A user-centric multi-criteria evaluation of mobility services for people with disabilities in a real territorial context

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ABSTRACT : In light of mounting concerns about the socio-environmental impact of transportation, mobility users as a whole must change their travel behaviors to support the ecological transition. However, categories of users with particular needs, such as those with disabilities (defined as individuals with at least one severe limitation in a physical, sensory, or cognitive function), face unique mobility challenges. This study aims to develop an evaluation framework for mobility services, with the objective of identifying which services are most suitable for the particular needs of people with disabilities. The first step in this study was to analyze the PAM (*Pour Aider à la Mobilité*, in French) service, an on-demand mobility service specifically intended for people with disabilities, operated by the *Département* of Seine-Saint-Denis, a local authority in the Paris region. This was followed by a comparison of various mobility services with PAM, with the aim of identifying the most suitable solutions for people with disabilities. This approach involved three distinct elements: (1) multi-criteria analysis (MCA), (2) PAM data analysis and (3) the creation of representative user personas. As an illustration, we evaluated nine mobility services in relation to twelve criteria applied to people with psychiatric disabilities, providing a ranking of the most suitable solutions. Consequently, we have developed a methodological framework for evaluating mobility services tailored to the particular needs of specific categories of users. Our findings are of use to local authorities when implementing on-demand mobility services in conjunction with the existing transportation system and emerging mobility services.

Keywords: People with disabilities; On-demand mobility; Multi-criteria analysis; Persona; PROMETHEE; Travel behaviour ; Equity

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1. INTRODUCTION

Amidst a rapidly changing context, particularly related to climate disruptions, mobility practices are dynamically evolving to address pressing socio-environmental challenges. New mobility services are emerging, offering potential remedies for addressing these challenges and helping local authorities achieve their objectives, including providing equitable local transportation systems. Among the most crucial objectives in transport planning is equity, and it becomes even more vital when considering people with disabilities. In France, people with disabilities represent 13% of the population (those aged 15 or older living at home and having at least one severe limitation in a physical, sensory, or cognitive function) [1]. In the Paris region, the PAM service is operated by *Départements* (local authorities) to assist people with disabilities in their daily mobility by providing an on-demand transport mobility service that can be used for any trip purpose.

In this paper, we aim to understand the specific needs and requirements of this specific category of mobility users, to explore performances of existing and new mobility services, and to identify the most suitable solution(s) according to a set of economic, social and environmental criteria. To do so, we propose a 3-step research protocol: (1) data set development (operator data and qualitative monitoring), (2) analysis of supply and demand (description of demand, analysis of supply, and identification/classification of alternative solutions) and definition of personas, and (3) the execution of the multi-criteria analysis. This work is fulfilled with the collaboration of the *Département* of Seine-Saint-Denis, a local authority in the Paris region, France, which manages the PAM service. It is based on two previous studies that established the methodological framework used here: Le Boennec et al. (2019) and Le Dréau et al. (2020).

In the rest of the paper, we propose a review of previous works on the evaluation of transportation systems using multi-criteria analysis methods or creating personas (Section 2). Then, we present the methodology to analyze mobility services (Section 3), the data used in the study (Section 4), and the results of the multi-criteria analysis (Section 5). Discussion of our results and concluding remarks are provided in Section 6.

2. RELATED WORK

2.1. Transportation and disability

The transportation needs of people with disabilities pose distinct challenges that vary significantly based on the type of disability. In some cases, these challenges may overlap with those faced by the elderly, who are also considered to have reduced mobility. Scholarly research in this field primarily focuses on vulnerability prevention, encompassing aspects such as urban design, the accessibility of mobility services, and the inclusion of people with disabilities in these services [2][3][4]. Additionally, some studies explore the design of transport modes and mobility applications as crucial factors in enhancing the satisfaction and well-being of people with disabilities [5][6]. Significant attention is devoted to on-demand mobility services tailored to meet the specific needs of people with disabilities [7][8][9][10]. Travel behaviors, including factors influencing mode choice, are also investigated from the demand side [11][12][13][14]. Furthermore, several forward-

looking studies explore the potential use of autonomous vehicles by people with disabilities, exploring both the supply side [15]16] and the intention-to-use aspect [17][18].

2.2. Transportation and multi-criteria decision analysis

Multi-criteria analysis methods have been extensively employed to evaluate infrastructure projects and mobility solutions, often compared to other commonly used evaluation methods in transportation [19][20]. Comparative studies between Cost-Benefit Analyses (CBAs) or Social Cost-Benefit Analyses (SCBAs) and MCDAs are frequently conducted [21][22][23][24]. Additionally, some studies employ MC As using different techniques to compare them with one another, such as AHP and TOPSIS [25], AHP and ELECTRE [26], and TOPSIS and MACBETH [27]. Furthermore, specific MCA techniques have been the focus of particular studies, including Fuzzy methods [28][29], MAMCA [30][31], and PROMETHEE [32][33].

However, the application of MCAs to disability in the transportation field has been limited. Two notable articles stand out in this context. Simunovic et al. [34] conducted an MCA to select an optimal pedestrian crossing, considering various stakeholder groups, including people with disabilities. The study employed AHP to assess different scenarios and highlighted the importance of traffic safety for both healthy pedestrians and people with disabilities. Agarwal et al. [35] evaluated the overall quality of Indian commercial airline websites using a combination of TOPSIS, AHP, and Fuzzy AHP techniques. The study revealed that certain website features affected the usability of the websites for people with disabilities, particularly hindering the use of assistive technology and accessibility for this user group. Table 1 provides a comparison of the advantages and limitations of major MCA techniques.

Table 1. Advantages and limitations of major MCA techniques

MCA technique (and derivatives)	Description	Advantages	Limitations	Applied in	Transportation issue considered
AHP	A structured technique for analyzing MCA problems according to pairwise comparisons	• Flexibility • Consistency • Ease of use • Requires little data	• No strict hierarchy in the results (depends on the case study) • Limited number of criteria and alternatives	Saaty (1995)	Route selection to a new airport (Pittsburgh, United States)
ANP	A generalization of AHP, which incorporates the interdependences among criteria	• Requires little data • Flexibility in the interdependence and relationships between the criteria and alternatives	• Difficult to use in comparison with AHP (matrix filling)	Banai (2010)	Light-rail route selection (Memphis, United States)
ELECTRE	Outranking method for ùa set of alternatives by determining their concordance and discordance indexes	• Mathematically proven • Clear view of alternatives (elimination of the less favorable ones) • Uncertainty and vagueness considered	• Only core of leading alternatives generated • Interpretation of the results	Bojkovic et al. (2010)	Transport sustainability at the European level
MAUT	A systematic method to identify and analyze multiple variables for providing a common basis for making a decision	• Uncertainty considered • Options for preferences	• Requires a lot of data • Description of preferences required	Zietsman et al. (2006)	Transportation corridor (South Africa)
PROMETHEE	Outranking method based on using a preference function for each criterion forming a MCA problem	• Ease of use	• Ambiguity in weights' assignment	Nassereddine and Eskandari (2017)	Public transport system (Tehran, Irantout)
TOPSIS	A method based on the distance from negative and positive ideal solutions	• Ease of use • Cardinal ranking options	• Uncertainty delicate to measure	Awasthi et al. (2011)	Carsharing, ride-sharing and park-and-ride options (La Rochelle, France)

Note: AHP is Analytic Hierarchy Process, ANP is Analytic Network Process, ELECTRE is Elimination and choice translating reality, MAUT is Multi-Attribute Utility Theory, PROMETHEE is Preference Ranking Organization METHod for Enrichment of Evaluations, TOPSIS is Technique for Order of Preference by Similarity to Ideal Solutions

Source: adapted from Moslem (2020), Yannis et al. (2020) and Keshavarz-Ghorabaee et al. (2022)

2.3. Persona creation methodology

According to Cooper [36], personas are fictional user models representing archetypal users used throughout the design process of a product or service [37]. These personas are based on real data and are intended to be credible and relatable individuals in everyday life [38]. Describing the context of use also provides valuable information about the environment in which the product or service will be used [39]. Utilizing the persona creation methodology allows decision-makers to better understand user behavior, infer their needs, and make informed decisions [38].

In the transportation field, the persona creation methodology is are commonly applied to capture diverse travel behaviors and develop services tailored to different users [37][40][41]. Some studies use personas to represent various public transport or ride-sharing users, considering their preferences and expectations regarding vehicle design and user experience [42][43][44]. Additionally, personas have been employed to explore user requirements and acceptance issues related to novel concepts like autonomous services [45]. However, we did not find any study that applies specifically the persona creation methodology to address the issue of disability in the field of transportation.

2.4. Summary

To summarize the related work:

- Disabilities in transportation are currently attracting substantial research interest, however:
    - They are focused on the identification of needs of people with disabilities and factors influencing their travel behavior ;
    - Studies on the identification of suitable mobility solutions are very limited ;
- Multi-criteria analysis is commonly used to evaluate transportation projects or services, but disability is almost not integrated ;
- Research on creating and analyzing personas to address disability in the field of transportation is nearly non-existent.

In this paper, we aim to fill these research gaps by undertaking an in-depth and territorial analysis of mobility solutions for people with disabilities, while providing methodological contributions:

- Proposing a user-centric multi-criteria analysis model, involving the creation of personas for people with disabilities to design criteria and assign weights for the evaluation process;
- Enriching the multi-criteria analysis using both real operating data and insights from scientific literature;
- Performing and validating the analysis with the collaboration of the local authority.

3. METHODOLOGY

3.1. Multi-criteria analysis model

As mentioned in Subsetion 2.2., there exists several multi-criteria methods. The PROMETHEE methodology has an advantage over other methodologies as it is widely used to analyze transportation issues. It is better applied to problems with many classification alternatives and different types of criteria, such as sustainable development evaluations . The method's main idea is to generate a partial or complete classification of alternatives according to the positive outranking flow, negative outranking flow and net outranking flow (see Equation (1) below).The leaving (positive) flow measures the strength of alternatives and the entering (negative) flow measures the weakness of alternatives. This classification is made according to the following mathematical algorithm (Brans et al., 1986).

We consider a preference function that reflects the preference of solution over solution *b*regarding the criterion i, with d = score(a) – score(b) defined as the difference of performance between a and b.For instance, for a V-criterion (**Figure 1**), the preference function adopts the following properties:

$$P_i(a,b)=\begin{cases} 1 & d>P \\ \frac{d}{P} & 0\le d\le P \\ 0 & d\le P \end{cases} \qquad (1)$$

Where **P** is the preference threshold fixed for each criterion.

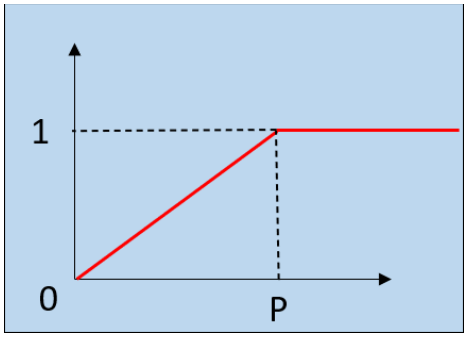


Figure 1. V-criterion function

We selected the V-criterion as it enables the establishment of a linear comparison of performances. The aggregate preference index to express the degree of preference for *a* over *b* for all criteria *k* is written:

$$\pi(a,b)=\frac{1}{\sum_{\square} w_i}\sum_{i=1}^{k} w_i P_i(a,b) \qquad (2)$$

Where is the weight assigned to each criterion.

Then, for n alternatives belonging to the subset A, are calculated the positive overcoming flow, that reflects how an alternative a exceeds all others, and the negative overcoming flow, that represents how an alternative a is overtaken by the others:

$$\Phi^{+}(a)=\frac{1}{n-1}\sum_{x\in A}^{\square}\pi(a,x) \tag{3}$$

$$\Phi^{-}(a)=\frac{1}{n-1}\sum_{x\in A}^{\square}\pi(x,a) \tag{4}$$

Finally, the net outranking flow is obtained:

$$\Phi(a)=\Phi^{+}(a)-\Phi^{-}(a) \tag{5}$$

The alternative with the highest net flow of improvement is classified as the best. To calculate the net outranking flow for each criterion, we use:

$$\phi_j(a)=\frac{1}{n-1}\sum_{b\neq a}\left[p_j(a,b)-p_j(b,a)\right] \tag{6}$$

with the following property:

$$\phi(a)=\sum_{j=1}^{k}W_j\phi_j(a) \tag{7}$$

The alternative with the highest net flow is classified as the best regarding the criterion.

To examine the interrelationships among criteria, we finally performed a Principal Component Analysis (PCA) by using a correlation matrix. We relied on the R statistical software. Our objective was to uncover underlying patterns in the data, particularly focusing on identifying potential trade-offs. This analysis was critical for facilitating a more informed decision-making process in the selection of mobility services within the context of our case study.

3.2. Evaluation of mobility solutions for people with disabilities

The general framework of evaluation of mobility solutions for people with disabilities is presented in Figure 2. It is structured into three main steps. Steps 1 and 2 are used to carry out the multi-criteria analysis as shown in Figure 2.

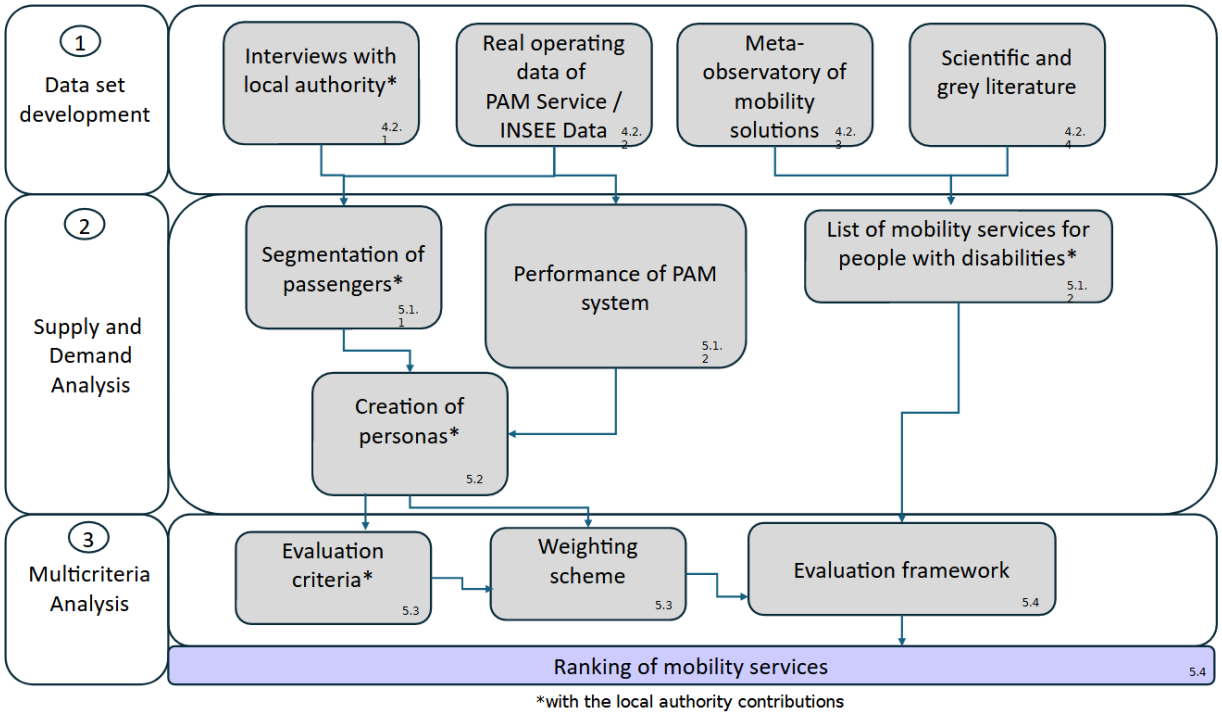


Figure 2. A 3-Step methodological framework

Source: Authors

To carry out the multi-criteria analysis and sort the most suitable mobility solutions for people with disabilities in the third step**,** three components are necessary: (a) the set of evaluation criteria, (b) a weighting scheme, and (c) the list of mobility services. To define these components, the complete methological framework is the following :

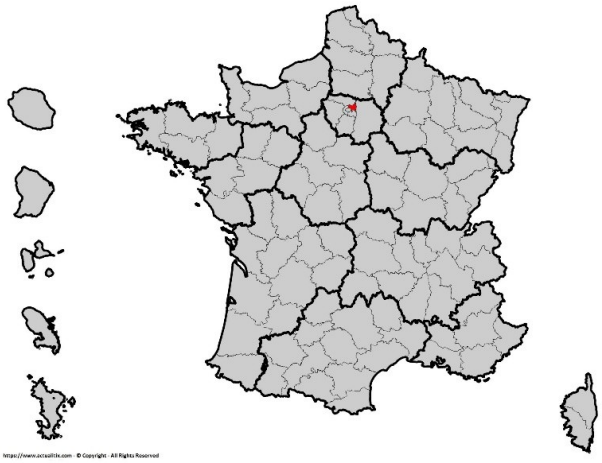
- The set of twelve *evaluation criteria* is obtained through the analysis of PAM operating data (step 1) and the insights gained from creating personas (step 2) ;
- The *weigthing scheme* is obtained from the personas;
- The *evaluation framewor*k is constituted by the reunion of the evaluation criteria and the weigthing scheme, that are applied to nine solutions identified from the first step, using the meta-observatory model developed in [46] and [47] and enriched with additional solutions extracted from both scientific and grey literature (governmental notes, industrial reports…) (Schöpfel, 2010).

In addition, discussions with the local authority throughout the process further enhanced the establishment of these three components.

4. MATERIALS AND DATA

4.1. Case study

The *Département* of Seine-Saint-Denis comprises 40 municipalities and has a total population of 1.6 million inhabitants (in 2019), with a density of 7,000 inhabitants per square kilometer.



Within the *Département*, approximately 140,223 individuals have at least one open right to compensation for disability from the MDPH (Local Office for People with Disabilities, Maison Départementale des Personnes Handicapées in French). Among these cases, 12% concern children and youth under the age of 20 (16,983), while 88 % are adults (123,240).

Seine-Saint-Denis exhibits 2.3 times more beneficiaries of disability-related benefits than the national average and has the highest poverty rate in France. The territory can be divided into 5 distinct socio-economic zones, as depicted in **Figure 3**.

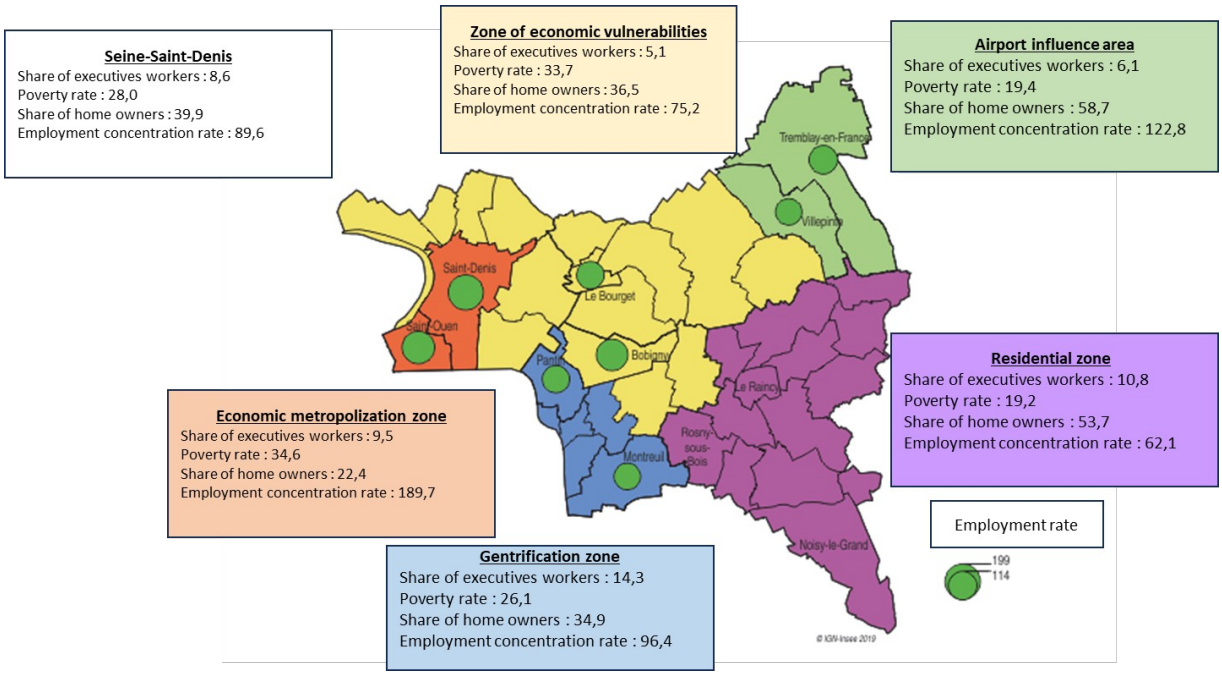


Figure 3. Map of Seine-Saint-Denis territory

4.2. Data collection

Data collection refers to the first step of our 3-step methodological framework (Figure 2). Data is collected through four main sources: (1) results of interviews with the local authority, (2) quantitative data from the mobility service's operator and the French Institute for Statistics and Economic Studies (Insee), (3) data from the meta-observatory model used in [46] and [47], and (4) scientific and grey literature (Fig. 2) .

4.2.1. Interviews with the local authority

In order to identify concerns of people with disabilities on the studied territory, several rounds of meetings were conducted with decision makers. During these meetings, these decision makers shared the technical (e.g. delays), economic (e.g. fare) and social issues that encountered by all stakeholders, including passengers, service provider, and the territorial authority. Additional technical and institutional reports, such as CERTU's report [49] or feedback from user associations, enabled to enrich our understanding of stakeholder's priorities.

4.2.2. Quantitative data

Real operating data of PAM service. Data has been provided by Flex'cité, the mobility operator for the PAM on-demand mobility service. A total number of 56,328 trip records were collected between January and December 2018. Each trip record includes the start time and start date of a trip, the purpose, the distance from origin to destination, the end time and end date of a trip, the delay as the difference between the planned and real departure and arrival times, the ridesharing with other passengers, and the type of disability of mobility users.

Census block-level data. In France, the municipalities with at least 10,000 inhabitants and most of the municipalities with 5,000 to 10,000 inhabitants are divided into IRIS (Ilots Regroupés pour l'Information Statistique) [48]. The Paris region is divided into 5620 IRIS 615 of them belonging to the *Département* of Seine-Saint-Denis . For each zone, data is reported by Insee for the area and the existing public transportation supply. The positions of daycare centers and transport stops are given by OpenStreetMaps.

4.2.3. Data from the meta-observatory of mobility solutions

A meta-observatory of emerging mobility solutions had been developed by VEDECOM Institute [46][47]. It contains 60 mobility solutions, which are assessed based on 23 key performances indicators (KPI), mostly sustainable development criteria. We used data from this meta-observatory to initialize the evaluation process. We then enriched it by incorporating additional solutions and adjusting the criteria and the weighting scheme to address the specific concerns of people with disabilities.

4.2.4. Scientific and grey literature

Last, additional technical and institutional reports, such as CERTU's report [49] or feedback from user associations, enabled to enrich our understanding of stakeholder's priorities.

5. RESULTS

The Results Section presents the intermediary, then final results obtained from the application of the second and third steps of our 3-Step methodological framework (Figure 2).

5.1. Descriptive Analysis

In this section, we conduct a detailed analysis of the factors related to mobility supply and demand. The supply aspect is focused on evaluating the PAM service and examining its potential alternatives. The investigation into demand involves an in-depth study of the segmentation and characterization of the current users of the service.

5.1.1 Demand side

As per the insights provided by the Local Office for People with Disabilities[50], it is evident that daily mobility stands as the primary and utmost concern for people with disabilities. The ability to navigate through their daily activities and move freely is a critical aspect that significantly impacts their independence, overall well-being, and participation in society.

After engaging in discussions with local stakeholders, a comprehensive understanding has been gained, leading to the identification of three distinct profiles of people with disabilities within the community. The first profile corresponds to individuals with psychiatric disabilities, so with "any mental or psychological disorder, such as emotional or mental illness, that substantially limits one or more of the major life activities of an individual" [1]. The second profile is constituted by individuals with physical disabilities, facing challenges related to mobility, accessibility, and physical independence. The third profile consists of individuals with visual impairments, who experience either partial or complete loss of vision. Our data of the service's usage indicates that a majority of passengers have psychiatric disabilities (52%), followed by passengers with physical disabilities (41%) and a smaller proportion with visual disabilities (7%). In light of the prevalence of profiles with psychiatric and physical disabilities in our data, we will focus on these two categories of mobility users for further examination and consideration. These two distinct profiles have specific needs and requirements, as reported by the Institut Paris Region [51] and illustrated in Table 2.

Table 2. Mobility challenges for people with disabilities in Paris Region

Difficulties encountered	Percentage of psychiatric disabled people concerned	Percentage of physically disabled people concerned
To climb stairs	20%	**100%**
To descend stairs	20%	**100%**
To use an escalator	13%	50%
Limited walking ability	20%	**85%**
To maneuver a door	13%	25%
To pass a toll gate	13%	35%
To board or alight a bus	20%	**100**%
To bridge the gap platform/train	13%	50%
Need for complete absence of stairs	13%	25%
Balance problems	20%	**85%**
Hearing information	3%	-
Reading information, orientation	**63%**	**-**
Using a ticket machine	**63%**	25%
Validating a ticket	20%	25%
Dealing with traffic disruptions	**83%**	100%
Total number of individuals affected in Paris region	80,000	**200,000**

Source: *Institut Paris Région, 2005*

In particular, three recurring difficulties specific to *individuals with psychiatric disabilities* have been identified:

- Unplanned changes to the transportation route due to disruptions can pose a significant risk to mobility users with psychiatric disabilities. This may result in feelings of confusion, disorientation, leading to potential difficulties in completing the journey successfully.
- Reading and comprehending information during the journey can be problematic. Difficulty in interpreting signage, schedules, or maps may hinder their ability to navigate effectively, causing additional stress and uncertainty.
- Purchasing a transport ticket from a machine can be challenging.

Furthermore, additional challenges may arise while using public transport, especially concerning uncertainties during boarding/alighting, waiting at stations, and interacting with other passengers.

Regarding individuals with *physical disabilities*, the mobility challenges differ are quite different as shown in Table 2. As expected, the issues of this category of mobility users encompass difficulties with walking, short stature, grasping, and using mobility aids, such as canes, crutches, walkers, or other assistive devices. The issue of accessing the mode of transportation, (i.e., during the first/last kilometer when walking is required) and vehicle access stand out as prominent concerns. In addition, a high occupancy rate of the vehicle can be ~~very~~ problematic in cases of high demand, as wheelchair circulation within the vehicle may be impossible, and accessing reserved spaces for wheelchairs may be difficult. Finally, these difficulties are greatly aggravated when traffic

disruptions occur, a phenomenon experienced by all types of disabilities, albeit for different reasons.

5.1.2. Supply side

Mobility solutions for people with disabilities. In addition to conventional modes (i.e., public transport, active modes), mobility services that could serve as alternatives to the PAM service (reference solution) are explored and discussed with the local authority. These potential solutions are classified according into five categories: (1) on-demand services, (2) personal assistance and training, (3) velotaxi, (4) electric vehicles, and (5) augmented multimodal information. Figure 4 illustrates these five categories and corresponding solutions.

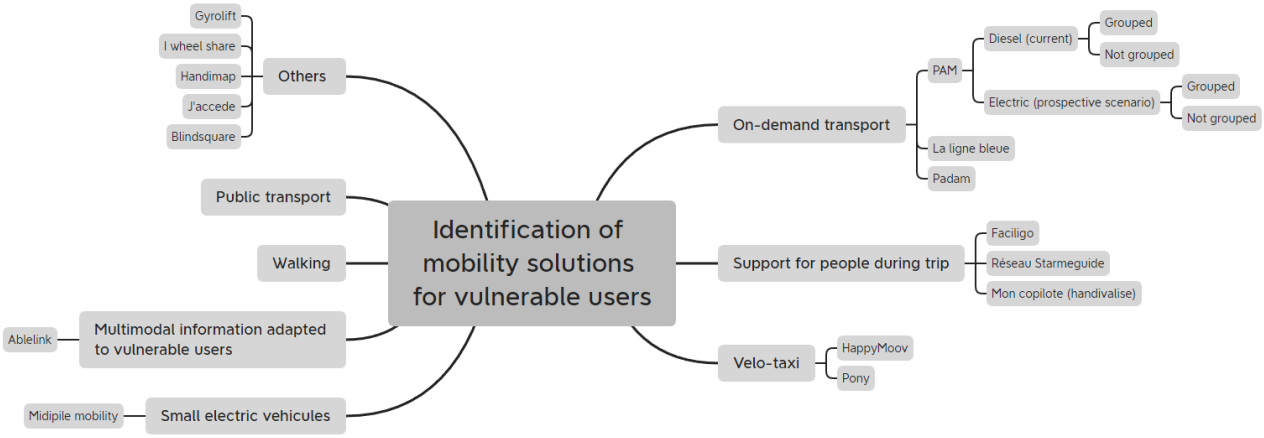


Figure 4. Mobility solutions for disabled people considered for the evaluation

Source: Authors

Based on discussions with the local authority, we know that the latter possess a substantial understanding of the identified mobility solutions and people with disabilities' mobility challenges. Despite some mobility solutions appearing unsuitable for disabled people, such as the velotaxi, they are retained for further evaluation to assess the relevance of their exclusion. In addition, a distinction is made between grouped and non-grouped PAM services, based on whether ridesharing is permitted or not . Furthermore, a PAM service based on optimization algorithms is considered, though it is not yet implemented. Similarly, high-capacity electric vehicles suitable for transporting people with disabilities are currently unavailable in the market. However, a prospective scenario of a PAM service based on such vehicles is assessed.

Performances of the PAM's service (reference). In order to understand the PAM usage, the service is analyzed based on aggregated statistics. Descriptive statistics includes the trip distribution by distance and by purpose, the trip regularity, the percentage of ridesharing, and the delay in arrival time due to ridesharing. The trip regularity indicates whether a trip occurs repeatedly over a period exceeding two months as part of an organized activity.

The descriptive statistics are considered for both people with psychiatric and people with physical disabilities (Table 3).

Table 3. Descriptive statistics

Indicator	Psychiatric disability	Physical disability	Others (visually impaired, hearing impaired…)	All disabled individuals
Total distance for the year	204,624 km	232,958 km	Not considered here	465,000 km
Number of daily trips	X	X	Not considered here	AVG = 220 trips; SD = 84 trips; MIN = 1 trip; MAX = 267 trips
Trips purpose	Activities (90%), Other Purpose (10%).	Activities (39%), Regular work (31%), Occasional leisure (12,5%), Personal initiative (9%), Other Purpose (8.5%).	Not considered here	Activities* (52%), Regular work (21%), Occasional leisure (15%), Personal initiative (5.5%), Other Purpose (6,5%).
Average distance per trip	AVG = 6.8 km; SD = 4,9 km; MIN = 0,2 km; MAX = 80,5 km.	AVG = 9.1 km; SD = 7,5 km; MIN = 0,2 km; MAX = 66,7 km.	Not considered here	AVG = 9 km; SD = 6,4 km; MIN = 0,2 km; MAX = 80 km.
Regular trips	93.4 %	75.6 %	Not considered here	79%

** The purpose 'Activities' is related to going to a daycare center.*

Source: Authors' calculations from PAM operator data

Table 3 shows that a great number of trips are delayed because passengers often have to rideshare and that the ratio of regular trips is high. People with psychiatric disabilities are more often subjected to ridesharing, they travel further, more regularly and mostly to daycare centers. These facilities are designed for adults with disabilities offering them a variety of activities and programs tailored to their specific needs and abilities. The overarching aim of these centers is to provide a nurturing and stimulating environment that enhances the quality of life for adults with disabilities, fostering their independence and social interaction. Psychiatric disabled people are more autonomous during journeys for combining various modes and are also not limited in walking or cycling, Consequently, we will focus in the following on this profile to perform the multi-criteria analysis.

High traffic hubs. IRIS could be classified according to their potential for trips production/ attraction. Zones that are generating or attracting highest numbers of trips during the day are identified at the scales of the *Département* of Seine-Saint-Denis and the entire Paris region. To analyze their connections to nearest transportation stations, a more detailed analysis is conducted then with the local authority to pinpoint local hubs that serves as main generators / attractors of trips. It is found that these hubs include daycare facilities, living facilities and medicalized reception centers.

5.2 Creation of personas

In this subsection, we create personas by incorporating both the qualitative data collected and the observed travel habits (from operator's data) (See Fig. 2). Two profiles have been established: people with psychiatric and people with physical disabilities. As presented above, these two categories of mobility users have distinct needs and requirements (cf. 5.1.2) and also specific travel behaviors (cf. section 5.1.1).Each persona is defined according to:

- The travel behaviors, that describe how individuals travel using the PAM service based on the main service indicators (Table 3) ;
- The objectives and challenges, that reflect the difficulties encountered by the personas in their mobility and the key factors that will influence their modal choices, (cf. 5.1.1) ;
- The perception of PAM service (feedback from user's association), that indicates the satisfaction with the service, cf. 5.1.1) ;
- The mobility issues, that contain specific operational issues encountered during travel.(cf. 5.1.1).

An illustration of the persona created with a specific type of disability is provided in Figure 5. Based on these characteristics, it is possible to define the weighting scheme and carry out the multi-criteria analysis model (third step of our 3-Step methodological framework, see Figure 2).

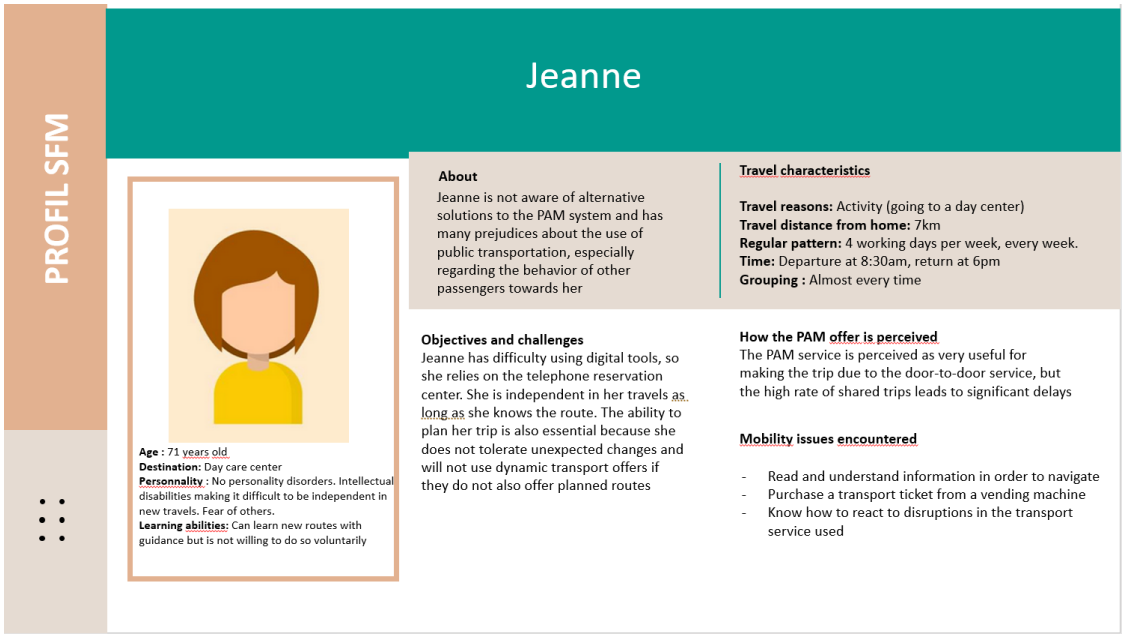


Figure 5. Illustration of a persona created people with psychiatric disabilities

Source: Authors

5.3 Definition of criteria and a weighting scheme

In this section, we define the list of criteria used to process the multi-criteria analysis and the assignment of weights.

The criteria (economic, technical, social and environmental) were established based on the analysis of personas, of performances of mobility services (from the VEDECOM's meta-observatory of new mobility solutions) and of the needs of the local authority (interviews and workshops) . These evaluation criteria were measured either quantitatively (e.g. operating data) or qualitatively (5-point scale). Table 4 shows the criteria retained for the evaluation, the methodology of calculation, and the weighting scheme.

Table 4. Definition of criteria and weights' assignment (psychiatric profile)

Criteria	Sub-criteria	Definition	Source	Method of measurement	Weights'assignment
Environmental	GHG emissions	GHG emissions (life cycle assessment) of solutions	Carbone 4 study	Life cycle assessment (gCO2eq/km.passenger)	Not a priority (1)
	Air quality	Reflects the impact of different mobility solutions in terms of fine particle emissions	Ademe	Qualitative 5-scale	Not a priority (1)
Economic	Cost	Pricing per trip undertaken	Workshop and meta-observatory monitoring	Qualitative 5-scale	Important (2)
Organizational	Implementation ease for LTA	Presence of the service in the market, governance, operational implementation difficulties, etc.	Workshop and meta-observatory monitoring	Qualitative 5-scale	Not a priority (1)
	Planning	Is it possible to plan the trip in advance?	Operating data	Qualitative 5-scale	**Very important (3)**
Technical	Safety	Safety provided by the mode of transportation	Workshop and meta-observatory monitoring	Qualitative 5-scale	Important (2)
	Required autonomy	Does the **solution**require autonomy to manage unexpected events (delays, service cancellations, etc.) ?	Workshop and meta-observatory monitoring	Qualitative 5-scale	**Very important (3)**
Quality of Service/ Social	Physical accessibility	Physical accessibility, can the solution be used by users regardless of their physical condition	Workshop and meta-observatory monitoring	Qualitative 5-scale	Important (2)
	Comfort	Seating capacity, quality of service (vehicle quality level, etc.).	Workshop and meta-observatory monitoring	Qualitative 5-scale	Important (2)
	Availability	Availability of the service at any time, on-demand or otherwise, frequency, booking lead times	Operating data	Qualitative 5-scale	Important (2)
	Digital accessibility	Does the solution require digital competence? Is access to information easy (booking through a call center, online-only, etc.)?	Workshop and meta-observatory monitoring	Qualitative 5-scale	**Very important (3)**
	Travel time	Evaluation of travel time compared to other evaluated solutions	Operating data	Qualitative 5-scale	**Very important (3)**

Source: Authors

The assignment of weights for criteria was defined by considering personas and their priorities. They were estimated by each stakeholder independently and then aggregated by discussing the points of disagreement during a workshop. In particular, a 3-point scale of importance was used: (1) 'Not a priority', (2) 'Important' and (3) 'Very important'. The weighting scheme obtained was then used in the software as digital values of importance: '1' was assigned to 'Not a priority', '2' was assigned to 'Important' and '3' was assigned to 'Very important'. Organizational and environmental criteria were assigned relatively lower weights, while technical and social criteria were given higher importance.

5.4. Calculation of outranking/ preference flows and ranking mobility solutions

As defined in Subsection 3.1., the PROMETHEE outranking flow represents an overall "score" that reflects the aggregation of all pairwise comparisons of alternatives (Brans et al., 1986). This ranking allows for the quick identification of the most suitable solutions, keeping in mind that this ranking serves as a discussion element and is heavily dependent on the model's configuration, particularly weights'assignment.

Table 5 presents the consolidated results for people with psychiatric disabilities. The evaluation had been performed by the local authority and researchers. Firstly, the research team scored the performances of each mobility service separately. Then, the respective scores were discussed and consolidated to provide one final score evaluation table used to process the multi-criteria analysis.

Table 5. Consolidated results for people with psychatric disabilities

Mobility services	GHG emissions	Air quality	Cost	Implementation ease for LTA	Safety	Physical accessibility	Comfort	Availability	Digital accessibility	Travel time	Planning	Required autonomy
Current PAM Service	385	1	4	5	5	5	4	5	5	5	5	5
Grouped Current PAM Service	192	2	4	5	5	5	3	5	5	3	5	5
Electric PAM Service	85	3	4	4	5	5	4	5	5	5	5	5
Grouped Electric PAM Service	42	3	4	4	5	5	3	5	5	3	5	5
Velo-Taxi	21	5	4	2	1	1	1	5	3	3	5	3
Assistance when using PT	1	5	5	3	4	4	4	4	3	3	4	4
Dynamic on-demand transport	385	1	5	5	5	5	4	5	5	5	5	5
Conventional PT (bus,train)	1	5	5	4	2	3	4	4	4	3	4	2
Walking	1	5	5	4	3	3	3	5	4	1	5	3

Note: PT=public transportation

Source: PROMETHEE

We then proceeded to the multi-criteria analysis using this evaluation table and the Weights column (Table 4) to obtain the ranking of mobility services. This final ranking is presented in Table 6.

Table 6. Ranking of mobility services for the psychiatric disabled profile

Rank	Mobility service	Description	Positive Flow	Negative Flow	Total Flow
1	**Dynamic on-demand mobility service**	Optimized on demand transport (real time reservation)	0,3514	0,0308	**0,3206**
2	**Electric PAM Service**	Current service with electric fleet	0,2874	0,0496	**0,2378**
3	**Current PAM Service**	Current service	0,2844	0,0698	**0,2146**
4	**Grouped Electric PAM Service**	Current service shared with users + electric fleet	0,2134	0,121	**0,0923**
5	**Grouped Current PAM Service**	Current service shared with users	0,2133	0,1284	**0,0849**
6	**Walking**		0,1727	0,2625	**-0,0897**
7	**Assistance when using public transportation**	Use public transit with a skilled assistant	0,1201	0,3526	**-0,2325**
8	**Conventional public transportation (bus,train)**	Public transit used in intermodality	0,1362	0,3891	**-0,2529**
9	**Velotaxi**		0,0855	0,4606	**-0,3751**

Source: PROMETHEE

Figure 6 provides a visual representation of the dominance relationships among the different mobility services. The higher a solution is positioned, the higher its score. The links between mobility services indicate comparability. Services at the same height are considered equivalent but not necessarily comparable.

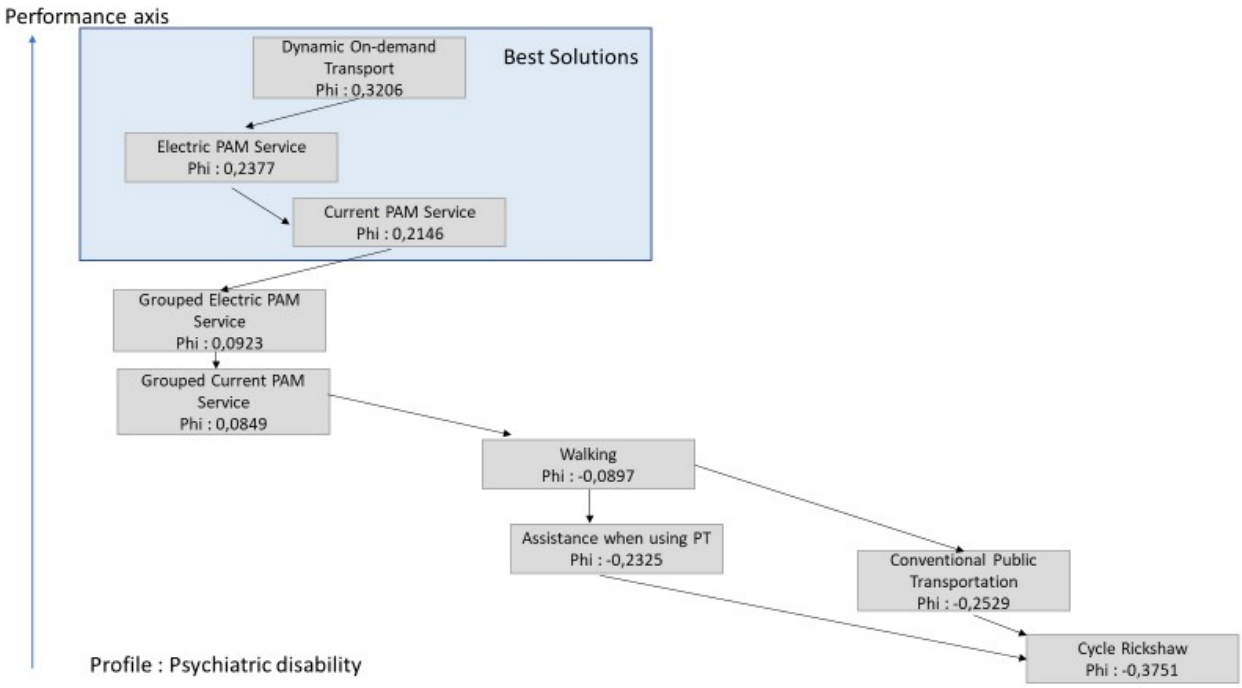


Figure 6. PROMETHEE Graph

Figure 6 shows that the dynamic on-demand mobility service is the most suitable solution according to the evaluation process. The only relationship of incomparability identified is between the assistance for riding public transport modes and using them independently.

6. DISCUSSION AND CONCLUSION

In this section, we discuss the results of the multi-criteria analysis by analyzing the rating of mobiliy services, then conclude.

6.1. MCA general results

The PAM service presents a logically sound solution for people with psychiatric disabilities, primarily owing to the presence of a trained driver ensuring seamless door-to-door service through on-demand mobility. Grouped PAM services, while effective and contributing to reduce externalities and lower emissions per passenger, may involve delays for passengers. User feedbacks suggest that current public transport modes may not meet the desired level of accessibility for people with psychiatric disabilities.

The dynamic on-demand PAM service should have been deployed in 2023. The main challenge would have been be the organizational shift between a local to a regional service using a unique digital platform. This shift should have provided a better and less expensive service, but the transition period could have led to malfunctions significantly reducing the quality of service.

6.2. Trade-off analysis

In order to identify the strengths and weaknesses of the mobility services compared, and with the aim of shaping public policies, we put our analysis in perspective by determining the correlations between the evaluation criteria of the model. To this end, we mobilize a principal component analysis **(Figure 7)**. This analysis supports the understanding of the required trade-offs when choosing the implementation of mobility services.

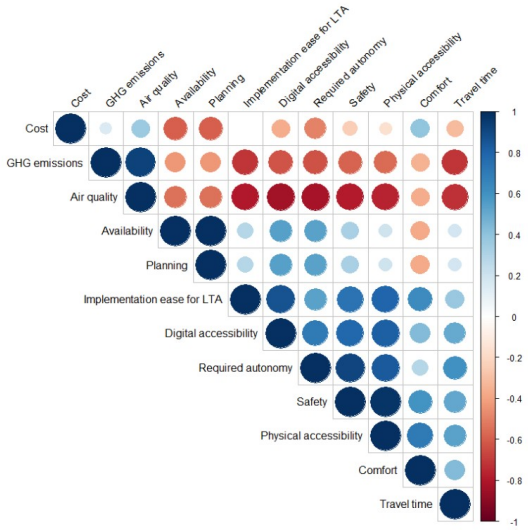


Figure 7. Correlation matrix for evaluation criteria

Source: PROMETHEE

Conducted using the R software, the correlation analysis offers several key insights:

- Low-emission solutions (GHG and particulate matter) are challenging to develop in the Ile-de-France Région, and their accessibility performance is also lower ;
- Flexible mobility services (available and plannable) are less comfortable, less environmentally friendly, and more costly for the user ;
- To satisfy the mobility user, it is observed that accessibility, safety, availability, comfort, and travel time criteria are correlated. Mobility services that perform the best on this group of criteria achieve the highest scores and logically emerge as the most suitable solutions in the evaluation model ;
- Ultimately, the analysis reveals the need to choose among the mobility services considered, as there is a trade-off between environmentally friendly and cost-effective solutions, and solutions that meet user expectations, particularly in terms of service quality.

Last, Table 7 presents the single-criteria flows as formalized in equations (6) and (7), allowing to verify that the best solutions are indeed the most performing in terms of these quality-of-service criteria, that were prioritized through the weights' assignment process.

Table 7. Single-criteria flow results

Flow by criteria	Physical accessibility	Comfort	Availability	Digital accessibility	Travel time
Current PAM Service (reference)	**0,28**	**0,25**	**0,25**	**0,38**	**0,44**
Grouped Current PAM Service (reference)	0,28	-0,13	0,25	0,38	-0,13
Electric PAM Service	**0,28**	**0,25**	**0,25**	**0,38**	**0,44**
Grouped Electric PAM Service	0,28	-0,13	0,25	0,38	-0,13
Velotaxi	-0,84	-0,88	0,25	-0,75	-0,13
Assistance when using public transportation	0	0,25	-0,88	-0,75	-0,13
Dynamic on-demand mobility service	**0,28**	**0,25**	**0,25**	**0,38**	**0,44**
Conventional public transportation (bus,train)	-0,28	0,25	-0,88	-0,19	-0,13
Walking	-0,28	-0,13	0,25	-0,19	-0,69

***Source*:** PROMETHEE

6.3. Concluding remarks

This paper aims at identifying mobility services that are best suited to the particular needs of people with disabilities. Compared to traditional evaluation processes applied to the transport field, the

proposed methodology enriches the multi-criteria analysis of mobility services by the creation of personas and the statistical and territorial analysis of real operational data.

Our approach primarily allows the characterization of specific categories of mobility users through the creation of personas without requiring costly household travel surveys. For local authorities as decision-makers, this approach enables the identification of the performance of mobility services in light of these users and their particular needs. This objectifies the performance of existing mobility services while comparing them to potential alternative or complementary services and provides local authorities with evaluation results able to guide the specification definition during the renewal or replacement of a mobility service.

By identifying users particular needs and mobility services performances on an established set of criteria and weighting scheme, this approach allows for the identification of critical criteria on which to act in order to improve service quality. As a result, several adaptations of the multi-criteria analysis first developed in Le Boennec et al. (2019) and Le Dréau et al. (2020) have been accomplished. In particular, this study is the first, to our knowledge, to measure evaluation criteria on the basis of real operating data and scientific monitoring, instead of classical experts' opinion. In addition, the weighting scheme adopted here relies on the personas' analysis, created also from the analysis of real data, instead of typically using stated preferences surveys. In fact, given that most of mobility users concerned by the evaluation process present psychiatric disabilities, a standard household travel survey was not the most suitable method for questioning user profiles with various difficulties.

In summary, using the Visual PROMETHEE software, we found that the reference case (the current PAM service) was the best option to meet the specific needs of people with psychiatric disabilities while respecting the constraints and priorities of the local authority. Low-ranked solutions would be considered as options to be deployed on a local scale, as a last-mile service provided by daycare centers. As another policy implication, our analysis also revealed that there exists a trade-off between environmentally friendly and cost-effective solutions, and solutions that meet user expectations, particularly in terms of service quality.

While we are encouraged by these exploratory results, we recognize that this study has limitations. Firstly, the multi-criteria analysis endeavors to incorporate main relevant qualitative and quantitative criteria. Some of the considered qualitative criteria depends on specific contexts of individuals, for instance the physical accessibility to the mobility service. The personas' analysis provides additional insights to consolidate the measurement of the criteria. Secondly, a more in-depth territorial analysis that considers different use cases should allow to identify the most appropriate markets for low-ranked solutions. Finally, considering other territories and user profiles (for example families with the problem of travel chains, young people in rural areas, etc.) wouldl enable to verify the duplicability of our approach in other contexts. This is left for future research.

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REFERENCES

1.DRESS. (2023). Le handicap en chiffres. Panoramas de la DRESS.

2.Ferrari, Laura, Michele Berlingerio, Francesco Calabrese, et Jon Reades. 2014. « Improving the accessibility of urban transportation networks for people with disabilities ». Transportation Research Part C: Emerging Technologies 45:27 40. doi: 10.1016/J.TRC.2013.10.005.

3.Martens, Karel. 2018. « Ageing, impairments and travel: Priority setting for an inclusive transport system ». Transport Policy 63:122 30. doi: 10.1016/J.TRANPOL.2017.12.001.

4.Lope, D. J., & Dolgun, A. (2020). Measuring the inequality of accessible trams in Melbourne. *Journal of Transport Geography*, *83*, 102657. https://doi.org/10.1016/J.JTRANGEO.2020.102657

5.Ingvardson, J. B., & Nielsen, O. A. (2019). The relationship between norms, satisfaction and public transport use: A comparison across six European cities using structural equation modelling. Transportation Research Part A: Policy and Practice, 126, 37–57. https://doi.org/10.1016/J.TRA.2019.05.016

6.Ralph, K., Morris, E. A., & Kwon, J. (2022). Disability, access to out-of-home activities, and subjective well-being. Transportation Research Part A: Policy and Practice, 163, 209–227. https://doi.org/10.1016/J.TRA.2022.06.006

7.Bearse, P., Gurmu, S., Rapaport, C., & Stern, S. (2004). Paratransit demand of disabled people. Transportation Research Part B: Methodological, 38(9), 809–831. https://doi.org/10.1016/J.TRB.2003.10.004

8.Knierim, L., & Schlüter, J. C. (2021). The attitude of potentially less mobile people towards demand responsive transport in a rural area in central Germany. Journal of Transport Geography, 96, 103202. https://doi.org/10.1016/J.JTRANGEO.2021.103202

9.Ashour, L. A., & Shen, Q. (2022). Incorporating ride-sourcing services into paratransit for people with disabilities: Opportunities and barriers. *Transport Policy*, *126*, 355–363. https://doi.org/10.1016/J.TRANPOL.2022.08.005

10.Eisenberg, Y., Hofstra, A., Tilahun, N., & Shanley, J. (2022). Rideshare use among people with disabilities: Patterns and predictors based on a large nationally representative survey. Travel Behaviour and Society, 29, 246–256. https://doi.org/10.1016/J.TBS.2022.07.001

11.Stern, S. (1993). A disaggregate discrete choice model of transportation demand by elderly and disabled people in rural Virginia. Transportation Research Part A: Policy and Practice, 27(4), 315–327. https://doi.org/10.1016/0965-8564(93)90004-5

12.Schmöcker, J. D., Quddus, M. A., Noland, R. B., & Bell, M. G. H. (2008). Mode choice of older and disabled people: a case study of shopping trips in London. Journal of Transport Geography, 16(4), 257–267. https://doi.org/10.1016/J.JTRANGEO.2007.07.002

13.Ermagun, A., Hajivosough, S., Samimi, A., & Rashidi, T. H. (2016). A joint model for trip purpose and escorting patterns of the disabled. Travel Behaviour and Society, 3, 51–58. https://doi.org/10.1016/J.TBS.2015.08.002

14.Zheng, Y., Wang, S., & Zhao, J. (2021). Equality of opportunity in travel behavior prediction with deep neural networks and discrete choice models. *Transportation Research Part C: Emerging Technologies*, *132*, 103410. https://doi.org/10.1016/J.TRC.2021.103410

15.Hwang, J., Li, W., Stough, L., Lee, C., & Turnbull, K. (2020). A focus group study on the potential of autonomous vehicles as a viable transportation option: Perspectives from people with disabilities and public transit agencies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *70*, 260–274. https://doi.org/10.1016/J.TRF.2020.03.007

16.Martínez-Buelvas, L., Rakotonirainy, A., Grant-Smith, D., & Oviedo-Trespalacios, O. (2022). A transport justice approach to integrating vulnerable road users with automated vehicles. *Transportation Research Part D: Transport and Environment*, *113*, 103499. https://doi.org/10.1016/J.TRD.2022.103499

17.Bennett, R., Vijaygopal, R., & Kottasz, R. (2019). Attitudes towards autonomous vehicles among people with physical disabilities. *Transportation Research Part A: Policy and Practice*, *127*, 1–17. https://doi.org/10.1016/J.TRA.2019.07.002

18.Petrović, Đ., Mijailović, R. M., & Pešić, D. (2022). Persons with physical disabilities and autonomous vehicles: The perspective of the driving status. *Transportation Research Part A: Policy and Practice*, *164*, 98–110. https://doi.org/10.1016/J.TRA.2022.08.009

19.Belton, V., & Stewart, T. J. (1999). *DEA and MCDA: Competing or Complementary Approaches?* 87–104. https://doi.org/10.1007/978-94-017-0647-6_6

20.Dimitriou, H. T., Ward, E. J., & Dean, M. (2016). Presenting the case for the application of multi-criteria analysis to mega transport infrastructure project appraisal. *Research in Transportation Economics*, *58*, 7–20. https://doi.org/10.1016/J.RETREC.2016.08.002

21.Tudela, A., Akiki, N., & Cisternas, R. (2006). Comparing the output of cost benefit and multi-criteria analysis: An application to urban transport investments. *Transportation Research Part A: Policy and Practice*, *40*(5), 414–423. https://doi.org/10.1016/J.TRA.2005.08.002

22.Beria, P., Maltese, I., & Mariotti, I. (2012). Multi-criteria versus Cost Benefit Analysis: A comparative perspective in the assessment of sustainable mobility. *European Transport Research Review*, *4*(3), 137–152. https://doi.org/10.1007/S12544-012-0074-9/TABLES/7

23.Annema, J. A., Mouter, N., & Razaei, J. (2015). Cost-benefit Analysis (CBA), or Multi-criteria Decision-making (MCDM) or Both: Politicians' Perspective in Transport Policy Appraisal. *Transportation Research Procedia*, *10*, 788–797. https://doi.org/10.1016/J.TRPRO.2015.09.032

24.Marleau Donais, F., Abi-Zeid, I., Waygood, E. O. D., & Lavoie, R. (2019). A review of cost–benefit analysis and multi-criteria decision analysis from the perspective of sustainable transport in project evaluation. *EURO Journal on Decision Processes*, *7*(3–4), 327–358. https://doi.org/10.1007/S40070-019-00098-1

25.Shelton, J., Medina, M., Shelton, J., & Office, P. (2010). Integrated Multiple-Criteria Decision-Making Method to Prioritize Transportation Projects. *Https://Doi.Org/10.3141/2174-08*,*2174*(2174), 51–57. https://doi.org/10.3141/2174-08

26.Sawadogo, M., & Anciaux, D. (2010).*Reducing the environmental impacts of intermodal transportation: a multi-criteria analysis based on ELECTRE and AHP methods*. 224. https://hal.science/hal-00631190

27.Kolak, O. I., & Feyzioglu, O. (2016). Sustainability Performance Evaluation of Transportation Networks Using MCDM Analysis. In *Proceedings of the World Congress on Engineering* (Vol. 1).

28.Bit, A. K., Biswal, M. P., & Alam, S. S. (1992). Fuzzy programming approach to multi-criteria decision making transportation problem. *Fuzzy Sets and Systems*, *50*(2), 135–141. https://doi.org/10.1016/0165-0114(92)90212-M

29.Ismael, S. F., Alias, A. H., Zaidan, A. A., Zaidan, B. B., Alsattar, H. A., Qahtan, S., Albahri, O. S., Talal, M., Alamoodi, A. H., & Mohammed, R. T. (2023). Toward Sustainable Transportation: A Pavement Strategy Selection Based on the Extension of Dual-Hesitant Fuzzy Multi-criteria Decision-Making Methods. *IEEE Transactions on Fuzzy Systems*, *31*(2), 380–393. https://doi.org/10.1109/TFUZZ.2022.3168050

30.Macharis, C., De Witte, A., & Ampe, J. (2009). The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: Theory and practice. *Journal of Advanced Transportation*, *43*(2), 183–202. https://doi.org/10.1002/ATR.5670430206

31.Keseru, I. K., Coosemans, T. C., Gagatsi, E. G., & Macharis, C. M. (2018). User-centric vision for mobility in 2030: Participatory evaluation of scenarios by the multi-actor multi-criteria analysis (MAMCA).

32.Panayiotou, N., & Aggelopoulos, V. S. V. Procurement of a Public Address System (PAS) in an urban rail transport company with the support of a PROMETHEE II multi-criteria decision-making process. In *8th International Symposium and 30th National Conference on Operational Research* (p. 41).

33.Morfoulaki, M., & Papathanasiou, J. (2021). Use of PROMETHEE MCDA Method for Ranking Alternative Measures of Sustainable Urban Mobility Planning. *Mathematics 2021, Vol. 9, Page 602*, *9*(6), 602. https://doi.org/10.3390/MATH9060602

34.Šimunovič, L., Grgurević, I., & Škrinjar, J. P. (2010). Selecting Optimal Pedestrian Crossing Using Multi-criteria Decision-making. *Promet - Traffic&Transportation*, *22*(2), 105–116. https://doi.org/10.7307/PTT.V22I2.169

35.Agrawal, G., Dumka, A., & Singh, M. (2022). Usability and accessibility-based quality evaluation of Indian airline websites: An MCDM approach. *Universal Access in the Information Society*, 1-13.

36.Cooper, A. (1999). *The Inmates are Running the Asylum*. 17–17. https://doi.org/10.1007/978-3-322-99786-9_1

37.Vallet, F., Puchinger, J., Millonig, A., Lamé, G., & Nicolaï, I. (2020). Tangible futures: Combining scenario thinking and personas - A pilot study on urban mobility. *Futures*,*117*, 102513. https://doi.org/10.1016/J.FUTURES.2020.102513

38.Brangier*, É., Bornet, C., Bastien, J. M. C., Michel, G., & Vivian, R. (2012). Effets des personas et contraintes fonctionnelles sur l'idéation dans la conception d'une bibliothèque numérique. *Le travail humain*, *75*(2), 121-145.

39.Bornet, C., & Brangier, E. (2013). La méthode des personas: principes, intérêts et limites. *Bulletin de psychologie*, *524*(2), 115-134.

40.De Clerck, Q., Van Lier, T., Messagie, M., Macharis, C., Van Mierlo, J., & Vanhaverbeke, L. (2018). Total Cost for Society: A persona-based analysis of electric and conventional vehicles. *Transportation Research Part D: Transport and Environment*, *64*, 90-110.

41.Eldeeb, G., & Mohamed, M. (2020). Understanding the transit market: A persona-based approach for preferences quantification. *Sustainability*, *12*(9), 3863.

42.Gargiulo, E., Giannantonio, R., Guercio, E., Borean, C., & Zenezini, G. (2015). Dynamic Ride Sharing Service: Are Users Ready to Adopt it? *Procedia Manufacturing*, *3*, 777–784. https://doi.org/10.1016/J.PROMFG.2015.07.329

43.Hildén, E., & Väänänen, K. (2019). Communicating User Insights with Travel Mindsets and Experience Personas in Intra-city Bus Context. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *11749 LNCS*, 34–52. https://doi.org/10.1007/978-3-030-29390-1_3/FIGURES/3

44.Mueller, A., Beyer, S., Kopp, G., & Deisser, O. (2020). User-Centered Development of a Public Transportation Vehicle Operated in a Demand-Responsive Environment. *Advances in Intelligent Systems and Computing*, *964*, 545–555. https://doi.org/10.1007/978-3-030-20503-4_49/COVER

45.Kong, P., Cornet, H., & Frenkler, F. (2018). Personas and emotional design for public service robots: A case study with autonomous vehicles in public transportation. *Proceedings - 2018 International Conference on Cyberworlds, CW 2018*, 284–287. https://doi.org/10.1109/CW.2018.00058

46.Le Boennec, R., Da costa, P., & Nicolaï, I. (2019). *Assessing 50 innovative mobility offers in low-density areas: A French application using a two-step decision-aid method*. *November*. https://doi.org/10.1016/j.tranpol.2019.08.003

47.Le Dréau, A. & Le Boennec, R. (2020). *Observatory of new mobility offers: methodological insights and French application. Webinar of the International Association for Energy Economics (IAEE), May 2020*

48. Insee. (2023). Découpage infracommunal. Table d'appartenance géographique des IRIS. https://www.insee.fr/fr/information/2017499

49.CERTU. (2013). *Handicaps et usages Certu CETE Nord Picardie Certu 2013/74*.

50.Observatoire départemental des données sociales, S.-S.-D. (2021). *Les personnes en situation de handicap en Seine-Saint-Denis*.

51.Allio, R., & Bertrand, J. (2005). L ' INFORMATION DESTINÉE AUX PERSONNES À MOBILITÉ RÉDUITE. *Institut Paris Région*.