Smart Public Transportation, Lessons learned from Barcelona for Montreal

ENGR 6991 Project and report

Supervisor: Dr. Nik-Bakht

Prepared by: Mitra Movasagh Khaniki

40019023

Ferbruary 2018

Content

Tables and Figures

1. Introduction

1.1. Smart city

A city is a complex and organic structure [30] which is a joint system of different aspects of health, education, real state, transportation, safety and many others. Over half of all human population currently lives in cities or close around them. According to Lierow (2014) it is anticipated that according to the urbanization trend, 70 percent of the world's population is expected to be living in cities by year 2050 [31]. Therefore cities are the main causes of climate change with regards to greenhouse gas emissions [32].

New technologies and tools made people from the country side to live in cities and work in order to live the promised life. Cities face diverse challenges, although they are getting smarter in some manners, getting bigger and denser [30].

Making a city smart is therefore a very multi-disciplinary challenge [31]. Smart city concept formed in 1990s to signify how urban development was turning towards technology, innovation and globalization. It comes from the research areas of 'virtual city', 'wired city', 'informational city', 'telecity', 'intelligent city', 'urban cybernetics', 'digital city' and others [30]. The concept of Smart City is used widely and also understood differently, sometimes the idea sounds even utopia, but in fact, it is not considered as a utopian concept [31]. **Synthesis of intelligence** that transcends mere utilization is essential for a city to be classified as smart. In order to be successful as a smart city, local authorities should develop digital structures, have free Wi-Fi access, build open data platforms, have accessible public information, create learning opportunities and provide on-the-job training. [30]. Smart City is a phenomenon which includes a wide range of sectors, such as transport, education, healthcare, administration, public security, infrastructure, logistics, ICTs, architecture, leisure, ecology, constructions, the effective consumption of resources, and many others [31]. It is difficult to find a region of the planet where cities have not embarked on some form of Smart City initiative [32].

Three main keys in smart city concept are universities, industrial and local government which are known as triple helix. In addition, Quadruple helix model has civil society as forth component [30]. In this variety of concepts it might become difficult to distinguish how the concept of Smart City differs in comparison with others [31]. There is no fixed definition for smart city concept, because of difference in characteristics and priorities of each city [30]. The concept of Smart City depends not only on historical development of cities themselves, but also on governmental policy, economic situation, social impact, technologies implemented, and many other different aspects [31]. Thus so far 23 different definitions has been made. These numerous descriptions have varying resonances to the different stakeholders who play a part in making the city smart. For instance the British Standards Institution offered a definition for smart city that a "smart city is an effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" [30].

There are 1119 smart cities and 1707 smart city applications which show that IoT (internet of things) moves faster than smart cities development. These numbers are gained by a survey which was done by august 2016, which includes the way by which a city became smart, with accordance to design or coincidence [30]. However these numbers shows cities that claimed to be smart, but they are not covering main initiatives of a smart city. By 2025, there may be 26 cities with all initiatives of what is called as smart city; most of them will be in Europe and North America [32].

Smart cities initiatives cover many aspects of city living. 31% of smart city projects were urban living lab, 22% smart government initiatives, 16% related to smart environment activities. In addition to these three top issues, 11% related to smart economy, 7% smart living, 5% smart people, 4% digital initiatives. The remaining percentages consist of projects related to new smart cities, public safety, smart infrastructure and health related projects [30].

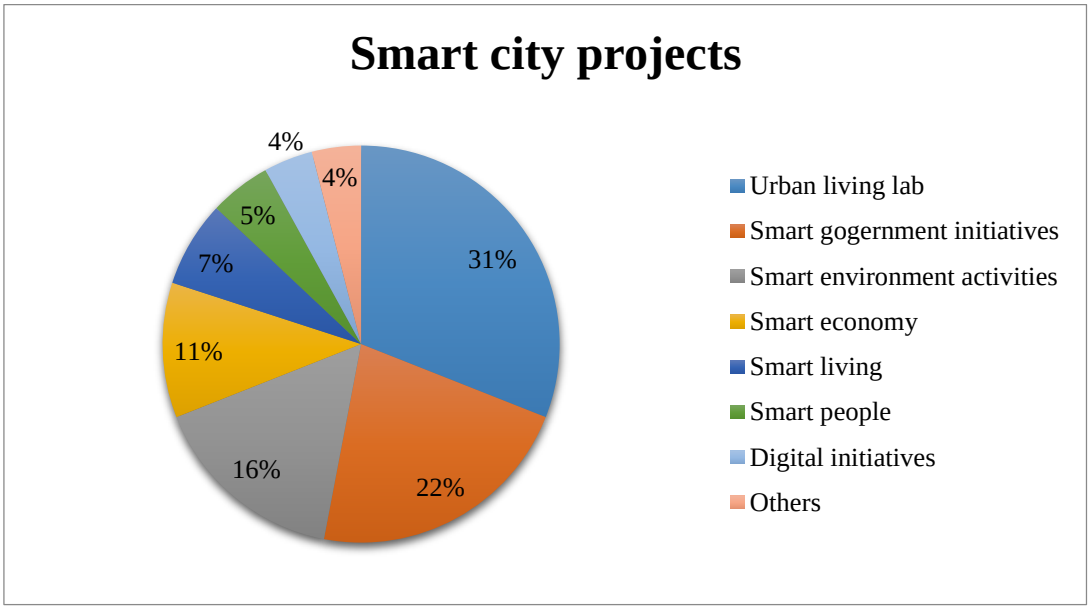


Figure (1), Smart city projects, source [30]

Besides smart city, **Soft city** is studied; where software and information technology (IT) augment the urban infrastructure and urban system, and where a new public/social space, the internet, becomes a very important part of everyday life [30].

Over the last 20 years, this ubiquitous and increasingly real-time IT has evolved into IoT which now promises to offer greater connectivity within the built and natural environment, whereby the entire physical world becomes a big connected database. Meanwhile, the term ‘smart’ has become very popular over the last 5 years or so. Outside academia, the general ‘smart’ concept became a generic term fused with data collection, sensors and various monitoring technologies, big data and the IoT [30].

Applying IT not only to speed up data processing but also to improve delivery of services, aid citizen interaction with local government and potentially increase political participation.

Nowadays, not only sharing the data with the citizens but also making sense of that data before sharing it becomes one of the most important new tools for city authorities [30].

The use of Information and communication technology (ICT) makes the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities [31]. Although ICT plays a big role in smart city development, there are some main concepts to create smart city which is its **citizens** [30] .They are the main ones who develop a city as a smart city. However they would not usually interested in involvement and contribution of cities, they are **the key to successful smartness of the city**. By focusing on people, the city would be smarter. They are mainly young generation who attempt to apply new tools and technologies in their everyday life [31].

Without the citizens, who make livability of a city, ICT cannot transform cities. So many activities involved in a smart city can be benefit mainly from citizen participation [30]. ICT merged so widely, that they are able to influence not only our close environment but also have an impact on the infrastructure and operation of the whole city. Also, smartness of people who live in the city should be considered as an empowerment for citizens to share the information with other citizens and with governmental bodies, to provide them with ideas and solutions, which would increase the smartness of the city [31].

The real smartness of the city is the ability to meet the needs of its citizens, so that the technology firstly must be served to citizens to meet their needs of a smart city. Integrating technologies into daily life of citizens provides an opportunity to share the feedback and gain new experiences, create new products. If ICT was not presented, the idea of smart city would have been faded, because it is a new tool of implementation of goals of managing a smart city. There are five main components for ICT which are as followed: Broadband network, smart devices and agents, smart urban space, development of Web and finally open government data (OGD) [31].

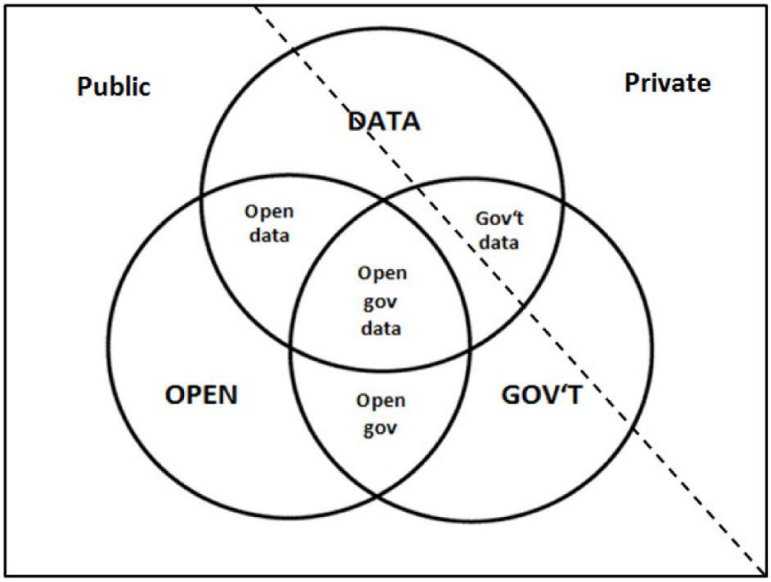


Figure (2), OGD, source: [31]

Human Smart Cities is an emergent approach where 'softer' features of 'smartness' are emphasized, such as clarity of vision, citizen empowerment, participation and so on, which can complement the technological drive of the underlying urban infrastructure. Citizens will need to be considered as one of the fundamental support mechanism for a successful smart city development20 [30].

By utilizing city-related apps and by just using the Smartphone, we, as users of these devices, are contributing towards the 2.5 Quintilian bytes of data. These data come from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records and cell phone Global Positioning System (GPS) signals to name but a few. Big data consists of massive, dynamic, varied, detailed, inter-related, **low-cost datasets** that can be connected and utilized in diverse ways, [30].

Nowadays, a wide range of activities from interaction to publishing, to transaction and data gathering, tale place between citizens and government as a matter of fact. These interactions are the source of **real-time city**. Real-time systems are defined by ability to constantly monitor environmental conditions vital to the operation of the system [30].

European smart cities:

Europe is home to many of the world's smart-city projects. This is not just because of the strict requirements that the European Union (EU) has made in regard to carbon reductions (80% by 2050) and sustainable production and consumption, but also because the EU started an **innovation partnership in 2012** called the **Smart Cities and Communities Initiative** to stimulate smart-city projects throughout Europe [32].

1.2. Project area

The project is done to study how smart public transportation can be developed. The main researches are done in bike sharing system and ticket system for both subway and bus usage. The information in this report is collected by field studies, comparison and analysis.

1.3. Case studies

The case studies are Barcelona and Montreal. Although there are differences in geographical and weather condition in these two cities, they are similar in public transportation system and city texture. Barcelona is studied as a role model for Montreal in smart transportation system with which Montreal can improve its transportation system in many facets.

1.4. Problem

In comparison to the bike sharing system in Barcelona, time of renting bikes in the city of Montreal is very limited. Thus many new users are not aware of this limitation which charges them by exceeding defined time for renting a bike.

The ticket system also fails in time management. People spend a high amount of time for purchasing a ticket or recharging cards from either a single vending machine in a long line, or a single representative in a booth. This old system causes time consumption especially at the beginning of each month.

1.5. Hypothesis

1.5.1. Bike sharing system:

The problem of bike sharing system is timing which is very limited. It is assumed that the time is very less and causes penalty for the users when they exceed the time. By enhancing the usage time of bike rental in Montreal, the users are going to be increased and they benefit more from using bikes.

The time can be extended in bike sharing system according to stations numbers and distances. By extending the time, the consent of people will be arise and the bike sharing system will be improved in a city which is considered as a smart city. The time expansion can effect users financially and mentally. They can manage their budget and time, by buying a single ticket and manage their time according their destination.

1.5.2. STM ticket system:

The STM ticket system is time consuming in Montreal. It is imagined by making the ticket payment in smart way such as online purchase and recharging, the time of getting on the subway trains and the buses is going to be risen and the passengers' consent will be improved. The STM ticket system can get smart by smartphone applications by which users can show up their phone screen to pass the gates either at subway station or on the bus.

2. Case studies

2.1. Barcelona

Barcelona is a European city with a population of 1.609 million people and a area of 101.4km^2[13]. The average salary of people is € 41,000 (= CAD$ 61,243.95) [12].

This city awarded iCapital prize as smart city in 2013. The competition was held among 58 cities, and the judgment was regarding using new technologies and the way they make city closer to its citizens. Barcelona was called ‘a people city’ project by the city council; the city includes creative and new technologies to increase life quality and improve the economic growth [30], [31], [32].

The smartness does not only mean digital, but a process in which the city agencies cooperate with each other and make the citizens involve in the city. However the citizens of this city ignore it as a smart city, they unconsciously adapted with the smartness of the city.

Smart projects of Barcelona are in urban, Economic, Social and Governance System. Bus system which is transportation component and urban system is equipped with eco-friendly engines and USB chargers on board. The bus stops have touch screen machines to illustrate the buses situation in the city, besides they can help passengers to find their way in the city. Bike sharing system is another component of transportation which in included as a smart project. Another urban system smart project is parking spaces with sensors to control reserved, available and taken parking spaces.

Pneumatic waste management system and transit system as smart projects are the ones which are counted as urban system components. Irrigation system which is sensor based to control water shortage can be considered as governmental system. In the field of social system, a project of 1500 spots with free WiFi can be named. Air quality control sensors installed on lampposts can be considered as both social and urban system. These mentioned smart projects are successful smart projects in the city of Barcelona.

Some smart projects which were not that successful maybe because of inaccurate design, integration and budget, for instance LED smart lights detecting people presence, noise and air condition, failed because of maintenance requirements. Another example is TIC building which supposed to be an energy efficient building, but on the contrary, it is one of the most energy consuming building [33].

Figure (3), iCapital selection criteria, source: [1]

2.2. Montreal

The area of study in city of Montreal is 365.13 km^2 and the city population is 1.741 million people [35]. The average income of people in Montreal is CAD$ 55,153 [2].

2.3. Comparison

Montreal and Barcelona were compared in several aspects for transportation system to find out their similarities and differences in order to develop Montreal's project in a smart way which is existed in Barcelona.

Studied aspects are as followed:

2.3.1. Weather

As it is known, Montreal is one of the North America's coldest cities, whereas Barcelona is a sunny and mostly warm city because of its geographical location.

Temperature: In this section, the high, low and average temperature of both Montreal and Barcelona are illustrated.

High temperature comparison during 2012 until 2016:

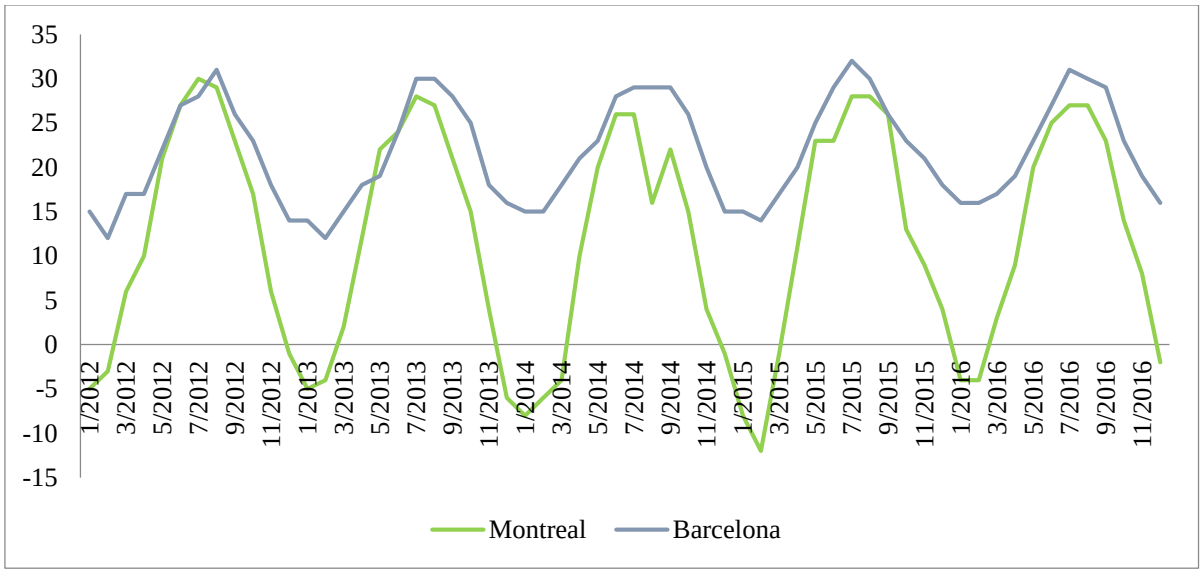


Figure (4), high temperature per month, source: [7]

According to figure (4) the lowest temperature of Montreal in high temperature in winter time is (−12°C), whereas it is (12°C) in Barcelona. The highest temperature of Montreal in high temperature is (30°C), and it is (32°C) in Barcelona in summer time during 2012 until 2016.

Low temperature comparison during 2012 until 2016:

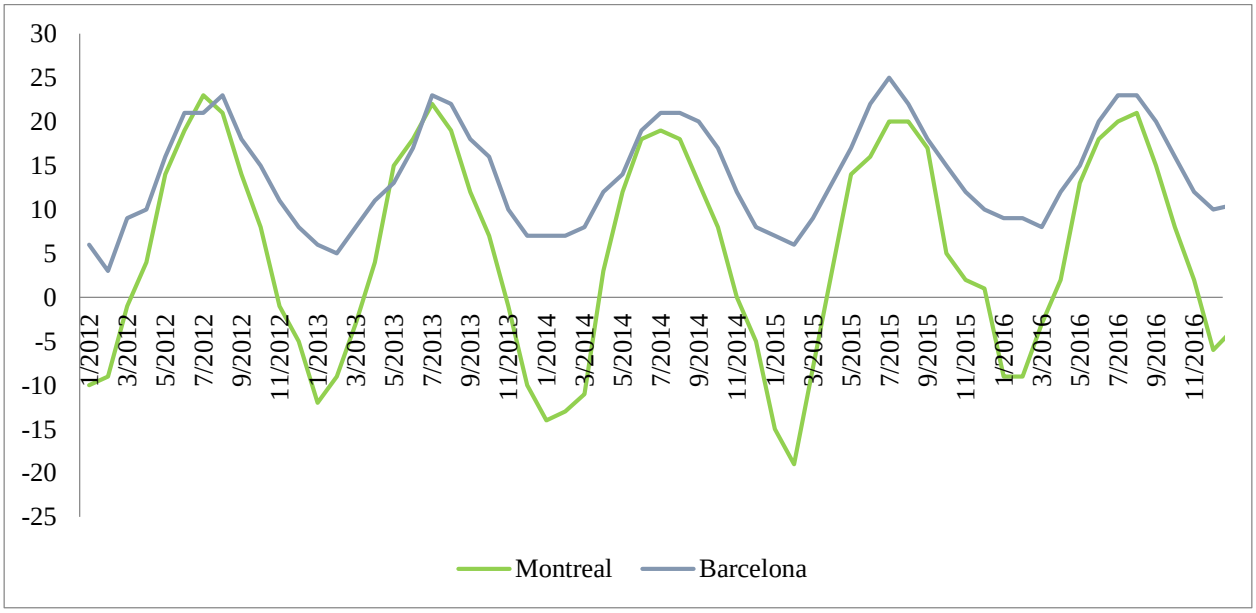


Figure (5), low temperature per month, source: [7]

By studying figure (5), the lowest temperature of Montreal in low temperature in winter time is (−19°C), whereas it is (3°C) in Barcelona. The highest temperature of Montreal in low temperature is (23°C), and it is (25°C) in Barcelona in summer time during 2012 until 2016.

Average temperature comparison during 2012 until 2016:

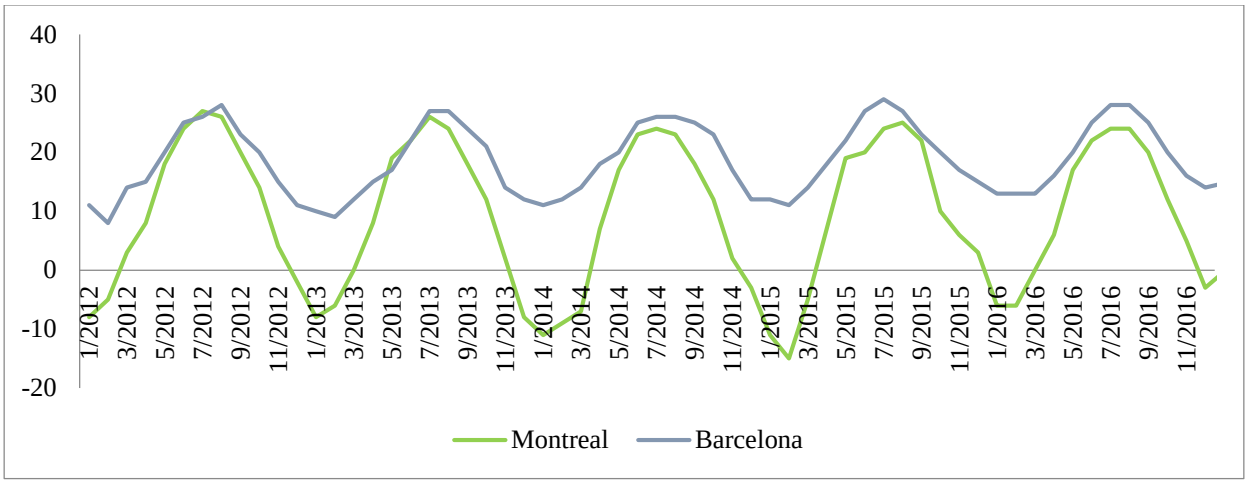


Figure (6), average temperature per month, source: [7]

The average temperature is the average of low and high temperature of the two cities during years 2012 to 2016. The highest average temperature of Montreal belongs to July 2012, and July 2015 for Barcelona. And the lowest average is February 2015 for Montreal, and February 2012 for Barcelona.

Temperature combination of Montreal during 2012 until 2016:

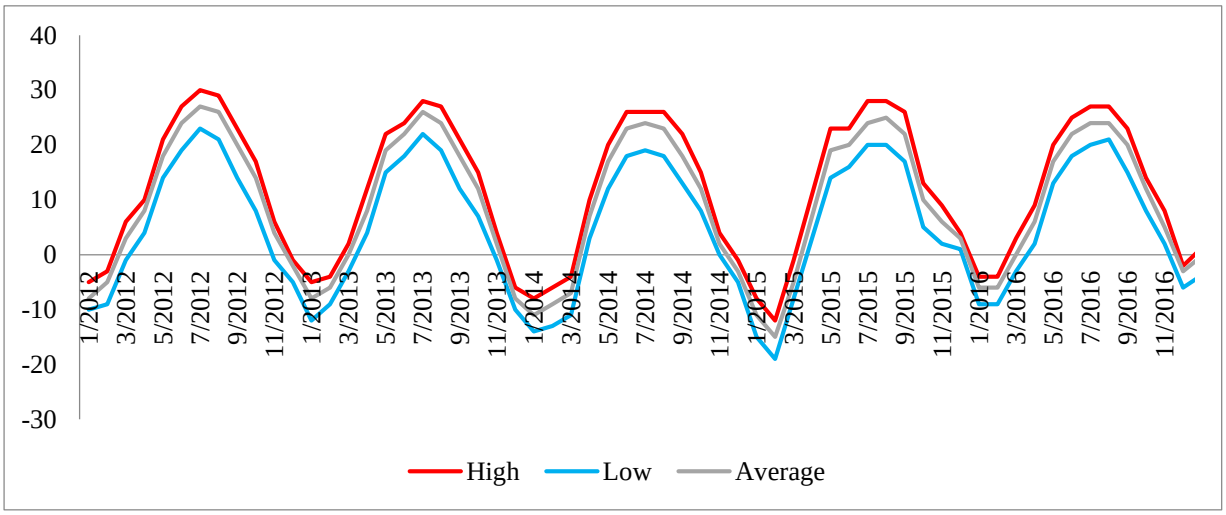


Figure (7), Montreal temperature per month, source: [7]

Due to the report in www.worldweatheronline.com the temperature goes below zero mostly during December and March. The coldest month during 2012 to 2016 is February 2015. The temperature started to increase the next two winters.

Temperature combination of Barcelona during 2012 until 2016:

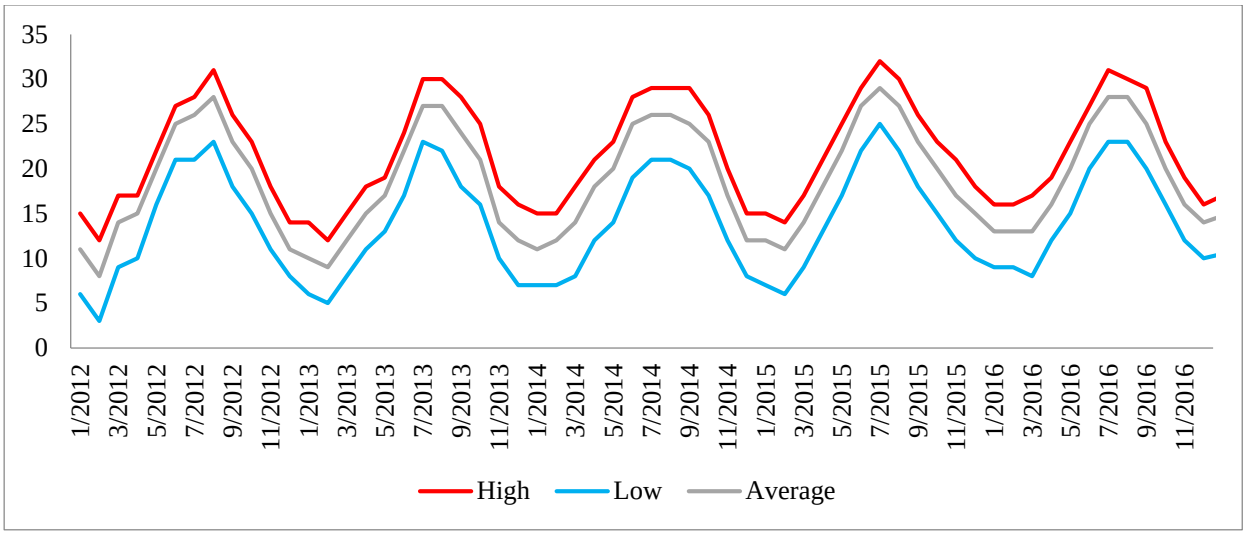


Figure (8), Barcelona temperature per month, source: [7]

According to figure (8), there is no temperature below zero, and the lowest temperature is February 2012 with (3°C). Weather is getting warmer after the mentioned time.

Rainfall: Average rainfall comparison during 2012 until 2016 in millimeter:

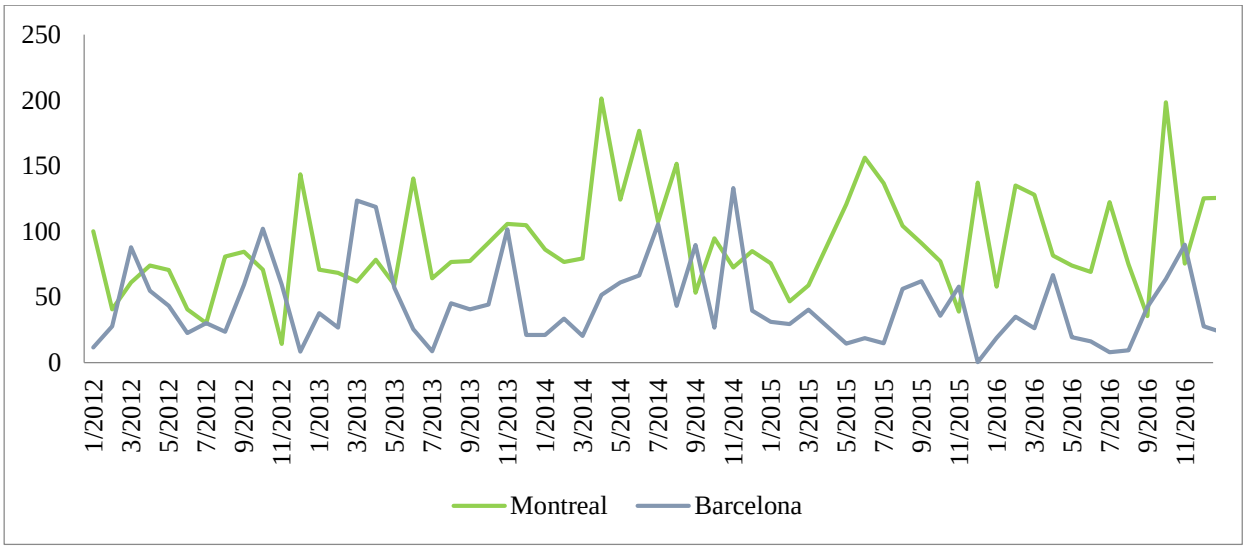


Figure (9), monthly rainfall (mm) per month, source: [7]

As figure (9) demonstrated, the amount of rainfall in Montreal is clearly higher than Barcelona. Although there are 9 exceptions in 60 studied months in which Barcelona had more rainfall compared to Montreal.

Rainy days comparison during 2012 until 2016:

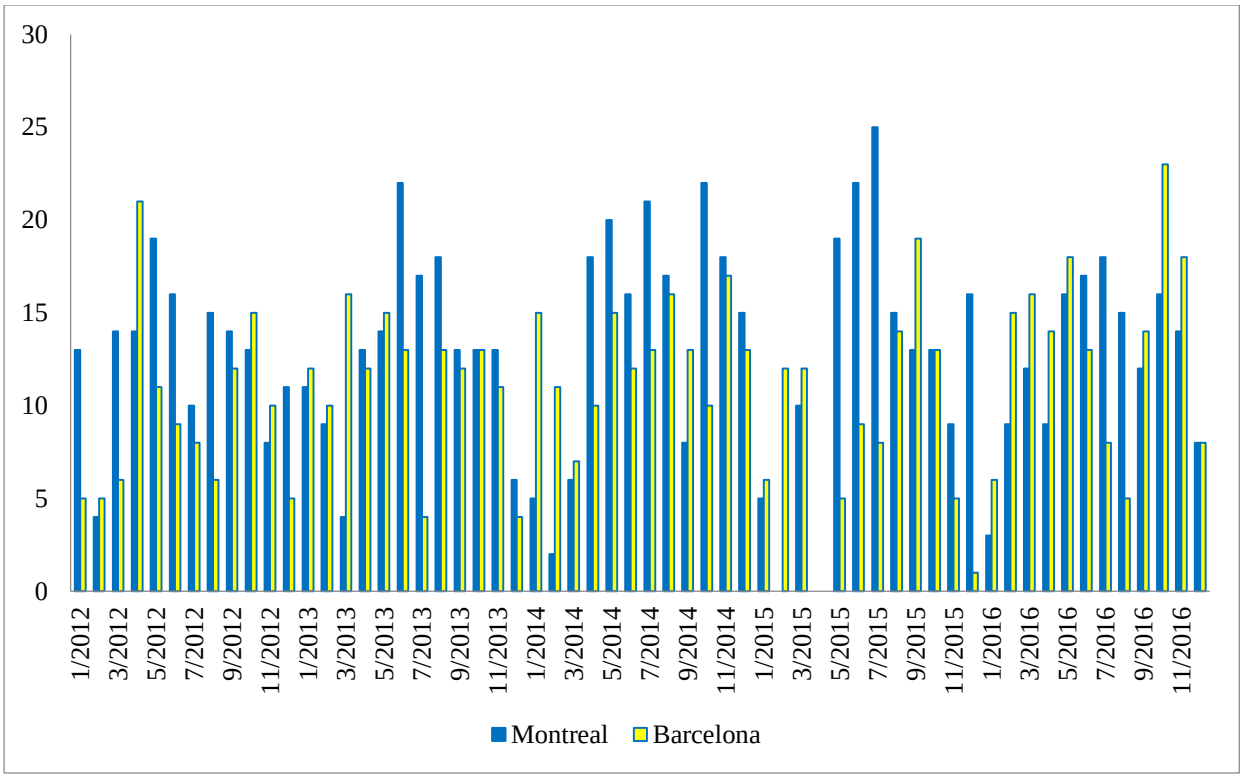


Figure (10), rainy days per month, source: [7]

Both cities has high amount of rainfall and the number of rainy days in each month is shown in figure (10). 23 months out of 60 studied months had more rainy days in Barcelona in comparison with Montreal. In general Montreal faces more rainy days with high amount of rainfalls.

Snowfall: Average snowfall during 2012 until 2016 in centimeter:

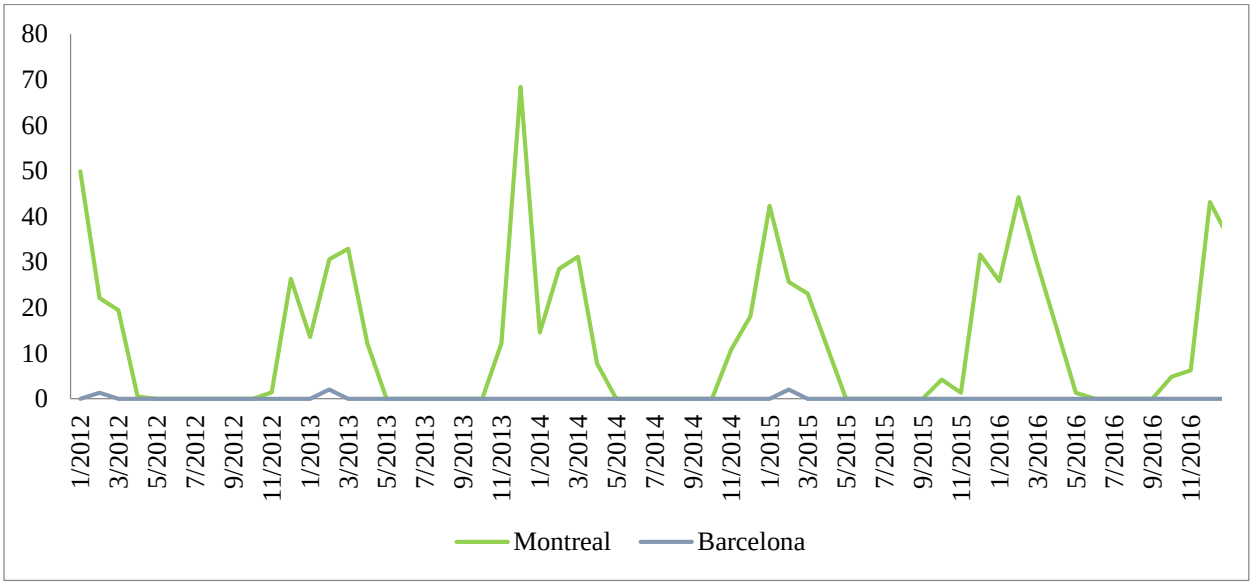


Figure (11), monthly snowfall (cm) per month, source: [7]

Figure (11) clearly shows Barcelona had only 3 months with snow during 60 studied months, and according to figure (12), each time lasts only for one day except from February 2012 which lasted 2 days.

Snowy days comparison during 2012 until 2016:

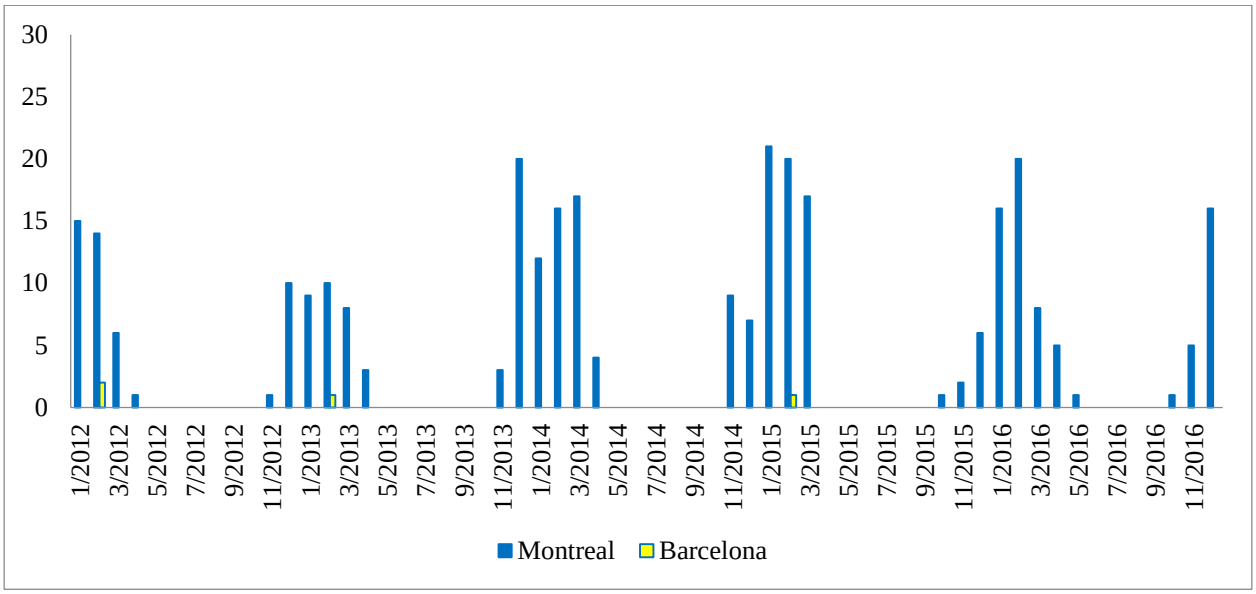


Figure (12), snowy days per month, source: [7]

Wind: Average wind speed (mph) comparison during 2012 until 2016:

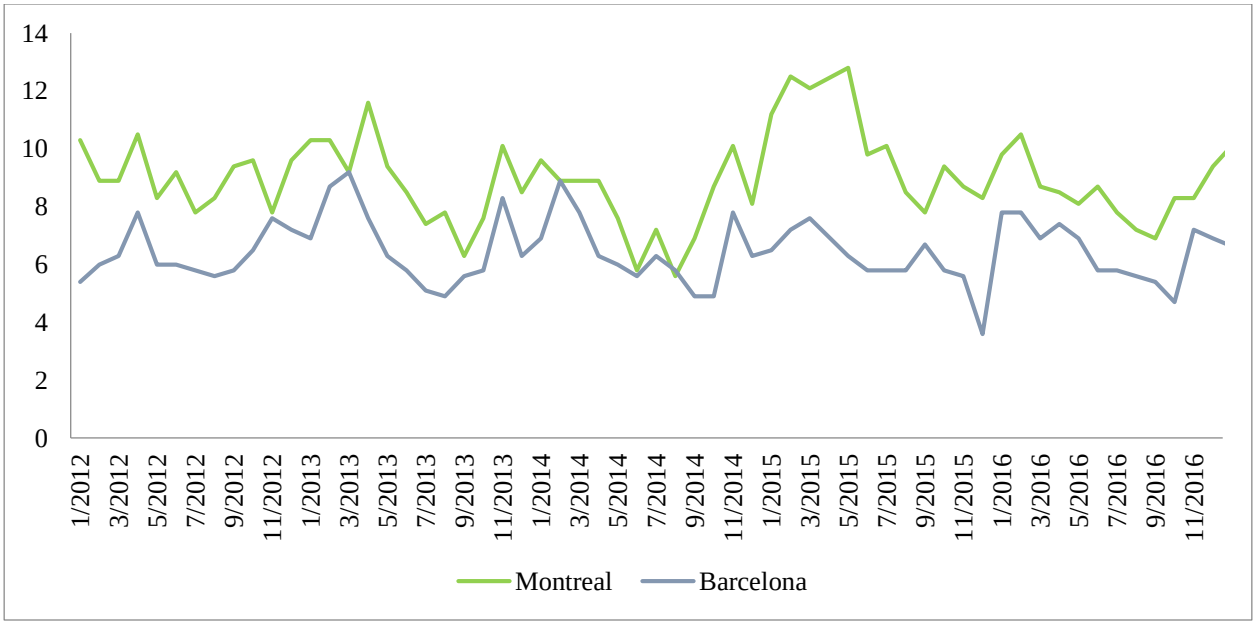


Figure (13), average wind speed (mph) per month, source: [7]

The study of wind speed shows Montreal's wind speed is extremely higher than Barcelona. There are only 2 month with same average wind speed, and 1 higher speed in August 2014.

Sun shine: Average sun shine comparison during 2012 until 2016:

Hours:

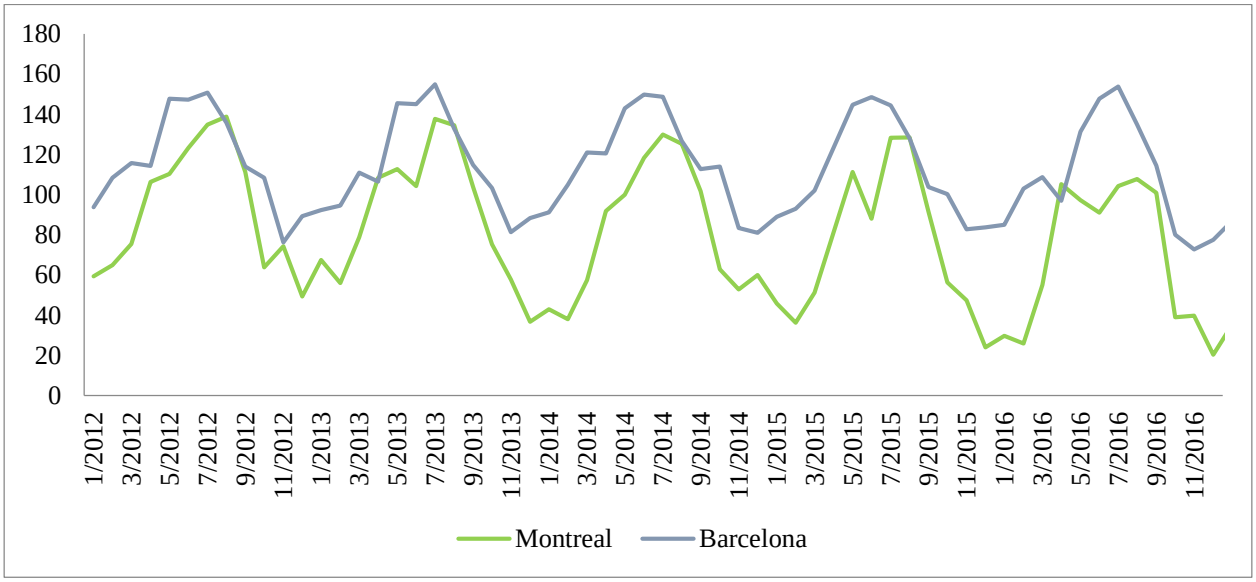


Figure (14), average sunny hours per month, source: [7]

Days:

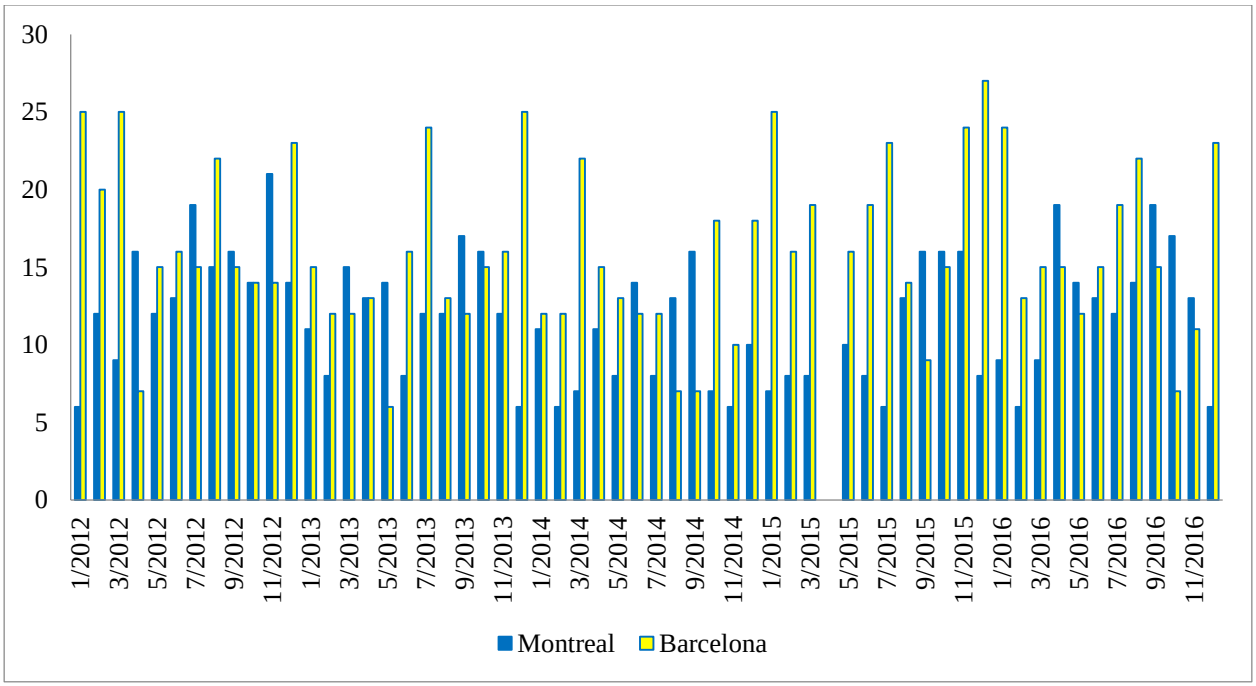


Figure (15), sunny days per month, source: [7]

As it is illustrated in figure (14) and (15), Barcelona faced more sunny days than Montreal which shows the use of sun can be pretty helpful for this city. Only 5 month Montreal faced more sunshine than Barcelona which is so little that can be ignored.

According to weather comparison in two cities of Barcelona and Montreal, it is clear the climate in Montreal is pretty cold. There is almost no snow in Barcelona in the last 4 years whereas half of each year was snowy in Montreal. In general, the climate is totally different in these two cities that makes the public transportation in some parts different as well.

The most effect of weather may be at bike sharing system. In Montreal in which there are four month of snow, the service is not available [21].

2.3.2. Topography

According to the topography map of Montreal, it is implied that elevation is diverse in different areas and diffused. The lowest elevation is approximately 9 meters and the highest is about 229 meters. It is possible to follow the elevation height of different areas of the city using http://en-ca.topographic-map.com/places/Montreal-689651/ [8].

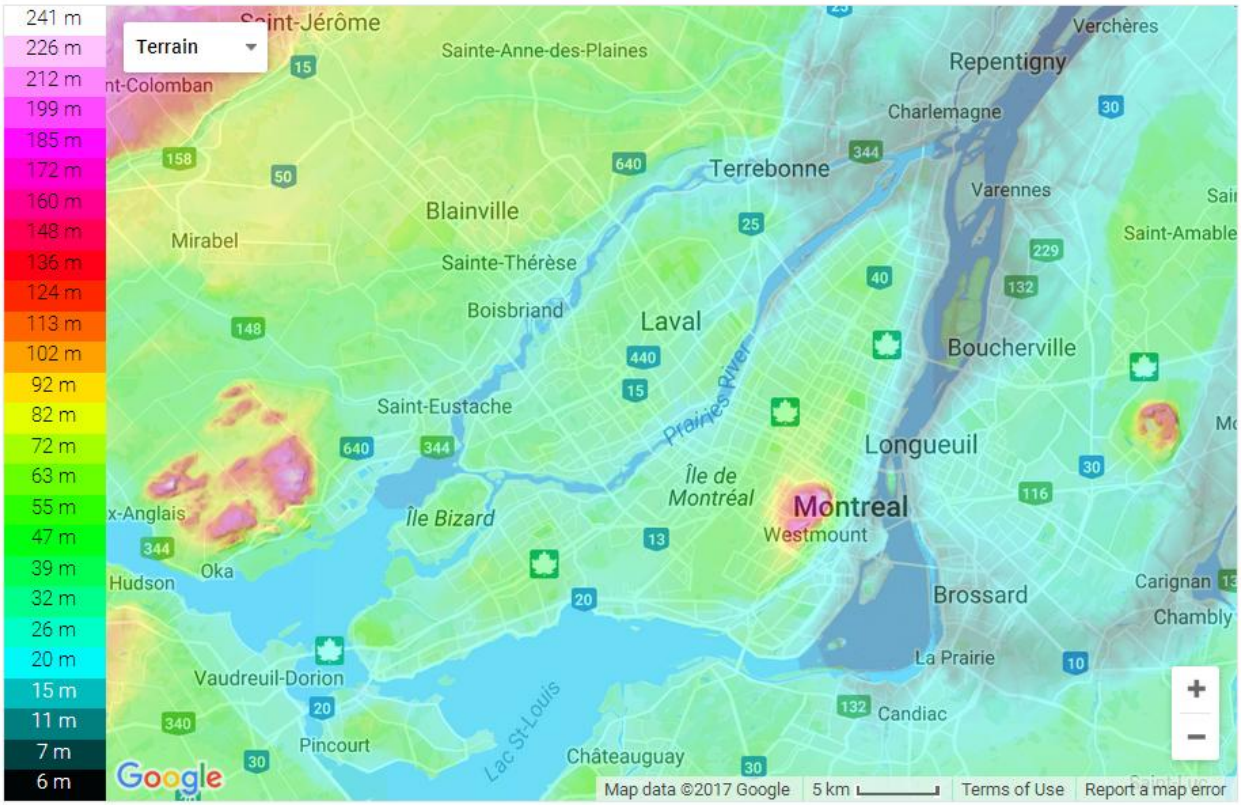


Figure (16), Montreal Topography, source: [8]

The topography map of Barcelona shows that there are more high elevations in comparison with Montreal which has some pointed high elevations. As it is illustrated in Figure (16), the highest elevation is 653 meters and the lowest one is 0 meter. It is possible to follow the elevation height of different areas of the city using http://en-ca.topographic-map.com/places/Barcelona-2744314/ [8].

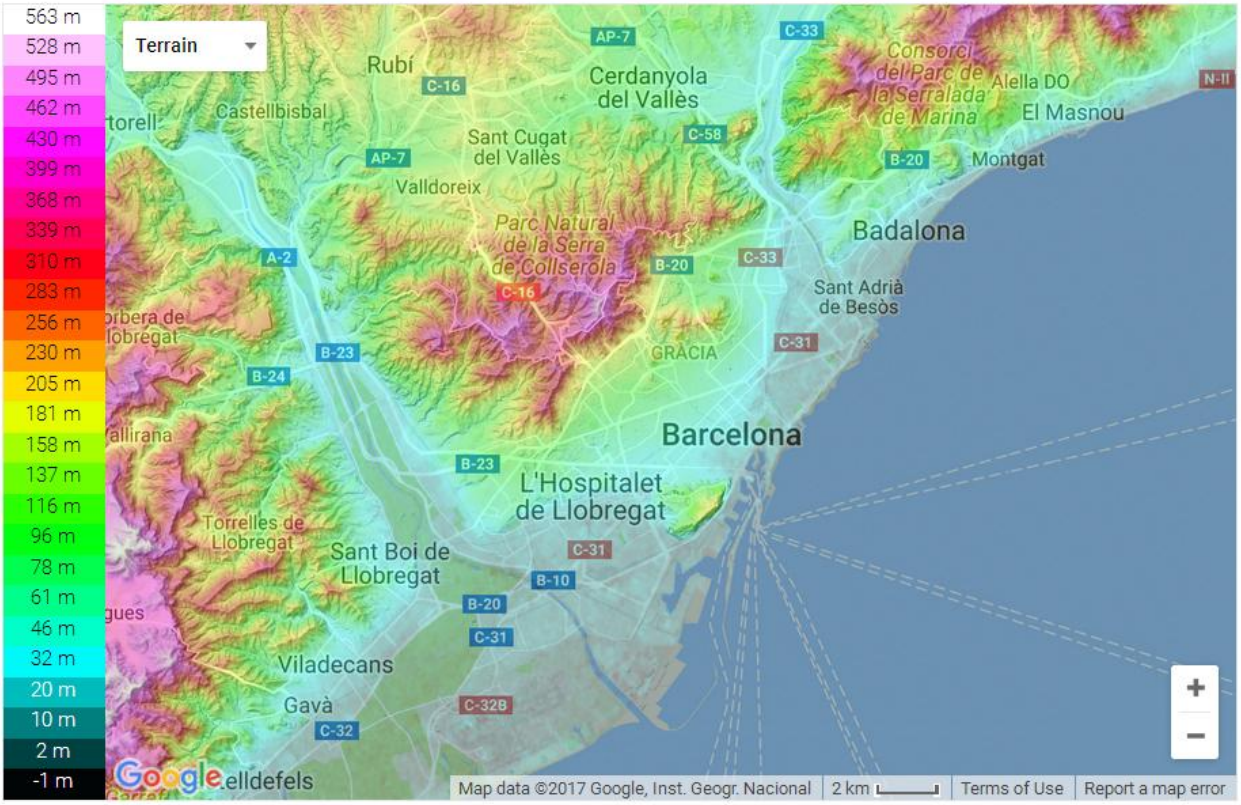


Figure (17), Barcelona Topography, source: [8]

It is clear that weather condition is affected by elevation. Elevation affects the temperature and rainfall. It means that as much as the elevation height is lower, the rainfall amount will be increased in a linear manner. By elevation height increase, the temperature gets colder, and the humidity will be decreased. This fact answers why mountains are dry on top [9].

There is website using NASA data about geographical information in which it is possible to specify an elevation height for a city and the defined height will be shown in color. The website is http://www.floodmap.net/ [10]

By comparing the two topography maps of two cities, it is illustrated that the higher levels in Barcelona are more than Montreal's high level which is concentrated in the area of Mont Royal.

2.3.3. Transportation

2.3.3.1. Public

According to the average income of people in Montreal and Barcelona, the public transportation is more expensive in Montreal [12], [2].

2.3.3.1.1. Subway

Subway system in Barcelona is called *TMB*. Montreal's system is called STM which its first 20 subway stations were constructed on October 14, 1966 [5].

Barcelona has **156 subway stations** with 600 ticket vending machines, which means more or less **3 machines for each station**. 473 of them are dealing with both cash and bank cards, and the other 127 machines only accept bank cards. All machines are equipped with multiservice program which is easily used with a simple navigation system. There is no human being and booth, and clients only can push the help bottom to connect you to a real person [12].

There are two types of cards, one for residence, called *T- something* that includes diverse plans of tickets, and one for tourists called *Hola BCN* which is an unlimited travel card [12].

Each station has TV screens illustrating the time of next train arrival in seconds. Barcelona's trains have the subway map equipped by lights on each station showing where the train is; thus it can be easily tracked by passengers not to get lost or miss their preferred station. Each station is announced by loudspeaker as well [11], [12].

Montreal has **68 subway stations** which most of them only have **one vending machine**. Machines can charge the STM system cards called *Opus*, only by bank card, and daily tickets can be bought by both cash and bank cards. There are also booths in every station, selling just daily tickets in cash [4]. It is mentioned that in peak hours the booths and the vending machines are all crowded and people need to spend a lot of time in lines to buy a ticket or to charge their Opus cards.

The comparison of numbers of stations in Barcelona and Montreal, shows however Montreal has less numbers of station, there number of vending machines per station is still low.

Each station has TV screens illustrating the time of next train arrival in minutes. Old STM trains only have a printed map installed on the wall, and each station is announced on loudspeaker and it is sometimes not hearable, therefore the risk of getting lost may be increased while using older generation of trains [11], [5].

Figure (18), Old STM trains

Figure (19), New STM trains

2.3.3.1.2. Bus

Bus system in Barcelona is based on both tickets and cash. There are vending machines discussed in the previous part. It is also possible to buy ticket from the bus driver in the bus by cash with a maximum change of €10. There are both glass bus stops and sign bus stops. The buses are equipped with ramps for passengers using buggies or wheelchair which can be activated while needed. In order for a passenger to get off the bus, s/he needs to press the red button which means stop is demanded [12].

Figure (20), Barcelona bus stop sign, source: [14]

The bus system is the same in Montreal with only a few differences, for instance the tickets which can be bought from the bus driver is only by coins and the passenger only can get 1 fare ticket which costs $3.25. There is no ramp in bus entrances, and instead, the buses stop beside the pedestrian way which is as high as the door level of the buses. There are also some USB outlets next to the seats that allow the passenger to plug in their devices and charge them the time they are on the bus [5].

Figure (21) Montreal bus stop sign, source: [15]

Figure (22), USB outlets on bus in Montreal

Charging the cards in Barcelona can be done either through vending machines or online by using their card number. However in Montreal, charging the transportation card cannot be done online, there is a card reader called *OPUS en ligne* which should be bought by users and it has its own policy that is listed below:

Information regarding OPUS en ligne card reader:

The device was released in July 2015 with a costs of $16.66 (tax and shipping included) [6], [36], [37]. Only computers with specific features are compatible (special RAM and Monitor) and tablets and smart phones are not compatible with it. Whereas it is compatible with browsers such as Firefox 33 or higher, Internet Explorer 11 or higher, Chrome 44 or higher, Chrome 44 or higher (for windows 7,8 and 10) and Safari 9 or higher (for Mac OSX version 10,8 or higher). Unfortunately, it does not work with windows XP, Vista and Linux [36].

To use the device, installing the program called *SmartCardPlugin* is required. Besides, installing JavaScript add-on is needed, but if not, the program will install the Yahoo toolbar and changes the computer search engine to Yahoo (without un-checking the message while installing SmartCardPlugin). And it is because Yahoo offers that pop-up [36], [37].

While using the card reader, it should be the only device which is connected to the computer (no more card readers) [36].The card reader can show the status of your card (for all OPUS family fares) [38]. What is more, one device can charge several cards [40].

Although it cost $7.6M to develop the device [39], there was no advertisement on Subway trains and buses, but in Twitter and Facebook. it is interesting to know that 3.8 percent of Quebec commuters bought one card reader. The cart reader production is related to RTC: Réseau de transport de la Capitale, which refused to interview with CBC News regarding the card reader. *"The RTC does not wish to comment further because the information request has been fulfilled and all pertinent information for its clients are available on the website," spokesperson Julie Drolet said in an email."* STM also refused to speak with CBC News about the technology [40], [34].

People's expectation is a wireless device or a smart phone application which makes them recharge their cards with just some clicks [38].

Bus and subway comparison conclusion:

The difference in number of bus lines shows the difference area of two cities. Although Barcelona is smaller than Montreal, it has a wider subway network and lines. The STM network only covers Montreal part and there are different networks in Laval and Longueuil with different pricings. The night buses in Barcelona are separated from TMB system and they might have different fares and tickets.

Based on comparison between the two cities ticket system, Montreal's STM ticket system is old fashioned and also less according to the population of the city. For instance the number of vending machines in each subway stations is less, and people should waste their time in lines to charge

their card or purchase a new ticket; whereas in Barcelona people recharge their tickets online with no external hardware.

The bus vending machines is also not completely user friendly and only accept the exact amount of $3.25; if you do not have the amount of a fare, either you cannot get on the bus or you will be penalized by the STM policemen because of having no ticket. Maybe the passenger has $4.00 dollars, the vending machine get the amount with no changes. Besides, the machines only accept coins, and no bills is accepted [5], [6].

2.3.3.1.3. Bike

Barcelona developed its bicycle program called *Bicing*, in 2007. Montreal also introduced somehow a same program called *Bixi* in 2009 [11].

	Terms and Conditions	Bicing [20]	Bixi [21]
1	Age of usage	+16 (age of 16-17 needs authorization signed by parent or legal guardian)	+14 and more than 1.24 meters. (minor users need authorization signed by parent or legal guardian)
2	Availability	(Maybe the whole year)	April 15 to November 15
3	Guarantee of return	-	$100 deposit for maximum of 10 days
4	Rent choices	(It was not mentioned)	1) Credit card for 1 way trip, 1 day and 3 days rental. 2) Opus card for 1 way trips. 3) Membership card
5	Usage time limitation	Maximum of 2 hours (first 30 minute is free, each additional 30 minutes is €0.74 Penalty for exceeding 2 hours: €4.49/hour	30 minutes for guests 45 minutes for members
6	Smartphone application	Yes	Yes
7	Re-rent time	10 minutes of returning previous bike.	2 minutes of returning previous bike.
8	Return policy	10 minutes free extra usage if the station is full.	15 minutes free extra usage if the station is full.
9	Weight can carry	NA	120 kg (265 lb) 8 kg (18 lb) for rack
10	Free usage	-	Sundays
11	Organization	-	Non-profit organization
12	Number of stations	400, every 300 meters	540
13	Number of bikes	6000	6200
14	If stolen	First tell police, and then go to customer service to luck the bike. No additional fee	Deactivate card by calling customer service. $5 additional fee for new key
15	Insurance	Yes	No

Table (1), bike sharing system comparison, source: [20], [21]

	Terms and Conditions	Bicing [20]	Bixi [21]
16	Bike with problems	3 minutes time to return and re-rent a new bike	-
17	Bike sharing price	One way: free for first 30 mins, € 0.74 per each additional 30 mins (up to 2 hours) (= $1.11) Penalty for exceeding 2 hours: € 4.49 per hour (= $6.71) One year membership: € 47.16 (= 70.46) Not for tourists, [20]	One way: $ 2.95 One day: $ 5 Three days: $ 14 One year membership: $ 89 90-days membership: $ 55 30-days membership: $ 30 For residents and tourists, [21]
18	Bike numbers per area	Every 300 meters [20]	No information was found
19	Bike numbers per station	465 stations, 6000 bikes [20] Approximately 13 to 39 per station [20]	540 stations, 6200 bikes [21] Approximately 10 to 89 per station [21] The ones with 89 bikes offer service in limited time and date.

Table (1) cont., bike sharing system comparison, source: [20], [21]

Bike sharing comparison conclusion:

Montreal is about four times greater than Barcelona, however Barcelona has more bike (according to the city area), and the bike network covers the entire city except from the higher part of the city (with respect to Barcelona topography) including natural park. Montreal consists of 3 parts of Montreal, Laval and Longueuil. The bike sharing in Montreal only covers some specific parts of each of these three areas which it is believed there must be an improved network to cover the entire city just like Barcelona.

Barcelona residences have higher salary than Montrealers, but the bike rental fees are lower than Montreal, and this is another key point. It also should be mentioned that Bicing is not useful for tourists; however tourists in Montreal can use their credit card to rent bikes from Bixi.

According to row number 5, the time renting bikes in Montreal is very less in comparison to Barcelona. This time limitation may cause inconvenience and extra charge for users. It also may causes stress and the users should pay attention only to available stations through the application, which make them not to be concentrated during riding the bike.

2.3.3.1.4. Parking

3. No.	Terms and Conditions	Barcelona	Montreal
1	Smartphone application	Yes (WeSmartPark, for private parking) [22] (apparkB) [24] B: SM (P+R) [23], [25], [26]	Yes (P$ Mobile Service) [28] *No occupancy is shown
		ParkMe Parking, for both cities [27]	
2	Booking service	Yes	Yes
3	Zoning	1) Green zone (1-2 hours) 2) Blue zone (up to 4 hours) 3) White zone (free) Each zone includes zone for residents of the areas, deliveries, scooters and motorcycles, coaches and other [29].	Four zones, including residents zone [28]
4	Ticket policy	Tickets to display on the window [24]	No ticket needed for on-street parking Tickets to display on the window for parking lots [27]
5	Free service	Green zone is free all day in August every year [24].	Indicate by sign, from 9:00 P.M. to 7:00 A.M. [28]
6	Parking meter	Yes	Yes
7	Time extend	Yes	Yes and at any station [28]
8	Extra services	-	Ticket issuance for 747 buses [28].
9	Stakeholder	(It was not mentioned)	1) Stationnement de Montréal 2) Board of Trade of Metropolitan Montréal 3) Accesum Inc. [28]
10	Controlling policy	Sensors	Camera and sensors in parking lots [28]

Table (2), Barcelona and Montreal parking system comparison, source: listed in each cell

Parking comparison conclusion:

The parking system in two cities are almost the same and both cities have somehow same installation and system. Therefore no research has been done in this field.

3.1.1.1. Private

3.1.1.1.1. Car sharing system

Car sharing system is widely used all around the world. Some car sharing systems have drivers and some do not. In the city of Barcelona, the car sharing system is mostly the one with the driver. A system called *Premium Traveler* let users rent car with drivers. All cars to share are Mercedes, with different sizes from luxury sedans, minivans and minibuses. This car sharing system is usually suitable for tourists who do not know the city and need someone to guide them [16]. Another car sharing system which works with black premium vehicles is called *myDriver*. It also has drivers with the cars [17]. These systems are somehow similar to taxicab system that work through smart phone applications.

Montreal has the system of sharing car with and without driver using applications on smart phones. The first system is called *Car2go* which offers car with two seats and they can be reserved 30 minutes prior riding it. There are a lot of parking spaces reserved for its cars in the city. Users can rent them, drive and park and leave it in reserve parking spaces. The cars work with both fossil fuel and electricity. They are equipped with solar cells on the ceiling and the side mirrors. And the new generations are made of poly carbonate material to save energy. These cars need to be charged every two to three days [18].

There is also another car sharing system called *Communauto* that does not have driver. There are two ways of renting, first is a round trip rental which users have to return the car where they took it, and the other one is Trips from point A to point B that lets users leave the car in their destination different from where they took the car. This system works with smart phone application as well. Their cars are mostly Toyota Yaris and Toyota Prius C. Nissan Versa working with gasoline, and Nissan LEAF, Chevrolet VOLT and Ford Focus are the ones working with electricity. This sharing system is suitable for families because 12% of their cars equipped with baby car seats [19].

Car sharing comparison conclusion:

This system is more similar to taxicab in Barcelona. Besides car sharing system is smarter in Montreal in comparison to Barcelona, because it holds the right meaning of car sharing system; users can rent car and drive it themselves.

However car sharing system is an interesting topic to do research on, it is smarter in Montreal in comparison to Barcelona which was not considered in this study.

3. Open data

Regarding the comparison between two cities in terms of public and private transportation system, the main differences were in the bus/subway part and bike sharing system. Following are precise data and information regarding the two systems.

3.1. Ticket system

The open data regarding ticket purchase was not available, therefore a questionnaire was created to ask people's opinion regarding the way of purchasing or recharging their cards. 86 responses were collected. The questionnaire's questions and their results are listed below:

1. How old are you?

10-14□ 15-17□ 18-24□ 25-34□ 35-44□ 45-54□ 55-64□ 65-74□ More than 74□

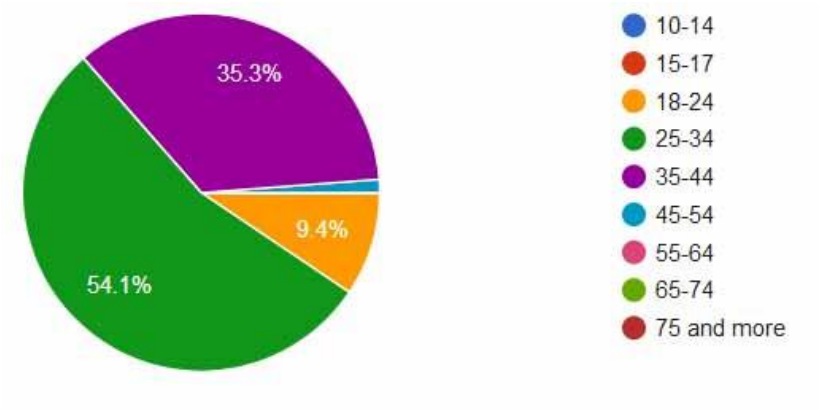


Figure (23), age range of interviewees

2. Do you have smart phone? Yes□ No□

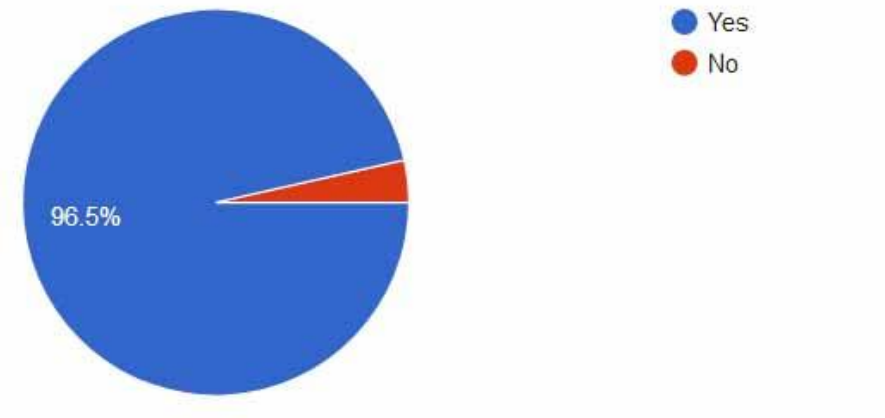


Figure (24), smart phone owners

3. Are you an OPUS card holder? Yes□ No□

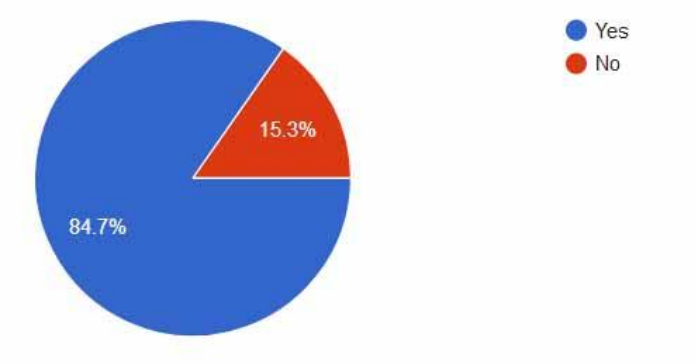


Figure (25), OPUS holders

4. Have you ever lost your (OPUS card/ ticket while it was useful)? Yes□ No□

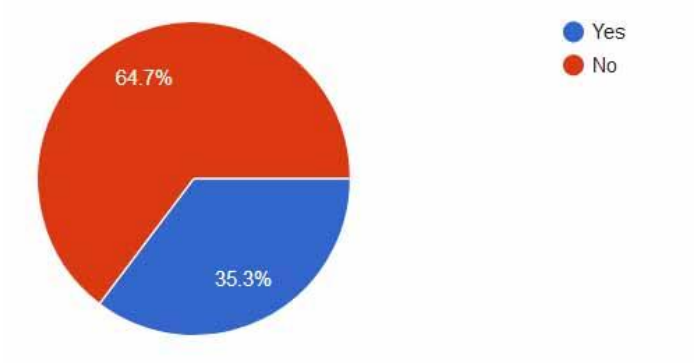


Figure (26), users who lost their tickets or cards

5. How often do you (charge your OPUS card/ buy ticket)?

Every month□ Every 4 month□ Every week□ Every 10 trips□ Every single trip□

Other□ (please explain: ……..)

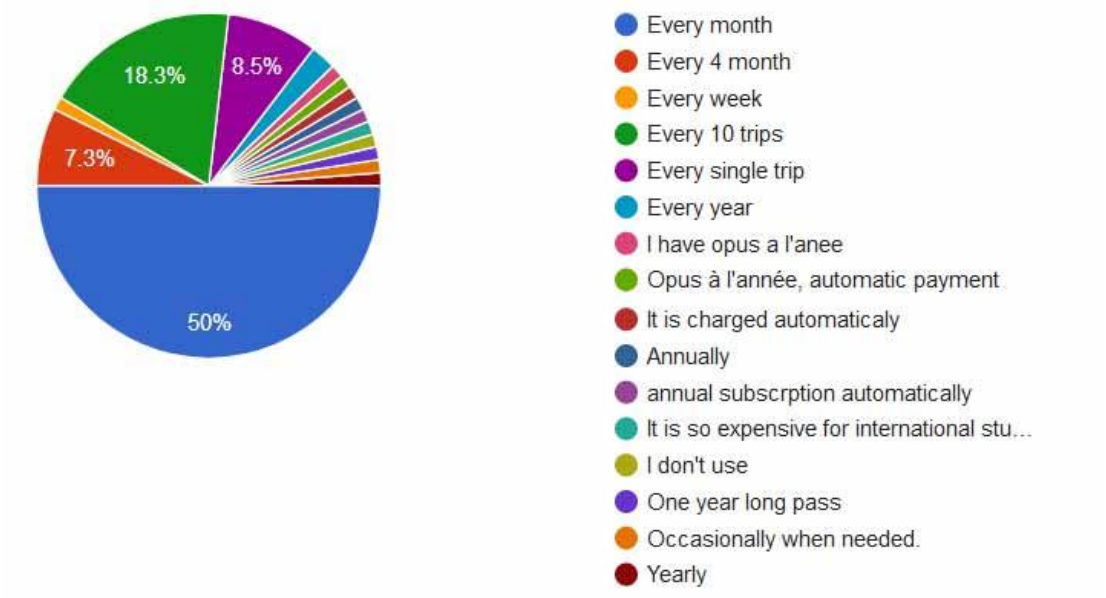


Figure (27), frequency of charge

6. Do you usually face a line while you want to
   (charge your OPUS card/ buy ticket)? Yes□ No□

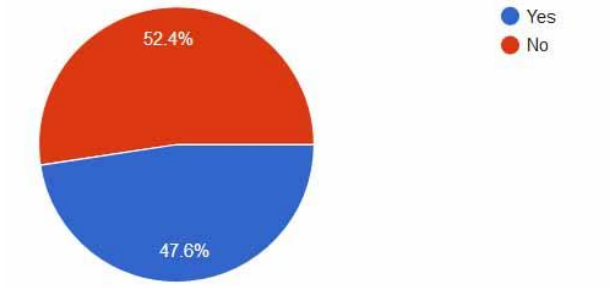


Figure (28), people facing line at vending machines

7. Do you like the (OPUS card/ ticket) to be
   (charged/ purchased) online? Yes□ No□

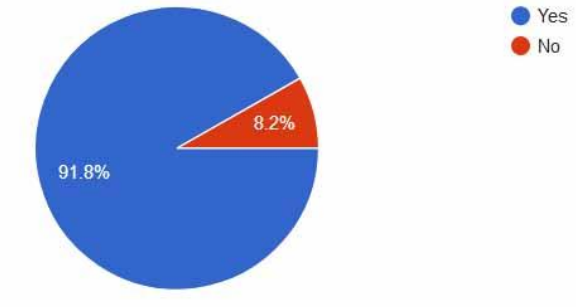


Figure (29), people agreement with online payment

8. Have you ever used the ticket machine on the bus? Yes□ No□

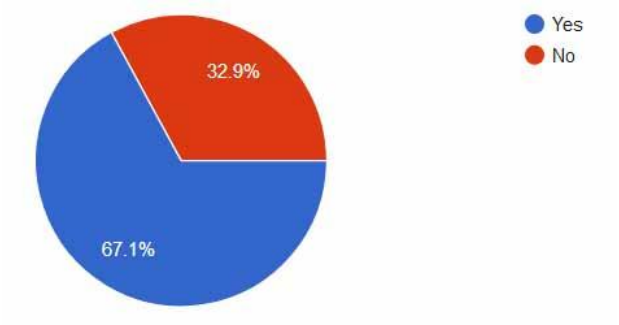


Figure (30), bus vending machine users

9. How often do you have enough coins ($ 3.25) in your pocket?

Always□ Sometimes□ Seldom□ Never□

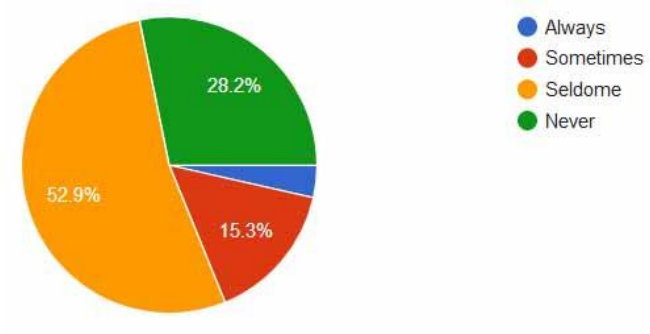


Figure (31), frequency of having coins

10. Do you like ticket machine on the bus to work with

Bank cards? Yes□ No□

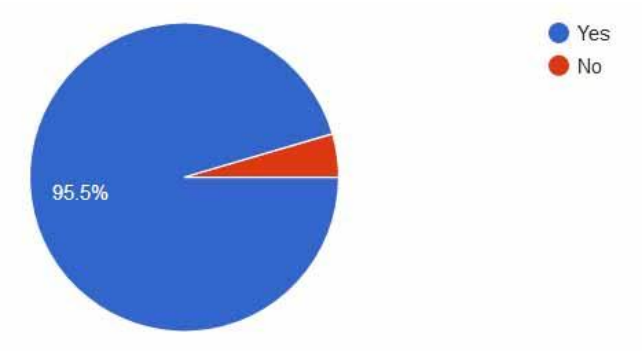


Figure (32), people agreement with card payment at buses

Most users are people with age range of 25 to 44 years old. 96.5% of interviewees had smartphones. Mostly people at the age of 25 to 34 did not have OPUS card and they are only

15.3%. People with age range of 25 to 44 with percentage of 35.3% have lost their cards and tickets.

Most of the interviewees had monthly pass (50%). They mostly face the long line for purchasing and recharging tickets and cards. 91.8% of them prefer online recharging and purchasing, and they would like ticket machines on the bus to work with bills and bank cards, because they seldom have coins in their wallets.

3.2. Bike sharing system

The bike sharing system is studied to solve the problem of limited time in Montreal. This study is done among the data shared in Montreal open data website. The data includes the information regarding station codes, longitude, latitude, start renting time, finish renting time, and member or non-member users. Since the station numbers are a lot, it is decided to pick stations randomly to study the effect of time on the behavior of users. Graph (1) indicates the stations and the travels occurred among them in a month. Each point is a station and the segments illustrate the travels among stations. The size of each point shows the number of bikes rented from

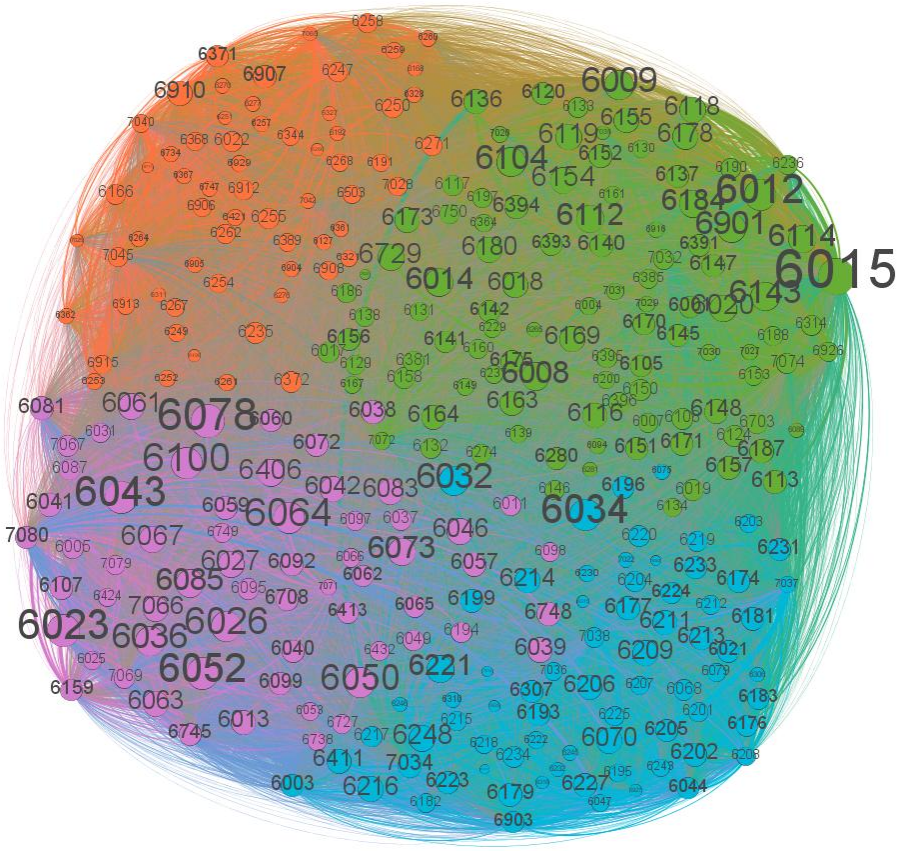


Figure (33), travels among Bixi stations

This graph can be more studied to recognize the stations with more travels and bike rents. The stations can be place on GIS map of Montreal to show the exact station location, therefore studying can be deeper and more accurate.

3.2.1. Purchase and trip history

3.2.1.1. Purchases

According to the open data of Bixi Montreal, the users, including members and non-members have been increased and the amount of non-member users are more than users with respect to purchasing. Charts (14) and (15) illustrate the purchase amount in years 2016 and 2017 respectively.

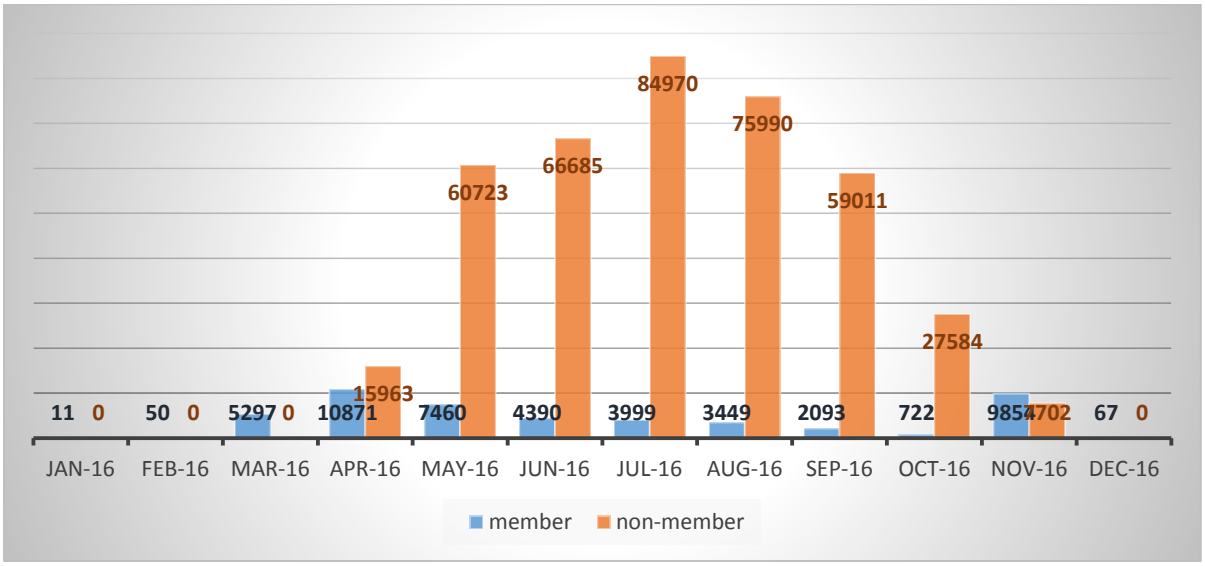


Figure (34), purchase amount in 2016, source: [21]

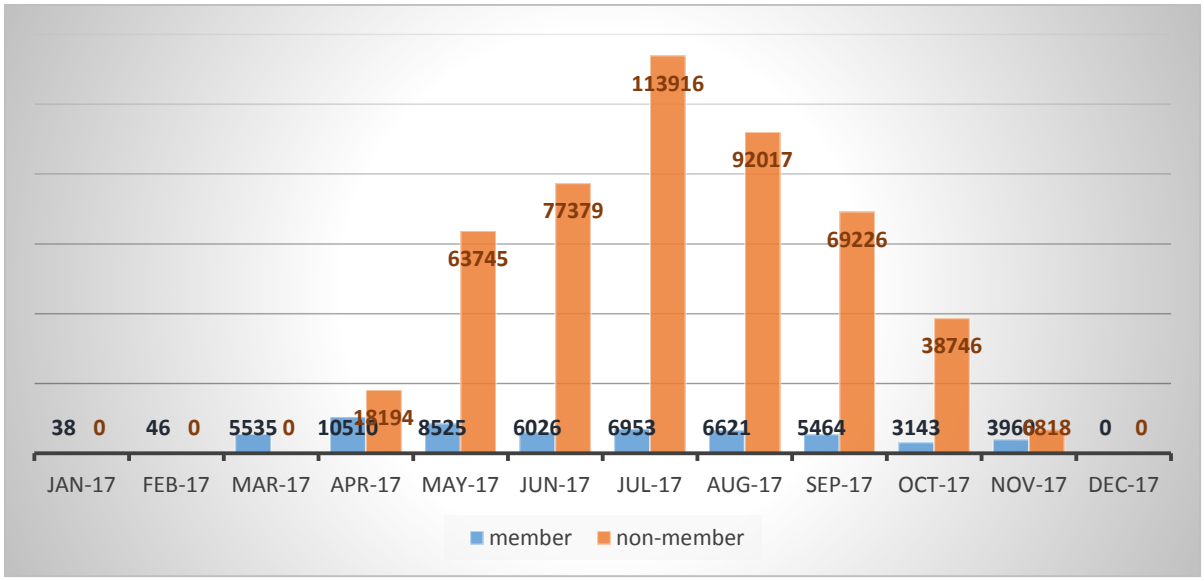


Figure (35), purchase amount in 2017, source: [21]

According to chart (16), the amount of users in the previous two years has been enhanced. The blue bars representing year 2016, whereas the orange bars indicate year 2017.

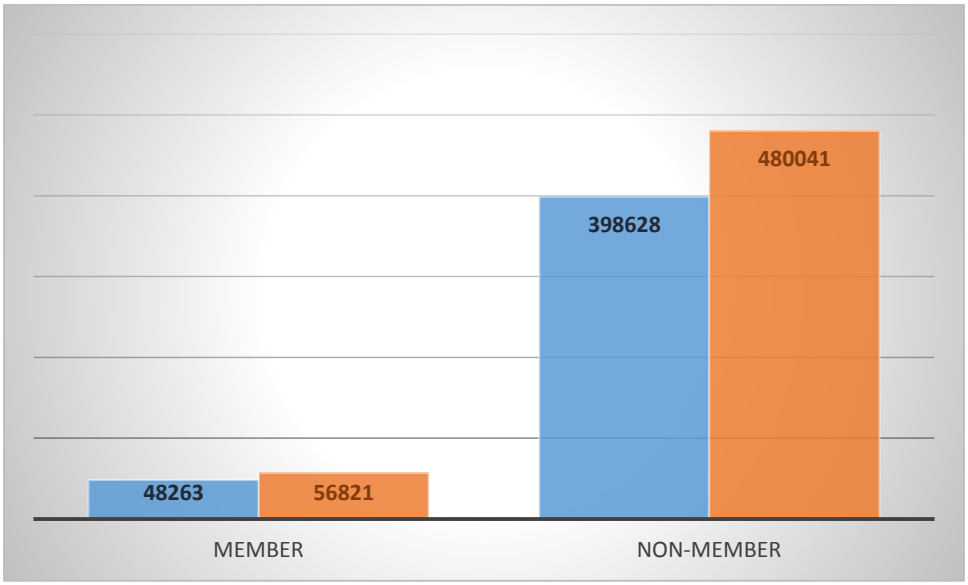


Figure (36), purchase comparison, source: [21]

3.2.1.2. Trips

The number of trips were also increased by the users from year 2016 to 2017. The non-member users traveled less than members. Charts (17) and (18) show the number of trips in 2016 and 2017 respectively.

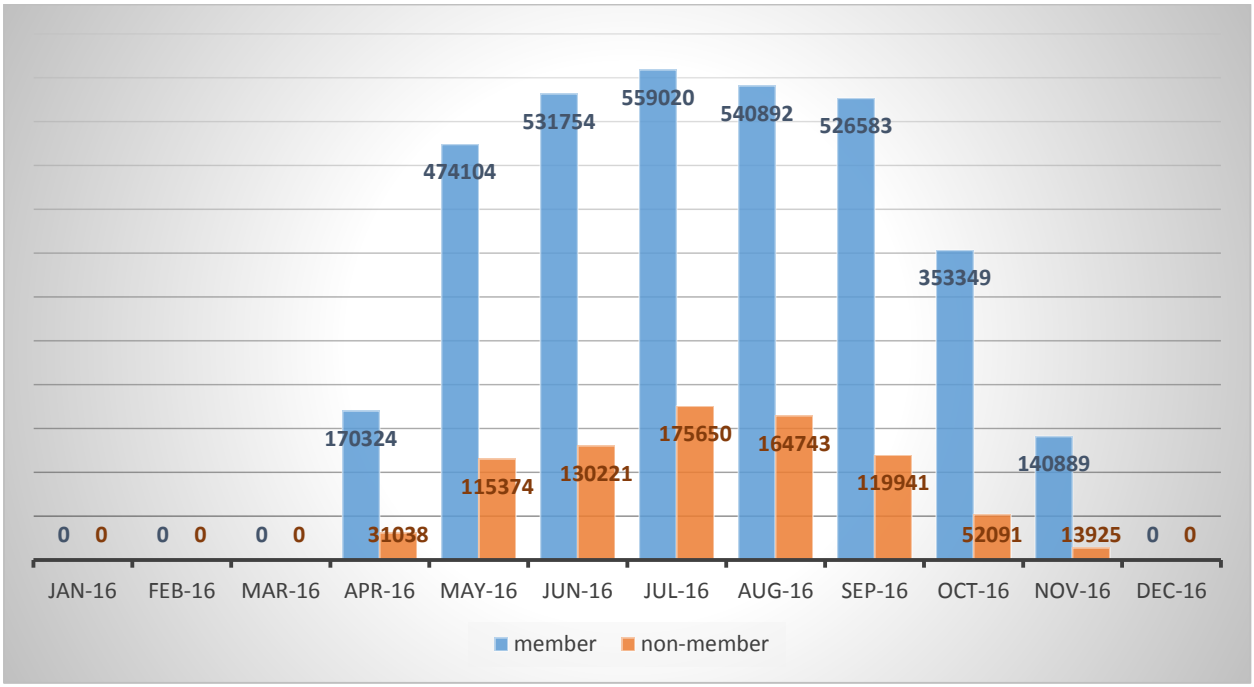


Figure (37), trips in 2016, source: [21]

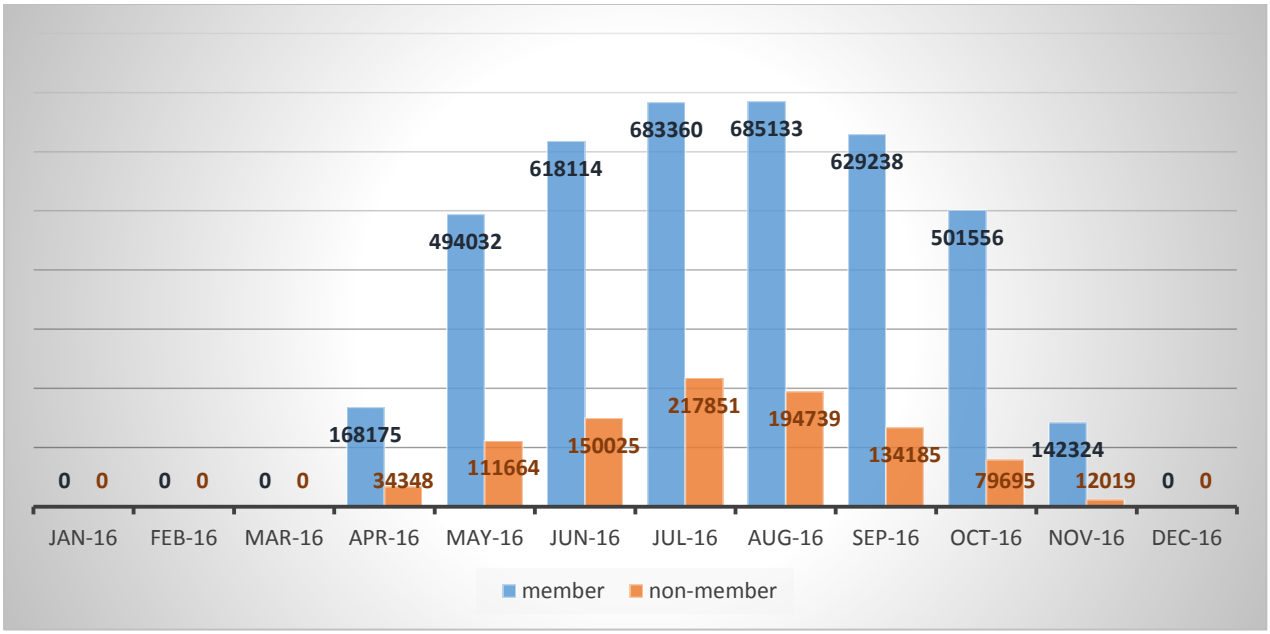


Figure (38), trips in 2017, source: [21]

According to chart (16), the amount of trips in the previous two years has been increased. The blue bars representing year 2016, and orange bars indicate year 2017.

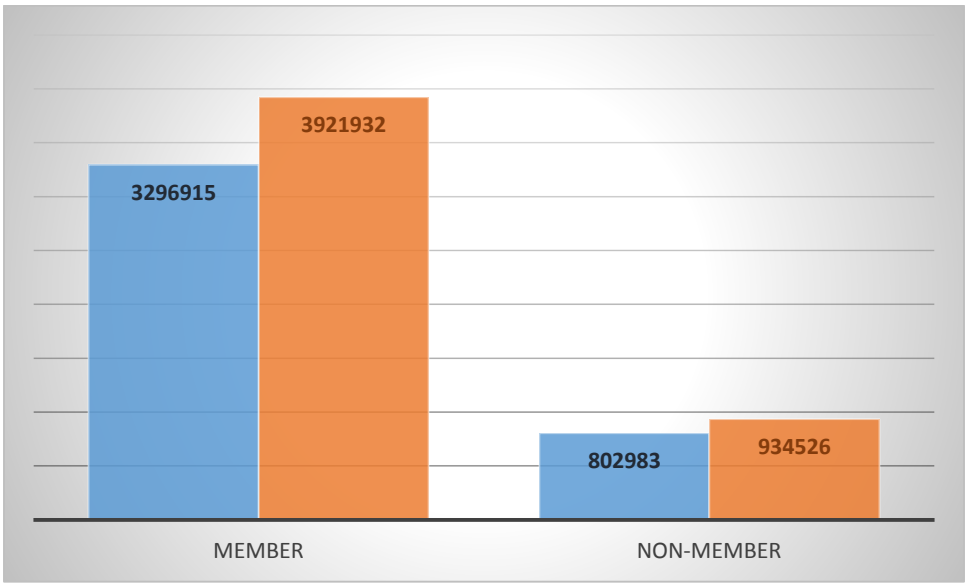


Figure (39), trip comparison, source: [21]

3.2.2. Random picks

Random stations in random months have been picked to study whether the time is a problem. the tables follows the patterns showed in table (3) and (4).

	members	non-members
total number of minutes of travels (T)	T_m	T_n
total number of minutes of exceeding (E)	E_m	E_n
E/T	$\frac{E_m}{T_m}$	$\frac{E_n}{T_n}$

Table (3), comparison of durations for each month

	members	non-members
number of travels (N)	N_m	N_n
number of travels with exceeding (n)	n_m	n_n
n/N	$\frac{n_m}{N_m}$	$\frac{n_n}{N_n}$

Table (4), comparison of frequencies for each month

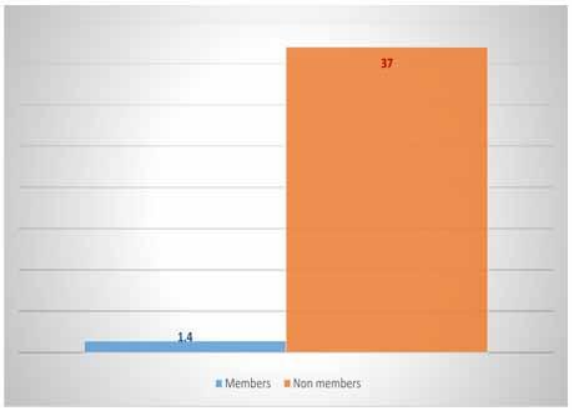
April 2016:

Station code: 5007

5007- 4/2016	members	non-members
total number of minutes of travels (T)	2014.25	885.4667
total number of minutes of exceeding (E)	29.43	332.7667
E/T	0.014611	0.375809

5007- 4/2016	members	non-members
number of travels (N)	110	24
number of travels with exceeding (n)	2	13
n/N	0.018182	0.541667

Comparison of durations of 4/2016



Comparison of frequencies of 4/2016

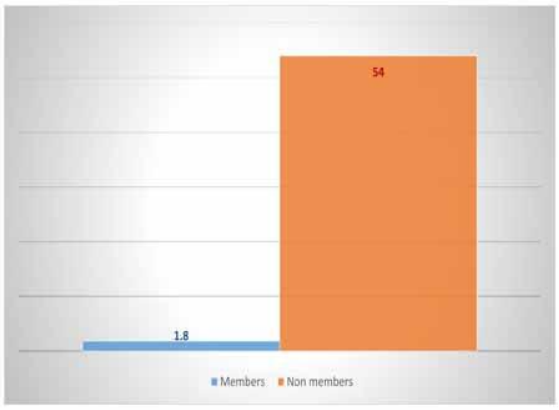


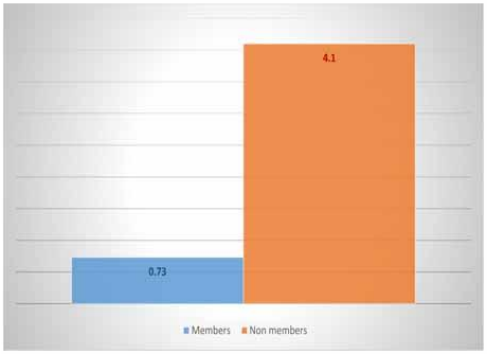
Figure (40), Comparison of durations and comparison of frequencies for each month, station 5007

Station code: 6140

6140- 4/2016	members	non-members
total number of minutes of travels (T)	7637.683	915.283
total number of minutes of exceeding (E)	55.88333	38.26667
E/T	0.007317	0.041809

6140- 4/2016	members	non-members
number of travels (N)	680	51
number of travels with exceeding (n)	8	1
n/N	0.011765	0.019608

Comparison of durations of 4/2016



Comparison of frequencies of 4/2016

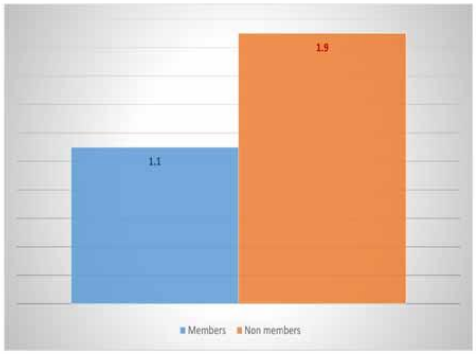


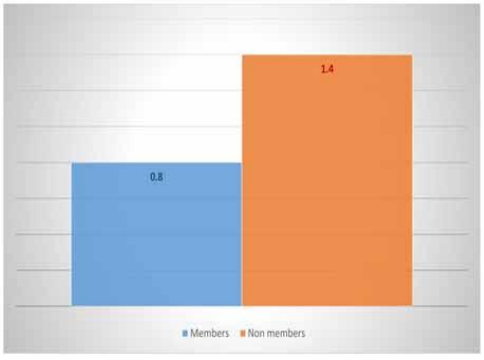
Figure (41), Comparison of durations and comparison of frequencies for each month, station 6140

Station code: 6929

6929- 4/2016	members	non-members
total number of minutes of travels (T)	4108.167	282.8
total number of minutes of exceeding (E)	32.95	4.033333
E/T	0.008021	0.014262

6929- 4/2016	members	non-members
number of travels (N)	317	19
number of travels with exceeding (n)	5	1
n/N	0.015773	0.052632

Comparison of durations of 4/2016



Comparison of frequencies of 4/2016

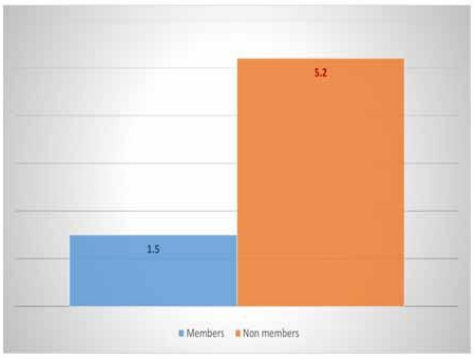


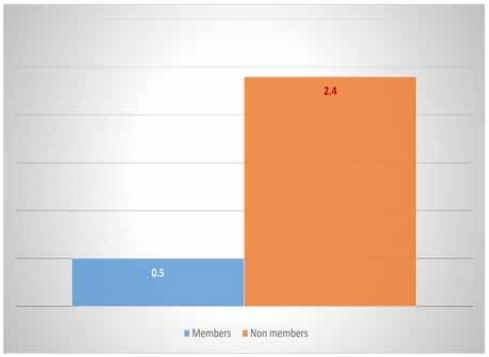
Figure (42), Comparison of durations and comparison of frequencies for each month, station 6929

Station code: 6260

6260- 4/2016	members	non-members
total number of minutes of travels (T)	4073.433	714.1167
total number of minutes of exceeding (E)	21.66667	17.81667
E/T	0.005319	0.024949

6260- 4/2016	members	non-members
number of travels (N)	310	43
number of travels with exceeding (n)	2	1
n/N	0.006452	0.023256

Comparison of durations of 4/2016



Comparison of frequencies of 4/2016

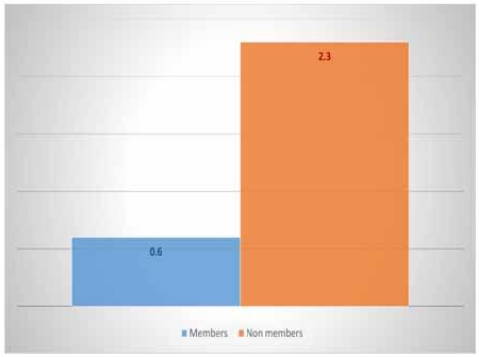


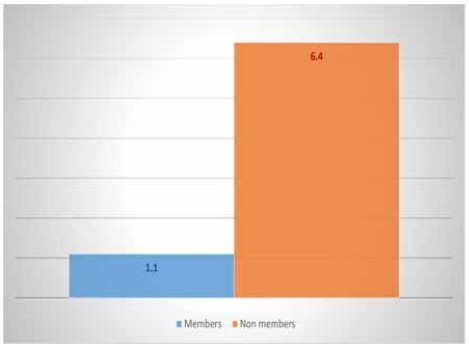
Figure (43), Comparison of durations and comparison of frequencies for each month, station 6929

Station code: 6924

6924- 6/2016	members	non-members
total number of minutes of travels (T)	4235.767	1275.883
total number of minutes of exceeding (E)	47.01667	82.65
E/T	0.0111	0.064779

6924- 6/2016	members	non-members
number of travels (N)	341	75
number of travels with exceeding (n)	3	4
n/N	0.008798	0.053333

Comparison of durations of 6/2016



Comparison of frequencies of 6/2016

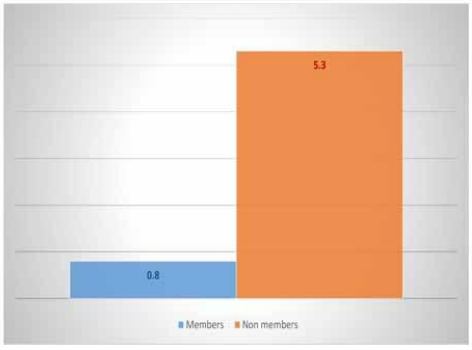


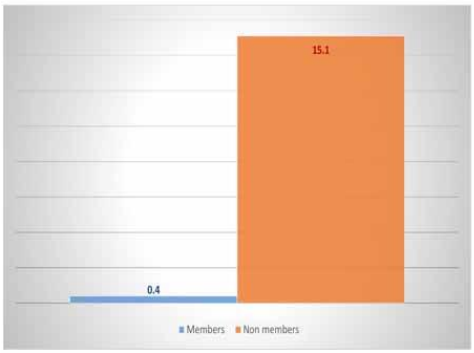
Figure (44), Comparison of durations and comparison of frequencies for each month, station 6924

Station code: 6401

6401- 6/2016	members	non-members
total number of minutes of travels (T)	9836.65	4613.467
total number of minutes of exceeding (E)	39.85	699.1833
E/T	0.004051	0.151553

6401- 6/2016	members	non-members
number of travels (N)	958	217
number of travels with exceeding (n)	7	43
n/N	0.007307	0.198157

Comparison of durations of 6/2016



Comparison of frequencies of 6/2016

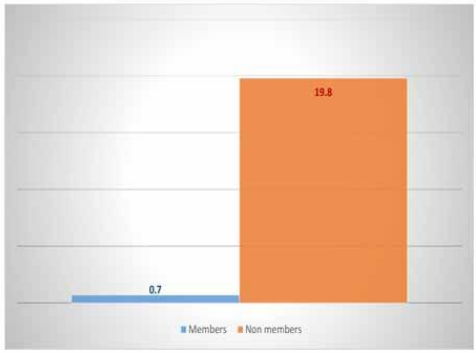


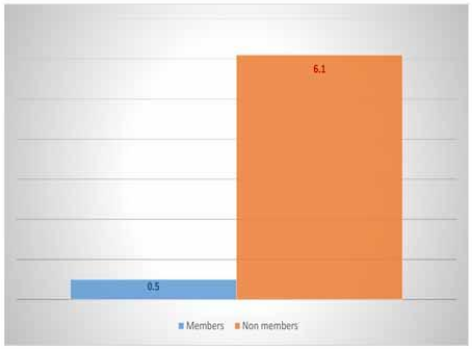
Figure (45), Comparison of durations and comparison of frequencies for each month, station 6401

Station code: 6263

6263- 10/2016	members	non-members
total number of minutes of travels (T)	3979.417	273
total number of minutes of exceeding (E)	20.95	16.8
E/T	0.005265	0.061538

6263- 10/2016	members	non-members
number of travels (N)	255	21
number of travels with exceeding (n)	2	2
n/N	0.007843	0.095238

Comparison of durations of 10/2016



Comparison of frequencies of 10/2016

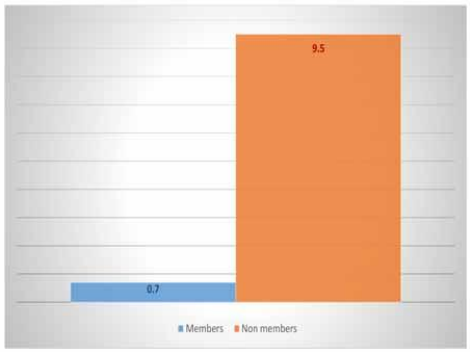


Figure (46), Comparison of durations and comparison of frequencies for each month, station 6263

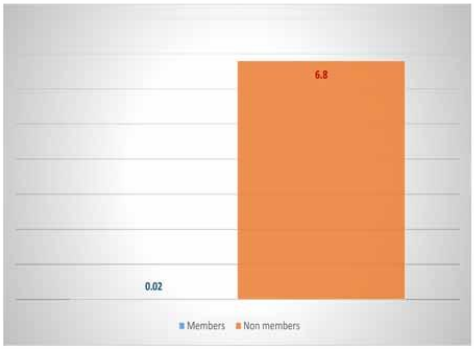
Station code: 6260

6027- 10/2016	members	non-members
total number of minutes of travels (T)	12107.23	2090.833
total number of minutes of exceeding (E)	3.466667	143.55
E/T	0.000286	0.068657

Comparison of durations of 10/2016

6027- 10/2016	members	non-members
number of travels (N)	1077	126
number of travels with exceeding (n)	1	10
n/N	0.000929	0.079365

Comparison of frequencies of 10/2016



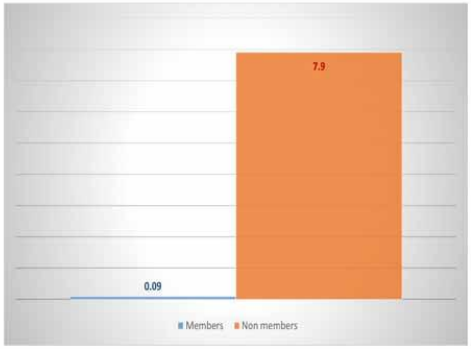


Figure (47), Comparison of durations and comparison of frequencies for each month, station 6929

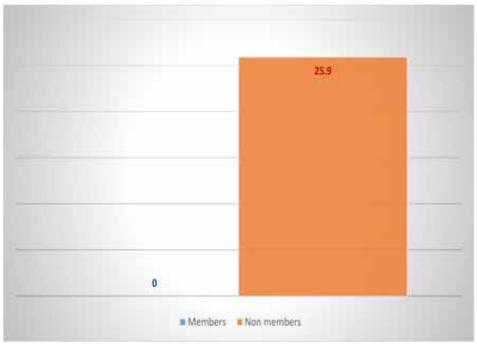
Station code: 6011

6011- 11/2016	members	non-members
total number of minutes of travels (T)	2684.583	250.15
total number of minutes of exceeding (E)	0	64.83333
E/T	0	0.259178

Comparison of durations of 11/2016

6011- 11/2016	members	non-members
number of travels (N)	297	12
number of travels with exceeding (n)	0	1
n/N	0	0.083333

Comparison of frequencies of 11/2016



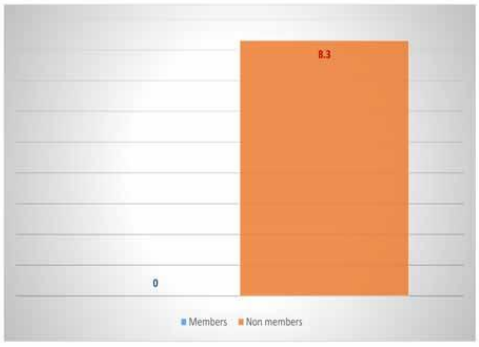
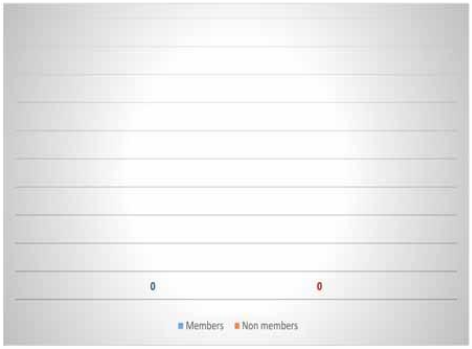


Figure (48), Comparison of durations and comparison of frequencies for each month, station 6011

Station code: 6167

6167- 11/2016	members	non-members
total number of minutes of travels (T)	3167.05	91.73333
total number of minutes of exceeding (E)	0	0
E/T	0	0

Comparison of durations of 11/2016



6167- 11/2016	members	non-members
number of travels (N)	311	7
number of travels with exceeding (n)	0	0
n/N	0	0

Comparison of frequencies of 11/2016

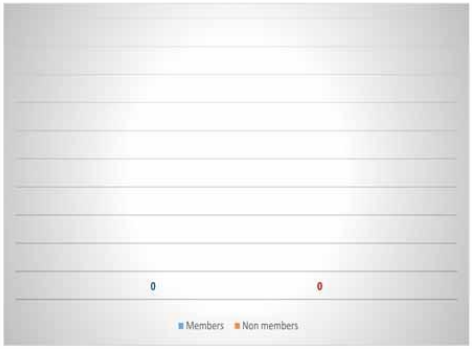
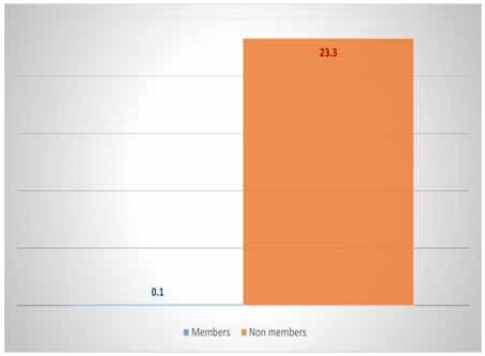


Figure (49), Comparison of durations and comparison of frequencies for each month, station 6167

Station code: 6081

6081- 4/2017	members	non-members
total number of minutes of travels (T)	5094.633	2183.333
total number of minutes of exceeding (E)	9.866667	510.7167
E/T	0.001937	0.233916

Comparison of durations of 4/2017



6081- 4/2017	members	non-members
number of travels (N)	463	93
number of travels with exceeding (n)	1	19
n/N	0.00216	0.204301

Comparison of frequencies of 4/2017

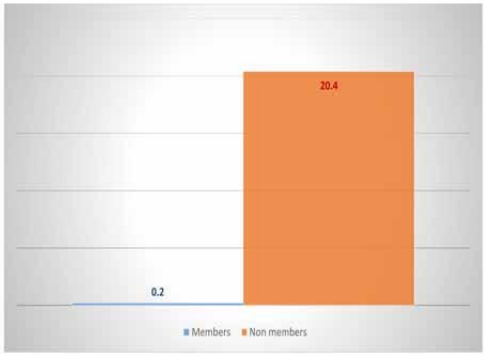


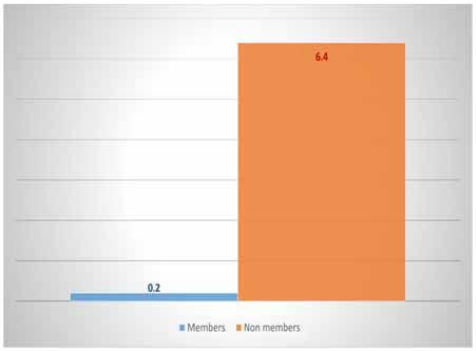
Figure (50), Comparison of durations and comparison of frequencies for each month, station 6081

Station code: 6394

6394- 4/2017	members	non-members
total number of minutes of travels (T)	5874.15	1302.6
total number of minutes of exceeding (E)	14.83333	83.55
E/T	0.002525	0.064141

6394- 4/2017	members	non-members
number of travels (N)	466	64
number of travels with exceeding (n)	2	11
n/N	0.004292	0.171875

Comparison of durations of 4/2017



Comparison of frequencies of 4/2017

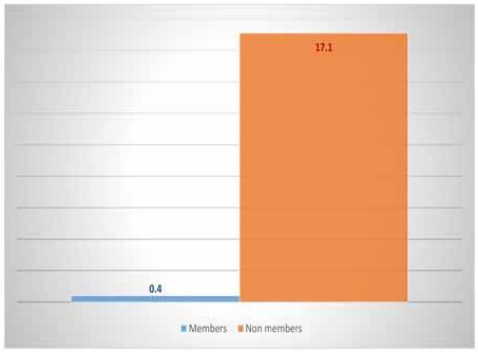


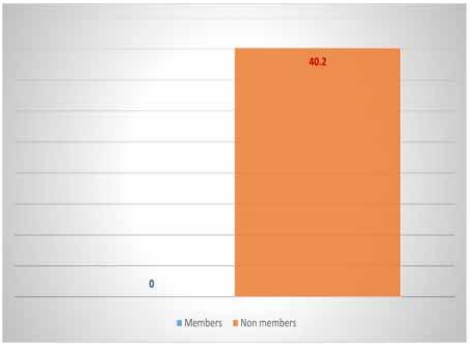
Figure (51), Comparison of durations and comparison of frequencies for each month, station 6394

Station code: 5003

5003- 4/2017	members	non-members
total number of minutes of travels (T)	253.15	73.31667
total number of minutes of exceeding (E)	0	29.5
E/T	0	0.402364

5003- 4/2017	members	non-members
number of travels (N)	15	2
number of travels with exceeding (n)	0	1
n/N	0	0.5

Comparison of durations of 4/2017



Comparison of frequencies of 4/2017

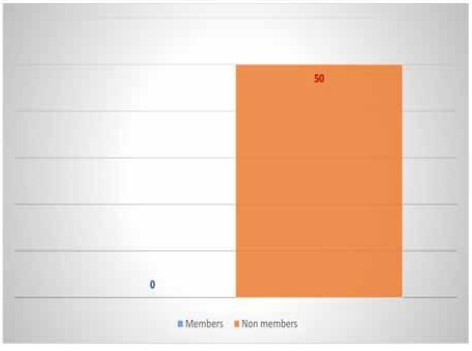
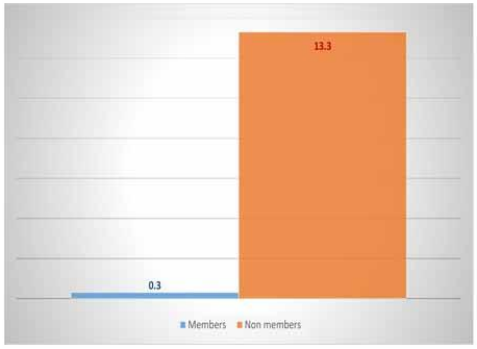


Figure (52), Comparison of durations and comparison of frequencies for each month, station 5003

Station code: 7081

7081- 5/2017	members	non-members
total number of minutes of travels (T)	4711.5	1720.883
total number of minutes of exceeding (E)	16.86667	229.0667
E/T	0.00358	0.13311

Comparison of durations of 5/2017



7081- 5/2017	members	non-members
number of travels (N)	394	76
number of travels with exceeding (n)	1	16
n/N	0.002538	0.210526

Comparison of frequencies of 5/2017

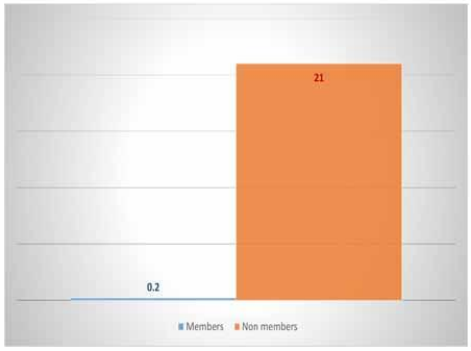
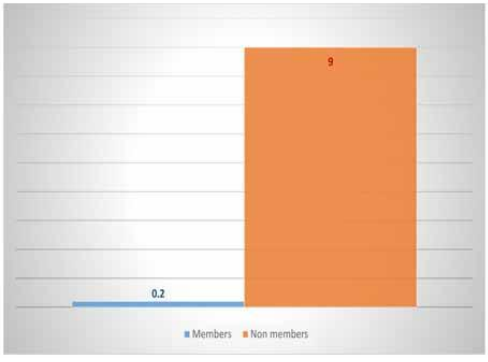


Figure (53), Comparison of durations and comparison of frequencies for each month, station 7081

Station code: 6218

6218- 5/2017	members	non-members
total number of minutes of travels (T)	10641.37	4146.967
total number of minutes of exceeding (E)	23.98333	376.9333
E/T	0.002254	0.090894

Comparison of durations of 5/2017



6218- 5/2017	members	non-members
number of travels (N)	1058	239
number of travels with exceeding (n)	4	30
n/N	0.003781	0.125523

Comparison of frequencies of 5/2017

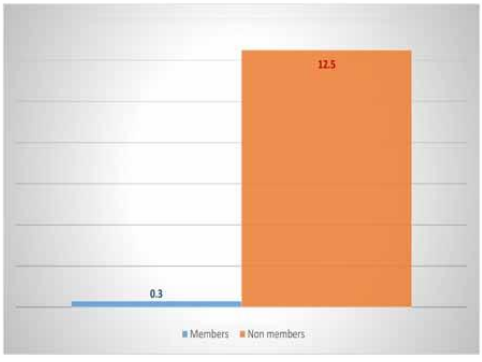


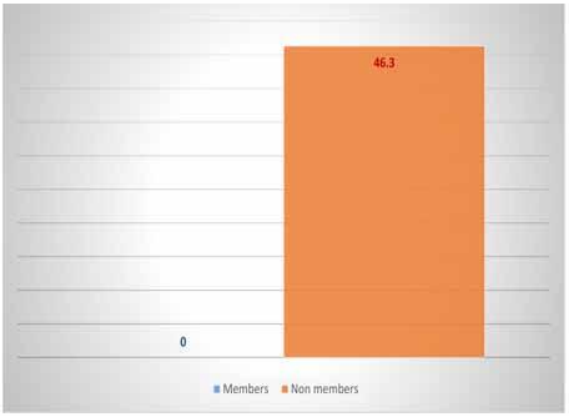
Figure (54), Comparison of durations and comparison of frequencies for each month, station 6218

Station code: 7075

7075- 5/2017	members	non-members
total number of minutes of travels (T)	717.7	223.4833
total number of minutes of exceeding (E)	0	103.4833
E/T	0	0.463047

7075- 5/2017	members	non-members
number of travels (N)	45	4
number of travels with exceeding (n)	0	4
n/N	0	1

Comparison of durations of 5/2017



Comparison of frequencies of 5/2017

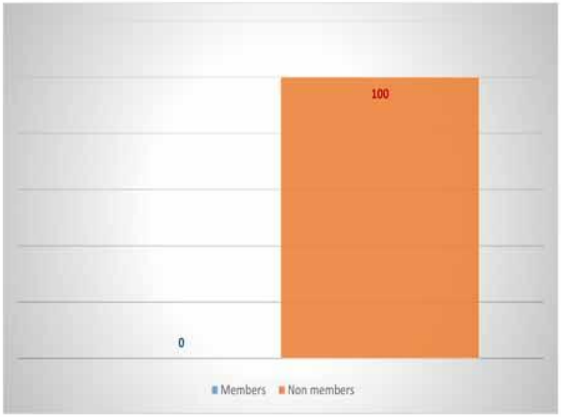


Figure (55), Comparison of durations and comparison of frequencies for each month, station 7075

4. Results and conclusion

4.1. Bike sharing system:

According to the analysis of random picks, the number of time exceed for non-member users are clearly higher than member users. This shows the weak timing system of Bixi, beside less information regarding using the public bike sharing system.

However there are three stations in sixteen randomly picked stations, which had zero percent time exceed for member users and one station with zero percent for non-member users, still most of the stations are facing the problem of time. Thus, the time of renting bikes should be expanded to reduce the problem users face using bikes in Bixi. The bike sharing system in Barcelona has the ticket with which users can ride the bike up to two hours, with charging for each 30 minute; the first 30 minute of ride is free.

The time and the problem of charging with a high amount of money may cause people not to use the public bike sharing system, and this can hurt the company in a long time. Therefore the time limitation can be removed and the users, respecting members and non-members can ride for a longer time and be charged for the next 45 minutes and 30minutes of use (member and non-member return time respectively). In this case the risk of not finding vacant stations to return and re-renting the bike will be eliminated.

To conclude, the results illustrate the presented hypothesis is correct, and the time of renting and using the bikes has to be expanded.

4.2. STM ticket system:

The ticket system in STM public transportation should become smart in terms of payment with accordance to users interview results. Because of no cooperation of STM managers and employees, the way with which the ticket system is better to be smart is still not obvious to the researcher. Therefore the hypothesis of making ticket system in a smart payment manner is true, but the exact method of making it smart is still unknown.

5. Future works

According to the limitations which were faced during the study regarding the high number of stations for Bixi, random stations in random months were picked to analyze. In order to go deeper in the problem of time in renting bikes in Bixi system, the stations in which the time exceed are more regular and the causes can be studied in future projects. In this case the result is going to be very accurate.

For STM ticket system, more data can be collected to prove the fact the current method is not preferred by the users. This fact is because of less information regarding purchasing and recharging the cards and tickets. What is more less cooperation of STM managers and employees caused limitation to the way with which the project could be improved with.

6. References

[1] Tomas. (12/2016). Barcelona named “iCapital” of Europe.

https://www.shbarcelona.com/blog/en/barcelona-icapital/

[2] Average Salary in Montréal, Québec, Canada. (01/2018).

http://www.payscale.com/research/CA/Location=Montr%C3%A9al-Qu%C3%A9bec/Salary#by_Job

[3] EUROPEAN COMMISSION. (03/2014). BARCELONA IS "ICAPITAL" OF EUROPE.

europa.eu/rapid/press-release_IP-14-239_en.doc

[4] Moskvitch, K. (2016), Barcelona: the world's smartest city?, *Engineering & Technology*, May 2016, pp 48-51

[5] STM (Société de transport de Montréal). (Last check 07/2017). http://www.stm.info/en

[6] TMB. (01/2018). https://www.tmb.cat/

(The website is in Spanish.)

[7] World Weather Online. (Last check: 05/2017). www.worldweatheronline.com

[8] Montreal. (Last check: 05/2017).

http://en-ca.topographic-map.com/places/Montreal-689651/

[9] Kasmaei, M. (2014), *Climate and Architecture, 5th edition*, Esfahan, Esfahan: Khak.

(The book is in Persian.)

[10] Flood Map: Water Level Elevation Map (Beta). (Last check: 05/2017).

http://www.floodmap.net/

[11] The Concordian. (09/2011). Barcelona vs. Montreal. theconcordian.com/2011/09/barcelona-vs-montreal/

[12] Ingrid. (02/2017). What are the salaries like in Barcelona?.

https://www.shbarcelona.com/blog/en/salaries-in-barcelona/

[13] Barcelona area. (Last check 01/2018). https://en.wikipedia.org/wiki/Barcelona

[14] Buses in Barcelona. (Last check 10/2017). https://en.wikipedia.org/wiki/Buses_in_Barcelona

[15] Dumas, M. (10/2010). Public transportation in Montreal. http://www.ariannerelocation.com/location/montreal-quebec-en/public-transportation-in-montreal/

[16] Premium Traveler Barcelona. (Last check 07/2017). http://premiumtravelerbarcelona.com/service/car-with-driver?gclid=CMCEuNncjNQCFQKsaQodF3sLZg

[17] Sixt my driver. (Last check 01/2017). https://www.mydriver.com/en/private-car-service/barcelona#/home?type=DISTANCE&startdate=2017-05-26T02:00:00

[18] Car2go. (Last check 01/2018). https://www.car2go.com/CA/en/montreal/

[19] Communauto. (Last check 01/2017). https://www.communauto.com/index_en.html

[20] Bicing. (Last check 10/2017). https://www.bicing.cat/ca

[21] Bixi. (Last check 10/2017). https://montreal.bixi.com/en

[22] We Smart Park. (Last check 07/2017). https://barcelona.wesmartpark.com/en/

[23] Eltis Mobility Portal. (06/2014).Barcelona Parking Space Management. https://www.youtube.com/watch?v=Ft70QlfCkS4

[24] Parking Zones in Barcelona. (Last check 07/2017). http://www.barcelonayellow.com/bcn-transport/492-parking-zones

[25] Barcelona Car Parking. (Last check 07/2017). http://www.barcelona.com/barcelona_city_guide/car_parking

[26] The European car parking guide. (Last check 07/2017). http://www.car-parking.eu/spain/barcelona/pr

[27] Barcelona parking. (Last check 07/2017). https://www.parkme.com/barcelona-es-parking

[28] Pstationement de Montreal. (Last check 07/2017). http://www.statdemtl.qc.ca/en?lang=en

[29] Sofia. (05/2015). How to figure out parking zones in Barcelona?. http://immovingtobarcelona.com/public-parking-zones-in-barcelona/

[30] Thompson, E. (2016), What makes a city ‘smart’?, *International Journal of Architectural Computing*,Vol. 14, No. 4, , pp. 358-371

[31] Siuryte, A. and Davidaviciene, V. (2016), An Analysis of Key Factors in Developing A Smart City, *Science – Future of Lithuania*, Vol. 8, No. 2, pp. 254-262

[32] C. Snow, C. and Dojbak Hakonsson, D. and Obel, B. (2016), A smart city is a collaborative community: Lessons from Smart Aarhus, BerkeleyHaas, Vol. 59, No. 1, pp. 92-108

[33] Almirall, E. and Bria, F. (2016), Smart Cities at the Crossroads: New Tensions in City Transformation, BerkeleyHaas, Vol. 59, No. 1, pp. 141-152

[34] RTC: Réseau de transport de la Capitale. (Last check 01/2018). https://www.rtcquebec.ca/

[35] Greater Montreal. (Last check 01/2018). https://en.wikipedia.org/wiki/Greater_Montreal

[36] Technical Assistance. (Last check 10/2017). https://stm.opusenligne.ca/en/technical-assistance

[37] Opus card reader review: It works, with a caveat. (07/2015).

http://www.btmontreal.ca/videos/4389649083001/

[38] Mio, K. (07/2015). Now you can top up your Opus pass online — with a card reader

http://montrealgazette.com/news/local-news/stm-launches-opus-card-readers-for-the-home

[39] The $7.6 million Opus card reader. (01/2016).

http://www.btmontreal.ca/videos/4711634035001/

[40] MacKinnon, C. (10/2017). Controversial OPUS card technology kept under wraps in Quebec City. www.cbc.ca/news/canada/montreal/quebec-city-opus-card-1.4342584