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Latin American bike sharing ecosystem overview: from data collection to implementation model portraits

Visão geral do ecossistema de sistemas de bicicletas compartilhadas na América Latina: da coleta de dados aos modelos de implementação

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Abstract

The growth in the number of Bike Sharing Systems (BSSs) has sparked interest in their institutional arrangements, business models and operational characteristics. When compared to experiences developed in North America, Europe, and Asia, knowledge about implementing and operating BSSs in Latin America is still limited to specific case studies. Thus, this article aims to make an exploratory analysis of the characteristics of BSSs implemented in Latin American cities. To do so, the Multiple Correspondence Analysis (MCA) was applied, using data from the systems in operation during the month of December 2019, available on an online platform called LABIKS. The application of MCA proved to be an efficient and objective methodology to compare the various experiences of implementing BSSs in Latin America. Although countries share several challenges in common, the context of the region is very diverse, which justifies the different models of management and

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operation found in this research. Furthermore, results show significant differences in the implementation and expansion between dock-based and dockless systems in Latin America, highlighting challenges and possibilities for promoting this resilient and sustainable mode of transportation.

Keywords: Bike Sharing. Latin America. Multiple Correspondence Analysis. Transport planning. Urban mobility.

Resumo

O crescimento do número de Sistemas de Bicicletas Compartilhadas (SBCs) despertou interesse em seus arranjos institucionais, modelos comerciais e características operacionais. Quando comparado às experiências desenvolvidas na América do Norte, Europa e Ásia, o conhecimento sobre a implementação e operação de SBCs na América Latina ainda está limitado a estudos de casos específicos. Assim, este artigo visa fazer uma análise exploratória das características dos SBCs implementados nas cidades da América Latina. Para isso, foi aplicada a Análise de Correspondência Múltipla (ACM), utilizando dados dos sistemas em operação durante o mês de dezembro de 2019, disponíveis em uma plataforma online chamada LABIKS. A aplicação da ACM provou ser uma metodologia eficiente e objetiva para comparar as diversas experiências de implementação de SBCs na América Latina. Embora os países compartilhem vários desafios em comum, o contexto da região é muito diverso, o que justifica os diferentes modelos de gestão e operação encontrados nesta pesquisa. Além disso, os resultados mostram diferenças significativas na implementação e expansão entre os sistemas baseados e não baseados em estações fixas na América Latina, destacando desafios e possibilidades para promover este modo de transporte resiliente e sustentável.

Palavras-chave: *América Latina. Análise de Correspondência Múltipla. Bicicleta Compartilhada. Mobilidade Urbana. Planejamento de Transportes.*

Introduction

Guided by their environmental, economic, and social benefits, several cities around the world have implemented and promoted the use of Bike Sharing Systems (BSSs) for commuting (Zhang & Mi, 2018). In Latin America (LA), the last decade has been marked by a significant increase in the number of systems, growing from 4 BSSs in 2010 to 92 in 2019 (Shaheen, Guzman and Zhang, 2010; LatinoSBP, 2020).

Despite this growth tendency, one can see that knowledge regarding models of setting up and operating BSSs in Latin America is still only marginally studied in the main scientific research bases (Ricci, 2015, Si et al., 2019). When compared to experiences developed in North America, Europe, and Asia, knowledge on the state of the practice for setting up and operating BSSs in Latin America is still limited to specific case studies, developed from a descriptive history of implementation experiences and an analysis of the main operational indicators observed in some of the region's major cities (De Maio, 2009; Shaheen, Guzman & Zhang, 2010; O'Brien, Cheshire & Batty, 2014; Fishman 2015; and Galatoulas, Genikomsakis, & Ioakimidis, 2020) Moreover, this study considers that these models have to be adapted to the conditions of the Latin-American context and therefore deserve to be studied as an innovation (Marchetti, Oliveira, and Figueira, 2019). This fact justifies a more detailed look at the process of implementing the BSSs in Latin American cities (Carbonai, Baum, & Camiz, 2020; Moro, 2019). Whether through the use of different technologies (e.g. dock-based vs dockless), adoption of different financing systems (e.g. public or private), or specific characteristics of the urban context, one can observe that the development models of BSSs in Latin America present an operational variety that is different from those carried out in developed countries and presented in studies of De Maio (2009), Shaheen, Guzman, & Zhang (2010), O'Brien, Cheshire & Batty (2014), Fishman (2015) or Galatoulas, Genikomsakis, & Ioakimidis (2020).

Thus, this article makes an exploratory analysis of the characteristics of BSSs in Latin America, contributing to the identification of the systems deployment characteristics, from a data collection that covers the entire universe of BSSs in the region. To do so, this research begins with the construction of a database with variables on the implementation characteristics capable of portraying the 92 BSSs in operation in the region in December 2019. After this data collection and structuring stage, a Multiple Correspondence Analysis study was conducted, to present a global analysis of the variables and the identification of associations among them in typical organizational clusters of the region (Carbonai, Baum & Camiz, 2020).

Based on this data collection and analysis, this article presents its contribution to the expansion of knowledge on business models and structuring of BSSs in the Latin American context beyond their main cities.

According to Moro (2019) business models need to be based upon careful consideration of what a bike-sharing system can do for a city and on whether the city can plan and manage such a system. In this regard, we use the term business model refers to a design for the successful operation of a business, identifying revenue sources, customer base, products, and details of financing. From the perspective presented by Moro (2019) on the feasibility of business models existing for financing bike sharing systems in Latin America, we will discuss the results found and the contribution of our study.

This study finds two main business model strategies operating in the Latin-American market: (a) a private BSSs model funded by user fees and advertising from financial and health stakeholders, not integrated with other transport infrastructures and operating in large cities (over 1M inhabitants); and (b) Public funded BSSs integrated with other transport services developed in cities with no more than 1M inhabitants. From a regional point of view, the first

group was mostly observed regarding the Brazilian and Mexican experiences while the second was associated with the BSS in Argentina and Colombia.

This paper comprises this introduction and five more sections: (i) Introductory Approach to Research; (ii) Literature Review; (iii) Research Methodology; (iv) Analysis of Results; and finally, (v) Research Conclusions and Future Considerations.

The development of bike sharing systems in Europe, Asia and North America

The scientific literature presents some papers that focus on comparing the deployment, operation and demand aspects among multiple BSSs in the world. These articles analyze the systems considering different variables that are related to the system's design, the operational characteristics, and the users' profile. The knowledge created by the results can be useful to understand the bike sharing development in Europe, North American and Asian cities. In table 1, below, it is possible to identify the references on this theme, as well as the scope of their analysis.

Table 1 - Literature Review: bike sharing experiences analyzed worldwide

Reference	Title	Geographic Scope	Data type
De Maio (2009)	Bike-sharing: History, Impacts, Models of Provision, and Future	Europe, Asia, Australia, and America	Operation, demand, and Deployment
Shaheen et al. (2010)	Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future	North America, Europe, Asia	Operation, demand, and Deployment
O'Brien, Cheshire and Batty (2014)	Mining bicycle sharing data for generating insights into sustainable transport systems	Europe, Asia, Australia, and America	Operation and Demand
Fishman (2015)	Bikeshare: A Review of Recent Literature	Europe, Asia, Australia and North America	Operation and Demand
Galatoulas, Genikomsakis and Ioakimidis (2020)	Spatio-Temporal Trends of E-Bike Sharing System Deployment: A Review in Europe, North America, and Asia	Europe, North America, and Asia	Operation and Deployment

Source: Developed by authors (2021).

The work of De Maio (2009) is one of the best known on the subject, and presents a historical approach to bike sharing systems, presenting an overview of the impacts of the systems and the business models that have enabled the success of this mode of transportation in cities in Europe, North America, Asia, and Australia. The author points out that most systems were financed by marketing companies, but there are different business models for operating this service. According to the author, those other possibilities for financing BSSs could be associated with their positive impacts on the environment, reducing the emission of greenhouse gases, besides inducing a significant increase in the number of bicycle trips. The main contribution of Shaheen et al. (2010)' work was the division into generations and the inclusion of electric bicycle systems as the fourth generation. In an analysis limited to Europe, North America, and Asia, the authors identified some challenges for the systems operating up to that point, namely: future demand, safety, sustainability of business models, limited cycling infrastructure, challenges to integrate

with public transportation systems, technology costs, and user convenience. The fourth generation, in addition to these characteristics, presents advances by allowing integration with public transport and includes a bicycle redistribution system. It is possible to find BBSs of this generation that also offer electric bicycles.

O'Brien, Cheshire & Batty (2014) in turn went further, by using data mining techniques to perform comparative analyses between systems. The model created by the authors obtained real-time data from stations and bicycles and made it possible to create indicators to compare and analyze the behavior of demand in a temporal and geographic space considering systems from different cities. The results made it possible to understand the operating characteristics of the systems and to identify metrics that define the high or low utilization of the service.

Fishman (2015), on the other hand, analyzed systems from developed countries with a focus on demand. The results of the study showed that convenience is the main motivator for bicycle sharing and that distance to a station can be a predictor for adherence to the system. In addition, it showed how bicycles reduce the difference in bicycle use by men and women.

Finally, Galatoulas, Genikomsakis & Ioakimidis (2020) presented an overview of shared electric bicycle systems. The authors showed that, despite entering the market only in the last two years, these systems are already integrated with conventional systems, attracting new users, and increasing the system's operation coverage.

The state of the art presented above suggests two limitations that justify the development of this study. The first concerns the lack of scientific studies on the process of implementing BSSs. This gap had already been mentioned in the Ricci study (2015) in a literature review on the impact of implementing BSSs that revealed that few studies are concerned with using a broad database of BSSs experiences in the world to analyze the implementation processes. Therefore, the author points out the need for research that explores BSSs features considering the business models and legal aspects related to the deployment of the systems.

The second gap relates to the geographical scope of studies on the subject. Taking as a basis for comparison the experiences observed mostly in cities in North America, Europe and Asia, these studies identify characteristics of business models that have enabled BSSs to succeed, such as, for example, the participation of marketing companies and public departments as the main sponsors or the need for a successful relationship between public and private entities in establishing contract risks (Shaheen et al., 2010; Beroud & Anaya, 2012). However, despite the importance of such research to characterize BSSs in the global context, it is evident how these results have limitations in terms of operational standards in developing countries, which makes it impossible to generalize the conclusions presented.

To solve these problems, LABIKS (Latin American Bike Knowledge Sharing) platform, in a collaborative effort involving the authors of this article, created a database on the characteristics of Latin American BSSs that were in operation during the month of December 2019. This data was used for the analysis developed in this research. The procedures used in the creation of the database and some results obtained in this survey will be presented below.

Data survey on data related to BSSs in Latin America: a LABIKS initiative

There are two internationally recognized open mapping projects that have been systematically used for the development of BSSs characterization studies: "The Meddin Bike-sharing World Map" (De Maio, 2007) and "Bike Share World Map" (O'brien, 2013). Comparatively, the data presented in both tools focuses on the general characteristics of the systems (e.g. number of stations and bicycles, opening date, system website, operator and technology used).

Created in 2007, "The Meddin Bike-sharing World Map" is mainly focused on consolidating information on the state and operation model of the systems, from the organization of public information found in institutional websites, news, reports and other publications. With a concentration on data collection via API, the "Bike Share World Map", created in 2010, differs from the previous initiative by allowing real-time monitoring of the systems, by considering, in addition to the structural variables already mentioned, the monitoring of information on stations and bicycles available at the time of consultation. However, this option, due to an automated information collection methodology, limits map coverage to those systems that have this information available.

Faced with this need, and the absence of a database with more comprehensive information, which included management and planning data for the systems (e.g., financing and tariffs), LABIKS undertook the effort to collect a database with more than twenty variables that made it possible to identify the deployment features of Latin American BSSs in different contexts.

LABIKS is a digital platform that emerges with the objective of gathering, sharing, and maximizing knowledge about BSSs in Latin America, based on the need to understand and analyze the impacts of the deployment and operation of BSSs in the region. The platform's mission is to generate open knowledge on this subject, hoping that access to this content will lead to the development of new and successful systems in Latin America, using data from the systems themselves as the basis.

The methodology for structuring and data collection will be presented below.

BSSs data collection: a review of the LABIKS method for Latin America

With the geographic scope defined and with clear objectives, an initial stage of identifying the variables related to planning, operation, management and financing was carried out, using technical references and academic articles dealing with the subject as a basis. The main technical reference used in the identification of the variables was the "Guide to Shared Bicycle Systems" (ITDP, 2018), which is internationally recognized for the quality and scope of its content. The data collected is based on the characteristics of planning, operation, management, and financing that is available on the web. However, some data (i.e. data on trips, station activities and number and characteristics of the users) had to be discarded from the analysis due to the unavailability of certain information for most systems. Table 2 presents all the variables used in the survey.

Table 2 - Database variables developed by LABIKS

Topics	Characteristics	Description
BSSs across Latin America	System	BSS name
	Country	BSS country location
	City	BSS city location
	Population	City or Metropolitan Area inhabitants
System's characteristics	Type	BSS typology
	Dock stations	Number of docked stations
	Virtual stations	Number of dockless stations
	Docks	Number of dock points
	Bikes	Number of bicycles available
	Current Technology	BSS equipment model in use
	Old Technology	BSS equipment superseded model
System's management	Operator	BSS operator
	Responsible Entity	trustee and manager of an investment in BSS
	Sponsor	BSS sponsor type

	Transit Integration	Indicates if the BSS and transit has payment integration
System's operation	Opening Hours	BSS working hours
	Fees	BSS pass fares
	Payment Options	BSS payment methods
	Overtime Charges	BSS overtime additional Fee
Implementation History	Launched	BSS release date
	Shut down	BSS closed
	Relaunch	BSS relaunch date
	Description Re-launch	Relaunch characteristics
System's data	Open Data	BSS payment methods
	API Data	Data availability by API

Source: Developed by LABIKS (2021).

The next step was to collect data. For this purpose, a systematic search was carried out on all systems in operation in LA during the month of December 2019, including: a review of the main references; access to city websites, systems and operators; and monitoring of reports on public and shared bicycle systems. The "Meddin Bike-sharing World Map" and "Bike Share World Map" platforms were the initial sources of identification of existing and operating systems, due to their great relevance and constant updating. Simultaneously, the "Google Alerts" tool was used to monitor news from the following keywords: "public bicycles" in Portuguese and Spanish, "shared bicycles" in Portuguese and "shared bicycles" in Spanish. The combination of both sources of information, maps and online search tools, allowed us to follow the inauguration, closure and expansion of Latin American systems throughout 2019.

Next, the crossing and validation of all data and information acquired was performed, comparing different data sources, both public and private. The process of cross-referencing and validation of the information gathered was fundamental to ensure the veracity and reliability of the data presented. It consisted in verifying the information collected on websites related to the systems, operators and/or official communication channels of the city where the system is located. This method of data collection was adopted after an attempt to contact the people responsible for the main systems in the region, who, despite some positive responses, returned with incomplete information and even less than what can be traced on the Internet.

All this effort has generated an unprecedented database on Latin American BSSs, which is of fundamental relevance to the understanding of the dynamic ecosystem of shared bicycles. With this data, some products were developed prior to this article, namely: a map, a report, and a data panel. Picture 1 presents a diagram with the stages of creation and design of the base. These data products are available on the LABIKS platform (http://labiks.org/en/).

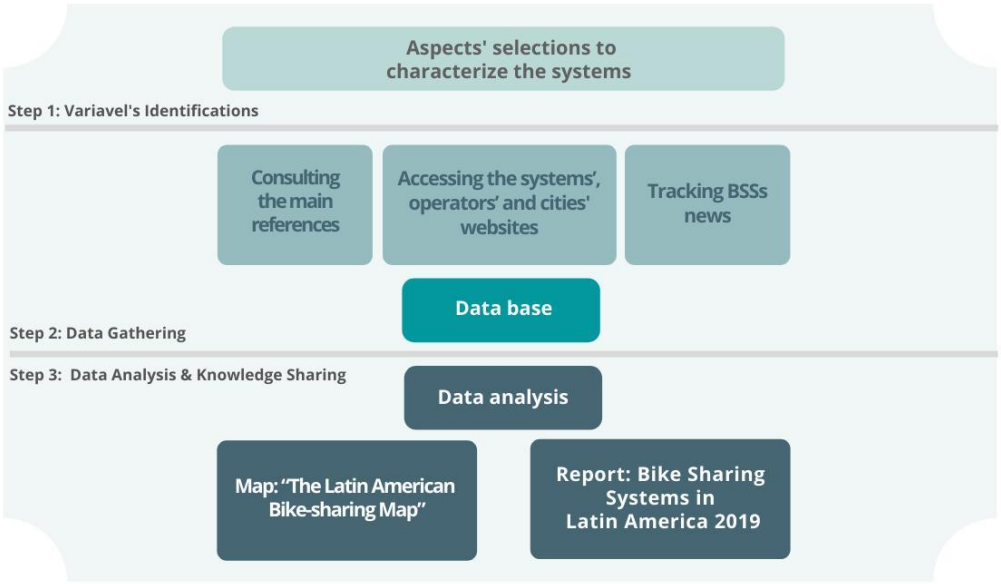

Figure 1 – Study stages. Source: Latin American Bike-sharing Systems Platform (2020).

A first look at the situation of BSSs in Latin America

From the time this database was consolidated, the study focused on the goal of designing the Latin American context of the BSSs deployment process. For this purpose, the first effort undertaken contemplated conducting a frequency analysis of the data collected. The main characteristics of the deployment of BSSs in Latin America that were identified through this study available by LABIKS are presented below:

- The countries with more systems are Brazil, with 42 systems in operation, Colombia, with 18 and Mexico, with 15 systems;
- Of the 92 BSSs in operation, 49% (or 45) are in cities with over 1 million inhabitants;
- 63.91% of the 92 systems in operation in the region use station-based service technology BSSs in operation have over 1 million inhabitants;
- The insertion of dockless systems is recent in Latin America and the first BSSs of this type appeared in the region in 2017;
- 55 of the 92 BSSs are privately operated;
- Financial and health insurance companies are the main private sponsors of these systems;
- 65% of the systems are subject to a fee.

In short, the data above, when analyzed independently, presents a deployment overview marked by BSSs operated mostly in cities with over 500 thousand inhabitants (63%) and privately financed, with high marketing appeal for companies in the financial sector and health plan operators and, finally, with a focus on charging the end user. However, this description of independent analysis does not really represent the operational model adopted in the region.

For instance, there is a distinction between the operation models of dock-based and dockless systems. This structural difference between these two groups, for example, is related to other variables such as the financing model (48% of dock-based systems do not charge a usage fee) and participation in government financing or subsidy (52% of the dock-based systems received government financing and/or subsidy).

The following section presents the multiple correspondence analysis methodology selected to be applied over the 92 Latin-America BSSs projects database. The MCA method is applied to capture the association of several independent variables in the construction of different BSS business models profiles and associate these profiles with the different countries' experiences in Latin-America. The option for this method was supported by the findings of Dias et al (2019) which have used this method to evaluate the most relevant factors for distinguished perceptions profiles (I.e. daytime or nighttime) of drivers and retailers regarding freight deliveries in the city of São Paulo.

Method of analysis

Multiple Correspondence Analysis (MCA) is a non-parametric statistical technique of Chi-square decomposition ($\chi 2$), considered a special case of conventional canonical correlation, useful when the research focuses on mapping values (levels) of categorical variables (Pronello & Diana, 2010). The technique defines a measure of distance between any two points, where the points are the values (categories) of discrete variables. As distance is a type of association measure (Pearson correlation), the distance matrix can be the input for the analysis of major components, just as correlation matrices can be the input for conventional factor analysis. However, where conventional factor analysis determines which variables are grouped, the MCA determines which category values are close to each other.

In this study, the authors used MCA (Husson et al, 2020) to perform an exploratory analysis of the database using open-source software (RStudio Cloud). The objective of the research was to understand if there are any differences in the deployment characteristics of BSSs in Latin American cities. Thus, it was possible to verify the quality of the data and suggest hypotheses (acceptance or rejection H0 /H1) for the data pattern observed at a certain level of significance (p-value ≤ 0.05). With this technique, the data is not subject to any restrictive assumptions, which allows us to understand whether there is a pattern associated with the implementation of BSSs in Latin America, especially about the associations between the characteristics of the system for each country, type of operation and management (see Table 2), and the intensity of these associations.

As previously mentioned, the accelerated growth and diversity of existing SBS models in Latin America pose a challenge to the research task, first because of the restricted access to the systems' data and second because of the lack of standardization of the published information. Although there are already good practices related to transparency and monitoring of public policies (Open Government Partnership - OGP) related to urban mobility and to open real-time data standardization protocols (General Bike Feed Specifications - GBFS) regarding BSSs, their deployment is still quite challenging for most cities with BSSs in Latin America.

Thus, due to the need to standardize available information for data analysis, 6 variables were selected from the original database (Table 2 – data input) transforming it in Table 3) data wrangling, after performing rounds of Chi-square independence tests of all variables (pair by pair) of the database. With these results, we rejected H0, by finding the existence of a statistically significant association (p-value ≤ 0.05) non-randomly. This procedure helped to avoid an arbitrary weighting process of the data and, subsequently, to prepare the stage for developing the contingency table or cross-tabulation table, which is the basis for MCA. This procedure helped to avoid an arbitrary weighting process of the data and, subsequently, to prepare the stage for developing the contingency table or cross-tabulation table, which is the basis for MCA.

Table 3 - Variable Selection for Multiple Correspondence Analysis

Topic	Variable	Categories	Data Type
System Characteristics	Countries_group	Brazil, Colombia, México, Argentina, Others	Categorical (Factor)
	City Pop_Group	Up to 100k, 100k-250k, 250k-500k, 500k-1000k, Over 1000k	Ordinal (Factor)
	System_Type	Dockbased; Dockless	Categorical (Factor)
System management	Fee	Yes, No	Binary (Factor)
	SponsorSector_Group	Financial, Government, Joint venture, Health, Other*	Categorical (Factor)
Systems operator	OperatoType	Private; Public	Binary (Factor)
	Transit Integration	Yes, No	Binary (Factor)

Source: Developed by authors (2021)

Through MCA it is possible to make a graphical representation of the variables and display them in a property space that maps their association in two or more dimensions, called perceptual map. From this map, it is possible to make inferences about similarities and differences in behavior between variables and their categories. The X and Y coordinates (abscissa and ordinate) of this map is obtained through the expressions (1) and (2), where Dr and Dc are the distance matrix of the variable, U and V are the eigenvectors of these matrix, and Λ are the eigenvalue of these matrices (Dias et al., 2019):

$$X = D_r^{-1}.(D_r^{1/2}.U).\Lambda \qquad (1)$$

$$Y = D_c^{-1}.(D_c^{1/2}.V).\Lambda \qquad (2)$$

In other words, the inertial decomposition of a given contingency table, is represented by the differences between the absolute observed and expected frequencies, can be decomposed into m components, which refer to the values of the partial principal inertias (variances) of each dimension and which are nothing more than the square of the eigenvalues of each dimension. Total inertia reflects the spread of points around the centroid (the weighted mean of the row and column profiles). The main object of correspondence analysis is to explain the inertia (variance) in this contingency table.

Then, based on the calculated coordinates (scores), we are finally able to build the perceptual map (Husson et al, 2020). It is from the masses and the configuration of their proportions in line

and column, therefore, that the perceptual map of the MCA begins to take shape. Perceptual maps are nothing more than scatter diagrams that represent the categories of variables in the form of points in relation to orthogonal coordinate axis. They are therefore category maps.

It is important to mention that the greater the total principal inertia, the greater will be the association between the categories disposed in row and column, which will affect the arrangement of the points in the coordinate system.

Results

From the MCA analysis, we obtained the perceptual map that allowed the detection of similarities and distinctions among the groups of categories of variables (See Annex Statistical Tests). Through MCA graphs, it is possible to analyze the categories separately and/or jointly, and thus point out the different deployment options by Latin American systems. The map can be seen in Figure 2.

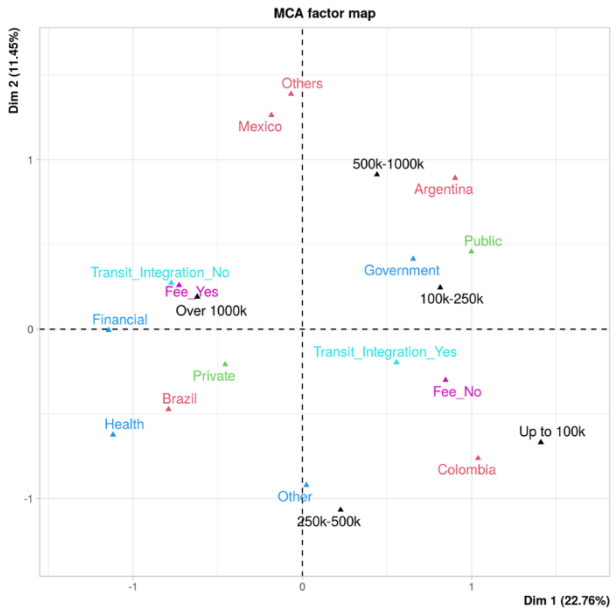

Figure 2 - Multiple Correspondence Analysis Perceptual Map Source: Developed in R by Authors, 2021.

At this point, dockless BSSs were excluded from the analysis, because as previously presented, the deployment of this model in Latin America is still very recent, and despite rapid growth in the last two years, there was a significant exclusion of systems in circulation as of 2020, which could generate an analysis that did not represent reality.

The perceptual map is built by the two components with the highest degree of explanation regarding the population studied with the MCA. These two components together represent an estimated 31.16% degree of explanation. In the map, it is possible to identify four clusters of BSSs design and deployment in Latin America:

- The first group is made up of systems financed by public resources, associated with Argentine systems and located mainly in cities with a population between 100 and 250 thousand inhabitants and between 500 thousand and 1 million inhabitants.

- The second group is made up of systems sponsored by private resources, mainly from the health sector and located in Brazil.
- The third group is made up of systems that charge fares, associated with those not integrated with the public transportation system, located in cities with more than 1 million inhabitants and financed by companies in the financial sector.
- And finally, the last group is made up by systems that do not charge fees, associated with those integrated to the public transportation system, located in Colombia and with a population of less than 100 thousand and between 250 and 500 thousand inhabitants.

In addition to the identified clusters, the map also shows that the variables "sponsor", "fee" and "integration with public transportation" are those that most influence the distinction between the characteristics of each system. It is worth mentioning mainly how the categories of the "fee" variables are at opposite points to each other and very close to the categories of the "integration with public transport" variable. This suggests the association between these variables and a relation between their categories so that the systems that charge a tariff are more associated with the category of systems integrated with public transport systems. These results will be discussed in the next section.

The Latin American experience with Bike Sharing Systems

The results described so far show how the experience of deploying BSSs in Latin America has come about in different ways depending on the type of system. The case of dock-based systems is characterized by partnerships between public and private entities, mainly in Brazil, and by public investment, as in the experiences of Mexico and Colombia, which enabled constant expansion throughout the decade. The case of dockless systems, on the other hand, is marked by investments exclusively from the private sector, following the startup model, due to the speed of market insertion. This has enabled an exponential growth in the number of these systems as of 2017, however, with a sharp drop in the number of these systems in 2020.

It has been noted that resources from the private sector account for most of the financing of dock-based systems in Latin America. This financing model was also pointed out by Shaheen et al. (2010) in experiences in Europe, Asia, and North America; however, in the Latin case, companies from the financial and private health sectors allocated most of the funds to operate SBSs.

One can also see that private financing of dock-based systems takes place mainly in cities in Brazil, which is also the country with the largest number of systems. Thus, the participation of the private sector has proved to be a success factor for the expansion of BSSs in Brazil. This is consistent with what is pointed out in Portes & Roberts (2005) regarding the degree of maturity of capital for investment in relation to a minimum state policy for investment in public infrastructure in main cities around Brazil during the second half of the 20th century.

Despite the importance of private investment in the expansion of BSSs, there is a need for greater effort on behalf of the Brazilian government, within its various levels, to allocate public funding for the deployment and operation of these systems, given their various benefits to the population, which include public health, urban environment quality, among others.

Mexico, Colombia and Argentina are the countries with most of the systems financed by the public sector. In these cases, resources can come directly from the municipality where the system will be operated or through partnerships with different departments (municipal, state, and/or

federal). In some cases, public participation in the financing of these BSSs has made it possible to make these systems free of charge in addition to providing easy integration with other public transportation systems in the municipality, which is evident in the association between Colombian and Argentine systems with the category that represents systems integrated with public transportation and without user fees (see Figure 2).

It is important to highlight the influence of private investment to deploy dockless systems BSSs in Latin America. Most of the operating companies appeared in the market as startups financed with resources from financial joint ventures. This investment model, coupled with the lack of regulatory mechanisms in the cities, allowed for rapid market insertion and considerable gains of scale in a short period of time.

However, it has been observed that the business model of most dockless operators systems is very dependent on market conditions, which makes them volatile to fluctuations in the economy, and makes the mobility conditions of the cities where they are implemented vulnerable. This instability was reflected in the closure of several services as early as 2020, only 2 years after the rapid expansion of these systems. Without the adoption of a commitment to local mobility policies, the operation of these systems causes negative impacts to the population without facing any consequences.

Despite these challenges, there are some cases in which this easy entry into the market has allowed cities without BSSs to offer this mode of transportation. In this sense, in order to create conditions for the entry of these systems it is more beneficial to mention the case of Mexico City, which developed a pilot operation for the deployment of dockless BSSs (Ciudad de México, 2019). During the operation, there were several initiatives carried out between operators and the government aimed at developing evidence-based policies that allowed for the regulated insertion of this type of SBS into the city's mobility system.

Conclusions

From the global perspective, bike sharing systems are now understood as a driving force to innovative business models in the urban mobility ecosystem. This requires dynamic cooperation between the public and private sector to cope with disruptive changes in market structures, consumers behavior, emerging technologies, and regulations.

In this context, as mentioned by Shaheen, Guzman, & Zhang (2010) and Moro (2019), for the implementation of a successful bike sharing business model it is necessary to create a value proposition for its users, as well as be able to offer operational and financial feasibility for cities.

Although Latin American countries share several common challenges, the region's context is very diverse, which justifies the need to identify different models for the development of systems, as shown in this research. The use of Multiple Correspondence Analysis proved to be an efficient and objective methodology to identify different characteristics for the deployment of Bike Sharing Systems in Latin America. This approach made it possible to distinguish the experiences in implementing dock-based BSSs, by identifying significant differences in business model among the countries that have the largest number of systems in operation, namely, Brazil, Mexico, and Colombia.

This study finds two main business model strategies operating in the Latin-American market: (a) a private BSSs model funded by user fees and advertising from financial and health stakeholders, not integrated with other transport infrastructures and operating in large cities (over 1M inhabitants); and (b) Public funded BSSs integrated with other transport services developed in cities with no more than 1M inhabitants. From a regional point of view, the first

group was mostly observed regarding the Brazilian and Mexican experiences while the second was associated with the BSS in Argentina and Colombia.

In the Brazilian case, in contrast with the other countries mentioned, the deployment of BSSs occurred with the predominant involvement of the private sector, coupled with marketing initiatives from banks and health services. Furthermore, the results have shown how the initiatives of dockless BSSs have not yet proved to be committed to the urban mobility policies of the cities.

It would not have been possible to achieve the results of this research without extensive collection and structuring of data from the systems. Since this data is a contractual and planning element of BSSs, it has been a challenge to access it, since in most cases, the operators and public entities in charge do not make this information directly available. This clearly shows the need for policies that guarantee the sharing and access to data related to the regulation and management of these systems.

In order for this to be feasible, LABIKS develops an advocacy work together with key stakeholders (academy, industry, governments, operators, and civil society) of this ecosystem to collaborate in the challenge of implementing the principles of open science and knowledge and reinforce the need to improve the transparency of data and public policies on BSSs, since most of the countries that make up the Latin American block are already signatories of some international commitments (Open Government Partnership; Open Science/Open Knowledge; General Bikeshare Feed Specification - GBFS), which seek good practices in this regard. Aligned with these good practices, this work was produced using open source platforms to analyze and share data and products developed by LABIKS, with the goal of stimulating and engaging the network collaboration between researchers and citizens.

The reviewed literature on the implementation of BSS systems pointed out two major gaps that motivated the development of this paper. The first was related to the lack of scientific studies that make use of public databases to analyze BSS implementation processes considering business models and their regulatory aspects. The second gap concerns the geographic scope of studies on the subject, especially on the global south. Using as a basis for comparison the experiences observed mainly in cities in North America, Europe, and Asia, these studies identify characteristics of the business models that have enabled the success of BSSs, such as, for example, the participation of marketing companies and public bodies as the main sponsors or the need for a successful relationship between public and private entities in establishing contractual risks (Shaheen et al., 2010; Beroud and Anaya, 2012). However, despite the importance of such research to characterize the BSSs in the global context, it is evident that these results have limitations in terms of operational standards in developing countries, which makes them not suitable for cities in Latin America (Marchetti, Oliveira, & Figueira, 2019; Moro, 2019).

Therefore, the major contribution of this paper is related to the development of the LABIKS (Latin American Bike Knowledge Sharing) platform, created through a collaborative effort involving the authors of this article, which produced an open database on the characteristics of Latin American BSSs that were in operation during the month of December 2019. These data were used for the analysis developed in this research and will be updated annually, which will allow the monitoring of the evolution of the Latin American bike sharing ecosystem.

An important limitation of this research is that it did not consider data on trips, station activities, and the number and characteristics of the users. Future studies can analyze this information associated with the planning and management variables already used in this article, seeking to identify the impacts and efficiency of different business models on the operation and

use of these systems. The database built and used in this study can serve as a basis for future research that seeks to understand specific aspects of the deployment of BSSs in Latin America, besides being a relevant tool for society, since it allows the transparent and periodic monitoring of these systems, as well as the evaluation of their impacts and benefits for cities.

DATA AVAILABILITY STATEMENT

The dataset that supports the results of this paper is available at SciELO Data and can be accessed via https://doi.org/10.48331/scielodata.9CQMA6.

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