our survey respondents and the OD. Despite this high representation of enthusiastic cyclists, we expect the findings to be of value to transport professionals trying to understand the different needs of the distinct groups of cyclists that are present in their region, though perhaps at different ratios.

Table 2 - Demographic Characteristics of respondents by typology compared to cyclists from the Origin-Destination survey of Montréal

	All respondents (n=1408)	Leisure cyclists (n=348; 24.7%)	Summer cyclists (n=510; 36.2%)	Occasional cyclists (n=181; 12.9%)	Dedicated cyclists (n=369; 26.2%)	OD 2018 cyclists
Gender						
Female	40,0%	40.5%	43.1%	42.0%	34.1%	35.6%
Male	56,3%	56.3%	54.5%	53.0%	62.1%	64.4%
Other	3,3%	3.2%	2.4%	5.0%	3.8%	-
Age						
Average	44	47	45	39	42	42
18-30	13%	10%	11%	22%	15%	25%
31-40	30%	25%	31%	33%	30%	26%
41-50	25%	23%	25%	20%	28%	22%
51-60	18%	21%	18%	13%	18%	17%
61 and more	14%	21%	15%	11%	9%	11%
Driver's license						
% of people with driver's license	87.5 %	91.1 %	86.9 %	82.3 %	87.5 %	85.40%
Household size						
Average	2.49	2.39	2.43	2.47	2.69	2.65
1	23.4%	25.6%	24.7%	24.3%	19.2%	23%
2	37.6%	38.8%	38.4%	40.3%	34.1%	31%
3	16.3%	17.2%	14.9%	13.8%	18.4%	17%
4	16.0%	11.5%	16.5%	16.0%	19.5%	20%
5 +	6.7%	6.9%	5.5%	5.5%	8.7%	9%
Household income *						
Average	$ 90,908.37	$ 95,646.26	$ 91,434.78	$ 79,753.09	$ 91,415.93	$ 90,343.63
< 20 000 $	6%	4%	6%	9%	7%	-
20 001 $ – 40 000 $	11%	11%	9%	12%	11%	-
41 000 $ - 60 000 $	12%	12%	13%	17%	9%	-
60 001 $ - 80 000 $	12%	10%	13%	14%	13%	-
80 001 $ - 100 000 $	15%	14%	16%	15%	15%	-
100 000 $ - 120 000 $	11%	12%	10%	11%	12%	-

120 001 $ - 150 000 $	11%	12%	10%	8%	12%	-
150 000 $ >	22%	26%	23%	14%	21%	-
Occupation◊						
Employed Full Time	69%	69%	71%	61%	72%	66%
Employed Part time	11%	7%	11%	16%	12%	8%
Student	13%	10%	12%	17%	14%	12%
Retired	8%	13%	7%	8%	4%	8%
Unemployed	3%	4%	2%	5%	4%	4%
At home	0%	0%	0%	1%	1%	2%

*not comparable with OD due to different brackets of incomes

◊ totals can exceed 100% because respondents were able to select multiple occupations (ex: student and employed part time)

Cyclist Behaviour and Secured Bicycle Parking Needs

As shown in Table 3 the four cyclist typologies were found to exhibit different cycling behaviour. Dedicated Cyclists make the most bicycle trips per week (9.6 on average) and most of their trips are for utilitarian purposes (7.5 trips out of the 9.6). This means that only 21% of their weekly trips are for leisure. Cycling is their main mode of transport, in fact 90% of their work trips and 65% of their shopping trips are made by bicycle, the highest percentages out of all groups. On average, they own 2.3 bicycles per person, the highest bicycle ownership out of all the other groups. Just over half of these cyclists (54%) have already had their bicycle stolen in Montréal. The bicycles they use for utilitarian purposes are on average worth $1,026, the highest average value out of all the groups.

Leisure Cyclists make the least bicycle trips for both utilitarian (3.2 trips/ week) and all purposes (4.9 trips/week). Instead, they make the highest proportion of leisure rides. In fact, 34% of their total bicycle trips are for recreational purposes. They are the cyclists with the lowest ratio of trips made by bicycle, only 35% of their shopping trips and 52% of their work trips are made with this mode. Leisure Cyclists also owned the lowest number of bicycles on average (1.5 bicycles/ person - something they shared with Occasional Cyclists) and have had their bicycles stolen less frequently than all other typologies (41%).

Occasional Cyclists own the least valuable bicycles ($772 average), and yet almost half (47%) have had their bicycle stolen at least once in Montréal. As stated previously, they also own less bicycles on average than other typologies (along with Leisure Cyclists). On average, they make 5.56 bicycle trips per week: 76% of which are for utilitarian purposes, and 24% of which are for leisure trips. Their percentages of trips made by bicycle are lower than the average of all respondents, 69% and 45% of their work and shopping trips are respectively made by bicycle. Though this may seem like frequent cycling behavior when compared to the general population, when compared to that of the other clusters, this group deserves their 'occasional' label. It is important to note that the survey was conducted in the summer during the peak of the cycling season, which can explain the levels of frequency of cycling among all identified groups. Summer Cyclists make almost 8 bicycle trips per week, 73% of which are for utilitarian purposes. About half (53%) of their shopping trips and almost three fourths (73%) of their work trips are made by bicycle. Their bicycles are worth, on average, approximately $850 and they own, again on average, 1.68 bicycles per cyclist. Just under half (48%) have had their bicycle stolen at least once in Montréal.

Table 3 – Cycling information by cyclist typology

	All respondents (100%)	Leisure cyclists (24.7%)	Summer cyclists (36.2%)	Occasional cyclists (12.9%)	Dedicated cyclists (26.2%)
Average total number of bicycle trips for utilitarian purposes last week	5.3	3.2	5.6	4.2	7.5
Average total number of bicycle trips last week	7.2	4.9	7.7	5.6	9.6
Average percentage of work trips made by bicycle last week	74%	52%	73%	69%	90%
Average percentage of shopping trips made by bicycle last week	51%	35%	54%	45%	65%
Average percentage of leisure trips made by bicycle last week	26%	34%	27%	24%	21%
Average bicycle ownership	1.8	1.5	1.7	1.5	2.3

Average value of utilitarian bicycle	$889	$842	$847	$772	$1,026
Percentage of people have had their bicycle stolen in Montréal	47%	41%	48%	47%	54%

Table 4 shows that the four cyclist typologies stated that bicycle parking is more important near work and metro stations than home and train stations. With regards to secured bicycle parking needs, the five most important characteristics were found to be the same across all cyclist typologies and all locations. These five characteristics are: being free, having a secured access, being close to the location, weather protection and the duration the bicycle will be parked. Interestingly, proximity was even more important for secured bicycle parking near the home and work than at public transport destinations (i.e., train and metro stations) where secured access was considered more important.

The top three characteristics of secured bicycle parking are shared across the typologies (being free (or low cost), having secured access, and being close to the final destination), however, the other two factors' importance varied across cyclist typology. This was also the case for the overall need for secured bicycle parking and the locations at which this infrastructure was needed.

Dedicated Cyclists desire secured bicycle parking the most (40% of the sample). Just like the other groups, around 70% of dedicated cyclists think it important to install secured bicycle parking next to metro stations and work locations. The majority, however, do not find it important to have secured bicycle parking next to their home or train stations. For Leisure Cyclists, who used their bicycle for utilitarian purposes at a lower rate compared to all other groups, having secured bicycle parking next to metro stations and work locations is important. Occasional Cyclists care the least about secured bicycle parking (25% of the sample). However, this group comprised the highest proportion (48.6%) of respondents who thought it would be

important to have secured bicycle parking near their home. Because these cyclists do not cycle as often as the other groups, perhaps this finding is because they park their bicycles for longer duration between infrequent trips. Finally, Summer Cyclists think that it is more important to have secured bicycle parking next to metro stations and work locations than next to train stations and their homes.

Table 4 - Opinions on Secured Bicycle Parking by cyclists' typologies

	All respondents (100%)	Leisure cyclists (24.7%)	Summer cyclists (36.2%)	Occasional cyclists (12.9%)	Dedicated cyclists (26.2%)
Interest in secured bicycle parking (% interested)	35.2%	32.8%	36.9%	25.4%	40.1%
Secured bicycle parking next to metro stations					
Interest in secured parking	68.7%	70.1%	68.4%	66.9%	68.6%
Important aspects	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Duration of stay	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Attendance	1 - Free 2- Secured Access 3- Proximity 4 - Duration of stay 5 - Weather protection	1 - Free 2- Secured Access 3- Proximity 4 - Duration of stay 5 - Weather	1 - Free 2- Secured Access 3- Proximity 4 – Duration of stay 5 – Weather protection
Secured bicycle parking next to train stations					
Interest in secured parking	38.8%	37.6%	39.6%	30.9%	42.5%
Important aspects	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Duration of stay	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Attendance	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Duration of stay	1 - Free 2- Secured Access 3- Proximity 4 - Duration of stay 5 - Weather protection	1 - Free 2- Secured Access 3- Proximity 4 - Weather protection 5 - Attendance
Secured bicycle parking next to their home					
Interest in secured parking	41.3%	38.5%	41.8%	48.6%	39.6%
Important aspects	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Duration of Stay	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Attendance	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 – Individual lockers	1 - Free 2 - Secured access 3 -Proximity 4 - Weather protection 5 - Duration of Stay	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Duration of Stay
Secured bicycle parking next to their work					
Interest in secured parking	70.0%	66.4%	71.4%	66.3%	73.2%
Important aspects	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Duration of Stay	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Attendance	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Duration of Stay	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 - Duration of Stay	1 - Free 2 - Proximity 3 - Secured access 4 - Weather protection 5 – Inside a building

As shown in Figure 2 across typologies, respondents are willing to walk on average 3.5 minutes from their destination to access secured bicycle parking. Those who indicated a willingness to pay for secured bicycle parking, stated they would pay an average amount of $1.5 per day for the service. Respondents are willing to pay the least amount of money for secured bicycle parking near their homes (0.5 $/day), and the most for secured bicycle parking next to train stations (2.25 $/day). Further, they are willing to walk the longest at train stations and the shortest at metro stations. All groups are willing to walk between 3.5 and 4 minutes to reach their work from secured bicycle parking, the location with the highest interest in this parking infrastructure. The second most desired location for bicycle parking was at metro stations. Here, participants were willing to walk 3.51 minutes.

Few notable differences existed across typologies. One exception is that Leisure Cyclists were willing to pay the most for secured bicycle parking for all locations. Further, Dedicated Cyclists are not as willing to walk longer distances to access secured bicycle parking near their home.

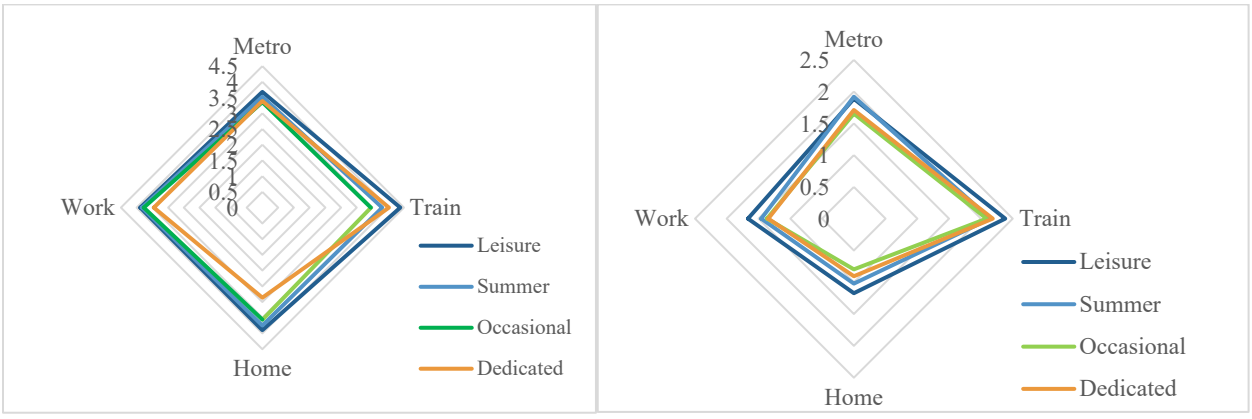

Figure 2 - Willingness to walk to a secured bicycle parking (in minutes) (left) and willingness to pay for a secured bicycle parking (in $/day) (right) by cyclists' typologies

Discussion and Conclusion

This study assessed secured bicycle parking preferences across four cyclist typologies: Leisure Cyclists, Summer Cyclists, Occasional Cyclists, and Dedicated Cyclists. In doing so, in contributes to the literature on bicycle parking and cyclist classification. In terms of classification, it contributes a data-driven and inductive approach which resulted in unique typologies. Further, because past research has found that different cyclist typologies have difference infrastructural needs and preferences, we hypothesized that different types of cyclists would have different bicycle parking preferences. However, though four distinct types of cyclists were identified, the top three most important secured bicycle parking characteristics identified were consistent across typologies. They are: Free, Secured Access, and Proximity. Further, people are most interested in secured bicycle parking near their work and metro stations. Interest is lower near home and at train stations.

Differences across typologies were observed when it came to the importance of secured parking overall. Specifically, while all types of cyclists believe it is relatively important to have secured bicycle parking in Montréal (range = 25.4% - 40.1%), dedicated cyclists find it most important, and are the group who will most likely adopt this service. This is likely due to the high cost of their bicycles, their willingness to cycle in all weather, and their frequent bicycle use. Though Dedicated Cyclists were most interested in secured bicycle parking, Leisure Cyclists were willing to pay and walk the most for secured bicycle parking. Perhaps this group is willing to pay more because they have the highest average household income of all groups. Occasional Cyclists not only cared the least about bicycle parking, they also were willing to pay and walk the least to access this infrastructure. This lack of interest may be due to the infrequency at which they cycle. Summer Cyclists are the most common cyclist typology, and yet their cycling behaviors and

secured parking needs are not distinct from the other typologies, they do not require special consideration with regards to secured bicycle parking compared to other groups.

This analysis can be used to inform policy recommendations, especially with regards to the location, spacing, price, and security of secured bicycle parking. In terms of location, results indicate that secured bicycle parking should be prioritized at metro stations and next to work locations, for example, the downtown core where many jobs are located. Furthermore, the distance between secured bicycle parking and cyclists' destinations seems to be an important aspect to consider as respondents are willing to walk 3.67 minutes on average (across cyclist typologies) to reach secured bicycle parking. This is not surprising given that more than half of the respondents stated they bicycle for efficiency.

Most respondents believed that secured bicycle parking should be free or at low cost. On average, potential users are willing to pay $1.59 per day on average for secured bicycle parking at all destinations. Whilst they are willing to pay more, $2.25 per day, for this service at train stations. If cities hope that secured bicycle parking will be used, we recommend it be offered for free or at low cost to attract the largest number of users and encourage cycling. Further, no matter the location, secured bicycle parking should include secured access (i.e., code or key pass) and should protect bicycles from bad weather. Finally, it should be located next to places where cyclists leave their bicycles for long periods of time since duration of stay was also an important factor.

While our study asked respondents about their cycling behavior before and during COVID-19, a longer-term longitudinal study could have perhaps given different results. Given that van Lierop, Grimsrud and El-Geneidy (*5)* found that women are less likely to have their bicycle stolen, future research could examine how secured bicycle parking needs vary by gender.

In this survey, respondents were asked to identify the location where they believed an on-street bicycle parking rack and secured bicycle should be installed. We also asked them to identify their home, work, and school locations. With this information, future work could provide more specific policy recommendations about exact locations where bicycle parking is needed.

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Declaration of Interest Statement

The authors declare no conflicts of interest.

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: Fournier, Ravensbergen, DeWeese, & El-Geneidy; data collection: Fournier, DeWeese, Ravensbergen, & El-Geneidy; analysis and interpretation of results: Fournier, Van Liefferinge; Ravensbergen, DeWeese & El-Geneidy; draft manuscript preparation: Fournier, Van Liefferinge, Ravensbergen, DeWeese & El-Geneidy. All authors reviewed the results and approved the final version of the manuscript.

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