Evaluating the Bicycle-Sharing System in a Medium-Sized City Located in the South of Brazil

Paola Pol Saraiva
Master's student in Architecture and Urbanism
Stricto Sensu Graduate Program in Architecture and Urbanism
PPGARQ, IMED
Passo Fundo, Brazil

Lauro André Ribeiro
Associate Professor
Stricto Sensu Graduate Program in Architecture and Urbanism
PPGARQ, IMED
Passo Fundo, Brazil

Alcindo Neckel
Associate Professor
Stricto Sensu Graduate Program in Architecture and Urbanism
PPGARQ, IMED
Passo Fundo, Brazil

Richard Thomas Lermen
Associate Professor
[b]Stricto Sensu Graduate Program in Civil Engineering – PPGEC
IMED. Passo Fundo, Brazil

Juliano Lima da Silva
Master's student in Architecture and Urbanism
Stricto Sensu Graduate Program in Architecture and Urbanism
PPGARQ, IMED
Passo Fundo, Brazil

Abstract

Seeking new solutions to urban mobility problems, the City of Passo Fundo, located in the State of Rio Grande do Sul, Brazil, recently implemented a bicycle-sharing system named "Passo Fundo: Vai de Bici (Goes by bike)". The general objective of this study is to analyze this new system and diagnose its performance on the first months of operation, as well to characterize the bicycle stations and their surroundings by trying to identify the regions with greater and lesser potential for cycling trips. Results presented in this work provide an initial overview of the operating system by highlighting the characteristics that influence the use of each station. They also present some possible future challenges, such as the need for stations in areas of the city that are not yet covered by this system, and stations that may receive more bicycles due to high demand. Finally, this study demonstrates how the surroundings influence either in a positive or in a negative way the use of the bicycle sharing service.

Keywords: shared bicycles; active mobility; sustainability; integrated management.

1. Introduction

According to Vasconcellos (2000), Shaheen, Guzman and Zhang (2010), Fishman, Washington and Haworth (2013), and Ho and Szeto (2017), global problems, directly linked to urban mobility on a world scale, vary increasingly due to the growth rate of motor vehicles on roads.

Among these problems generated by the increase of the automotive market, Fishman, Washington and Haworth (2013), Figueroa et al. (2014), Ho and Szeto (2017), Hiselius and Svensson (2017) and Fournier, Christofa and Knodler (2017) highlight that such problems also result in the following issues: constant growth of traffic congestion, accidents, noise and atmospheric pollution, climate change, and unsatisfactory indexes in population life quality. Figueroa et al. (2014), Ambrosino et al. (2016) and Zhang et al. (2017) state that world population is at the mercy of urban mobility decrease in small, medium and large-sized cities. Nunes, Rosa and Moraes (2015) also mentioned that the United Nations (UN) confirms the decline of issues related to well-being and satisfaction of urban population in relation to transportation means, especially regarding the lack of alternative transportation options, such as bicycle use. Over the past ten years, the growth of automobiles in Brazil are also confirmed by the National Department of Transport- DENATRAN (2016)that recorded 27,868,564 vehicles in circulation in Brazil in December 2006 and 51,296,982 in December 2016. This means that the number of vehicles increased 84% during this decade. Therefore, according to Lowry and Loh (2017), the options for active and sustainable mobility means of transportation are little, both due to the lack of infrastructure and emphasis on sustainable mobility in Brazilian municipal public policies.

Ambrosino et al. (2016), and Lowry and Loh (2017) point out that discussions on alternative mobility means have been gaining ground as the population experiences negative impacts related to traditional urban mobility. In this sense, Buehler and Pucher (2012) and Bandeira et al. (2017) state that active mobility, which is understood as one that only uses physical effort of the human being for transportation, appears as an alternative to minimize these problems. Schuijbroek, Hampshire and Van Hoeve (2017) state that cycling and walking are the most common forms of active mobility, and are also considered the most sustainable ways to get around. Ho and Szeto (2017) and Zhang et al. (2017) affirm that the more spaces are designed for pedestrians and cyclists, the safer and more sustainable a city will be. In accordance with Strauss et al. (2017), among the alternatives in search for active mobility, bicycle sharing systems have been gaining popularity in many cities worldwide. According to Demaio (2009), Institute for Transport and Development Policy - IPTD (2014) and Bandeiraet al. (2017), a set of stations spread throughout the urban network, containing a set of bicycles available for the population to use and return them later is considered. Moreover, Demaio (2009) also mentioned that this initiative of sharing bicycles came to light in 1965 in Amsterdam, with the aim of reducing vehicle traffic in the city. As stated in IPTD (2014) and Demaio (2009), in 1991, Copenhagen replicated this idea and introduced this system in the city. The latter also sought improvements for the system, since it faced difficulties related to bicycle theft, thus making this stage known as the second-generation system of bicycle sharing.

According to IPTD (2014), Demaio (2009), and Bauman et al. (2017), the third-generation system was implemented in Rennes, France in 1998, with the introduction of smart cards technology, and this development provided a real-time control of bicycles use, making the system easier to monitor, safer and with an improved billing system. In the shared bicycles world map developed by Meddin and DeMaio (2017) during February 2017, approximately 1,200 cities worldwide have bicycle-sharing systems in operation, and about 350 cities have system either under construction or planning. Demaio (2009), Shaheen, Guzman and Zhang (2010), Kabra, Belavina and Girotra (2016), Zhang et al. (2017) and Bauman et al. (2017) argue that the use of bicycle sharing systems tends to generate several benefits. For instance, some of the benefits are increasing mobility ease, reduction of polluting emissions, reduction of traffic and increased accessibility for a larger portion of the population. In addition, there are a series of public health benefits of traveling by bicycle as a physical activity. For Ho and Szeto (2017), Schuijbroek, Hampshire and Van Hoeve (2017), bicycle sharing systems tend to generate improvements in the cities' layout, that is, the city is perceived as more dynamic and modern. In this context, this work analyzes the city of Passo Fundo, located in Southern Brazil, with a population of approximately 197,800 people according to the Brazilian Institute of Geography and Statistics - IBGE (2017). Passo Fundo has about 125,644 motor vehicles (DENATRAN, 2016) that offer an ideal scenario for studies aimed at increasing active mobility in the city.

This city was not planned to accommodate such a high flow of pedestrians, and especially vehicles. The increase of the motorized vehicles from 65,256 in 2006 to 125,644 in 2016 represents about92.5% (DENATRAN, 2016). This fact makes bicycles an alternative transportation mode to improve the urban circulation system. The major traffic congestion area in Passo Fundo is in its main avenue named Avenida Brasil (Brazil Avenue).Therefore, the general aim of the present study was to collect and analyze transportation data in a quantitative and qualitative way regarding the bicycle-sharing system.

This system was recently implemented in the city of Passo Fundo belonging to the "Passo Fundo Vai de Bici" (Passo Fundo goes by bike) program, and estimates the potential use of each shared station considering its surroundings. This study was conducted through a collection of data from the Passo Fundo City Hall records, and from a survey obtained in the shared stations with information of their surroundings and their main attraction sites. The main inflow trips and main aspects that contribute to the use of the shared bikes were then analyzed. These aspects were highlighted by Schuijbroek, Hampshire and Van Hoeve (2017) as follows: education (number of educational institutions in the area), green areas (quantity of parks, squares or flower beds), traffic safety (proximity to bike lane or cycle path), proximity to other stations and attractive hub for people (number of sites that generate daily activities in the surroundings). Finally, a linear regression analysis was conducted to estimate the potential use of the bicycle sharing system proposed by the City Hallusing the software Minitab. Fournier, Christofa and Knodler (2017) help justify the importance of creating and analyzing cycling models that will favor active mobility, as in the case of the city of Passo Fundo that like most medium-sized cities, it faces serious problems related to locomotion. For Lowry and Loh (2017), Bauman et al. (2017) and Strauss et al. (2017), research involving bicycles use as a mean of transport can contribute to possible projects for cities that can be improved and, therefore, contribute to the possible expansion of bicycle sharing networks, serving as an example for other medium-sized cities worldwide.

2.Methodology

The methodology is divided into three stages. The first stage describes the data collection procedures used to diagnose the operation of the "Passo Fundo Vai de Bici" project in the first eight months. The second stage presents the description of the surroundings of the stations. Finally, the third stage describes how the station surroundings characteristics were analysed for each aspect, besides the description of the mathematical model developed to estimate the potential of the stations. To describe the first eight months of the "Passo Fundo Vai de Bici" project operation, monthly reports regarding the use of the system, were analysed from data collected from Passo Fundo City Hall. These data refer to the system users' profile, the number of trips made at each station, times and days when there is more frequent use of bicycles, and general data such as total number of trips and total number of kilometres travelled. These data refer to the period between May 11th, 2016, when the operation of the system began, and January 20th, 2017, totalling approximately 8 months of operation. Subsequently, a survey of the current situation of the ten stations implemented in the city and its surroundings was conducted. It considered a radius of approximately 500 meters around each station, and identified the main attraction sites that generate trips. Figure 1 shows a map which demonstrates the location of each station in the city. After the completion of this stage, an analysis was made of the surroundings of the ten stations previously mentioned, in relation to five aspects, which are highlighted in Schuijbroek, Hampshire and Van Hoeve's (2017) studies, such as education(number of educational institutions in the surroundings), green areas (quantity of parks, squares or central flowerbeds with sufficient length for their use), traffic safety (proximity to a bike lane or cycle path for traveling), proximity to other stations and attractive hub for people (number of sites that generate daily activities in their surroundings, like shopping malls, hospitals, and cultural centers). For each aspect, these researchers assigned grades from 0 to 4, for each of the ten stations by following pre-established criteria developed by them, as described in Table 1.

Table 1. Considered aspects and criteria with their corresponding scores

Score		Education	Green Areas	Traffic Safety	Attractive Hub For People	Proximity To Other Stations
Non existent	0	There are no educational institutions	Lack of green space	Station located more than ten blocks from the bike path/bike lane	Lack of demand generating points	More than ten blocks
Satisfactory	1	One educational institution	Central flower bed	Station located from six to ten blocks from the bike path/bike lane	1 point	From nine to ten blocks
Good	2	Two educational institutions	Square	Station located from four to five blocks from the bike path/bike lane	2 points	From six to eight blocks
Very good	3	Three educational institutions	Park	Station located up to three blocks from the bike path/bike lane	3 points	From four to five blocks
Excellent	4	More than three educational institutions	More than one green area	Station located along the bike path/bike lane	More than 3	Up to three blocks

The following aspects, namely education, green areas, traffic safety, proximity to other stations and attractive hub for people were listed as being the main demand generators for the use of "Passo Fundo Vai de Bici" stations. In the green areas, the central flower beds used as small squares, squares and parks were chosen in order to make the environment more harmonious and pleasant, besides working as attractive areas for sports and leisure activities. For the traffic safety aspect, the proximity to the existing cycle network in the city was evaluated. For the proximity to the other stations aspect, the number of blocks one station was from the nearest station was assessed. For the education aspect, the number of institutions present in the station surroundings, from schools to colleges and other institutions were taken into account. As for the attractive hub for people aspect, attraction sites that interest a considerable number of visitors daily (which generate trip origins and destinations for different purposes) were considered. Establishments such as Bella Cittá Shopping Mall, Vera Cruz Cemetery, Roseli Doleski Pretto Cultural Space, Nossa Senhora Aparecida Cathedral, hospitals, among others were considered. However, workplaces and event centers were not considered because they attract people only on specific occasions. Finally, by using the Scout Graph 1.0 Statistics Software to facilitate the analysis of the quantitative information of checked out and returned bikes registered in the first stage, and of the values attributed to aspects of each station, an empirical data analysis was performed by means of linear regression of the history of bicycle use from the ten stations, aiming to obtain an additive first order differential equation which comprises the influence of green areas, traffic safety, education, attractive hub for people, and proximity to other stations in relation to the average number of bicycles borrowed and returned. The equation makes it possible to quantitatively estimate the use (borrowings and returns) of bicycles at stations through the grades given to aspects of their surroundings, as well as enables the evaluation of statistical significance of each aspect, by considering valid aspects with a level of significance (P-value) of 0.1 (10%) or less.

Table2: Evaluation of four aspects of the ten stations of Passo Fundo

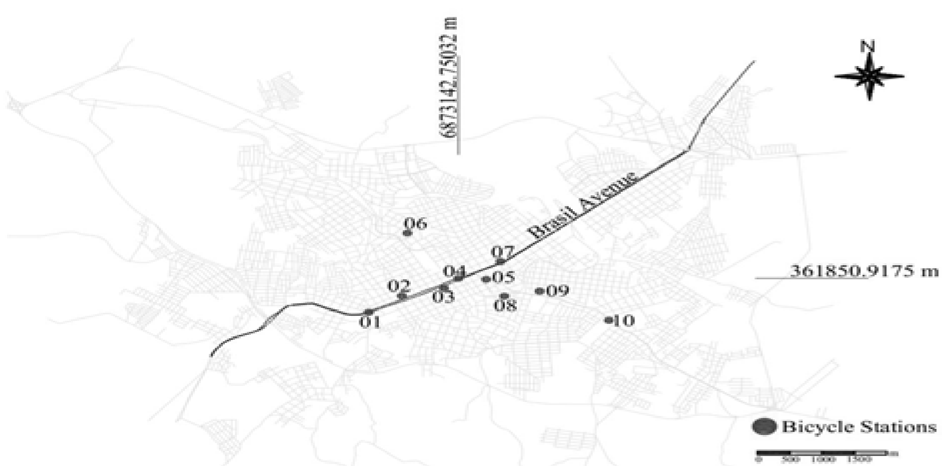
Stations	Aspects					Total
	Green Areas	Traffic Safety	Education	Attractive Hub for People	Distance to the Nearest Station	
01 Boqueirão Legal	1	4	3	0	3	11
02 Instituto Educacional	2	4	2	0	3	11
03 Notre Dame	4	4	4	2	3	17
04 Teixeirinha	4	3	3	4	4	18
05 Marechal Floriano Square	4	2	0	3	4	13
06 Vera Cruz	0	0	3	1	0	4
07 Tochetto Square	4	1	3	3	3	14
08 Gare Park	4	4	2	1	3	14
09 Santa Terezinha Square	2	2	4	0	2	10
10 Brigada Militar	2	0	4	1	1	8

3.Results and Discussions

3.1 The first eight months of operation of the "Passo Fundo Vai de Bici" project

The project was inaugurated in May 2016through an initiative of the Passo Fundo City Hall. According to the website Passo Fundo Vai de Bici (2017), the bicycle sharing system operates daily through the implementation of ten docking stations spread throughout the city. These stations are equipped with ten bikes each, and hold a total of 15 bikes spaces for returns. In addition, these stations have an automated electronic controlled system for self-service, in which through a free pre-registration, population can take away and return bicycles. They can be taken from 6 a.m. to 10 p.m., but not at other periods of time. Users can stay with the bikes for two consecutive hours and, after this pre-established period of time, it is necessary to return the bicycle at one of the stations.

Figure-1: Location of the10 stations in the city of Passo Fundo/RS (Brazil).

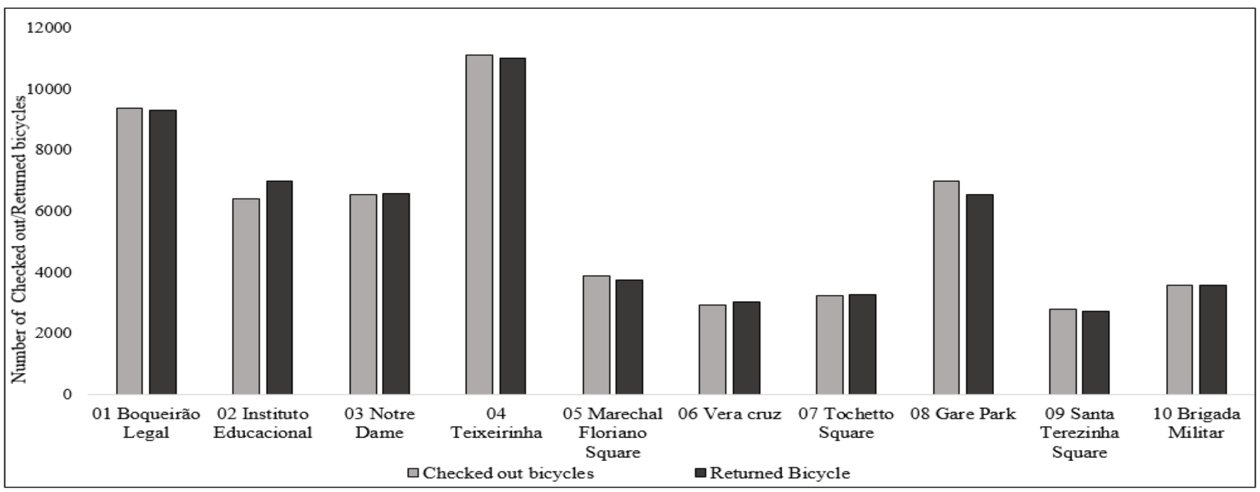


If the users want to borrow the bicycle again, they are allowed to take the bike again after 15 minutes after they returned it.The objective of the implementation of this system was based on the idea of stimulating active mobility in the city. As a result, it makes the city more sustainable, and attempts to reduce the use of private vehicles, as the city currently faces problems of growing traffic congestion. According to Zhang et al. (2017), these problems need to be addressed when focusing on sustainability of urban mobility. The Mobility Plan of the city of Passo Fundo (a) shows that the infrastructure dedicated to mobility is considered above the national average for cities of the same size, but it is not enough to guarantee quality of life for its residents, and (b) presents warning signs which, according to Lowry and Loh (2017), justify the need to encourage the use of active modes of transportation. The collected data from the City Hall demonstrate that 70% of users of shared bicycles are male. As for the age group, approximately 40% of users are between 20 and 30 years old and about 25% are between 30 and 40 years old, thus showing that the system reaches mainly the young population of the city.

As for education, it was observed the following: 28% of the users had completed high school, 25% had attained incomplete higher education, and 14% had completed higher education. As for income, 30% of users do not have any source of income, 19% receive up to one minimum wage, and 25% receive between one to two minimum wages.

Therefore, these numbers indicate that, in general, users have low incomes. As for the use of bicycles, 74% of the users, which corresponds most of them, borrow bicycles during weekdays. As far as timing is concerned, 23% use the system in the morning (from 6 a.m. to 11:59 a.m.), 48% in the afternoon (from12 p.m. to 5:59 p.m.), and 29% in the evening (from 6 p.m. to 10 p.m.).Figure 2 presents the demand per station, according to the number of bicycles taken away and returned. As can be seen, four out of the five stations located on Avenida Brasil (Instituto Educational, Boqueirão Legal, Notre Dame and Teixeirinha), which is the city's main avenue and concentrates important activities of commerce, services and education, are the most used stations for both check-outs and returns of bicycles. Gare Park (Parque da Gare) station is also one of the most used, possibly because the Park has been recently revitalized, thus attracting many people daily for either leisure or sports. It can also be noticed that the stations which are farthest from the city center (Brigada Militar (Military Police)), Santa Terezinha Square and Vera Cruz) are the least used, except for Tochetto Square station, which is located also in a central area, but is among the least used ones. This is possibly due to the fact that these stations are more distant from each other, thus making it difficult to use them in these regions. Therefore, according to Bauman et al. (2017) and Strauss et al. (2017), the proximity between bicycle sharing stations is important and should be at the most 500 meters away from each other in order to maximize their use. According to the general data provided by Passo Fundo City Hall, the number of registered users by January 20th, 2017 was 19,723; the total number of kilometres travelled was 275,803 km, an average of 225 trips per day, and 6,349 trips per month. This enables the researcher's toanalyze the functioning of the system in the first months of operation, especially the number of users registered, which represents approximately 10% of the total population of the city of Passo Fundo.

Figure 2: Demand per station according to number of bicycles checked out and returned within their first 8 months of use.



From this general analysis, it is possible to list some recommendations found in the literature on bicycle sharing systems. First, according to Fishman, Washington, Haworth (2013), ITDP (Institute for Transportation and Development Policy)(2014) and Lowry and Loh (2017), a good performance indicator is the number of trips per day per bicycle, which should be from four to eight. According to the data collected, the analyzed system performs 2.2 trips per bicycle per day. In addition, ITDP (2014) recommends that there should be fromten to 16 stations per km², that is, about one station per 300 m. Studies developed by Bachand-Marleau, Lee, and El-Geneidy (2012) and Strauss et al. (2017) on the *Bixi* bicycle sharing system in Montreal found that users living within 500m radius from the station use the system three times more than other users.

3.2 Characterization of the surroundings of each station

At this stage, the surroundings of each station were analyzed in order to identify the main docking sites that generate travel demands, that is, places where important daily activities occur, thus increasing the use of existing stations. At station 01, called Boqueirão Legal Station, the central flower bed where the station is located was identified as travel location generators it is a place for leisure and sports, it is equipped with a bike lane and urban furniture, and it is where Institute to Educational Metodista School, Fasurgs College, and Menino Deus School are found. At station 02, denominated Instituto Educational Station, Joaquim Fagundes dos Reis School, Instituto Educational Metodista School (since it is within the range of stations 01 and 02) and MãePretaSquareare located. At Station 03, denominated Notre Dame Station, Notre Dame School, Círculo Operário School, Nicolau Araújo Vergueiro School, Tamandaré Square, São Vicente de Paulo Hospital, UPF School of Medicine, Fronteira Sul Federal University, Bella Cittá Shopping Mall are found.

At Teixeirinha Station, number 04, Bella Cittá Shopping Mall is again found (since it is in the same coverage radius as stations 03, 04,05 and 08), Roseli Doleski Pretto Cultural Space, Marechal Floriano Square, Commercial Country Club, Anhanguera Faculty, and once again São Vicente de Paulo Hospital, UPF School of Medicine and Fronteira Sul Federal University. At station number 05 named Marechal Floriano Square Station, Marechal Floriano Square, Nossa Senhora Aparecida Cathedral, Bella Cittá Shopping Mall, Caixeira Campestre Country Club and Gare Park are identified. At station 06 called Vera Cruz Station, Vera Cruz Cemetery, João de Césaro School, National Industrial Learning Service – SENAI, and Ernesto Tochetto School are found. At station 07 denominated Tochetto Square station, Tocheto Square itself, Protásio Alves School, Health Center, Conceição Marista School, Anhanguera College, Juvenil Country Club, City Hospital, and Antônio Xavier Square are identified. At station 08 at Gare Park where the Park itself is a highlight, Senac Technology Faculty, Ecoar College, and again Bella Cittá Shopping Mall and Marechal Floriano Square are also identified. AtSanta Terezinha Square station, number 09, Captain Jovino Square, Menino Jesus School, Instituto Meridional - IMED, Berthier Higher Education Institute of Philosophy, and Tiradentes Schoolare found. BrigadaMilitar (Military Police) station, number 10, the Military Police itself, Cecy Leite Costa State School, Cecy Square, Igaí Events, Georgina Rosado School, Passo Fundo Shopping Center (which is under construction), Jerônimo Coelho School, Alberto Pasqualini School, and Semeato Industry and Commerce can be identified.

Therefore, according to García-Polomares, Gutiérrez and Latorre (2012) and Ho and Szeto (2017), the main factors that influence implementation success of shared bicycles is the location of stations, that is, they must be positioned according to the potential demand of users. In other words, they should be located near places where important activities occur and can be connected to other modes of transport in order to maximize the coverage area of each one of them.

It is recommended that the system's implementation initially concentrates on the stations located at central areas where are more densely populated. Gradually it can be expanded to more peripheral areas such as residential neighborhoods and industrial areas to function as an integrated transport system. In addition, García-Polomares, Gutiérrez and Latorre (2012) and Bauman et al. (2017) emphasize that the capacity of each station (number of bicycles and free docking spaces) should be calculated according to the demand of each region. According to ITDP (2014) and Bauman et al. (2017), the coverage area of each station corresponds to a radius of 500 meters around it and must contain a significant number of points of origin and destination. Therefore, since most stations in Passo Fundo have a common coverage area, the total coverage area of the system is 5.68 km².In addition, as a result of surveys carried out in this study, it can be noticed that seven out of ten stations are located near schools ;nine out of ten stations are either located in squares and parks, or very close to them. Of the ten stations, seven are located near higher education institutions and only one station is located near an industry. It is possible to observe that 50% of the stations are located on Avenida Brasil (Brazil Avenue), which is the main route of the city that connects many important areas.

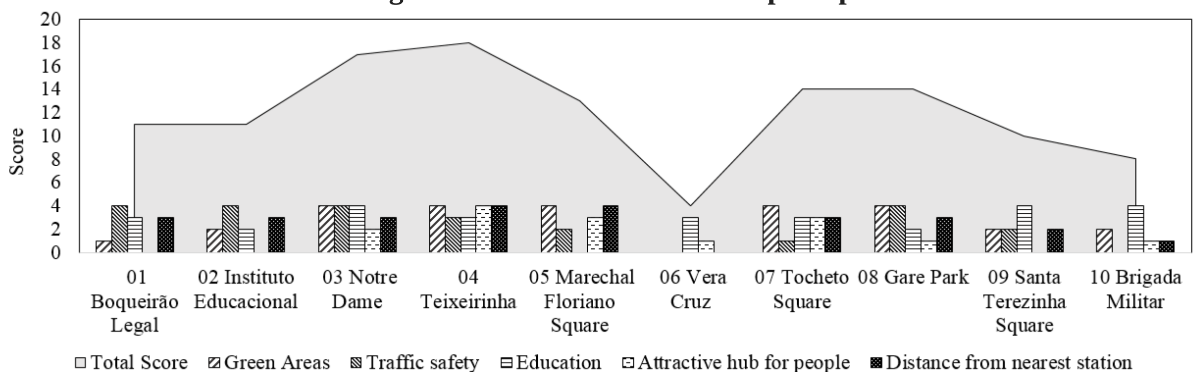
Only stations 6 and 10 were implemented in suburbs, away from the central area of the city. Thus, Frade and Ribeiro (2014) point out that bicycle sharing systems can be used as an isolated service or as an intermodal service, complemented by other transportation modalities. In the case of the "Passo Fundo Vai de Bici" project, the bicycles of the system are used, in most cases, to complement trips, since the suburbs of the city do not have stations and most of the population depends on other means of transportation to get to central areas.

3.3 Analysis of the surroundings of each station

Table 2 shows the evaluation performed for each of the ten stations according to five already mentioned aspects. For each aspect, a grade was assigned from observation of the station surroundings. Thus, it was possible to obtain a total score by being able to visualize the stations that obtained higher and lower scores, with significant differences between them.

Zhang et. al (2017) affirm that the impact of urban particularities of different parts of the city directly influences the choices of local population, that is, the greater the density, diversity, accessibility and infrastructure dedicated to bicycles are, the greater the acceptance of the users will be. This statement are in line with the results achieved in this score, in which most central stations that have greater infrastructure and diversity were the ones that reached the highest score and are also the most used ones, according to the collected data from Passo Fundo City Hall. Figure 3 presents the analysis result of five aspects in each of the ten stations. It is possible to visualize the most balanced stations regarding the five aspects studied, that is, the stations that have the least disparity between analysis. In this sense, Notre Dame, Teixeirinha and Gare Park stations stand out. Also, in Figure 3, it is possible to visualize the total score in each of the ten stations. It can be seen that Notre Dame, Teixeirinha, Tocheto Square and Gare Park were the stations that reached the highest scores.

Figure 3: Score result of the 5 aspects per station.



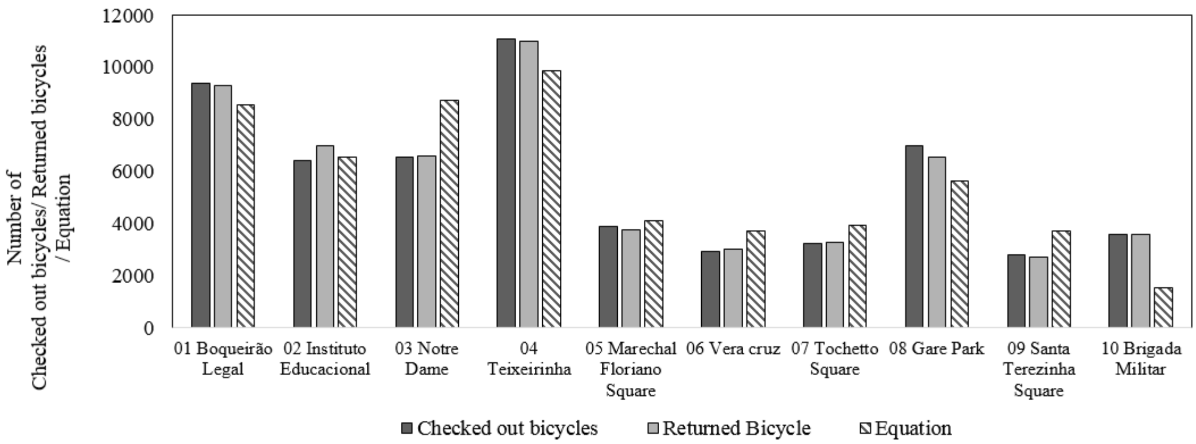
Only Tochetto Square station was among the highest scores in this analysis, but it is not among the most used according to the data obtained from Passo Fundo City Hall, possibly due to the distance from the cycle network.In general, stations far from the city center were the ones that scored less, namely Brigada Militar (Military Police) and Vera Cruz stations. However, it is worth mentioning that they are extremely important stations, since they enable bicycle use for longer trips and include inhabitant's from these peripheral regions, by increasing the coverage area of the system. García-Polomares, and Gutiérrez and Latorre (2012) claim that stations located in the outskirts of the city function mainly as points of origin and are essential for the proper functioning of bicycle sharing programs. Finally, a linear regression analysis was performed by relating the chosen aspects for evaluating the stations with bicycle use history actual data in each station (check-outs and returns). As a result, the following mathematical model for regression was used: $Y = \beta_0 + \sum_{i=1}^{n} \beta_i * x_i$ Where: Y = average value of bicycles used; β_0= constant; β_i = regression coefficient; x_i = independent variables (according to the aspects:G for green areas, S for traffic safety, and Efor education, A for attractive hub for people, and D for distance from other stations).

Initially, regression was made by considering all aspects, and disregarded the constant β_0 to isolate the equation in relation to the variables. Consequently, the following equation was obtained: $Y = -1543 * G + 1731 * S + 628 * E + 1676 * A + 542 * D$ However, it was possible to verify a very high significance value in the variable for distance (P-value = 0.61). Therefore, a new linear regression with the same data was designed, but excluded the 'D' variable of the equation, this time obtaining P-value values lower than 0.1 (10%) in all aspects, thus reaching the criteria set forth in the methodology. The equation that enables to estimate the potential of a place or a new station for the use of shared bicycles, according to the variables raised in this article, is, as follows:

$$Y = -1378 * G + 2023 * S + 612 * E + 1870 * A$$

Considering the analyzed data collected from Passo Fundo City Hall, each aspect has the following portions of importance for the equation: Green areas (G) represent 23.54%; Traffic safety (S) represents 34.33%; Education (E) represents 10.39%; and Attractive hub for people (A) represents 31.74%.

Figure 4: Results of the equation developed together with the number of bicycles checked out and returned per station.



Therefore, the scores attributed to each aspect have an importance equivalent to the percentages presented previously, which altogether represent 100%.This instrument was used to evaluate the variable system, that is, to assess the four aspects which were taken into account, and can be verified in Figure 4, which shows the comparison between the values collected with the City Hall (bicycles checked out and returned) and the values obtained with the regression equation device. It is observed that they were very close, except for Notre Dame Station, where there was a greater disparity, possibly, due to the excessive residual values related to the size of the history analyzed by the instrument, as well as the quantity and values of the variables considered in this station. These results helped to understand the operation of the "Passo Fundo Vai de Bici" system, as well as demonstrate how the surroundings of bicycle stations directly influence the use of the system. As a result, this study can contribute to possible further network expansion projects in the city and for other cities to implement their own bike sharing systems.

4. Conclusions

With the objective of carrying out a quantitative and qualitative analysis of the "Passo Fundo Vai de Bici" system and of proving each station potential, according to the characteristics of their surroundings, this study demonstrated that the evaluation of different scenarios and assessment of five aspects in each station contributed to the demand estimation of each one of them and to perceive the stations that have greatest potential, such as Teixeirinha, Notre Dame and Gare Park stations, which have significant points of origin and destination very close to the stations, are located in downtown area, and comprise all the aspects evaluated in this study, such as proximity to the city cycling network and to other stations, presence of green areas, teaching institutions and an attractive hub for people where multiple activities occur in their surroundings. Due to this potential, these stations may receive more bicycles when the network is expanded which, according to Schuijbroek, Hampshire and Van Hoeve (2017), and Zhang et al. (2017), would make the city more sustainable, thus contributing to the well-being of the population and movement dynamics.

It was also possible to identify stations with less potential, such as Vera Cruz, Brigada Militar and Santa Terezinha which despite having travel generating sites, they are far from the central area and distant from other stations. However, these stations play an important role in the dynamics of the system, since they help the network to cover the most peripheral areas of the city and reach a larger number of users. In network expansion projects, it is recommended that more stations are created in these areas. Based on the results of this study, it is possible to evaluate the potential of different locations for implementing new bicycle stations, thus contributing for future extension projects of the "Passo Fundo Vai de Bici" program, and to avoid implementations that are less useful for users, thus generating unnecessary costs for the local government.

References

Ambrosino, G. et al. (2016). Enabling intermodal urban transport through complementary services: From Flexible Mobility Services to the Shared Use Mobility Agency. Transportation Economics, 59, 179-184.doi: 10.1016/j.retrec.2016.07.015

Bachand-marleau, J., Lee, B., El-geneidy, A. (2012).BetterUnderstanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. Journal of the Transportation Research Board,2314, 66-71.doi: 10.3141/2314-09

Bandeira, A. S. et al. Factors associated with bicycle use for commuting and for leisure among Brazilian workers. Sport Sciences for Health, 1-6.Doi: 10.1007/s11332-017-0350-0

Bauman, A. et al. (2017). The unrealised potential of bike share schemes to influence population physical activity levels – A narrative review. Preventive Medicine, 1-17. doi: 10.1016/j.ypmed.2017.02.015

Buehler; R., Pucher, J. (2012). Walking and Cycling in Western Europe and United States. [online] Available:http://onlinepubs.trb.org/onlinepubs/trnews/trnews280WesternEurope.pdf(January 18, 2017).

Demaio, P. (2009). Bike-sharing: History, Impacts, Models of Provision, and Future. Journal of PublicTransportation, 12, 41-56.

DENATRAN.(2016).Frota de veículos no Brasil por ano. [online] Available: http://www.denatran.gov.br/index.php/estatistica/237-frota-veiculos (February 05, 2017).

DENATRAN. (2016). Frota de veículos no Brasil por município. [online] Available: http://www.denatran.gov.br/index.php/estatistica/237-frota-veiculos (February 05, 2017).

Figueroa, M. et al. (2014). Energy for Transport. Annual Review of Environment and Resources, 39, 295-325. doi: 10.1146/annurev-environ-031913-100450

Fishman, E., Washington, S., Haworth, N. (2013). Bike Share: A Synthesis of the Literature. Transport Reviews, 33, 148-165.doi: 10.1080/01441647.2013.775612

Fournier, N.Christofa, E., Knodler, M. A. (2017). A sinusoidal model for seasonal bicycle demand estimation. Transportation Research Part D: Transport and Environment, 50, 154-169.doi: 10.1016/j.trd.2016.10.021

Frade, I., Ribeiro, A. (2014). Bicycle Sharing Systems Demand. Procedia - Social And Behavioral Sciences, 111, 518-527. doi: 10.1016/j.sbspro.2014.01.085

García-Palomares, J. C., Gutiérrez, J., Latorre, M. (2012). Optimizing the location of stations in bike-sharing programs: A GIS approach. Applied Geography, 35, 235-246.doi: 10.1016/j.apgeog.2012.07.002

Hiselius, L. W., Svensson, Å. (2017).E-bike use in Sweden – CO2 effects due to modal change and municipal promotion strategies. Journal Of Cleaner Production, 141,818-824.doi: 10.1016/j.jclepro.2016.09.141

Ho, S. C., Szeto, W.Y. (2017).A hybrid large neighborhood search for the static multi-vehicle bike-repositioning problem. Transportation Research Part B: Methodological, 95, 340-363.doi: 10.1016/j.trb.2016.11.003

IBGE- Instituto Brasileiro de Geografia e Estatística. (2017). Senso 2010.[online] Available:www.ibge.gov.br/cidadesat (March 04, 2017).

ITDP- Instituto de Políticas de Transporte e Desenvolvimento. (2014) Guia de Planejamento de Sistemas de Bicicletas Compartilhadas.[online] Available:http://2rps5v3y8o843iokettbxnya.wpengine.netdnacdn.com/wpcontent/uploads/2014/11/ITDP-Brasil_Guia-de-Planejamento-de-Sistemas-de-BicicletasCompartilhadas(September 13, 2017).

Kabra, A.,Belavina, E., Girotra, K. (2016). Bike-Share Systems: Accessibility and Availability [online] Available: https://ssrn.com/abstract=2555671 (February 22, 2017).

Lowry, M.,Loh, T. H. (2017). Quantifying bicycle network connectivity. Preventive Medicine, 95, 134-140. doi: 10.1016/j.ypmed.2016.12.007

Meddin, R., Demaio, P. (2017). The Bike Share World Map. [online] Available: http://www.metrobike.net/the-bike-sharing-world-map/(February 11, 2017).

Nunes, T.; Rosa, J. S.; Moraes, R. F. (2015). “Sustentabilidade urbana: impactos do desenvolvimento econômico e suas conseqüências sobre o processo de urbanização em países emergentes: textos para as discussões da Rio+20: volume 1 mobilidade urbana”. Brasília: MMA.

Passo Fundo- Prefeitura Municipal. (2014),Plano Diretor de Mobilidade de Passo Fundo. Passo Fundo/RS, Brasil.

Passo Fundo Vai de Bici.(2016). [online] Available: http://pfvaidebici.mobhis.com.br(September 15, 2016).

Schuijbroek, J., Hampshire, R.C., VanHoeve, W.J. (2017). Inventory rebalancing and vehicle routing in bike sharing systems. European Journal of Operational Research, 257, 992-1004.doi: 10.1016/j.ejor.2016.08.029

Shaheen, S.; Guzman,S.; Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia. Journal of the Transportation Research Board, 2143, 159- 167.doi: 10.3141/2143-20

Strauss, J. et al. (2017). Cyclist deceleration rate as surrogate safety measure in Montreal using smartphone GPS data.Accident Analysis & Prevention, 99, 287-296.doi: 10.1016/j.aap.2016.11.019

Vasconcellos, E. A. de.(2000).Transporte Urbano nos Países em Desenvolvimento:Reflexões e propostas. (3rd. ed.) São Paulo: Annablume.

Zhang, Y. et al. (2017).Exploring the impact of built environment factors on the use of public bikes at bike stations: Case study in Zhongshan, China.Journal of Transport Geography, 58, 59-70.doi: 10.1016/j.jtrangeo.2016.11.014