Spatial factors influencing bike–sharing usage - a "mobility culture" approach -

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Abstract

This research contributes to enhancing active modes of transportation through bike-sharing systems (BSS) by understanding the most influencing spatial factors of their usage. Previous studies have focused on objective factors such as the built environment; however, spatial subjective factors, such as social milieus, political regulations, and mobility behavior have rarely been studied. Therefore, we want to fill this literature gap by identifying the most influencing objective and subjective factors influencing the usage of BSS. In order to know which factors should be studied, in addition to the previously analyzed factors found in the literature, we want to include the objective and subjective actors that shape the concept of mobility culture. In order to identify the most influencing factors, a three-steps methodology is proposed: (1) the data collection, (2) data analytics, and (3) model building and variables selection. As a case study, a high performing, hybrid system in Munich, Germany was selected. As an expected outcome, the most influencing spatial factors included in the concept of mobility culture are listed and ranked, and potential demand models are built. This approach opens the possibility to include perceptions, preferences, and values of the users in the planning and design of BSS.

1 Introduction

On account of environmental, economic, and social negative impacts caused by urban transportation, actions are required to develop sustainable transportation systems in urban areas, such as, reducing the need to travel by private cars, reducing the trips' length, and shifting trips to active modes [3, 29]. An example of an active mode of transportation are bike-sharing systems (BSS).

BSS are defined as the shared use of a bicycle, in which a user can access a fleet of bicycles that is offered in the public space within a service area [5, 31]. A user has to join an entity that maintains the fleet by usually paying a fee for renting a bike [28]. BSS can be classified into three categories regarding the availability of docking stations or not: a) Station-based bike-sharing (SBBS), b) Free-floating bike-sharing (FFBS) and c) hybrid bike-sharing (HBS), which is a mix of station-based and free-floating [13]. In contrast with SBBS, FFBS avoid the cost of docking stations. Thanks to their installed GPS, this transportation system can be tracked in real time allowing smart management and reduce the probabilities of bicycles theft. Mostly, FFBS are more convenient for users than SSBS because the average walking distance to their destination is shorter and users do not need to worry about the bike's storage in a docking station [26]. In contrast, HBS has the advantages of both SBBS and FFBS.

BSS are globally spread in more than 1,940 operating systems (including SBBS, FFBS, HBS, and electric bikes) [22]. The growing trend of BSS can be associated with their proven positive impacts such as "increased mobility, reduced greenhouse gas emissions, decreased automobile use, economic development, and health benefits" [7]. However, not all BSS have been deploying successfully. Some of them have been misused, vandalized and perceived as a public nuisance [17]. Historical reasons for a system failure were bicycles' low quality, lack of funding, over–saturated market, delayed expansion, inconvenient system design, oversupply, unfair fares, low political support, among others [17, 23].

To prevent over or undersupply and inconvenient system design, it is imperative to understand how BSS work and to identify the historical influencing factors on their usage. Commonly, factors affecting the historical usage of BSS are identified and understood by learning them from historical ridership. A categorization of spatial factors is objective and subjective. Objective factors are those that can be perceived with the senses (e.g. roadways length), while subjective factors are those that have to be asked to people in order to be known (e.g. social status of a person). However, as shown in Section 2, there is a research gap in factor analysis studies including spatial subjective factors, such as the mobility behavior, political regulations, social milieus, but also, including objective and subjective spatial information together in the factor analysis. Identification of both objective and subjective factors and their interactions will help to understand deeply and estimate better users' behavior.

We chose the mobility cultures concept as a theoretical framework to select potential objective and subjective influencing factors to be studied. Mobility cultures are defined as socio–cultural settings consisting of material and social dimensions of a transportation system, including mobility behavior, policy making, and governance, perceptions, and lifestyle orientations, spatial structure, and transport supply [8, 19, 18, 20]. This framework serves for analyzing the current and estimated behavior of a transportation system because it integrates objective and subjective elements [19]. This approach can help to compare the behavior between different spatial regions and to understand the behavior beyond the infrastructure of a transportation system, by including set of norms, values, beliefs, and meanings of users [18].

The purposed research contributes by understanding which spatial factors influence BSS's usage and thus, mitigating the system's drawback related to the "*inconvenient system design*" and over and undersupply. The main objective of this study is to identify the most influencing spatial objective and subjective factors included in the framework of mobility cultures on the usage of BSS. Therefore, this research will explore the question: which objective and subjective factors included in the framework of mobility cultures influence the most the usage of BSS?.

This short paper continues in Section 2 with a literature review of the proven spatial influencing factors on the usage of BSS in previous researches and in guidelines, and of the mobility culture framework. Section 3 summarizes the methodology to identify the most influencing factors, and finally, section 4 explains the expected outcome of the research.

2 Literature Review

2.1 Most influencing objective and subjective factors on the usage of BSS

The most midterm influencing factors found in related work and design guidelines are shown in Table 1. These factors can be classified mainly in six components: 1) social environment, 2) mobility behavior, 3) political regulations 4) built environment, 5) user's preferences, and 6) the BSS design itself.

Previous work dealing with spatial (i.e. georeferenced) factors included mostly the demography, the built environment and elements of the design of BSS (e.g., stations density). The main factors of the built environment are represented by the transport infrastructure, points of interest (POIs) and the urban structure. However, spatial subjective factors including the mobility behavior, social media use, political regulations, social milieus are commonly not evaluated, as well as considering in the study both objective and subjective spatial factors together.

According to the methodology, the most implemented regression modeling technique to build the potential demand model and identify the most influencing factors is ordinary least squares regression. As a dependent variable, the logarithm of the historical rentals is usually considered. Mostly log-likelihood (LL), R^2 and Akaike information criterion (AIC) and Bayesian information criterion (BIC) are used for assessing the models [9].

2.2 Mobility culture framework

In order to continue enhancing BSS, their understanding must no longer be considered as a simple part of transport but as a culture, i.e. a mobility culture [20]. The framework of mobility cultures includes objective

Table 1: Example of influencing factors on bike-sharing usage

Factors			Guideline				No georeferenced data studies		Georeferenced data studies			
			[1]	[15]	[5]	[31]	[10]	[2]	[32]	[12]	[11]	[24]
Social environment	**Demography**	City population	✓	✓	✓				✓			
		Population density	✓	✓		✓				✓	✓	
		Employment density				✓			✓		✓	
	Socio-Demography	Age					✓	✓				
		Gender						✓		✓		
		Household income					✓	✓				
		Household size					✓			✓		
		Education level					✓					
Mobility Behaivor	Mode to commute (work/school)		✓		✓		✓					
	Time / distance to commute						✓					
	Bicycle ownership							✓				
	Cycling propose							✓				
	Driver license ownership							✓				
	Already combine cycling and PT							✓				
Political regulations	**Trans. Reg.**	Traffic calm zones	✓									
	Safety	Bicycle thefts						✓				
Built environment	**Topography**	Slope (max 4%)	✓			✓						
		Altitude							✓	✓		
	Urban Structure	Distance to city center	✓	✓				✓			✓	
		Accessibility		✓	✓			✓				
		Mixed use land use	✓	✓								✓
		Industrial land use		✓								
		Single land use		✓								
		Residential land use										✓
		Commercial activity				✓						
	Transport infrastructure	PT stops	✓	✓	✓	✓						
		Metro									✓	✓
		Railway station							✓			
		Major roads									✓	
		Streets									✓	
		Enbankment road							✓			
		Transport POIs								✓		
		Cycling infrastructure	✓	✓	✓	✓					✓	
	POIs	Student residence							✓			
		Cinema							✓			
		Worship POIs								✓		
		Hotel								✓		
		Restaurant							✓	✓	✓	
		Universities	✓			✓					✓	
		Parks		✓								
		Sports Centers	✓									
		Recreation POIs								✓		
		Tourist attractions				✓						
Preferences	Environmental consciousness						✓					
Design	Capacity		✓	✓	✓	✓			✓	✓	✓	✓
	Density		✓	✓	✓	✓			✓	✓	✓	

and subjective actors, which their interrelations help to understand mobility behavior. Figure 1 shows the actors and their interactions in the framework of mobility cultures.

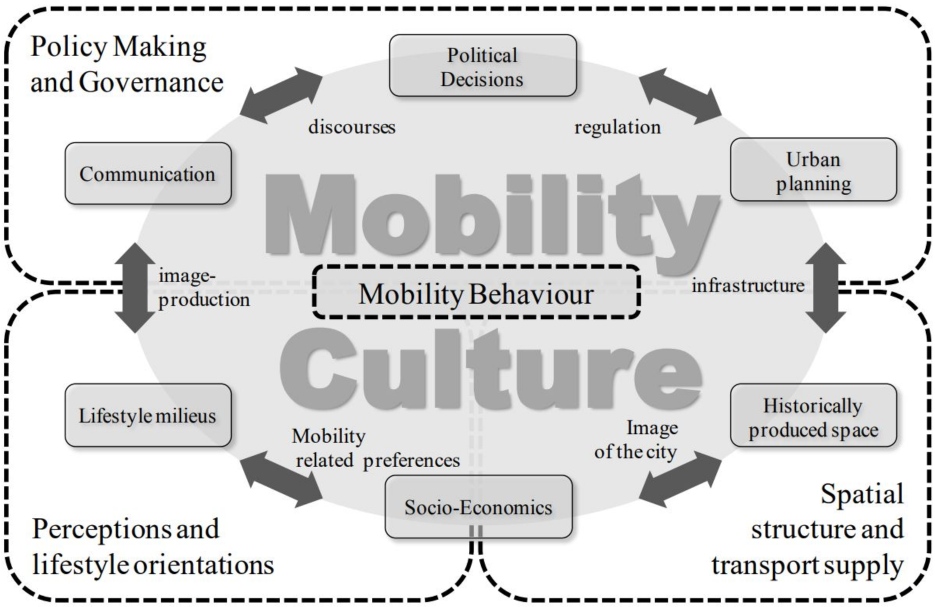

Figure 1: Mobility culture framework. Source: [20]

The subjective dimension of perceptions and lifestyle orientations include mainly mobility related preferences and lifestyles milieus. Milieus are groups of people with similar lifestyles and basic value orientations such as everyday attitudes to work, to family, to leisure, to money and consumption). These clusters are decision-making tools for strategic marketing, product development, and communications, among others [21]. They might also be useful to obtain a better understanding of peoples mobility behavior and therefore, a better understanding of a transportation system and its planning.

The framework of mobility cultures has been used in previous research to cluster administrative boundaries after considering objective and subjective spatial factors at different scales. On a global scale, Priester et al., 2013 [27] clustered 41 metropolia around the world in eight different mobility cultures types. Haustein Nielsen, 2016 [18] made a clustering study to categorize the mobility cultures of 28 European countries to identify the success of sustainable mobility supporting measures after the preferred mode of transport, reasons for using it and the problem awareness. In a regional level, Klinger et al., 2013 [19] classified 44 German cities according to their mobility culture to demonstrate how "urban mobility patterns vary within the same political and national context." They considered the objective factors of the urban form indicators, socioeconomic characteristics, transport infrastructure, transport demand indicators and the subjective factor of mobility-related perceptions. Finally, Beckmann et al., 2008 [4] provide an example of local clustering of different mobility types including in ten districts of the city of Cologne in Germany. They examined live situations and live styles related to the day-to-day mobility embedded in space-time structures to develop strategies for residential areas in the context of the metropolitan region.

As BSS being part of a mobility culture, not only their objective influencing factors should be analyzed but also, potential influencing subjective factors, such as preferences, lifestyle orientations, communications, and political regulations. In addition, as in Beckmann et al., 2008 [4], we want to cluster different zones in a city according to objective and subjective variables, in other words in term of the mobility culture, and then, identify the influencing factors per cluster.

3 Methodology

In order to meet the main objective of the study, a three-steps methodology is proposed (see Figure 2), which includes: 1) data collection, 2) data analytics 3) model building and factors analysis.

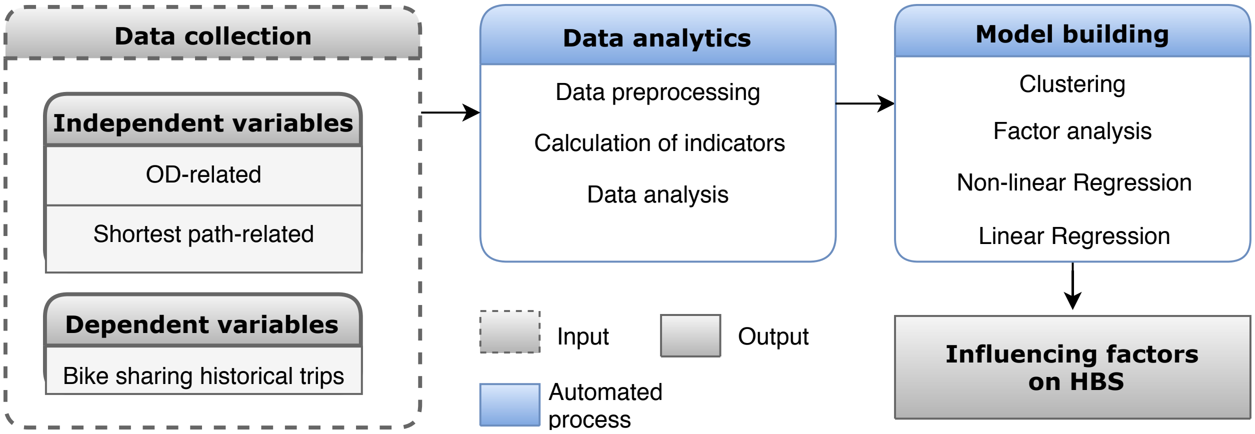

Figure 2: Methodology overview

1. *Data collection.* The data collected are objective and subjective factors (independent variable) and the historical BSS arrivals and departures (dependent variable). The independent variables related to the origin and destination are based on objective and subjective included as actors in the concept of mobility culture (see Figure 3). They are classified into two objective categories: natural and built environment, and four subjective categories: political decisions, social environment, mobility behavior, and communications.

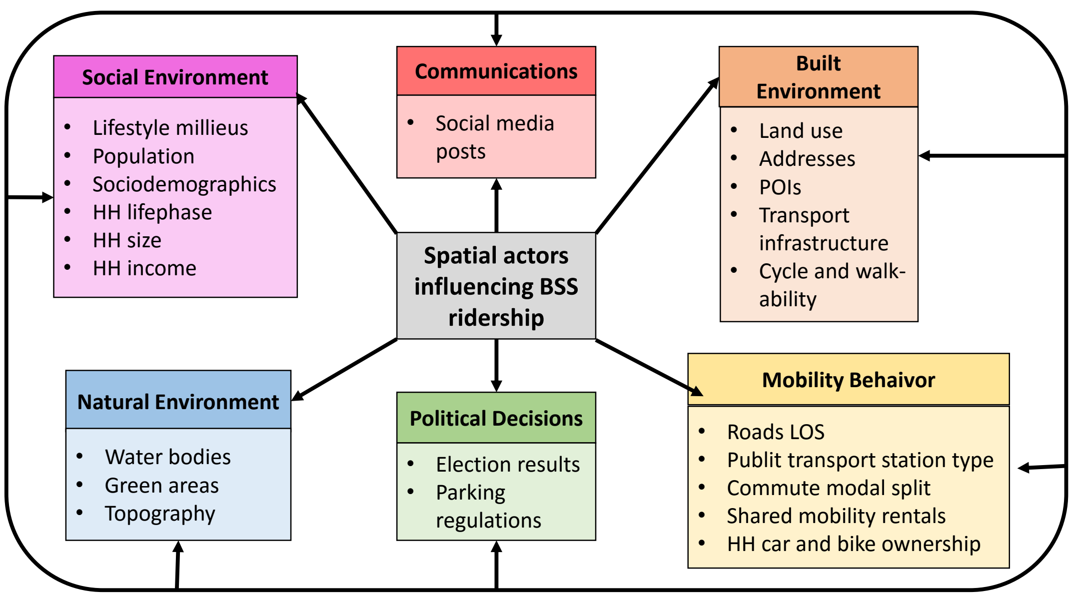

Figure 3: Potential objective and subjective factors

2. *Data analytics.* Arrivals and departures are aggregated into zones of influence, which are defined as the maximum walking area that a user is willing to walk to rent a bike. To consider the temporal influence, the rentals are differentiated temporally in 6 day-time intervals: peaks and off peaks periods during the morning, afternoon and night. Indicators such as proximity, density, entropy, weighted average are calculated assigned to the variables regarding their type in the zone of influence of the stations.

3. *Model building and factors analysis.* Zones of influence are clustered according to the independent variables. Then, models are built by correlating the number of arrivals and departures with the independent variables included in Figure 3. Different models are formulated per each zone of influence cluster and per each time interval considering the season, the day of the week (workday or weekend) and time of the day (morning, afternoon, night on peak and off-peak hours). Linear and non-linear regression techniques are tested to choose the technique that fits better the data and selects the fewest number of variables. The linear techniques for model building and variables selection are stepwise linear regression [6], generalized linear models (GLM) adapted with a LASSO selection technique [30], and for the non-linear approach Gradient Boosting Machine (GBM) [14] will be applied. These techniques were chosen after the good perforce shown in Duran-Rodas et al., 2019 [9].

3.1 Case study

As a case study, the HBS system in Munich was selected due to its high performance and because HBS systems have not been deeply studied to the best of the authors' knowledge. The rentals were collected during the period from March 2107 to May 2018.

According to the potential independent variables, the built environment variables are obtained from OpenStreetMap (OSM) [25]. OSM data quality is satisfactory in major cities in Germany and still acceptable midsize towns [16, 33]. Therefore, we can expect that data from OSM has an acceptable accuracy to meet for the objectives of the research. Subjective variables are collected from Twitter (`https://twitter.com/`), the statistical council in Munich (`https://www.muenchen.de`), microm (`https://www.microm.de/`), Mobilität in Deutschland (`http://www.mobilitaet-in-deutschland.de/`), among others.

4 Expected outcome

This research learns from BSS historical usage and searches for potential objective and subjective influencing factors under the framework of mobility cultures. The expected outcomes are potential demand models and a list of recurring objective and subjective factors that influence the usage of the HBS in Munich. The identification of these influencing factors will help:

- To assist operators and policymakers on their deployment of HBS.
- To increase the reliability of implementations and policies.
- To reduce the risk of supply-demand imbalance in existing systems.

Integrating subjective and objective variables spatially are rarely carried out on studies searching for BSS influencing factors. To the best of our knowledge, this would be the first study that integrates the approaches of shared mobility and mobility culture. This approach opens the possibility to include perceptions, preferences, and values of the users in the planning and design of BSS. The methodology suggested will not only be for BSS but it can be extended to other transportation systems to understand their behavior under a "mobility culture approach".

The proposed methodology can be applied to identify a pattern that looks for a potential optimal location of stations and boundaries of the service area. However, it is not suitable to a) assess if the implementation/expansion of BSS are going to be successful or not, b) carry out a short-term forecast of rentals, c) forecast every possible trip purpose.

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