Perception-Based Analysis of the Perspectives of Users and Non-users of Different Shared Mobility Services

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ABSTRACT
Perception-Based Analysis (PBA) is conducted in this study to specify users' and non-users' perceptions about shared mobility systems, including their opinions, attitudes, and actual understanding. Multi-Actor Multi-Criteria Analysis (MAMCA) and Bayesian Best-Worst Method (BWM) are used in this regard. From the weight analysis, the conclusion is drawn that the three most important criteria for users and non-users of shared mobility services are traveler safety, cost, and accessibility, respectively. Further, the scores of the criteria given by users are generally higher than those of non-users, except for the travel cost of scooter-sharing services, which may show that non-users underestimate it.

Furthermore, from the perception analysis, it is figured out that the criteria accessibility and comfort show the largest view gap between the users and non-users. Also, based on the analysis of the eight criteria examined in this study, car-sharing services are preferred by both users and non-users beyond their actual market share. In addition, the cost is the only criterion that has the least contribution to the car-sharing choice by both users and non-users, which in their view, is due to its higher service cost. Additionally, the accessibility of bike-sharing and scooter-sharing contributes more to the value of these two services for their users, while the opposite is true for non-users. Finally, non-users value the speed of scooter-sharing less than users. This study offers insights into users' and non-users' perceptions, especially for some qualitative choice criteria seldomly considered in econometric models.

Keywords: Perception-based Analysis, Multicriteria Analysis, Car Sharing, Bike Sharing, Scooter Sharing

INTRODUCTION

Global concerns about climate change and increasing motorization rates have heightened interest in sustainable transportation strategies. Within such a framework, shared transportation services can play an important role in lowering transportation impacts. For instance, each shared car is used more efficiently than private vehicles and can even substitute them, depending on the system operational scheme (1; 2), while less polluting. Similarly, shared stand-up e-scooters (electric kick/standing scooters) are available in many cities as short-term rental options (3), and they are now a more common means of transportation (4). Also, bike-sharing programs have spread swiftly throughout the world in recent decades (5). Hence, it is worthwhile to understand better the determinants of the demand for shared mobility services to promote their spread further, and more specifically, to which extent car-sharing, scooter-sharing, and bike-sharing are viewed as distinct or similar means belonging to the "shared mobility world". Moreover, the perspectives of users and non-users should be separately assessed since those new mobility services have a varying level of diffusion among different social groups.

Most literature on the demand for shared mobility services considers the following five categories of characteristics that have affected demand. The first one can be labelled trip-related characteristics, including travel time (6), travel distance (7), departure time (8), and trip purpose (9). The second one encompasses travel mode characteristics, including travel cost (10), travel comfort (11), infrastructure, trip ends and en-route facilities, and transportation facilities (12). The third one covers availability and accessibility issues, including land use (13) and the easiness of reaching a destination (14). The fourth one points to environmental conditions, including road hilliness (15), weather conditions (16), temperature (17), air pollution (10), and season effects (18). Last but not least, the fifth category contemplates the socio-demographic characteristics of the decision maker (19), including gender (7), age (20), Occupation and economic status (8), Vehicle ownership status (21), household size (22), marital status (6), presence of children (23), residence status (24), and education level (25).

In this study, some important characteristics which receive less attention in the literature, including traveler safety, operational speed, user-friendliness, image, comfort, and the possibility of carrying items, are studied to bridge the gap in the literature. Moreover, the difference between non-users views compared to users is specified. Besides, this study help to understand which shared mobility system is most appropriate to implement in Turin according to users' and non-users' perceptions. Choice determinants studied in the present work are "a priori", i.e., without considering them in relation to a specific trip to make, as done in mode choice models. Also, some of the criteria considered here (such as image, easiness of use, or comfort) are difficult to quantify in an objective way and, therefore, to consider in standard travel analysis methods since they are rather qualitatively assessed by travelers. Nevertheless, subjective factors substantially affect the decision to use a new service: previous research has shown that attitude and perceptions have a stronger impact than socio-demographic characteristics and performances of competing travel modes whenever such modes are not well known or experienced by individuals, and therefore the choice situation is rather hypothetical (26).

On the basis of such considerations, rather than relying on econometric methods, this paper proposes a Perception-Based Analysis (PBA) to understand the relative importance given by both users and non-users to a set of criteria that lead to the choice of traveling with a given shared mobility service (car-sharing, scooter-sharing or bike-sharing). More specifically, the three research questions of this study are as follows.

1. How do users and non-users score the importance of the comparison factors?
2. Which shared mobility system is the most suitable one according to users' and non-users' perceptions?

3. Is there a difference in the perceptions of users and non-users about the importance of one criterion?

The rest of the study focuses on the methodology used in this study to apply PBA. Then, the data collection process is explained, and finally, the results and conclusions are presented.

METHOD

This study uses PBA to measure users' and non-users' perceptions of shared mobility systems. One of the appropriate methods for performing PBA is Multi Criteria Decision Making (MCDM), which is suitable for this study since it is often used for estimating how one makes decisions considering multiple criteria, including some that are qualitative and/or conflicting and therefore less easily captured by utility-based methods. In order to answer the above research questions, the importance of each criterion should be determined, and this can be done by using MCDM (15).

For conducting PBA, among the MCDM methods, the Multi-Actor Multi-Criteria Analysis (MAMCA) is chosen for this research (27). MAMCA can be synthetically described as an MCDM instance that enables decision-makers to simultaneously evaluate alternatives (in this research; car-sharing, scooter-sharing, and bike-sharing) (28). One of the most important advantages of MAMCA is that the views of different groups are explicitly considered, which is a key requirement in this research, given the abovementioned questions. In fact, users and non-users are the two groups of stakeholders that are considered here.

MAMCA requires the identification of the main evaluation criteria of alternatives and the computation of the related weights that measure the relative importance of each criterion (29). Weighs will be computed through a Bayesian best-worst method (BWM) since it requires a small amount of data compared to more traditional approaches such as Analytical Hierarchical Process (AHP), Ideal Solution (TOPSIS), Preference Ranking for Organization Method for Enrichment Evaluation (PROMETHEE), and Elimination and Choice Translating Reality (ELECTRE) (29). In addition, compared to other multicriteria analysis methods, other advantages include fewer inconsistencies between criteria, lower equalizing bias (31), and better transparency for decision-makers compared to PROMETHEE, ELECTRE, and TOPSIS (27; 32).

Bayesian BWM will be used to calculate the aggregate final criteria weights for a group of stakeholders at once. Also, it is important to note that Bayesian BWM can provide much more information than the original BWM. For example, Bayesian BWM can provide the credal ranking and Confidence Level (CL) in the weight-directed graph, as later introduced. This helps to understand the importance perceived by stakeholders of one criterion over other criteria (30). To the authors' knowledge, Bayesian BWM has never been used to characterize the demand for shared mobility services.

The formal definition of the problem is presented below. Let us consider a set of alternatives (car-sharing, scooter-sharing, and bike-sharing in our case). As presented in **Equation (1)**, let V_i be the overall value of alternative i when considering a set of decision criteria indexed by j. Then, these values can be computed as follows (30):

$$V_i = \sum_{j=1}^{n} w_j \, p_{ij}^{norm}$$
$$w_j \geq 0, \sum w_j = 1 \quad (1)$$

Where

w_j: weight assigned to criterion j

p_{ij}^{norm} : the normalization of each score p_{ij} that is expressing the evaluation of stakeholders of each criterion j and for each alternative i (i = 1, …, m, and j= 1, …, n); these scores are generally elicited through interviews.

In turn, the weights of the criteria w_j are determined through Bayesian BWM. Overall, the five BWM steps include the following:

1) Defining decision criteria
2) Determining the best and the worst criteria by users and non-users
3) Determining the preference of the best criterion over other criteria by users and non-users
4) Determining the preference of other criteria over the worst criterion by users and non-users separately
5) Finding the optimal weights through Bayesian BWM.

Optimal weights for both groups of users and non-users are evaluated through the joint probability of the group decision, as shown in **Equation 2** (30):

$$P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K}) \propto P(A_B^{1:K}, A_W^{1:K} | w^{agg}, w^{1:K})\, P(w^{agg}, w^{1:K}) = P(w^{agg}) \prod_{k=1}^{K} \mathrm{P}\left(A_W^k \middle| w^k\right) \mathrm{P}\left(A_B^k \middle| w^k\right) \mathrm{P}\left(w^k \middle| w^{agg}\right) \tag{2}$$

Where

$P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K})$: the joint probability of the group decision for the Bayesian BWM

A_B^k: vector of preferences of the best criterion over other criteria (BO vector) of the k-th decision-maker

A_W^k: vector of preferences of all criteria over the worst criterion (OW vector) of the k-th decision-maker

$A_B^{1:K}$: BO vectors of all K decision-makers

$A_W^{1:K}$: OW vector of all K decision-makers

w^k: optimal weights of the k-th decision-maker

$w^{1:K}$: optimal weights of all K decision-makers

w^{agg}: aggregated weight (optimal group weight after aggregation).

According to **Equation 2**, the joint probability of Bayesian BWM can be obtained by determining the distribution of each element. In this regard, $A_B^k|w^k$ and $A_W^k|w^k$ are defined as shown in **Equation 3** (30).

$$A_B^k | w^k \sim multinomial\left(\frac{1}{w^k}\right), \forall \mathrm{k} = 1, \dots, \mathrm{K}$$
$$A_W^k | w^k \sim multinomial\left(w^k\right), \forall \mathrm{k} = 1, \dots, \mathrm{K} \quad (3)$$

Furthermore, $w^k | w^{agg}$ (w^k conditioned on w^{agg}) can be formulated as the underlying Dirichlet distribution following **Equation 4** (30).

$$w^k | w^{agg} \sim Dir(\gamma \times w^{agg}), \forall \mathrm{k} = 1, \dots, \mathrm{K} \quad (4)$$

Where

γ: concentration parameter (non-negative).

Equation 4 states that the weight vector w^k associated with each decision-maker must be adjacent to w^{agg} because the latter is the distribution's mean, while the non-negative parameter γ controls their proximity, this technique is applied to various Bayesian models (33). The concentration parameter is modeled through a gamma distribution since it satisfies non-negativity constraints. Ultimately, w^{agg} is modeled through an uninformative Dirichlet distribution with the parameter $\alpha = 1$. After finalizing the probability distribution of all parameters, the posterior distribution is computed utilizing the Markov-chain Monte Carlo (MCMC) technique (30). In this regard, Bayesian BWM is implemented utilizing JAGS - Just Another Gibbs Sampler (34).

Utilizing samples acquired from JAGS, Mohammadi and Rezaei (30) computed credal ranking, an approach for probabilistic comparison of a set of criteria that can be visualized utilizing directed graphs. The credal ranking is a ranking scheme for decision criteria, where a CL is determined to measure the preference of a group of decision-makers for one criterion over another.

The Bayesian BWM brings forward the credal ranking concept to measure the relationship between a pair of criteria (30). Compared to the traditional method, which utilizes only two figures to specify the superiority of confidence, it can design a Bayesian test in order to calculate the confidence of each credal ranking. By employing this principle in the real-world case, the superiority of confidence between different pairs of criteria can be calculated (35). Credal ranking can assess the degree of superiority of one criterion over another. The posterior distribution of weights assists in measuring the confidence of the relationships between different criteria. A weighted directed graph visualizes the credal ranking, through which the interrelation of criteria and confidences are more intuitively understood. Each node represents a criterion in this graph, and each edge indicates the confidence obtained. **Equation 5** describes the credal ordering O, for a pair of criteria c_i and c_j (30).

$$O = (c_i, c_j, R, d) \quad (5)$$

Where

R: the relationship between the criteria c_i and c_j, i.e., $>$, $<$, or $=$;

$d \in [0, 1]$: confidences of the relationship

For a set of criteria $C = (c_1, c_2, c_n)$, the credal ranking is a set of credal orderings that contains all pairs (c_i, c_j), for all $c_i, c_j \in C$.

Confidence in the credal ordering can offer more information to decision-makers who can make better decisions in particular. **Equation 6** provides a Bayesian test according to which the confidence of each credal ordering can be calculated (30).

$$P(c_i > c_j) = \int I_{(w_i^{agg} > w_j^{agg})} P(w^{agg}) \tag{6}$$

Where

$P(w^{agg})$: posterior distribution of w^{agg}

$I: \begin{cases} 1 & \text{if the condition in the subscript is met} \\ 0 & \text{otherwise} \end{cases}$

This integration can be estimated from the Markov-chain Monte Carlo (MCMC) samples. Having Q samples of the posterior distribution, the confidence can be calculated as shown in **Equation 7** (30).

$$\begin{aligned} P(c_i > c_j) &= \frac{1}{Q} \sum_{q=1}^{Q} I\,(w_i^{agg_q} > w_j^{agg_q}) \\ P(c_j > c_i) &= \frac{1}{Q} \sum_{q=1}^{Q} I\,(w_j^{agg_q} > w_i^{agg_q}) \end{aligned} \tag{7}$$

Where

w^{agg_q}: q^{th} sample of w^{agg} from the MCMC samples.

Therefore, one can calculate the confidence of superiority CL over the other for each pair of criteria. Credal ranking can be changed to traditional one (the conventional method of ranking criteria): since $P(c_i > c_j) + P(c_j > c_i) = 1$, c_i is more important than c_j if and only if $P(c_i > c_j) > 0.5$. Thus, the traditional ranking of criteria can be achieved by setting a threshold of 0.5 for credal ranking. The closer the CL is to 1, the more pronounced the degree of certainty about the relation, which indicates that one criterion is certainly considered more important than another (30).

It is important to note that the credal ranking can be changed into the conventional ranking merely by applying the threshold of 0.5 to the obtained confidence. However, the threshold can vary from problem to problem, and choosing a particular threshold value is entirely up to the decision-maker. In other words, credal ranking can be shaped so that they show the ranking of criteria in various problems based on the confidence desired by decision-makers (30).

There is no specific classification to describe CL in the literature. Hence, this study intends to introduce the CL classification to explain the results according to the previous studies (30; 35; 36). In this regard, **Table 1** introduces a description of each CL range for a threshold value of 0.50.

Table 1: Description of each CL range for a threshold value of 0.50.

CL range	Description
0.80 ≤ CL	One criterion is certainly more important than the other
0.60 ≤ CL < 0.80	One criterion is more important than another
0.50 ≤ CL < 0.60	The superiority of one criterion over another is not well established

It should be noted that when the threshold value is 0.5, values less than 0.5 must be interpreted inversely. For instance, when the CL for comparing C1 and C2 is 0.30, C2 is more important than C1, with a confidence of 0.7 (i.e., $1 - 0.3 = 0.7$).

To the best of the authors' knowledge, there is no specific classification related to CL in the literature. Hence, According to some previous studies (30, 35, 36), this study assumed that a CL above 0.8 could indicate that one criterion is definitely more important than another. Also, a CL between 0.6 and 0.8 can show that one criterion is more important than another. Finally, when the CL is between 0.5 and 0.6, it can be stated that the superiority of one criterion over another is not well established. On the other hand, when CL < 0.5, the former criterion is less important than the latter. For instance, when the CL for comparing C1 and C2 is 0.30, C2 is more important than C1, with a confidence of 0.7 (i.e., $1 - 0.3 = 0.7$).

FIELD ACTIVITIES AND DATA

In this study, a survey was designed to understand the perspectives of users and non-users of shared mobility services in Turin, Italy. Turin is one of the cities where various shared services have been developed. As such, it is a good case study for that country. The survey started with a set of BWM-related questions eliciting ranking exercises on the relative importance of eight different criteria that are normally considered when choosing a shared means.

The following criteria have been considered in the present research, adapting them from a similar study (27) to our context:

1. *Traveler safety*: the level of safety of the individuals during the trip, such as the rate of accidents, harassment, assault, and theft.
2. *Operational speed*: the average velocity with which a shared mobility system operates.
3. *Accessibility*: ease of access, availability of a shared vehicle, proximity to the location of the parked shared vehicle.
4. *User-friendliness*: easy for beginners to learn, use, and provide travel information in the app used to book a vehicle.
5. *Image*: the image of a shared mobility system in passengers' eyes. The image of a car-sharing service differs from a bike-sharing service or a scooter-sharing service.
6. *Comfort*: vehicle characteristics that make passengers feel comfortable during the trip. Also, this can vary between shared transportation services.
7. *Cost*: expenses for shared mobility usage, such as service subscription fees or usage fees.
8. *Possibility of carrying items*: possibility of carrying luggage or bags or shopping items in the shared vehicle. For instance, passengers can carry their luggage by shared car but not by scooter-sharing.

In the BWM-related questions, users and non-users were first asked to identify the most important and the least important criteria among the above eight when deciding to use a shared mobility service (step 2 of the BWM). Then, they rated the preference of the best criterion over other criteria (step 3 of the BWM). Finally, they rated the preference of other criteria over the worst criterion (step 4 of the BWM). In order to have a sound understanding of this explanation, **Figure 1** illustrates the BWM-related questions. **Figure 1** shows the conditions in which the respondent chooses accessibility and image as the most important and least important criteria, respectively. It is worth noting that previous studies only considered some of these criteria (37, 38; 39).

B1. There are several characteristics that could be considered in selecting shared mobility to make a trip.

In your opinion, what is the MOST IMPORTANT, and what is the LEAST IMPORTANT characteristic among the above eight that could drive your choice?

	Select the most important characteristic in the cell below	Select the least important characteristic in the cell below
Travelers safety	o	o
Operational speed	o	o
Accessibility	o	o
User-friendliness	o	o
Image	o	o
Comfort	o	o
Cost	o	o
Possibility of carrying items	o	o

B2. In the above question, you have chosen *accessibility* as the most important characteristics. Could you please rate to which extent you consider *accessibility* as more important than the other seven characteristics?

	Equal importance 1	2	3	4	5	6	7	8	Extremely more important 9
Image	o	o	o	o	o	o	o	o	o
Travelers safety	o	o	o	o	o	o	o	o	o
Operational speed	o	o	o	o	o	o	o	o	o
User-friendliness	o	o	o	o	o	o	o	o	o
Comfort	o	o	o	o	o	o	o	o	o
Cost	o	o	o	o	o	o	o	o	o
Possibility of carrying items	o	o	o	o	o	o	o	o	o

B3. Also, you have chosen *image* as the least important characteristics. Could you please rate to which extent you consider the other six characteristics as more important than *image*?

	Equal importance 1	2	3	4	5	6	7	8	Extremely more important 9
Travelers safety	o	o	o	o	o	o	o	o	o
Operational speed	o	o	o	o	o	o	o	o	o
User-friendliness	o	o	o	o	o	o	o	o	o
Comfort	o	o	o	o	o	o	o	o	o
Cost	o	o	o	o	o	o	o	o	o
Possibility of carrying items	o	o	o	o	o	o	o	o	o

Figure 1: Screenshot of the survey with BWM-related questions.

The above importance ranking exercise was complemented by 3*8 = 24 rating questions to gather the respondents' evaluations on the performance of car-sharing, bike-sharing, and scooter-sharing related to each of these eight criteria. 7-point semantic scales were used to this effect, ranging, for instance, from very unsafe to very safe for the first criterion, from very poor to very good for the second criterion, and so on. An example of a 7-point semantic scale question is illustrated in **Figure 2**.

Please answer the following questions to determine your opinion on characteristics affecting car-sharing, bike-sharing, and scooter-sharing use.

Q1. How safe do you feel on car-sharing trips?

- 1 (Very unsafe)
- 2
- 3
- 4
- 5
- 6
- 7 (Very safe)

Q2. How safe do you feel on bike-sharing trips?

- 1 (Very unsafe)
- 2
- 3
- 4
- 5
- 6
- 7 (Very safe)

Q3. How safe do you feel on scooter-sharing trips?

- 1 (Very unsafe)
- 2
- 3
- 4
- 5
- 6
- 7 (Very safe)

Figure 2: A sample of a 7-point semantic scale question.

The survey was administered online between November 2021 and February 2022 to a market research panel of respondents in order to achieve good representativeness of both users and non-users in the study area in terms of standard socio-demographic characteristics. Given the relatively low number of answers needed by BWM, responses from 100 users and 104 non-users were collected. After checking the quality of the data and the consistency of rating through BWM, the responses of 45 users and 55 non-users have been retained.

RESULTS

This section starts by analyzing which criteria among the previously introduced eight are the most important when users and non-users consider whether to use shared mobility to make a trip. On the basis of the resulting weights, a perception analysis of both groups is then presented for the three different shared mobility services.

Relative Importance of Shared Mobility Services Evaluation Criteria

The optimal weights for both users and non-users of the criteria for shared mobility services are listed in **Table 2**, along with their ranks.

Table 2: Weights of the criteria assigned by users and non-users of shared mobility services.

Criterion	Users		Non-users	
	Weights	Ranking of criteria	Weights	Ranking of criteria
Cp1.Traveler safety	0.1781	1	0.1802	1
Cp2. Operational speed	0.1229	5	0.1205	5
Cp3. Accessibility	0.1385	3	0.1303	3
Cp4. User-friendliness	0.1171	6	0.1267	4
Cp5. Image	0.0694	8	0.0728	8
Cp6. Comfort	0.1260	4	0.1179	6
Cp7. Cost	0.1437	2	0.1433	2
Cp8. Possibility of carrying items	0.1042	7	0.1083	7

The left side of **Table 2** indicates that traveler safety is the most important criterion for users, followed by cost and accessibility. Notably, these three criteria are related to the services' operations, which are at least partially under the operator's control. Comfort is the fourth most important criterion, whereas operational speed is surprisingly less important than all previous criteria. As in any MCDM study, it should be considered that relative rather than absolute importance measures are elicited, and other criteria seem more important in urban settings. Nevertheless, speed would probably still be quite important if considered per se. This interesting result questions the standard approach in modeling modal choices whenever such services are considered since one of the key exogenous variables is usually the travel time. On the other hand, operational speed could also be associated by travelers with negative instances, such as less safety (which is the most important criterion) or hastiness, whereas minimizing travel time has no such negative connotation from an emotional viewpoint, even if it clearly depends on speed on more rational grounds. Finally, user-friendliness, the possibility of carrying items, and the image of a shared mobility system are the least important for users. Also, **Table 2** shows that the most important criterion for users, namely safety, is about 2.57 times more important than the least important one, i.e., image.

Turning attention to non-users, the last two columns of **Table 2** show that the three most important criteria are still traveler safety, cost, and accessibility. However, user-friendliness is now coming up to the fourth position, which underlines the importance of such a factor to increase the penetration of shared mobility services and, at the same time, identifies the most important barrier to achieving this goal. Conversely, the importance of comfort for non-user is slightly diminished compared to other criteria.

The computation of credal ranking can complement the above information to understand to which extent each criterion is more or less important than all the others. Credal ranking can be most efficiently presented through charts for both users (**Figure 3**) and non-users (**Figure 4**), where they are displayed next to each arrow, going from the most important to the least important criterion. For ease of showing the criteria in **Figures 3** and **4**, the symbols Cp1, Cp2, Cp3, Cp4, Cp5, Cp6, Cp7, and Cp8 are used to respectively, indicate the eight criteria traveler safety, operational speed, accessibility, user-friendliness, image, comfort, cost and possibility of carrying items.

As mentioned in the methodology section, the threshold value is 0.50, and any CL above 0.80 indicates that one criterion is definitely more important than another. It can therefore be seen that the difference in importance among different criteria is almost always confirmed, with the partial exception of cost versus accessibility, comfort versus speed and speed versus user friendliness for shared mobility users, and accessibility versus user-friendliness, user-friendliness versus speed, and speed versus comfort for non-users.

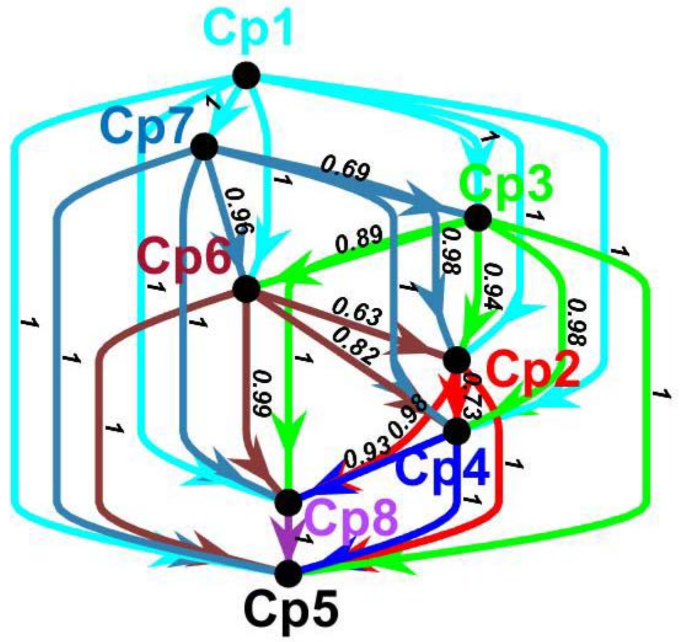

Figure 3: Credal ranking of criteria from users' view of shared mobility services.

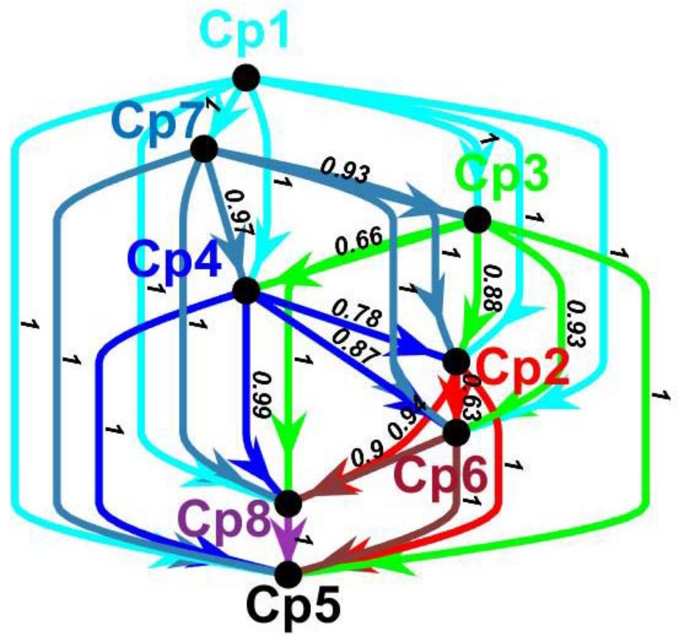

Figure 4: Credal ranking of criteria from non-users' view of shared mobility services.

Perception analysis of users and non-users

Table 3 report the scores p_{ij}, i.e., the indicator values expressed by both users and non-users of each shared mobility service were obtained from the above-described survey. Differences between the two groups are determined as well. All scores are based on a 7-point scale; therefore, the closer any indicator in both tables is to 7, the better the related shared mobility service performs on that specific criterion. For instance, for criterion cost, 1 means very expensive, and 7 means very cheap. Also, concerning, i.e. the possibility of carrying items, car-sharing is obviously better assessed than bike-sharing and scooter-sharing. As expected, scores from users are generally higher than the corresponding scores of non-users, with the only exception of the cost of scooter-sharing, which is probably pointing to an underestimation of the monetary costs of using such service by those that have no experience. Quite interestingly, accessibility and comfort show the widest gap between users and non-users.

Table 3: Scores p_{ij} obtained from users and non-users of each shared mobility service.

Criterion	Car-sharing services			Bike-sharing services			Scooter-sharing services		
	Users	Non-users	Diff.	Users	Non-users	Diff.	Users	Non-users	Diff.
Traveler safety	5.40	4.94	0.46	4.31	3.96	0.35	3.18	3.09	0.09
Operational speed	5.24	5.04	0.20	4.56	4.29	0.27	4.64	4.05	0.59
Accessibility	5.07	4.53	0.54	5.09	4.22	0.87	5.16	4.45	0.71
User-friendliness	5.11	4.60	0.51	4.91	4.42	0.49	4.91	4.49	0.42
Image	5.38	4.95	0.43	4.82	4.36	0.46	4.69	4.11	0.58
Comfort	5.36	4.65	0.71	4.53	3.96	0.57	3.84	3.15	0.69
Cost	3.76	3.75	0.01	4.29	4.15	0.14	3.80	3.91	-0.11
Possibility of carrying items	5.47	5.20	0.27	3.07	2.71	0.36	2.58	2.16	0.42

The next step is to calculate the perceived value of each alternative according to **Equation 1**, multiplying each weight reported in the second and fourth columns of **Table 2** by the corresponding scores reported in **Table 3**. It should be stated that since all scores from **Table 3** have the same unit or scale ([1-7]), there is no need to normalize them, thus $p_{ij}^{norm} = p_{ij}$, $\forall i$, $\forall j$. Results are reported in **Tables 4** and **5,** respectively, for users and non-users, while the last row of each table represents the overall value of each service V_1, V_2, and V_3. Relative changes in % of the perceived value of bike-sharing and scooter-sharing compared to car-sharing are reported in brackets. The higher the users' or non-users' perceptions of the overall value of a type of shared mobility service (compared to other types of shared mobility services), the greater the users' or non-users' preference for that type of shared mobility service (compared to other types of shared mobility services).

Table 4: Perception of the value of each shared mobility service for users.

Users	Shared mobility services (% change compared to car-sharing)		
	Car-sharing services	Bike-sharing services	Scooter-sharing services
Criterion	**Perceived value**	**Perceived value**	**Perceived value**
Traveler safety	0.9617	0.7676 (-20%)	0.5664 (-41%)
Operational speed	0.6440	0.5604 (-13%)	0.5703 (-11%)
Accessibility	0.7022	0.7050 (0%)	0.7147 (2%)
User-friendliness	0.5984	0.5750 (-4%)	0.5750 (-4%)
Image	0.3734	0.3345 (-10%)	0.3255 (-13%)
Comfort	0.6754	0.5708 (-15%)	0.4838 (-28%)
Cost	0.5403	0.6165 (14%)	0.5461 (1%)
Possibility of carrying items	0.5700	0.3199 (-44%)	0.2688 (-53%)
V_i	5.0654	4.4497 (-12%)	4.0506 (-20%)

Table 5: Perception of the value of each shared mobility service for non-users.

Non-users	Shared mobility services (% change compared to car-sharing)

	Car-sharing services	Bike-sharing services	Scooter-sharing services
Criterion	**Perceived value**	**Perceived value**	**Perceived value**
Traveler safety	0.8902	0.7136 (-20%)	0.5568 (-37%)
Operational speed	0.6073	0.5169 (-15%)	0.4880 (-20%)
Accessibility	0.5903	0.5499 (-7%)	0.5798 (-2%)
User-friendliness	0.5828	0.5600 (-4%)	0.5689 (-2%)
Image	0.3604	0.3174 (-12%)	0.2992 (-17%)
Comfort	0.5482	0.4669 (-15%)	0.3714 (-32%)
Cost	0.5374	0.5947 (11%)	0.5603 (4%)
Possibility of carrying items	0.5632	0.2935 (-48%)	0.2339 (-58%)
V_i	4.6798	4.0129 (-14%)	3.6583 (-22%)

As seen in **Table 4,** the users' perception of the overall value of car-sharing (5.0654) is higher than their perception of the overall value of bike-sharing (4.4497) and scooter-sharing (4.0506). Similarly, **Table 5** shows that the non-users' perception of the overall value of car-sharing (4.6798) is higher than their perception of the overall value of bike-sharing (4.0129) and scooter-sharing (3.6583). Therefore, based on the analysis of the eight criteria examined in this study, car-sharing services are preferred by both users and non-users. Having a closer look at the different patterns related to the contribution of each criterion to the overall value of one alternative, it is not surprising to note that cost is the only one that gives the lowest contribution to choosing car-sharing compared to its influence on choosing usually cheaper scooter-sharing and bike-sharing services (in line with the scores in **Table 3**), as indicated by the positive percent changes shown in the last two columns of the third last row of Tables 4 and 5. Because on the 7-point survey for criterion cost, 1 means very expensive and 7 means very cheap, car-sharing receives a lower score for this measure than bike-sharing and scooter-sharing, which leads to a lower perceived value for the criterion cost of car-sharing. Also, bike-sharing and scooter-sharing accessibility give a larger contribution to the value of these two services for their users, while the opposite is true for non-users. Finally, scooter-sharing speed is much less appreciated by non-users than by users. Note that this latter gap, embedding the weights of each criterion according to **Equation 1**, is relatively wider than the average scores of the two groups related to scooter-sharing speed reported in **Table 3**.

CONCLUSION

In this study, PBA is conducted to specify users' and non-users' perceptions of shared mobility systems. In this regard, MAMCA and Bayesian BWM are used. From the analysis of the weights, it was concluded that the system should be (in order of importance): safe, low-cost, and highly accessible to both attract non-users and encourage more users to use it. Moreover, the scores (of the criteria) given by users are generally higher than those of non-users except for the cost of scooter-sharing, which may indicate that non-users underestimate the travel cost of scooter-sharing services. It is worth mentioning that the two least important criteria affecting the choice of shared mobility service from both users' and non-users' points of view are (in order of importance) the possibility of carrying items and the image.

Furthermore, from the perception analysis, it is clear that based on the analysis of the eight criteria examined in this study, car-sharing services (compared to bike-sharing services and scooter-sharing services) were preferred by users and non-users of shared transportation services in Turin, Italy. Besides, the cost is the only criterion with the least contribution to the choice of car-sharing services (compared to the other two shared mobility services) by both users and non-users. This result is different from the results obtained from the analysis of weights, from which it was concluded that the cost of travel is the second most important criterion in choosing a shared transportation service. As people have stated in their scoring, car-sharing services cost more than bike-sharing and scooter-sharing services, which makes up the difference because car-sharing receives a lower score, leading to a lower perceived value for this criterion.

It should be pointed out that the scooter-sharing service has the lowest priority among the three shared transportation services for users and non-users. The most important reason is carrying fewer items with this service than car-sharing, which is also less safe and comfortable. Besides, from the standpoint of users and non-users, bike-sharing services are less preferred than car-sharing services due to less possibility of carrying items, safety, and comfort. This is while it was concluded from the analysis of weights that the possibility of carrying items is one of the least important criteria. As people have noted in their scoring, both scooter-sharing and bike-sharing have less possibility to carry things than car-sharing, which causes the difference between the results of the weights analysis and perception analysis. Besides, it should be stated that the lower operational speed of bike-sharing (compared to car-sharing) contributes to its low preference, especially in the eyes of non-users. In addition, it is interesting to mention that the criteria accessibility and comfort show the greatest perception gap between the users and non-users. Also, bike-sharing and scooter-sharing accessibility can contribute more to the value of these two services for their users, while the opposite is true for non-users. Finally, the speed of scooter-sharing is much less appreciated by non-users than users. Note that this gap, embedding the weights of each criterion, is relatively wider compared to the average scores of the two groups related to scooter-sharing speed.

The above results shed light on the relative importance of a set of criteria in choosing different mobility-sharing services for both its users and non-users. However, results are not necessarily correlated to the actual market share of the service. Indeed, car-sharing has the overall best value, but it serves fewer trips compared to bike-sharing in Turin. This is because different considerations might arise when considering the choice situation at the trip level. In other words, the above-presented methodology is not a tool to forecast travel behaviors or market shares of different services but rather to gain a deeper understanding of the factors that are stronger drivers of the choices, including those that cannot easily or readily be captured by observed or even latent variables or psychological constructs.

Much of the literature is only focused on some particular criteria and only considers users' perspectives. Conversely, in this study, some important characteristics which received less attention, including traveler safety, operational speed, user-friendliness, image, comfort, and the possibility of carrying items, are analyzed from the viewpoints of both users and non-users. The present research, therefore, offers insights into users' and non-users' perceptions, especially for some qualitative choice criteria seldom considered in econometric models. Some criteria investigated in this research, such as image, ease of use, or comfort, are difficult to quantify objectively and, therefore, to consider in standard travel analysis methods since travelers qualitatively assess them. Following this research avenue, additional criteria beyond the eight considered here could be considered in future research extensions, including service quality, environment-friendly systems, and service availability in densely populated areas. Also, the views of other stakeholders of shared mobility services, such as government members and operators, can be relatively easily taken into account with the method showcased in this paper.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Ehsan Amirnazmiafshar, Marco Diana; data collection: Ehsan Amirnazmiafshar, Marco Diana; analysis and interpretation of results: Ehsan Amirnazmiafshar, Marco Diana; draft manuscript preparation: Ehsan Amirnazmiafshar, Marco Diana. All authors reviewed the results and approved the final version of the manuscript.

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