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Identifying key elements for user satisfaction of bike-sharing systems: a combination of direct and indirect evaluations

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Abstract

Bike-sharing systems (BSS) are gaining popularity in cities worldwide, as a part of a generalized strategy to mitigate the problems derived from motorized transportation (congestion, pollution, noise, etc.). These systems have proved to have positive effects on cities, moreover, many of them have reached a performance peak and require improvements to attract/retain users and compete against emerging soft mobility alternatives. Whilst there are broad studies evaluating BSS demand and design, less attention has been paid to user satisfaction and the complexities underlying the relationships between the system attributes importance. This study proposes a novel combination of two methodologies for satisfaction assessment that allows decision-makers to identify the most influential system attributes on user satisfaction. The combined methods are the direct, explicit, *Importance Performance Analysis* (IPA), and the nonlinear, implicit *Three-Factor Theory* (3FT), which combined generate a three-dimensional scheme that facilitates the comprehension of the results. The combination was applied to a dataset of Madrid´s BSS to identify the attributes that perform poorly, and then assess their implicit influence on satisfaction to establish improvement priorities. The results suggest that *station occupancy and bicycle availability* and *totem functioning* are key service attributes to enhance satisfaction. Also, the combination of the two methodologies makes it possible to differentiate that *maintenance* is a priority for subscribers and *network extension* for occasional users. The *pedelec* system is a key attribute that might help overcome Madrid´s unfavorable cycling environment. This user-centric evaluation is a valuable tool that guides precise measure implementation, service operation, future design, and planning oriented to increase ridership.

Keywords User satisfaction · Bike-sharing · Attribute importance · Importance-performance analysis · Three-factor theory.

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Introduction

Large urban agglomerations are becoming economic, innovation and productivity hubs. Moreover, the urbanization process causes common problems in cities, such as low air quality levels, road congestion, traffic noise, and the deterioration of public transport like buses and underground. The problems derived from urbanization are prompting public authorities to pay more attention to the design, operation, and management of urban transportation systems seeking to optimize and attract users to sustainable modes of transportation(Banister 2005; Goldman and Gorham 2006). A common strategy is to reduce the benefits of private motorized vehicles (European Commission, 2011) and speed up the transition toward sustainable mobility seeking carbon neutrality by 2050 (European Commission, 2019).

A popular measure to increase active and sustainable mobility is the implementation of public bike-sharing systems (BSS) (Fishman et al. 2013). Cycling is one of the oldest modes of transport, nonetheless, it has regained popularity in cities since the 80s as a sustainable and healthy transportation alternative. To date, there are nearly 2,000 BSS in the world (Meddin and DeMaio 2021), because of the impulse of governmental promotion not only for sustainability purposes but also to give cycling visibility as a practical mode in urban environments. The spreading of bike-sharing systems has increased over the last twenty years, especially in Europe, East Asia (DeMaio 2009) and North America, where it is considered the cornerstone of the bicycle renaissance (Pucher et al. 2011; Shaheen et al. 2010). BSS evolution is recognized in four generations, the last comprising state-of-the-art technology, including GPS tracking automatic locking, solar-powered stations, and public transport integration. Some authors even recognize the dockless systems as a fifth generation (Julio and Monzon 2022).

Since these systems have been around for a while, many of them have reached a performance peak, and need improvements to attract and retain users. A common approach to raising the number of users of transport services is to increase the user's overall satisfaction with the given service. The relationship between service quality and customer satisfaction is usually recognized as a pivotal determinant of long-term business success. Hence, BSS service operators, following a user-centric approach, must concentrate their resources on measures that increase user satisfaction to strengthen the satisfaction-profit chain (Anderson and Mittal 2000; dell'Olio et al. 2010). To draw precise measures for improving user satisfaction, it is required to conduct an appropriate evaluation of the influence of BSS elements. Thus, this paper's goal is to identify the system attributes that have a higher influence on user satisfaction, to strengthen user loyalty.

Among the available methods for service quality assessment, Importance-Performance Analysis (IPA) is one of the most widespread in public transportation Martilla and James (1977). Benefits such as its simplicity and graphic results are appealing to transport managers and decision-makers. This quadrant analysis is useful to identify system attributes that are explicitly important for users and perform poorly. However, taking decisions based merely on IPA could lead to resource misallocation. For instance, two attributes that fall on the same "*focus here*" IPA quadrant, appear to have the same urgency for improvement. Notwithstanding, equal interventions might not have the same impact on satisfaction since the implicit importance is not being considered. The Three-Factor Theory (3FT), on the other hand, is a methodology that accounts for the non-linear relationship between importance and satisfaction. By using implicit importance, it differentiates attributes into three-factor categories, linear, basic, and excitement (Busacca and Padula 2005). This factor structure is helpful to discriminate attributes that are basic to achieve minimum levels of satisfaction, from others that, although explicitly important, do not provoke dissatisfaction when underperforming. In this research, we have applied the Importance Grid, developed by IBM Consulting Group to classify the attributes based on their implicit and explicit importance. Like IPA, the attributes are distributed in four quadrants. The coordinates of the attributes are the average values of explicit importance and the statistically obtained values of implicit importance. High explicit-high implicit are key linear attributes; low explicit-high implicit are excitement non-linear attributes; low explicit-low implicit are unimportant linear attributes; high explicit-low implicit are basic non-linear attributes.

Whilst both methods provide useful information, it is partially incomplete for optimal decision-making when analyzed individually. IPA only identifies the attributes that are explicitly important and underperform, whereas the 3FT only classifies the attributes based on the factor structure.

In this paper, we propose a novel combination of both methodologies, which takes the simplicity, graphic representation, and directness of IPA, and add a third axis, to observe the non-linear effects and classify the BSS attributes according to the 3FT. This approach is helpful for simple evaluation and precise decision-making targeted to maximize satisfaction. We applied the combined method to the pioneer e-bike-sharing system from Madrid, BiciMAD to different user types to answer the following research questions: (1) which elements of the bike-sharing system have more influence on user satisfaction? and (2) how do both approaches (IPA and 3FT) complement each other? to provide better quality information for more effective resource allocation. Results may be of special interest to service operators, planners, policymakers, and researchers as they shed light on potential policy implementations.

This paper is structured in six sections. The following section reviews the relevant literature and methods for user satisfaction in transportation services and BSS. Section 3 describes the methodological framework, the main characteristics of the case study, and the survey structure and data collection techniques. Section 4 contains the results, which are then compared and analyzed. Section 5 discusses the applicability of the method and the results and finally, Sect. 6 outlines the conclusions that can be drawn from the main findings.

User satisfaction and the methods to evaluate attributes performance

Capturing user satisfaction: application to BSS

Customer satisfaction is directly related to customer loyalty, as the greater the increase in satisfaction, the more likely it is that the user will continue to be a client of the service (Anderson and Sullivan 1993; Boulding et al. 1993; Yi, 1991). This relationship directly affects profitability, future revenues and the financial sustainability of the system (Bolton 1998).

The evaluation of public transport (PT) performance has traditionally been done only from the perspective of service managers, based mainly on the cost efficiency and cost-effectiveness of the services and operations (Hensher and Daniels 1995; Pullen 1993). In recent decades, a more user-centric approach, based on service quality (SQ) has also become a major concern for managers and researchers in the PT sector. SQ is recognized as an essential tool for public transport agencies and transport planners to capture and retain passengers (De Oña and De Oña 2015). SQ and satisfaction are derived from the disconfirmation theory (Parasuraman et al. 1988). Oliver (2010) defines SQ as a cognitive judgement (thinking/judging) that summarizes the good or bad elements of a service, whereas customer satisfaction is an affective judgement (liking/pleasure), a consumer's fulfilment response based merely on personal experiences.

Satisfaction has been the focus of many studies in the transport scientific literature, given the demonstrated relevance in attracting and retaining users. There are numerous studies, including PT infrastructure and combined modes (Abenoza et al. 2018; Hernandez et al. 2016; Susilo and Cats 2014), bus (Efthymiou et al. 2018; Echaniz et al. 2018; Figler et al. 2011), rail (Nathanail 2008; Zhang et al. 2017; Machado-León et al. 2017; Eboli and Mazzulla 2015; Eboli et al. 2018) and airlines (Chow 2015; Pakdil and Aydin 2007) An exhaustive literature review on this subject was developed by van Lierop et al. (2018), helpful for researchers and practitioners studying on this matter.

Satisfaction with BSS

Recently, the introduction of shared mobility in cities has become a trending topic in transportation literature. Machado et al. (2018) provide a well-structured bibliographical review that encompasses the diverse modalities to be found in cities. Since BSS are part of the shared mobility ecosystem, Fishman (2016) develops a detailed bibliographic review, and Si et al. (2019) map the latest research. our research lines can be identified on this topic: (1) history, evolution, and implementation suitability; (2) functioning and governance; (3) integration and network; and (4) user satisfaction.

Recently, there has been an increase in the study of the perceived quality of BSS. Manzi and Saibene (2017) analyze the validity of Customer Satisfaction Surveys (CSS) applied to BSS and the potential of new technologies for improving transport systems. Kim et al. (2017) evaluate policy strategies for optimal BSS implementation. Alvarez-Valdes et al. (2016) study the influence of imbalances in bicycle distribution among the stations and the service quality perceived by users. Albiński et al. (2018) describe that the success of a BSS relies on many factors, but the two with the greatest influence on user satisfaction are bike functionality and pricing. Médard de Chardon et al. (2017) conduct a comprehensive analysis of 75 BSS to assess their performance in terms of the number of trips per day per bike (TDB), while Eren and Uz (2020) analyze external factors such as weather, land use, PT connection and the influence of safety on bike-sharing demand. Morton's (2018) appraisal identifies to what extent the service quality of London's BSS can retain or attract new users. Lately, the travel satisfaction experienced with dockless bike-sharing systems has been further studied, in close relationship with stages, attitudes and built environment, finding that attitudes have higher relevance to travel satisfaction than the built environment (Chen et al. 2022).

This review shows some of the scientific literature focused on user satisfaction with BSS. Moreover, it also evidences the unexplored relationship between explicit and implicit importance of system attributes with user satisfaction. Topics such as the imbalances described by Alvarez-Valdes et al. (2016) need to be further explored to determine the extension of their influence on user satisfaction, accounting for explicit/implicit attribute importance. Indeed,

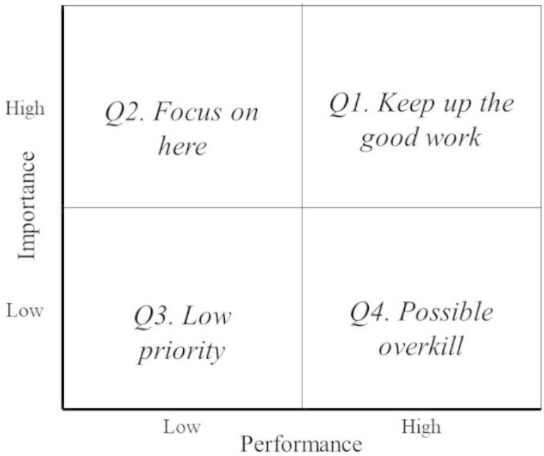

Fig. 1 Strategy definition based on importance-performance analysis

bicycle availability is one of the contemplated attributes in this research and this paper investigates its implications on overall satisfaction.

Application of IPA in transportation

Originally introduced by Martilla and James (1977), IPA is one of the most widely used quadrant analysis techniques corresponding to the *"disaggregate models based only on performance"* (De Oña and De Oña 2015). IPA has been widely applied to public transport systems in various fields. For instance, Weinstein (2000) applied an IPA to study the importance ranking of various service attributes in the San Francisco Bay Area Rapid Transit (BART) and compared the results with a simple regression analysis. Chou et al. (2011) applied the IPA to appraise the quality of Taiwan's high-speed rail service and performance, and Chen and Chang (2005) used the IPA to construct a service attribute evaluation map to identify areas for improvement in airline services. Iseki and Taylor (2010) applied an IPA to examine users' perception of stops and stations in the Los Angeles metropolitan area, and Cherry and Townsend (2012) used the same methodology to evaluate the metro-bus transfer experience in Bangkok, Thailand. Finally, Hernandez et al. (2016) proposed a methodological framework, including IPA, to identify the potential strengths and weaknesses of urban transport interchanges. However, to the best of the authors' knowledge, there is no record of the application of this method to bike-sharing systems.

IPA helps to identify attributes that require urgent attention based on the conceptual foundations of multi-attribute choice models. The identification in categories is made by placing each attribute in quadrants of a two-dimensional matrix, where performance (satisfaction) lies on the *x-axis* and explicit importance on the *y-axis*. The service attributes are divided into four groups depending on their performance (high/low) and importance to the customer (high/low). This distribution in quadrants produces four strategies (Fig. 1).

Adapted from Martilla and James (1977).

The attribute classification according to Matzler et al. (2003) for each quadrant is: In Q1 are attributes evaluated high in satisfaction and importance. They represent opportunities for gaining or maintaining competitive advantages and are labelled as *keep up the good work*. Low-performance and high-importance attributes fall in Q2 *focus here*. Service administrators should concentrate on these attributes to enhance overall satisfaction. If they are ignored, these attributes pose a serious threat to overall user satisfaction. The attributes that fall in Q3 are both low in satisfaction and importance. There is no need to focus additional efforts on these attributes, which are labelled as *low priority*. Attributes that fall in Q4 are rated high in satisfaction but low in importance, resulting in resources being committed to attributes that could be employed elsewhere. They are labelled as *possible overkill*.

The matrix is built with data from a satisfaction survey. Users rate the satisfaction and importance of each of the service attributes on a scale, so each attribute has a coordinate on the matrix. The axis intersection in the matrix is somewhat arbitrary (Sampson and Showalter 1999). However, following several authors criterion, we have established the average value of both importance and satisfaction as the intersection of the axes (Chen and Chang 2005; Chou et al. 2011; Freitas 2013).

Although IPA is considered a simple but effective tool, the assumption that the relationship between attribute performance and overall satisfaction is linear and symmetric undermines its complete validity for attribute assessment (Matzler et al. 2004). Recent research suggests that implicit importance is a better indicator for decision making than the traditional rating (Echaniz et al. 2019; Cao and Cao 2017) and that attributes fall into three categories: basic, performance and excitement factors (Anderson and Mittal 2000). To classify the factors, it is necessary to obtain implicit importance. One of the most common techniques is to conduct a statistical regression to obtain the factor implicit influence on overall satisfaction. This classification is known as the Three-Factor theory, which is described in the next section.

The three-factor theory of customer satisfaction in transportation research

Unlike the original IPA, the application of the three-factor theory to transportation is scarce and practically inexistent with BSS. Based on 2013 survey data from Indore, India, Zhang et al. (2017) applied the 3FT to find that *comfort while riding* and *safety while waiting* are common basic attributes across the three types of public transport evaluated. Cao and Cao (2017) conducted an analysis using the 3FT with data from metro transit riders in Guangzhou, China and compared their results with a traditional IPA. More recently, Wu et al. (2018) used regressions with dummy variables to identify the three types of factors among a series of bus attributes and found that *comfort*, *travel time* and *reliability* should be addressed as the first priorities to enhance user satisfaction. The non-linear effects of travel service attributes and asymmetric influence on the overall travel experience are evaluated in detail by Abenoza et al. (2019), finding that a "one size fits all" approach is not adequate for identifying the needs of distinct traveler segments and using different travel modes.

The 3FT derives from the model of customer satisfaction proposed by Kano & N. (1984), which suggests that service attributes fall into three categories, each with a different impact on user satisfaction (Fig. 2 - left).

(1) *Basic attributes* cause dissatisfaction if poorly perform but do not lead to customer satisfaction if fully deliver. These *dissatisfier attributes* are minimum requirements. They are prerequisites that customers take for granted and are a necessity for basic satisfaction.

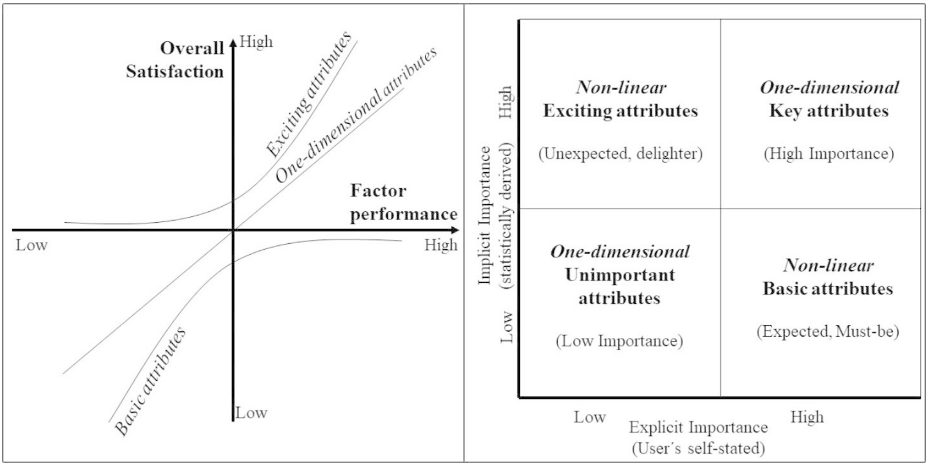

Fig. 2 The three types of factors (left) and the Importance Grid (right). Adapted from Kano & N. (1984) and Vavra (1997)

(2) *One-dimensional attributes* cause satisfaction if fully perform and dissatisfaction if they do not. They correspond to the traditional concept of the linear and symmetric relation between satisfaction and performance.
(3) *Exciting attributes* cause satisfaction if fully deliver but do not lead to dissatisfaction if they do not. These satisfier attributes are unexpected, generating delight when properly performed. They can serve as added values to attract users.

One method to classify attributes following the three-factor structure is the Importance Grid (Fig. 2 - right). It is a quadrant analysis technique, like IPA, developed by the IBM Consulting Group. It is a two-dimensional matrix that combines explicit (customer self-stated) and implicit (statistically derived) importance. The implicit importance is obtained with a statistical regression, while the explicit is obtained with a satisfaction survey. The coordinates of each attribute in the grid are determined by the value of the statistical implicit and the explicit importance of each attribute. The axes intersection is defined by the average values of the implicit and explicit importance.

A newer research line, based on the principles of the 3FT, applies the Impact-Asymmetry Analysis (IAA) for an accurate evaluation of non-linear effects (Cao et al. 2020; Dong et al. 2019; Fang et al. 2021; Lan et al. 2022; Wu et al., 2020). These papers identify the most influential factors on user satisfaction, accounting for the non-linear relationships. They deal with bus riders, urban walkability, and neighborhood attributes, providing useful insights into the validity of the factors approach. Although, IAA classifies attributes into five categories, which could be considered an extension of the three original ones. This method is strong in attribute identification but requires a sophisticated application and complex results interpretation.

The methods mentioned before offer valuable information for decision-making, nonetheless, it is partially incomplete. In the next section, we describe the complementarity of both, IPA and Importance Grid methods and the contribution to decision-making processes.

Methods complementarity

Transport administrations usually have limited resources for service improvements and need the most accurate information to implement the best cost-effective measures. IPA is a useful method to easily identify the attributes that require urgent attention (those falling in Q2. Figure 1). These are explicitly important attributes that do not perform well, generating user dissatisfaction. Notwithstanding, if there are several attributes in this quadrant, there is no sufficient information to prioritize interventions on the attributes that could have a higher impact on user satisfaction and/or draw strategies targeted to specific user profiles.

The importance grid technic classifies the service attributes in categories following the 3FT structure by using the implicit (statistically derived) importance. Moreover, it does not provide information about the attribute performance since it only identifies the influence that each attribute has over user satisfaction. In both cases, attributes are classified in four quadrants. The axis intersection is defined by the mean values of explicit/implicit importance and satisfaction, there will always be attributes evenly distributed among the fourth quadrants.

The difference between explicit and implicit importance is that the first is directly obtained with satisfaction surveys. The user is asked to assign a score on an importance scale to each attribute. The implicit importance, on the other hand, can be obtained with different methods. The most common is to conduct a statistical regression in which the dependent variable is the overall satisfaction, and the independent variables are the satisfaction scores assigned to each attribute. The implicit importance is related to the coefficients of the regression, being the most important of those with extreme values. The main difference is that while the explicit importance is a conscious rational value assigned by the user, the implicit is derived from the influence of each attribute on the overall satisfaction.

Later methods use more sophisticated ways to classify factors, such as impact-asymmetry analysis (IAA), Wu et al., (2020) suggest that "*Although the three-factor theory captures the non-linear influence of service attributes on overall satisfaction and illustrates threshold effects, it does not consider the size of the influence when identifying improvement priority and classifying service attributes*". The application of IAA helps to classify attributes accounting for the size of their influence on satisfaction, by identifying five types of factors: *frustrators, dissatisfiers, hybrid, satisfiers, and delighters*. Although IAA generates a more granular classification, the factors are an extension of the 3FT since the first two are basic factors and the last two are excitement factors. Following this research line, several studies applied IAA and gradient boosting decision threes (GBDT) to examine a variety of user satisfaction topics, such as, elderly and public transport (Lan et al. 2022), bus and BRT riders (Fang et al. 2021; Wu et al., 2020) and neighborhood and urban planning (Cao et al. 2020; Dong et al. 2019). We, aware of the limitation of using the 3FT alone, mixed implicit and explicit importance with attribute performance to graphically identify attributes' relationship with satisfaction. This combination is aligned with the IAA since it provides a prioritizing scheme accounting for the size of the attribute's influence on satisfaction.

Since IPA and the 3FT share the explicit importance axis, it is possible to combine them into a three-dimensional scheme. The results provide complete information on the low-performance attributes, their explicit and implicit importance, and their relationship to user satisfaction. Further details of the combined method are developed in the next section.

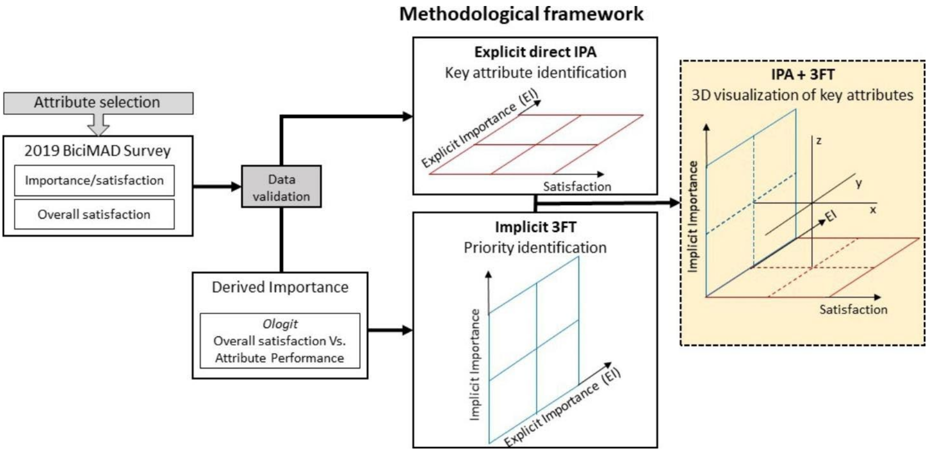

Fig. 3 Methodological procedure

Methodological framework

Combined methodology

The methodological framework is displayed in Fig. 3. The attributes included in the survey were specially selected for the case study characteristics, following literature recommendations. Once the survey has been conducted and the data has been cleaned, the next step is to conduct the attribute appraisal.

First, we conducted an IPA with the average satisfaction on the *x-axis* and average explicit importance on the *y-axis* of each attribute. This step generates the first two-dimensional plane, which classifies attributes as described in Sect. 2.2, identifying those underperforming. Second, to classify the attributes based on the 3FT, we obtained the derived importance, by conducting an ordered logistic regression which is described next section.

The second two-dimensional plane was built with the explicit importance on the *y-axis* and the implicit importance on the *z-axis*, as shown in Fig. 2. Since both planes share the explicit importance in the *y-axis*, it is possible to combine them to form a three-dimensional configuration in which is possible to identify the attributes that need urgent attention, and then, prioritize those with extreme implicit importance. The coordinates of the attributes in the three-dimensional scheme are a projection of the average value of satisfaction (x-axis), the average value of explicit importance (y-axis) and the implicit importance (z-axis) statistically obtained in the model.

The combination serves to easily identify the key elements for the enhancement of user satisfaction, which could then be formulated into targeted measures. The attributes are in a three-dimensional scheme, classifying them in a simple but effective way, providing another dimension to the traditional IPA or 3FT importance grid.

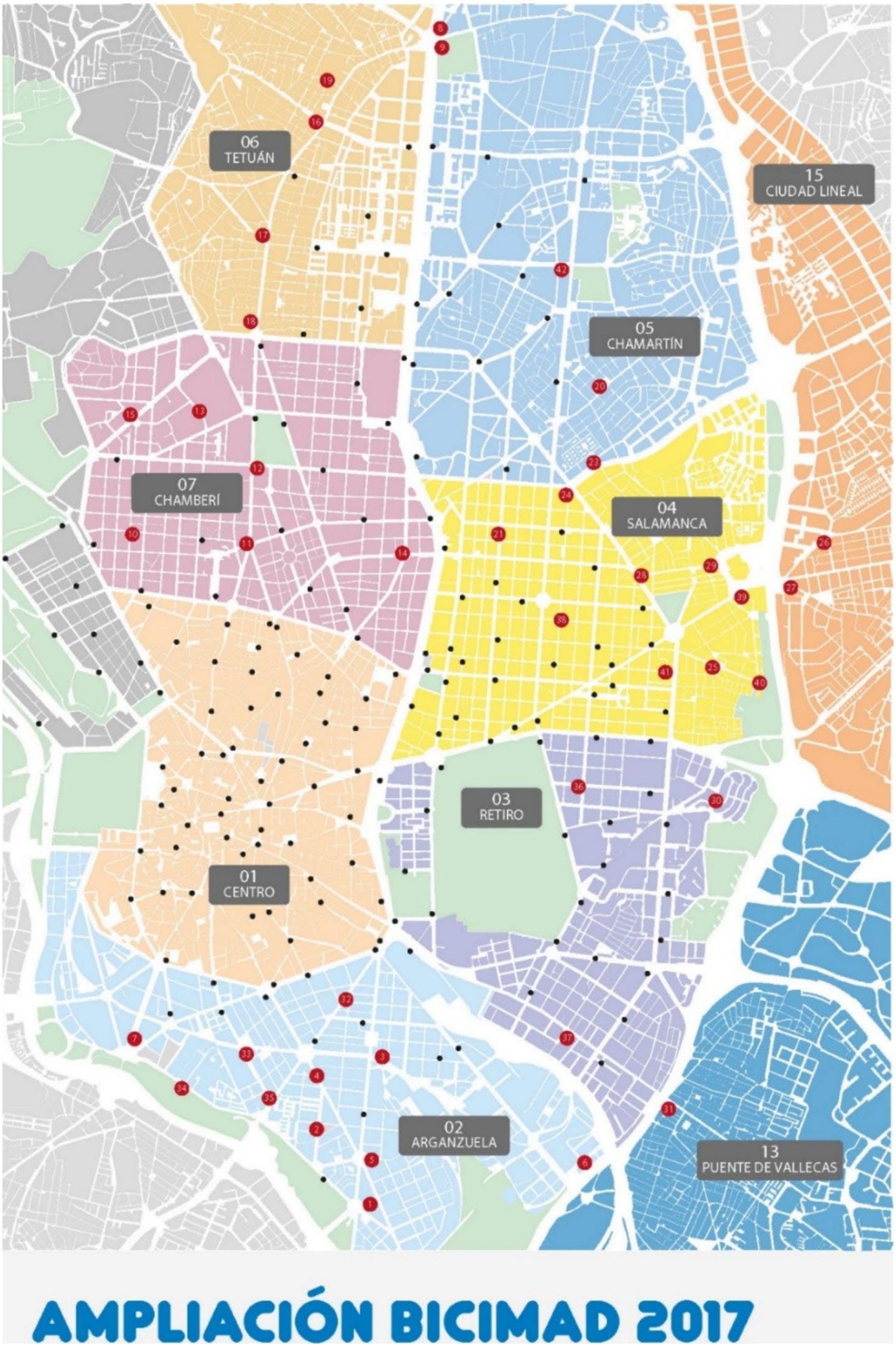

Fig. 4 BiciMAD stations. (Black: first phase; Red: network extension)

Modelling considerations. An ordered logit model

Two ordered logit regression models were estimated to obtain the derived importance, given the categorical nature of the dependent variable. The models, one for subscribers and one for occasional users, contained the *overall satisfaction* as the dependent variable and the 24 service attributes performance as independent variables.

Ordered logit models are based on traditional logit models based on the theory of random utility. According to Ortúzar and Willumsen (2011), the theory of random utility assumes that each individual allocates the resources in a way that maximizes her/his utility or personal satisfaction. Next, a short formulation of ologit models is described, extracted from UCLA: Statistical Consulting Group, (2021).

Let Y be an ordinal outcome with J categories. Then $P(Y \leq j)$ is the cumulative probability of Y less than or equal to a specific category $j = 1, \ldots, J-1$. Note that $P(Y \leq J) = 1$. The odds of being less than or equal to a particular category can be defined as:

$$\frac{P(Y \leq j)}{P(Y > j)} \tag{1}$$

For $j = 1, \ldots, J-1$ since $P(Y > J) = 0$ and dividing by zero is undefined. Alternatively, it is possible to write $P(Y > j) = 1 - P(Y \leq j)$. The log odds is also known as the logit, so that:

$$log\frac{P(Y \leq j)}{P(Y > j)} = logit\,(P(\,Y \leq j\,)) \tag{2}$$

The ordinal logistic regression model can be defined as:

$$logit\,(P\,(Y \leq j)) = \beta_{j0} + \beta_{j1???1} + \cdots + \beta_{jp}x_p \tag{3}$$

for $j = 1, \ldots, J-1$ and p predictors. Due to the parallel lines assumption, the intercepts are different for each category but the slopes are constant across categories, which simplifies the equation above to:

$$logit\,(P\,(Y \leq j)) = \beta_{j0} + \beta_{j1???1} + \cdots + \beta_{p}x_p \tag{4}$$

Once the model was run on STATA 15 software, we estimated the implicit importance of each attribute by obtaining the odds ratio (OR) of the modelled coefficients, following the procedure described in Zhang's et al., (2015).

$$OR = exp(\beta) - 1 \tag{5}$$

The detailed interpretation of the implicit importance coefficients obtained with the ordered logit regression could be found in Abenoza et al. (2017). The axes intersection was defined by the average values of explicit and implicit importance and satisfaction for each attribute. The categorization according to each quadrant followed the description in Sect. 2, based on the attribute coordinates. The combined analysis and graphics were obtained using MATLAB R2021a software.

Case study

BiciMAD is Madrid's BSS. It was introduced in 2014, to promote cycling in a city with a low share of bicycle use (0.5%), conditioned by the lack of infrastructure, extreme weather, and hilly topography (differences in elevation of up to 200 m) (Muñoz et al. 2013). However, a positive movement of cycling collectives and public authorities favored the implementation of BiciMAD, the development of cycling infrastructure – 282 km in 2018 (MITECO 2020) –, the prioritization of roads in the city center for cyclists and pedestrians and active campaign strategies to raise awareness of the benefits of cycling are encouraging people to cycle.

BiciMAD was a pioneer demand-responsive system (Munkácsy and Monzon 2017), the first city-wide with an entire pedelec (electric pedal-assisted bicycles) fleet in the world. It was originally deployed in the inner and denser districts of Madrid with approximately 15,000 to 30,000 inhabitants per km^2. At that time the system had 123 stations and 1,560 bicycles.

The main characteristics of the system are:

- The whole fleet is GPS-tracked. Although the system is mainly station based, a small number of free-floating bikes have been recently introduced (BiciMADgo).
- The electric engine activates only when the cyclist is pedaling, providing assistance on three levels (low, medium, high) up to 25 km/h. Beyond this speed, the bicycle works as a regular bike.
- Minimum fee per use of €0.50, including the 30 first minutes. Subscribers should charge their balance accounts in advance, of which the basic fee of 0.50 € is deducted, in addition to the proportions of half hours used. Bikes could be unlocked with the subscription card, the public transport card or a QR code. The system is demand-responsive and fully integrated into the public transport system.
- Occasional user scheme, with a 2€ fee for the first hour and subsequent 4€ or fraction (available for tourists).
- User-based redistribution rewards users by applying a discount of €0.10 for taking a bike from a full station and €0.10 for returning it to an empty station.
- The user interface is fully supported by online mobile applications and solar-powered totems at the stations.

It is possible to use the service under two modalities:

- *Subscribers* are frequent users who pay an annual fee of €25 (€15 if they are public transport pass holders) and a basic fee of €0.50 for each half-hour use. The general characteristics of BiciMAD subscribers are (Ayuntamiento de Madrid, 2017):
- 35% women, 65% men.
- 30% between 14 (minimum age for registration) and 30 years old, 40% between 30 and 40 years old, and 30% older than 40 years old.

- 85% have a university degree, 13% general certificate of education or vocational studies, and 2% have primary or secondary studies.
- *Occasional* use scheme, with a 4€ per hour pay-by-use fee structure. This scheme is intended to match the price per hour of the tourism companies offering bicycle renting. The fare structure is intended to offer potential subscribers the possibility to try the service for commuting purposes, but not for tourism or leisure.

Julio and Monzon (2022) present a detailed description of the BiciMAD system, its evolution, and the effects of its introduction on subscribers' mobility patterns.

Source: Ayuntamiento de Madrid (2019).

Figure 4 shows the distribution of BiciMAD stations in the city districts; black dots denote the original stations and red dots the stations implemented between 2017 and 2019. The system has grown to 258 stations, 2,964 bicycles and over 60,000 subscribers.

Data collection

There are several methods in the field of public transport such as focus groups, interviews, and surveys to evaluate service attributes and overall satisfaction. Customer satisfaction surveys (CSS) are frequently used by academics and practitioners to assess the quality of the public transport service (Eboli and Mazzulla 2007) since it is crucial for transport administrations to identify the key attributes influencing user satisfaction (Abenoza et al. 2017).

In this research, the data was collected in a two-phase survey, conducted in May 2019:

Phase 1. The BiciMAD administration sent an email with the survey link to the 65,436 subscribers registered in the system database, following an online methodology, obtaining 6,151 responses, of which 4,713 were valid.

Phase 2. A hybrid method was developed by Monzon et al. (2020) and was used to get answers from occasional users. The method combines the advantages of personal intercept surveys with online questionnaires, namely good data quality, representativeness, and minimal costs. By the end of the one week of using the hybrid campaign, 1,007 responses were received resulting in 827 valid responses. Therefore, the final database consists of a total of 5,540 responses.

The survey had five sections: (1) general mobility, (2) attributes importance/satisfaction and overall satisfaction, (3) Madrid's cycling infrastructure and pro-pedestrian/cycling policies, (4) shared mobility (free-floating bicycles and electric scooters), and (5) socioeconomic questions. Respondents answered different sets of questions depending on their user profile, as the survey had a three structure of logic questions.

The 24 attributes included in the survey were specially selected for the case study, following literature recommendations (Carrillat et al. 2007; De Oña and De Oña 2015), nonetheless, many of them are common in the 4th generation of BSS. The attributes are listed in Table 1 and were evaluated based on a 1–5 Likert (1932) scale for both, importance and satisfaction. The five categories for satisfaction ranged from very unsatisfied, unsatisfied, indifferent, satisfied and very satisfied. In a similar way, for importance they ranged from completely unimportant, unimportant, indifferent, important, very important.

Table 1 BiciMAD system attributes

Category	Attribute	Description
Bike	1. Handling	Bicycle maneuverability
	2. Pedelec system	Electric pedaling assistance
	3. Speed and power	The intensity of the electric assistance
	4. Battery duration	If the charge of the battery is enough to complete a trip
	5. Bike design and ergonomics	Comfort with the cycling position and appearance
	6. Carrier utility	Front basket functionality
	7. Maintenance	State of maintenance of the bicycles
Stations	8. Network extension	The total service area
	9. Distance between stations	Separation between stations
	10. Anchorage functioning	The easiness to lock (un-lock) a bike at the station
	11. Bicycle availability	
Tariff	12. Annual subscription	25€ (15€ to PTC)
	13. First half-hour tariff	For subscribers 0.50 €
	14. Subsequent half-hour tariff	For subscribers 0.60€
	15. First hour for occasional users	2€
	16. Second hour for occasional users	4€ or fractions
	17. Discount for taking a bike from a saturated station	0.10€
	18. Discount for returning a bike to an empty station	0.10€
Interface	19. Mobile application	The functionality of the mobile phone app
	20. Website	The functionality of the service website
	21. Totem functioning	The easiness and functionality of the touchscreen kiosk at the station.
	22. Registration procedure	Procedure to register as a subscriber of the service
	23. Notification system	Communications between the service provider and users
	24. User support	Call-center

The attributes were analyzed by applying the combined method and the results are further described on the next section

Results

Sample description and representativeness

The database comprised responses from 5,218 subscribers and 126 occasional users. An exploratory analysis was conducted to verify the representativeness of the sample. The

Table 2 Sociodemographic characteristics of the sample

User profile		Subscribers			Occasional users		
		Freq.	%	Cum.	Freq.	%	Cum.
Gender	Male	3353	64.26	64.26	86	68.25	68.25
	Female	1865	35.74	100	40	31.75	100
Age	14–24	250	4.79	4.79	27	21.43	21.43
	25–34	1653	31.68	36.47	51	40.48	61.9
	35–44	1777	34.06	70.53	25	19.84	81.75
	45–54	987	18.92	89.44	14	11.11	92.86
	55–64	462	8.85	98.29	6	4.76	97.62
	> 64	89	1.71	100	3	2.38	100
Education	Decline to answer	65	1.23	1.23	0	0	0
	Primary education	14	0.27	1.51	0	0	0
	Secondary education	60	1.15	2.66	9	7.14	7.14
	General certificate of education	307	5.88	8.55	18	14.29	21.43
	Vocational education and training	345	6.61	15.16	7	5.56	26.98
	Higher education/bachelor's degree	1001	19.18	34.34	24	19.05	46.03
	Master's degree	3102	59.45	93.79	62	49.21	95.24
	PhD	324	6.21	100	6	4.76	100
Occupation	Employee	3736	71.6	71.6	66	52.38	52.38
	Self-employed	776	14.87	86.47	16	12.7	65.08
	Unemployed	247	4.73	91.2	7	5.56	70.63
	Retired	99	1.9	93.1	4	3.17	73.81
	Student	343	6.57	99.67	31	24.6	98.41
	Housekeeper	17	0.33	100	2	1.59	100
Monthly income	Decline to answer	56	1.07	1.07	15	11.9	11.9
	< 800	382	7.32	8.39	19	15.08	26.98
	800–1300 €/m€	982	18.82	27.21	24	19.05	46.03
	1300–2000 €	1759	33.71	60.92	33	26.19	72.22
	2000–3200 €	1367	26.2	87.12	16	12.7	84.92
	> 3200	499	9.56	96.68	12	9.52	94.44
	No income, parent-dependent	125	2.4	99.08	6	4.76	99.21
	No income, partner-dependent	48	0.92	100	1	0.79	100
	N	5218			126		

sociodemographic characteristics displayed in Table 2 were compared with the general characteristics of BiciMAD's users' population (Ayuntamiento de Madrid, 2017).

The characteristics shown in Table 2 match the general description of the user profile presented in reports from the BiciMAD administration. These results allow us to validate the sample and continue with further analysis.

Key attributes identification based on IPA

In this section, we identify the low-performance attributes that require urgent attention to increase user satisfaction. To facilitate the interpretation of the graphics, the symbols representing each attribute are labelled with a number from 1 to 24, according to Table 1. The attributes on which service operators should focus are those falling on the second quadrant, *"Q2"*, described in the methodology section of the paper.

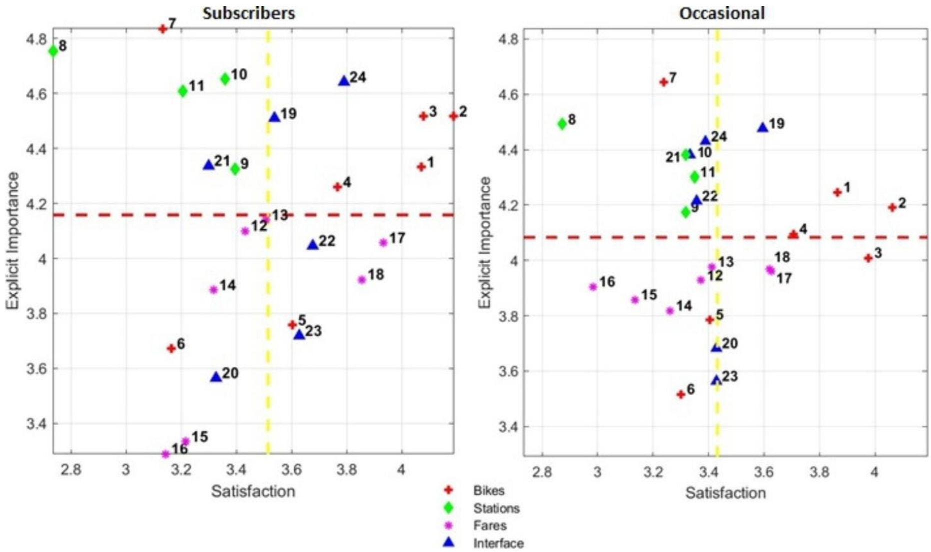

Fig. 5 IPA – Service Subscribers (left) and occasional users (right)

Key attributes for subscribers

Six attributes fall on the second quadrant (focus here) for subscribers (Fig. 5 - left):

- *7 Bicycle maintenance*.
- *8 Network extension*.
- *9 Distance between stations*.
- *10 Anchorage functioning*.
- *11 Bicycle availability*.
- *21 Totem functioning*.

Four of them are related to BiciMAD stations, one refers to the bicycles, and one is related to the interface with the user. These attributes are explicitly important for users, nonetheless, they perform poorly. Most of the attributes related to the bicycles have high satisfaction scores, except for attribute 6 (*carrier*) and attribute 7 (*bicycle maintenance)*. Nonetheless, attribute 6 has low relative importance, consequently, there is no need for additional efforts. Noticeably, the *network extension, the distance between stations, anchorage functioning*, and *bicycle availability* (all the station-related attributes) fall in the second quadrant, showing low user satisfaction and high explicit importance. On the other side, below the importance threshold, there are the attributes related to the fees per use and the discounts. Interface attributes such as *mobile app, totem functioning*, and *user support* are roughly distributed over all the quadrants.

So far, it is possible to identify two very important attributes with low performance. Attribute 7 is *bicycle maintenance* and attribute 8 corresponds to *network extension*. Therefore, and based on the original assumption of linearity the administration should "focus here" and try to increase the satisfaction of these attributes to improve the overall satisfaction of subscribers.

Key attributes for occasional users

For occasional users, there are two more attributes on the second quadrant, making eight requiring urgent attention (Fig. 5 - right).

- *7 Bicycle maintenance*.
- *8 Network extension*.
- *9 Distance between stations*.
- *10 Anchorage functioning*.
- *11 Bicycle availability*.
- *21 Totem functioning*.
- *22 Registration procedure*.
- *24 User support*.

Attributes 7 (*bicycle maintenance*) and 8 (*network extension)* have the lower satisfaction and highest importance. The attributes related to fares are below the importance threshold. Almost all the attributes related to the bicycles have satisfaction above the threshold, except the 5 (*ergonomics and design*), 6 (*carrier*) and 7 (*maintenance*). Nevertheless, only the last has importance over the threshold.

Like the subscribers, IPA identifies attributes 7 (*maintenance*) and 8 (*network extension*) as the attributes to act upon to improve and increase the satisfaction of occasional users. Nonetheless, it does not provide further information on which should be prioritized, among the other attributes that fall in this quadrant.

To complement this information, we propose to include the *z-axis*, with the implicit importance, to form a three-dimensional scheme that allows classifying attributes following the 3FT structure.

Factor structure based on the three-factor theory

The addition of the implicit importance provides complementary information for the interpretation of the results. The plane formed by the explicit (*y-axis*) and the implicit (*z-axis*) importance form the Importance Grid, a quadrant method for the factor classification described in Sect. 2.3. Attributes that fall in the first quadrant have high explicit and implicit importance, hence, there are key linear attributes. Intervening to improve satisfaction with these attributes will increase the user's overall satisfaction with the system.

Factor structure for subscribers

In the case of service subscribers, the two attributes identified on the IPA, 7 (*maintenance*) and 8 (*network extension*), fall on the *Key* quadrant of the 3FT diagram displayed in Fig. 6. Any increase in satisfaction with these attributes will improve the overall satisfaction with the system. By adding the additional axis with the implicit importance, it is possible to observe that attribute 7 has higher implicit importance than attribute 8. Meaning that *main-*

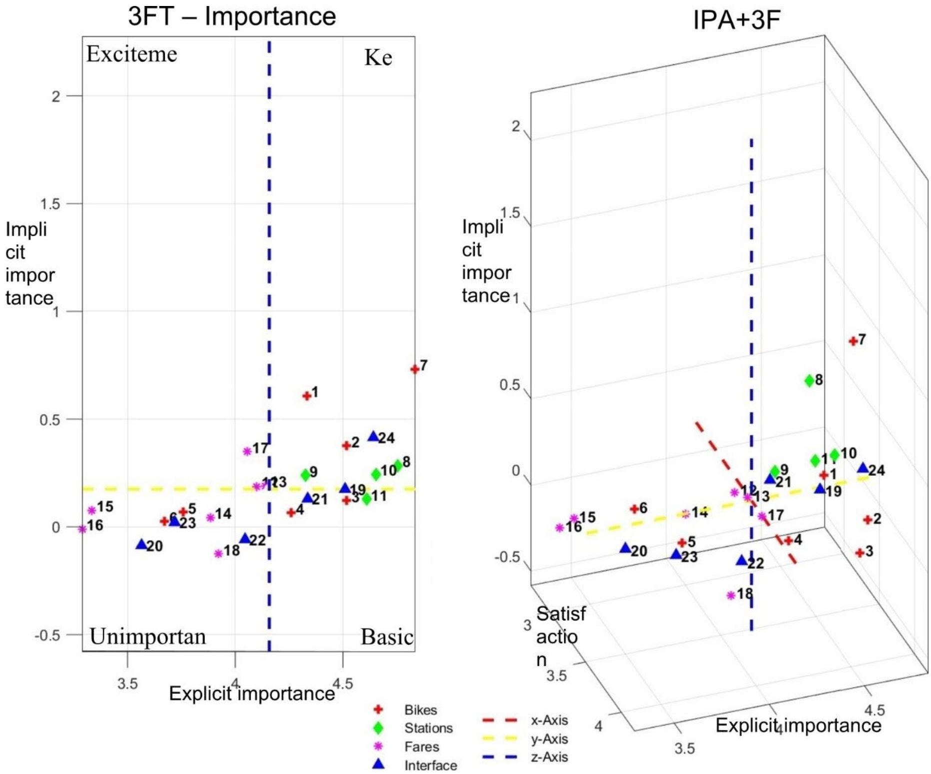

Fig. 6 3FT Importance Grid (left) and the combined analysis (right) – Service Subscribers

tenance is a priority for subscribers. This provides decision-makers with more thoughtful information for resource allocation further discussed in Sect. 4.

Figure 6 also allows classifying attributes according to the factor structure. Attribute 17 (*0.10€ discount for retiring the bike at a saturated station*) is an exciting factor, bringing unexpected delight to subscribers. Attribute 4 (*battery lasting*) is a basic attribute which should perform well to meet basic satisfaction requirements. Most of the *fares* attributes fall in the *unimportant* quadrant, low for explicit and implicit importance.

Factor structure for occasional users

Figure 7 displays the factor structure for occasional users. The introduction of the implicit importance for the interpretation of the results provides surprising information. While IPA only classified attributes 7 and 8 on the "focus here" quadrant for both, occasional and subscribers, the addition of the *z-axis* shows that they have opposite importance for each user's group. The *network extension* is a priority for occasional while bicycle *maintenance* is a priority for subscribers.

Therefore, the inclusion of the third axis allows us to observe that attributes overlapped on the IPA have different implicit importance. This difference is observed in Fig. 7 between

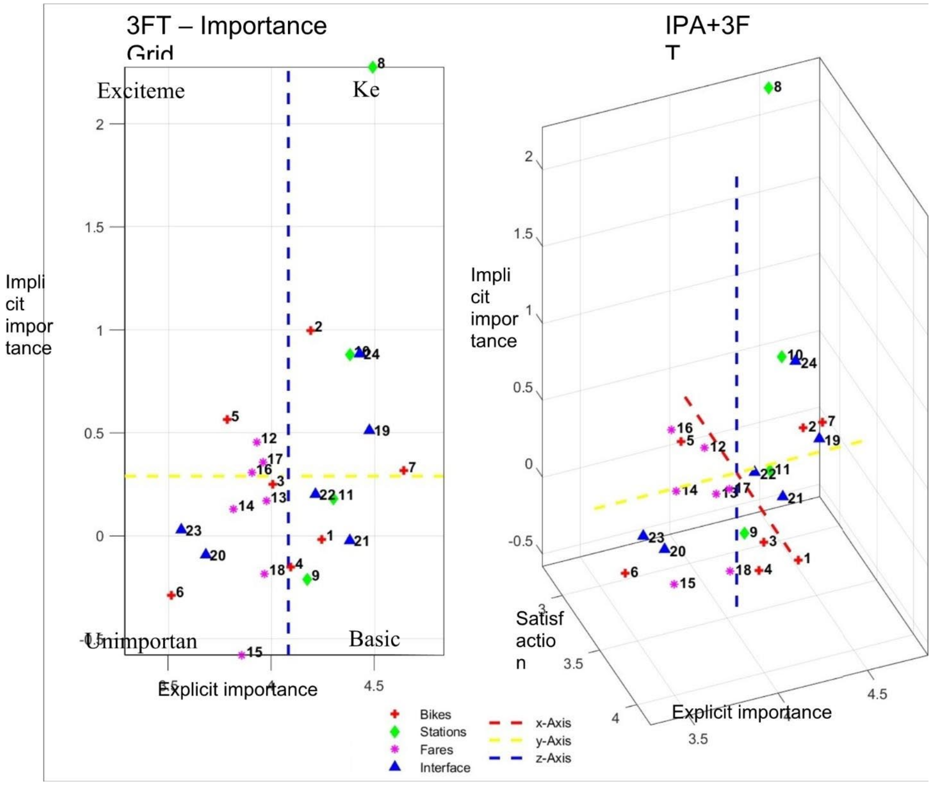

Fig. 7 3FT Importance Grid (left) and the combined analysis (right) – Occasional users

attribute 10 (*anchorage system)* which is a key attribute and attribute 21 (*totem functioning*) which is a basic attribute.

The factor structure is slightly different for occasional users than it is for subscribers. There are more clearly differentiated excitement attributes; attribute 5 (*Bicycle ergonomics and design*) and attribute 12 (*Annual subscription of 25€*) fall in this quadrant in addition to attribute 17. Attribute 21 (*totem functioning*) is a clear basic attribute for occasional users, while attributes 6 (*carrier utility*) and 15 (*first 2€ hour fare for occasional users*) are unimportant.

Tables C and D in the appendix display the coefficients of each attribute, which are the coordinates in Figs. 6 and 7.

Priorities for improvement of BiciMAD derived from the combined analysis

To facilitate the identification of priorities, Table 3 shows the categorization of the two combined methodologies. Figure 8 helps to identify the order of priorities: attributes within the cube labelled 1 are top priorities, then those on the cube labelled 1–2, then 3 and finally 4. The combination of both methods provides detailed information for decision-makers. While IPA identifies the “focus here” attributes based on the relationship between explicit

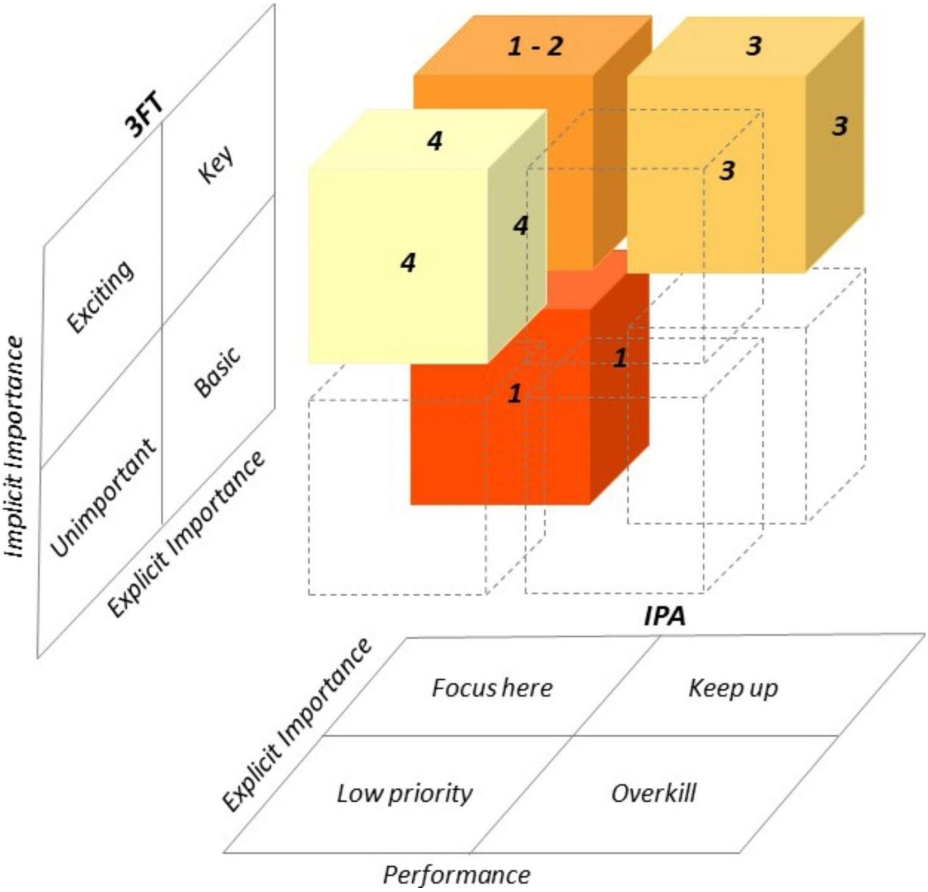

Fig. 8 Order for improvement prioritization

importance and performance, the three-factor theory, based on implicit importance, helps to define priorities.

Based on the literature for the hierarchy of priorities (Matzler et al. 2003), we followed the criteria below:

1st Basic 3FT attributes that fall in the Focus here IPA quadrant. As well as Key performance 3FT attributes with the lowest satisfaction of the Focus here IPA.

2nd Key performance 3FT attributes that fall in the Focus here IPA quadrant.

3rd Key performance 3FT attributes below the third quartile of performance (3.601 for occasional users and 3.772 for subscribers). Performance factors can increase satisfaction whenever they are improved, although it may not be cost-effective to invest resources in attributes that are already well positively evaluated.

4th Exiting 3FT attributes that perform poorly, which can enhance satisfaction.

Table 3 shows the rank of priorities for each group of users. Five of the twenty-four attributes match in the same priority ranking for subscribers and occasional users. Interventions in these attributes have the potential to increase the overall satisfaction of all the users. *Station occupancy and bicycle availability* and *totem functioning* are top priorities. In the sec-

Table 3 Ranking of improvement priorities based on IPA and three-factor theory

Nº	Attribute	Subscribers			Occasional		
		Priority rank	IPA	3 F importance grid	Priority rank	IPA	3 F importance grid
Bicycle	1. Maneuverability/ease of use	**4th**	Keep up	Key		Keep up	Basic
	2. Pedaling assistance		Keep up	Key		Keep up	Key
	3. Speed, acceleration, power		Keep up	Basic		Possible overkill	Unimportant
	4. Battery duration		Keep up	Basic		Keep up	Basic
	5. Bicycle ergonomics and design		Possible overkill	Unimportant	**4th**	Low priority	Excitement
	6. Carrier utility		Low priority	Unimportant		Low priority	Unimportant
	7. Bicycle maintenance	**1st**	Focus here	Key	**2nd**	Focus here	Key
Stations	8. Network extension	**2nd**	Focus here	Key	**1st**	Focus here	Key
	9. Distance between stations	**2nd**	Focus here	Key	**1st**	Focus here	Basic
	10. Anchorage functioning	**2nd**	Focus here	Key	**2nd**	Focus here	Key
	11. Station occupancy and bicycle availability	**1st**	Focus here	Basic	**1st**	Focus here	Basic
Tariffs	12. Annual subscription (20€)	**4th**	Low priority	Excitement	**4th**	Low priority	Excitement
	13. First half-hour tariff for subscribers (0.50€)	**4th**	Low priority	Excitement		Low priority	Unimportant
	14. Next half-hour fractions for subscribers (0.60€)		Low priority	Unimportant		Low priority	Unimportant
	15. First-hour tariff for occasional users (2€)		Low priority	Unimportant		Low priority	Unimportant
	16. Next hour fractions for occasional users (4€)		Low priority	Unimportant	**4th**	Low priority	Excitement
	17. Discount for saturated station (0.10€)	**4th**	Possible overkill	Excitement	**4th**	Possible overkill	Excitement
	18. Discount for anchor reservation (0.10€)		Possible overkill	Unimportant		Possible overkill	Unimportant
Interface	19. Mobile app		Keep up	Basic	**3rd**	Keep up	Key
	20. Website		Low priority	Unimportant		Low priority	Unimportant
	21. Totem functioning	**1st**	Focus here	Basic	**1st**	Focus here	Basic
	22. Registration procedure		Possible overkill	Unimportant	**1st**	Focus here	Basic
	23. Email notifications		Possible overkill	Unimportant		Low priority	Unimportant
	24. Customer support	**3rd**	Keep up	Key	**2nd**	Focus here	Key

Ranking

1st

2nd

3rd

ond place, improvements in *anchorage functioning* can increase the satisfaction of all users. There are no common attributes in third place and two ranked fourth, *annual subscription* and *discount for taking the bicycle from a saturated station (0.10€)*. By targeting policies to enhance general satisfaction with these attributes, service providers could gain occasional users who may potentially become subscribers over time.

In addition to the common attributes, there are some priorities for individual groups. For subscribers, *bicycle maintenance* is a priority while *network extension* and *distance between stations* are second, followed by *customer support*, and finally *maneuverability* and *first half-hour tariff* as excitement factors. In this order of priorities, the suggested improvements may not impact only subscribers, as they are also influential attributes for the satisfaction of occasional users.

To enhance the satisfaction of occasional users we identified, the *network extension*, *distance between stations* and *registration process* are top priorities to be improved. The *registration process* could represent an entry barrier. In second place *customer support* and third *mobile app*. In fourth place, as an excitement factor appears *bicycle ergonomics* and the tariff for the *next hour fractions for occasional users (4€)*.

Attributes closer to the axis, or axis intersection should be evaluated depending on the quadrant they fall according to Fig. 8. Nonetheless, attributes close to the axis, or axis intersection have in general low priority of improvement, compared to those in the further extremes.

Differences and common priorities between user types

The main observed difference between user types is that occasional users assign higher priority to the network-related attributes, while subscribers to functional.

Most occasional users live outside the service area. Indeed 77% of the survey respondents live in neighborhoods with no coverage or low station density. Therefore, seems reasonable that they demand a bigger and denser network, as their main trip origin/destination is out of the service area. It was also found that the registration process is a top priority for occasional users. They likely failed to subscribe, due to unexplored complications of the process, whilst subscribers already passed this barrier. Thus, it is worthy to revise the user experience to facilitate the registration process. Improving these attributes has the potential to improve the occasional users' satisfaction.

In the case of subscribers, functional characteristics such as bicycle maintenance, bike and station availability are top priorities. These attributes are directly related to travel time reliability, and the fact that subscribers prioritize their importance is linked to the utilitarian purposes of their usage. A subscriber who is commuting wants to reach his/her destination by relying on the expected travel time, without breakdowns and finishing the trip at the closest station to the destination. The network extension in their case is not the priority, likely due that they already live within the network coverage and already have their most frequent trips sorted.

The totem functioning is a common priority for both groups. The totem (known also as a kiosk) is a device like an ATM located next to the service stations, which integrates many functions, such as registration, information and payment and card pick-up point. It is the handiest interface between the users and the system, and it is the first registration option for passers-by and account balance recharging point. Since this attribute malfunctioning complicates both tasks for both types of users, it is presumably one of the main reasons it is a common priority.

Remarkably, the only attribute with high performance and positive linear influence on user satisfaction is the pedelec system for both groups of users. The implementation of BiciMAD as a complete e-bike system represents a potential reason for it to be successful, mainly conditioned to the hilly streets of Madrid, the warm summers, and the heavy traffic. These reasons make this attribute positively evaluated by all the segments."

Discussion and future research

Practical implications of the results

In this paper, we have identified that improvement priorities depend on the user profile, subscribers or occasional users. It has been identified that *maintenance* is a low-performing attribute influential on subscribers' satisfaction, and *network extension* for occasional users. Depending on the strategy, the service operator should concentrate resources either to build subscribers' loyalty or try to convince occasional users to subscribe. Nevertheless, there are common priorities, that might be better cost-effective-wise, such as the *bicycle availability* and the *totem functioning*. These attributes are relevant for user satisfaction, nevertheless, their influence on use frequency has not been appraised. For an exhaustive cost-effective assessment, before any investment, an evaluation to determine to what extent improving user satisfaction with the identified attributes would increase use frequency. We suggest conducting this analysis as a future research line. Some authors suggest IAA to evaluate these effects in more detail.

Other regions or systems might base their user-centric evaluation on these results since the identified attributes are shared with many systems belonging to the fourth BSS generation. The transferable results are double. On one hand, those attributes that underperform and might be improved to elevate satisfaction (above described), and the identification of those that are optimal to promote cycling, such as the *pedelec* system, which is a key high-performing attribute.

Regarding the data collection process, the feedback received suggested that the survey was too long, as respondents had to rate both the importance and performance of the 24 attributes. Nonetheless, we obtained a significant number of responses, probably due to the cyclists' positive engagement with BiciMAD. Other transport modes might not enjoy this effect of community support, complicating the process of data collection and achieving a representative sample.

In this research work, we have focused the satisfaction appraisal on two general groups: subscribers and occasional users. Further research might concentrate on the evaluation of specific user segments, especially those with accentuated inequalities, such as female users in other to improve their satisfaction, increase usage and reduce gender gaps.

Methodological contribution

This is the first study to apply a combination of the IPA and the Importance Grid in transportation research, to graphically identify user importance and satisfaction attributes, on a simple but effective way. The results of the combined IPA and the 3FT are consistent. In fact, no *key* attributes (3FT) are classified as *low priority* (IPA). Most of the *unimportant* attributes (3FT) are either *low priority* or *possible overkill* (IPA) attributes. It is also worth noticing that the *excitement* (3 F) attributes are either *low priority* or *possible overkill* (IPA), indicating that these attributes are not explicitly important, but when they perform well produce surprise and delight.

Therefore, it can be deduced that IPA and 3FT methods are complementary, as IPA identifies the key elements from the user's perspective, while 3 F guides a better-reasoned identification of priorities, in agreement with Wu et al. (2018). The attributes that do not require any intervention for improvement are well-performing *basic* or *key* 3FT attributes or attributes falling on the *unimportant* 3FT quadrant and *low priority* IPA.

Indeed, what we present in this paper is a structured methodological application of a combination of the 3FT and performance/satisfaction level of service evaluation. Previous research on the application of the before-mentioned combination has accomplished satisfactory but limited results. For instance, Yin et al. (2016) evaluated 27 attributes from residential neighborhoods. Despite they intend to combine 3FT with IPA, once they classify the factors according to the first method, they use factors performance to set a priority order, without actually combining it with IPA. Instead of using the defined strategies from IPA (*keep up, focus here, low priority* and *overkill*), they set thresholds of performance by dividing the 27 evaluated attributes into three equal parts. "*The top nine are the best performed attributes; the last nine are the worst performed attributes; and other attributes have mediocre performance*" [P468 to 469]. In our proposal, we use the well-established IPA strategies, combined with the Importance Grid to generate a three-dimensional scheme to set 4 priority orders, displayed in Fig. 8 of the paper.

The application of this methodology could be replicated to assess other modes of public transport or to other BSS. To conduct the beforementioned evaluation, a customer satisfaction survey including questions addressing the importance and satisfaction of each attribute evaluated is required. Considering all these elements might enlarge the survey extension, limiting the capacity to conduct other complementary analyses.

As with other satisfaction surveys measured on a five-point Likert scale, the distribution was skewed to the left. Further studies could focus on the quantitative evaluation of the influence of policy interventions on specific attributes on overall satisfaction through the application of regression models. In addition, it would be recommended to include a question enquiring about the probability to recommend the service, to apply a Net Promoter Score and evaluate the service loyalty in future research.

Conclusion

Although there is abundant research on the relationship between public transport quality and satisfaction, very little work has been done to evaluate the influence of the elements of a BSS on user satisfaction. To explore more deeply in this matter, this research achieves a twofold objective. First, it proposes and successfully applies a combination of methodologies, to identify improvement priorities based on implicit and explicit importance. Second, it provides solid information on the key attributes for enhancing satisfaction, building subscribers' loyalty and attracting more users. The results validate the applicability of the three-factor theory, which is prevalent in marketing literature but scarce in transportation.

By conducting this research, it has been possible to provide more complete information for decision-making than obtained by the IPA or the 3FT separately. *Bicycle maintenance* is determinant for increasing subscribers' satisfaction and *network extension* is primary for occasional users. The results suggest that, even though attributes *maintenance* and *network extension* are in the same IPA quadrant (focus here) for both groups of users, they have different priorities when their implicit importance is assessed. If these attributes would be evaluated only with the 3FT, both would be classified as "key" attributes, but there would not consider their need for improvement. Only by combining the methods, it is possible to differentiate that if the administration's goal is to build subscriber loyalty, it is necessary to address bicycle maintenance, and if it is to gain more subscribers it is necessary to extend the network. These results seem logical since subscribers are frequent commuters, therefore, bicycle reliability obtained with appropriate maintenance is crucial. On the other hand, occasional users might be residents of districts out of the influence area of the service, therefore they demand the system network extension.

The 24 BiciMAD attributes were evaluated and divided into four categories, bicycle, stations and network, tariff, and user interface. The results suggest that attributes such as *bicycle maneuverability*, *pedelec system* and *customer support* are key factors that might be determinants of the system performance. *Station occupancy and bicycle availability* and *totem functioning* are basic attributes that must meet minimum quality levels to enhance the overall satisfaction among both types of users. For occasional users, the *registration procedure* appears to be an entry barrier, as some may fail to complete the registration, therefore, this attribute requires urgent improvement. The *totem functioning* is a critical attribute that requires urgent attention since occasional users might try to register as subscribers, and due to malfunctions cancel the process. The importance assigned to the *network extension* by occasional users supports the network effect, as described in Médard de Chardon et al. (2017) research. The results also reveal that excitement factors are mainly related to tariffs; users might be surprised by the relationship between price and service quality since electric bicycles favor cycling on hilly sections. Any improvement in these attributes would have a significant influence on overall satisfaction, even though users assign them low explicit importance. This study also demonstrates that user types perceive service attributes differently, providing insights to develop tailored interventions for specific segments.

The attributes improvement hierarchy should come from a combination of the riders' perspectives and strategies based on a comprehensive evaluation of the cost-effectiveness of the IPA+3FT results. The interventions should be oriented to obtain the highest positive impact on user satisfaction.

The 3FT-importance grid can be applied to bike-sharing systems, as well to other modes of transport for user evaluation studies. Two-thirds of the attributes selected do not have a linear influence on user satisfaction, supporting the validity of the 3TF for transportation research and particularly for e-bike-sharing evaluation, a unique but increasing in popularity case study. The combination of these two methods, therefore, offers a more granular interpretation of the priorities and should be applied to identify the most appropriate policy interventions in each case.

Appendix

Table A Priorities for improvement– IPA values

Attributes	Subscribers			Occasional		
	Imp	Perf	Quadrant label	Imp	Perf	Quadrant label
Maneuverability / ease of use	4.333	4.070	Keep up	4.246	3.865	Keep up
Pedaling assistance	4.517	4.188	Keep up	4.190	4.063	Keep up
Speed, acceleration, power	4.517	4.079	Keep up	4.008	3.976	Possible overkill
Battery duration	4.260	3.766	Keep up	4.095	3.706	Keep up
Bicycle ergonomics and design	3.759	3.603	Possible overkill	3.786	3.405	Low priority
Carrier utility	3.672	3.163	Low priority	3.516	3.302	Low priority
Bicycle maintenance	4.835	3.133	Focus here	4.643	3.238	Focus here
Network extension	4.755	2.735	Focus here	4.492	2.873	Focus here
Distance between stations	4.326	3.395	Focus here	4.175	3.317	Focus here
Anchorage functioning	4.653	3.360	Focus here	4.381	3.317	Focus here
Station occupancy and bicycle availability	4.609	3.206	Focus here	4.302	3.349	Focus here
Annual subscription (20€)	4.100	3.431	Low priority	3.929	3.373	Low priority
First half-hour tariff for subscribers (0.50€)	4.140	3.507	Low priority	3.976	3.413	Low priority
Next half-hour fractions for subscribers (0.60€)	3.885	3.317	Low priority	3.817	3.262	Low priority
First hour tariff for occasional users (2€)	3.334	3.217	Low priority	3.857	3.135	Low priority
Next hour fractions for occasional users (4€)	3.289	3.143	Low priority	3.905	2.984	Low priority
Discount for saturated station (0.10€)	4.057	3.932	Possible overkill	3.960	3.627	Possible overkill
Discount for anchor reservation (0.10€)	3.923	3.855	Possible overkill	3.968	3.619	Possible overkill
Mobile app	4.510	3.538	Keep up	4.476	3.595	Keep up
Website	3.565	3.326	Low priority	3.683	3.429	Low priority
Totem functioning	4.336	3.299	Focus here	4.381	3.333	Focus here
Registration procedure	4.046	3.677	Possible overkill	4.214	3.357	Focus here
Email notifications	3.719	3.628	Possible overkill	3.563	3.429	Low priority
Customer support	4.641	3.790	Keep up	4.429	3.389	Focus here
Threshold	*4.158*	*3.515*		*4.083*	*3.432*	

Table B Factor structure derived from the 3FT-importance grid

Attribute	Subscribers			Occasional users		
	Explicit	Implicit	Category	Explicit	Implicit	Category
Maneuverability / ease of use	4.333	0.608	Key	4.246	-0.016	Basic
Pedaling assistance	4.517	0.376	Key	4.190	0.998	Key
Speed, acceleration, power	4.517	0.123	Basic	4.008	0.249	Unimportant
Battery duration	4.260	0.066	Basic	4.095	-0.153	Basic

Table B Factor structure derived from the 3FT-importance grid

Attribute	Subscribers			Occasional users		
	Explicit	Implicit	Category	Explicit	Implicit	Category
Bicycle ergonomics and design	3.759	0.068	Unimportant	3.786	0.563	Excitement
Carrier utility	3.672	0.025	Unimportant	3.516	-0.289	Unimportant
Bicycle maintenance	4.835	0.731	Key	4.643	0.317	Key
Network extension	4.755	0.283	Key	4.492	2.276	Key
Distance between stations	4.326	0.238	Key	4.175	-0.210	Basic
Anchorage functioning	4.653	0.243	Key	4.381	0.878	Key
Station occupancy and bicycle availability	4.609	0.128	Basic	4.302	0.181	Basic
Annual subscription (20€)	4.100	0.187	Excitement	3.929	0.455	Excitement
First half-hour tariff for subscribers (0.50€)	4.140	0.191	Excitement	3.976	0.169	Unimportant
Next half-hour fractions for subscribers (0.60€)	3.885	0.043	Unimportant	3.817	0.130	Unimportant
First hour tariff for occasional users (2€)	3.334	0.076	Unimportant	3.857	-0.581	Unimportant
Next hour fractions for occasional users (4€)	3.289	-0.011	Unimportant	3.905	0.306	Excitement
Discount for saturated station (0.10€)	4.057	0.349	Excitement	3.960	0.357	Excitement
Discount for anchor reservation (0.10€)	3.923	-0.125	Unimportant	3.968	-0.183	Unimportant
Mobile app	4.510	0.175	Basic	4.476	0.512	Key
Website	3.565	-0.086	Unimportant	3.683	-0.092	Unimportant
Totem functioning	4.336	0.130	Basic	4.381	-0.023	Basic
Registration procedure	4.046	-0.058	Unimportant	4.214	0.202	Basic
Email notifications	3.719	0.021	Unimportant	3.563	0.029	Unimportant
Customer support	4.641	0.415	Key	4.429	0.883	Key
Threshold	4.158	0.175		4.083	0.290	

Table C Attributes coordinates on the three-dimensional schemes. Subscribers – Fig. 6

	System element	Satisfaction x	Explicit Importance y	Implicit Importance z
1	Maneuverability / ease of use	4.070	4.333	0.608
2	Pedaling assistance	4.188	4.517	0.376
3	Speed, acceleration, power	4.079	4.517	0.123
4	Battery lasting	3.766	4.260	0.066
5	Bicycle ergonomics and design	3.603	3.759	0.068
6	Carrier utility	3.163	3.672	0.025
7	Bicycle maintenance	3.133	4.835	0.731
8	Network extension	2.735	4.755	0.283
9	Distance between stations	3.395	4.326	0.238
10	Anchorage functioning	3.360	4.653	0.243
11	Occupation and bike availability	3.206	4.609	0.128

Table C Attributes coordinates on the three-dimensional schemes. Subscribers – Fig. 6

	System element	Satisfaction x	Explicit Importance y	Implicit Importance z
12	Annual subscription (20€)	3.431	4.100	0.187
13	First half hour tariff for subscribers (0.50€)	3.507	4.140	0.191
14	Next half hour fractions for subscribers (0.60€)	3.317	3.885	0.043
15	First hour tariff for occasional users (2€)	3.217	3.334	0.076
16	Next hour fractions for occasional users (4€)	3.143	3.289	-0.011
17	Discount for saturated station (0.10€)	3.932	4.057	0.349
18	Discount for anchor reservation (0.10€)	3.855	3.923	-0.125
19	Mobile app	3.538	4.510	0.175
20	Web page	3.326	3.565	-0.086
21	Totem functioning	3.299	4.336	0.130
22	Registration procedure	3.677	4.046	-0.058
23	Email notifications	3.628	3.719	0.021
24	Customer support	3.790	4.641	0.415
	Axe intersection	*3.515*	*4.158*	*0.175*

Table D Attributes coordinates on the three-dimensional schemes. Occasional users – Fig. 7

	System element	Satisfaction x	Explicit Importance y	Implicit Importance z
1	Maneuverability / ease of use	3.865	4.246	-0.016
2	Pedaling assistance	4.063	4.190	0.998
3	Speed, acceleration, power	3.976	4.008	0.249
4	Battery lasting	3.706	4.095	-0.153
5	Bicycle ergonomics and design	3.405	3.786	0.563
6	Carrier utility	3.302	3.516	-0.289
7	Bicycle maintenance	3.238	4.643	0.317
8	Network extension	2.873	4.492	2.276
9	Distance between stations	3.317	4.175	-0.210
10	Anchorage functioning	3.317	4.381	0.878
11	Occupation and bike availability	3.349	4.302	0.181
12	Annual subscription (20€)	3.373	3.929	0.455
13	First half hour tariff for subscribers (0.50€)	3.413	3.976	0.169
14	Next half hour fractions for subscribers (0.60€)	3.262	3.817	0.130
15	First hour tariff for occasional users (2€)	3.135	3.857	-0.581
16	Next hour fractions for occasional users (4€)	2.984	3.905	0.306
17	Discount for saturated station (0.10€)	3.627	3.960	0.357
18	Discount for anchor reservation (0.10€)	3.619	3.968	-0.183
19	Mobile app	3.595	4.476	0.512
20	Web page	3.429	3.683	-0.092
21	Totem functioning	3.333	4.381	-0.023
22	Registration procedure	3.357	4.214	0.202
23	Email notifications	3.429	3.563	0.029
24	Customer support	3.389	4.429	0.883
	Axe intersection	*3.432*	*4.083*	*0.290*

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