A user-centric multi-criteria evaluation of mobility solutions for people with psychiatric disabilities using data-driven persona

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SHORT SUMMARY

This study aims at identifying which mobility solutions are most suitable for addressing the particular needs of people with psychiatric disabilities. We developed a 3-step evaluation framework: (1) development of a dataset (operator data and qualitative monitoring), (2) analysis of supply and demand of mobility solutions for people with psychiatric disabilities, and (3) processing of a multi-criteria decision analysis. This framework is used to analyze the 'PAM' service, an on-demand mobility solution specifically intended for people with disabilities in Seine-Saint-Denis (Paris region, France). The results highlight the strong performance of on-demand transport services in supporting routine mobility needs, while underscoring the importance of robustness to preference and evaluation uncertainty in service assessment. From a policy perspective, the framework provides local authorities with evidence-based recommendations to compare mobility solutions and support the design or renewal of services better aligned with the specific needs of people with psychiatric disabilities.

Keywords: People with disabilities; On-demand mobility; Multi-criteria decision analysis; Latent class analysis; Persona; Travel behavior.

1. INTRODUCTION

Climate disruption and rapidly changing societal conditions accelerate transformations in mobility practices and intensifying the need for equitable transport systems. Equity is understood as the fair distribution of transportation benefits (e.g., access, speed, comfort) and costs (e.g., fares, time, pollution exposure) across population groups (Bruzzone et al., 2023). Equity is a central objective in transport planning and is particularly critical for people with psychiatric disabilities. In France, 8.7% of the population aged 15 or older report at least one severe limitation in sensory, mental, cognitive, or psychological functions (DREES, 2023). Yet, despite growing interest in disability and transport, most studies focus on identifying needs and barriers rather than evaluating how specific mobility solutions perform for this user group.

To compare mobility solutions, multi-criteria decision analysis (MCDA) is widely used for transport infrastructure and services (Broniewicz and Ogrodnik, 2025). However, it has rarely been applied to disability-related mobility. At the same time, user segmentation tools such as personas are increasingly used in transport to represent heterogeneous travel behaviors and guide service design (Vallet et al., 2020). Personas are often created through clustering methods (Salminen et al., 2020) such as Latent Class Analysis (LCA) (Vermunt and Magidson, 2002).

This study combines LCA persona-based segmentation with MCDA to evaluate mobility services for people with psychiatric disabilities using operational data. We address key research gaps: (1) Proposing a user-centric multi-criteria decision analysis focusing on mobility solutions for people with psychiatric disabilities (2) Enriching the MCDA with persona definition using both real operating data and insights from academic literature.

2. METHODOLOGY

The general framework for evaluating mobility solutions for people with psychiatric disabilities is presented in Figure 1.

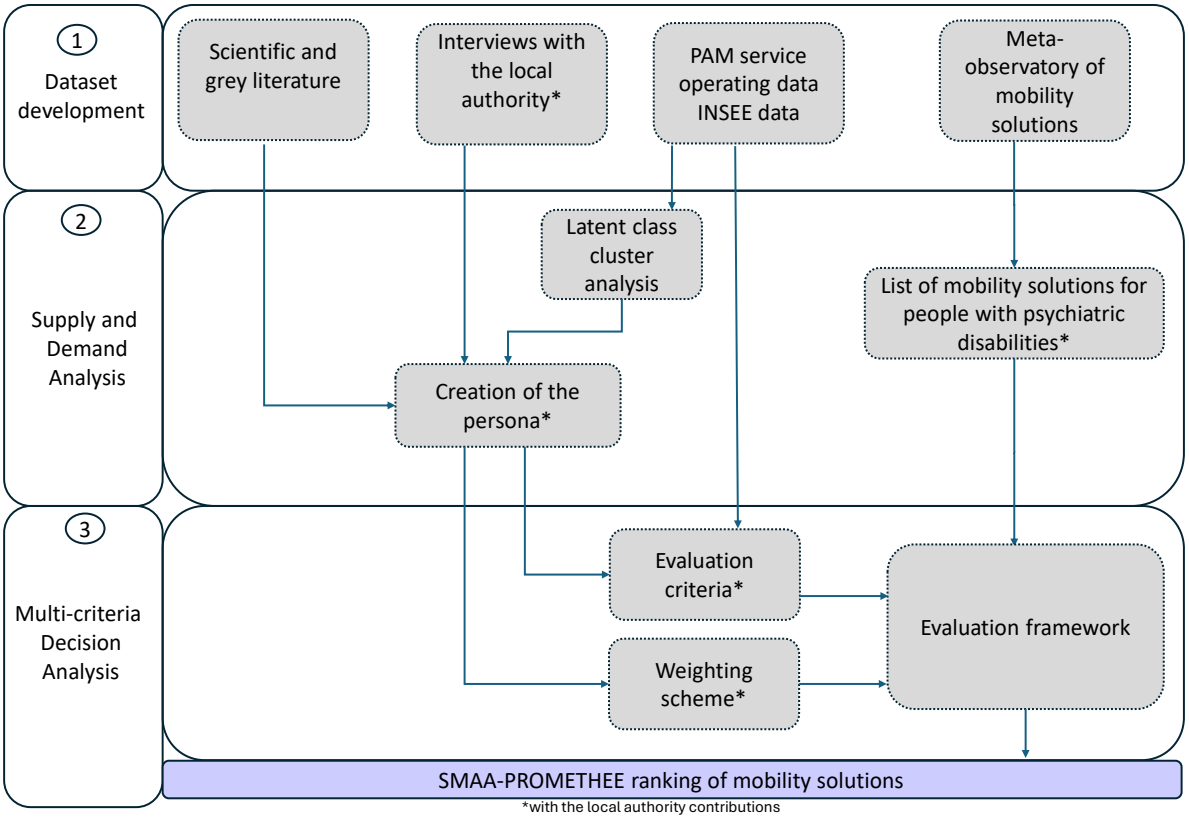


Figure 1 : a 3-step methodological framework

We adopt a 3-step methodological framework, First, the dataset is built (1), then we provide a supply and demand analysis (2) to finally build the MCDA framework (3). The local authority contracts the operation of the service to a dedicated operator. The service operator data are used to process a LCA in order to identify trip categories (33197 trips for the year 2018). Methodological reviews highlight sensitivity to variable selection and the need to complement quantitative outputs with qualitative insights when using clustering methods (Salminen et al., 2020). The LCA is then completed with qualitative information about people with psychiatric disabilities'needs gathered from scientific and grey literature and interviews with the local authority to build a user persona. Doing this offers a probabilistic and user-centric approach to identify behavioral segments from travel patterns. In parallel, the meta-observatory of new mobility solutions (Le Boennec et al., 2019) allowed us to select a first list of criteria and mobility solutions to be discussed with the local authority.

By analyzing the persona, evaluation criteria from the meta-observatory were adapted based on user needs, the operating data of the PAM service, and the objectives of the local authority (Fig. 1). Criteria weights were defined using verbal statements method on a three-level scale ("not a priority", "important", "very important"). Mobility solutions were then evaluated on a five-point scale, and weights and scores were subsequently discussed and consolidated during a workshop. This evaluation frame is then used to process the MCDA with the SMAA-PROMETHEE methods. While PROMETHEE–GAIA (Brans et al., 1986) provides a deterministic representation of preferences based on fixed weights, Stochastic Multiobjective Acceptability Analysis (SMAA) extends this framework by incorporating uncertainty to ensure the robustness of the evaluation (Corrente et al., 2014). In SMAA, weights and, when relevant, evaluations are treated as random elements.

This stochastic formulation thus systematically accounts for uncertainty in weights and/or evaluations and yields a statistically grounded assessment of robustness and preference sensitivity for PROMETHEE II rankings. We defined 6 alternatives scenarios of uncertainties (Table 1).

Table 1. Scenario description

Scenario name	Inputs perturbed	Main purpose	Weight priority rule[1]	Score noise[2]
S_1	Weight only	Baseline with the tightest weight constraints: checks whether the winner holds when priorities are strictly non-overlapping	Strict	None
S_2	Weights only	Baseline with a permissive weight space: tests sensitivity to imprecise priorities without score noise	Flexible	None
S_3	Weights + scores	Assesses joint uncertainty when priorities are strictly ordered, showing whether strict priorities buffer moderate score noise	Strict	±1 (15% / 70% / 15%)
S_4	Weights + scores	Stress test under strict priorities: persistence of leaders here signals strong robustness to score noise	Strict	±1 (25% / 50% / 25%)
S_5	Weights + scores	Quantifies the combined impact of preference imprecision and realistic rating noise, indicating shortlist stability	Flexible	±1 (15% / 70% / 15%)
S_6	Weights + scores	Maximal uncertainty (widest weight space + strongest score noise)	Flexible	±1 (25% / 50% / 25%)

[1]Weights priority: Strict: total weight of "Not a priority" < "Important" < "Very important". Flexible: each "Important" criterion has a higher weight than any "Not a priority" criterion, and each "Very important" criterion has a higher weight than any "Important" criterion. [2]Score noise: Scores vary by -1 or +1. For scenario S3, 15% are lower by 1, 70% unchanged, 15% increase by 1.

SMAA-PROMETHEE was performed using Rstudio software (R version: R- 4.3.3, 2025).

3. RESULTS

3.1 Mobility solutions to assess

In addition to conventional modes of transport (i.e. public transport, active modes), we used the meta-observatory of new mobility solutions, completed with an international benchmark and discussions with the local authority. The final set of solutions comprises public transport, walking, the PAM service, assisted use of public transport, and pedicabs.

Within the PAM offer, a distinction is made between grouped and non-grouped trips, depending on whether ridesharing is imposed on users. Variants also differ by powertrain (thermal or electric). In addition, the evaluation includes an enhanced dynamic electric PAM configuration based on optimization algorithms, although this option has not yet been implemented in practice.

3.2 LCA results and persona creation

A LCA was conducted and revealed four distinct mobility patterns. The resulting classes are presented in Figure 2.÷

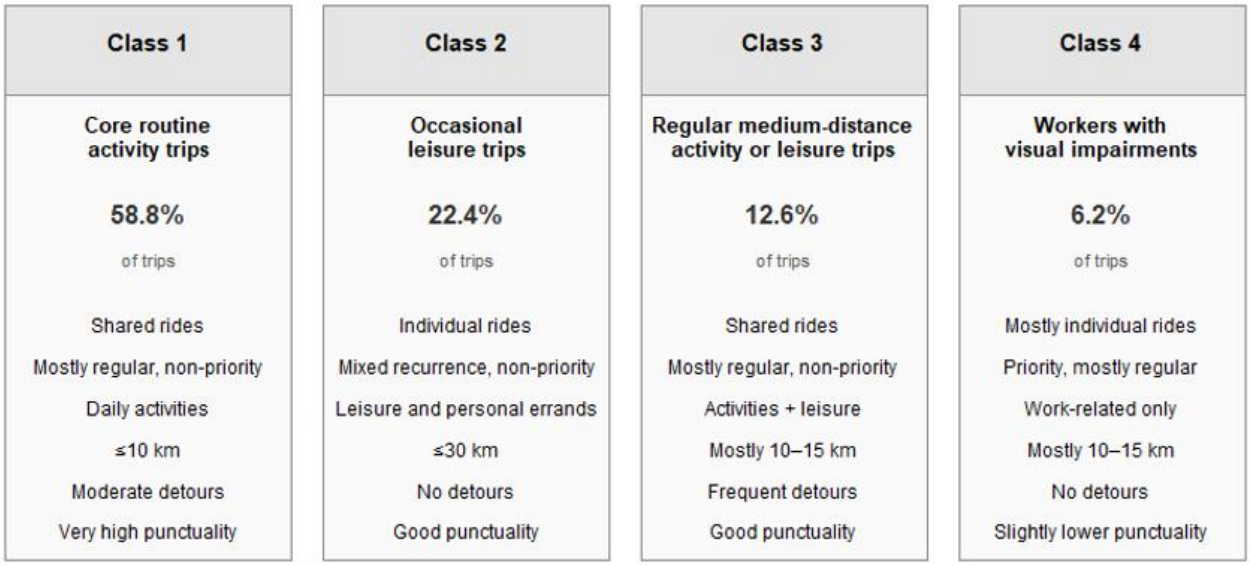


Figure 2: LCA results – class identification

The results suggest that the dominant operational pattern in the dataset (Class 1) corresponds to high-volume, schedulable sharing on short links for recurrent activities. The persona creation was then based on this class.

Since no information was given about user profiles in the data, we completed this quantitative analysis of trip segments by a qualitative analysis of the particular needs of people with psychiatric disabilities.

Three recurring mobility difficulties specific to people with psychiatric disabilities were identified through interviews with the local authority and academic and grey literature (see Fig. 1). First, unplanned route disruptions can generate confusion and disorientation, increasing the risk of unsuccessful trips. Second, reading and interpreting travel information (such as signage, schedules, or maps) may hinder navigation and create additional stress during journeys. Third, purchasing tickets from automated machines can be challenging. Public transport may also involve uncertainty when boarding or alighting, waiting at stations, or interacting with other passengers.

Based on these findings, a persona (Figure 3) was developed by combining (1) travel behaviors derived from LCA results, (2) the mobility objectives and challenges identified, and (3) perceptions of the PAM service.

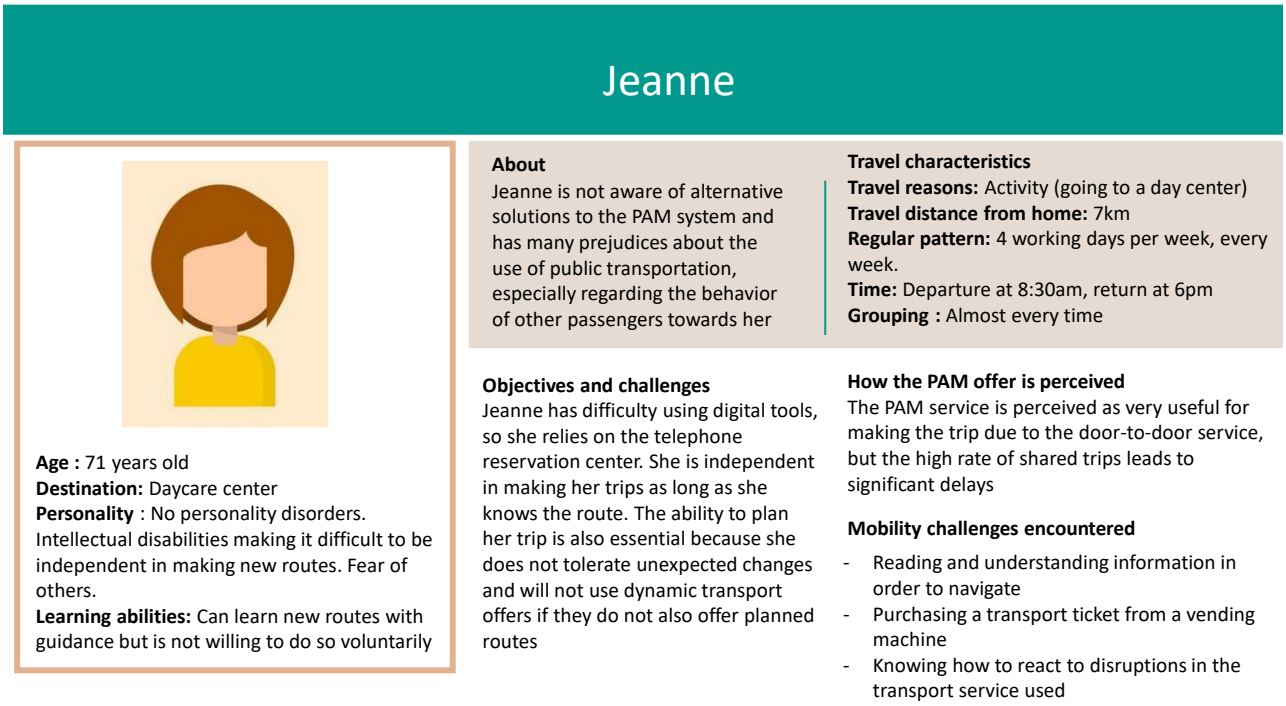


Figure 3. Illustration of a persona created for people with psychiatric disabilities.

3.3 Evaluation criteria definition, weighting and scoring

Based on this persona and the meta-observatory framework, evaluation criteria were defined in line with user needs, PAM operating data, and the objectives of the local authority (Fig. 1). Table 2 summarizes the criteria, weights, and performance scores used in MCDA.

Table 2. Evaluation framework for people with psychiatric disabilities

	(1) GHG emissions	(1) Air quality	(1) Ease of implementation for the LTA	(2) Cost	(2) Safety	(2) Physical accessibility	(2) Comfort	(2) Availability	(3) Digital accessibility	(3) Travel time	(3) Planning	(3) Required autonomy
Current PAM Service Grouped	1	1	5	4	5	5	4	5	5	5	5	5
Current PAM Service	2	2	5	4	5	5	3	5	5	3	5	5
Electric PAM Service Grouped	4	3	4	4	5	5	4	5	5	5	5	5
Electric PAM Service	4	3	4	4	5	5	3	5	5	3	5	5
Pedicab	5	5	2	4	1	1	1	5	3	3	5	3
Assistance when using public transportation	5	5	3	5	4	4	4	4	3	3	4	4
Dynamic on-demand transport	1	1	5	5	5	5	4	5	5	5	5	5
Conventional public pransportation (bus,train)	5	5	4	5	2	3	4	4	4	3	4	2
Walking	5	5	4	5	3	3	3	5	4	1	5	3

Note: Importance of each criterion: (1)'Not a priority', (2)'Important' and (3)'Very important'; PAM = Pour Aider à la Mobilité

3.4 MCDA

We then proceeded to the SMAA-PROMETHEE analysis. Table 3 and 4 compare the results for the 6 scenarios, indicating:

- The probability of being ranked 1 and to be in the top 3 (Table 3)
- The average net PROMETHEE II flows (Table 4)

We highlight alternatives that have at least 25% probability of being ranked 1 or 50% probability of being in the top 3 in each scenario. These cut-offs are far beyond Monte-Carlo error with 10,000 draws (Standard Error <0.005) and balance statistical and practical relevance, identifying credible winners and options more likely than not to appear on the top 3 short-list.

Table 3: Rank 1 probability by scenario, with Top-3 probability shown in parentheses.

Mobility solution	S1	S2	S3	S4	S5	S6
Dynamic on-demand transport	100,00% (100,00%)	82,29% (98,34%)	63,48% (88,19%)	48,92% (83,90%)	50,44% (81,34%)	39,00% (75,94%)
Electric PAM Service	0,00% (100,00%)	17,41% (97,87%)	18,98% (73,98%)	22,96% (70,10%)	27,73% (75,13%)	29,02% (70,20%)
Current PAM Service	0,00% (99,57%)	0,00% (68,45%)	12,60% (68,48%)	17,91% (65,48%)	10,05% (58,77%)	14,64% (56,37%)
Grouped Electric PAM Service	0,00% (0,43%)	0,00% (27,33%)	3,02% (37,13%)	5,73% (40,92%)	7,81% (44,00%)	10,37% (46,34%)
Grouped Current PAM Service	0,00% (0,00%)	0,00% (3,53%)	2,10% (31,94%)	4,50% (37,38%)	3,01% (32,91%)	5,26% (36,71%)
Walking	0,00% (0,00%)	0,30% (3,25%)	0,01% (0,12%)	0,00% (0,65%)	0,57% (3,63%)	0,64% (5,12%)
Assistance when using public transportation	0,00% (0,00%)	0,00% (0,95%)	0,00% (0,14%)	0,00% (1,26%)	0,33% (2,59%)	0,73% (5,77%)
Conventional public transportation (bus,train)	0,00% (0,00%)	0,00% (0,01%)	0,00% (0,04%)	0,01% (0,28%)	0,15% (1,29%)	0,34% (2,79%)
Pedicab	0,00% (0,00%)	0,00% (0,27%)	0,00% (0,00%)	0,00% (0,04%)	0,02% (0,40%)	0,02% (0,76%)

Table 4. PROMETHEE II flows obtained for the six scenarios

Mobility solution	PROMETHEE II flows by scenario					
	S_1	S_2	S_3	S_4	S_5	S_6
Dynamic on-demand transport	0,33	0,28	0,27	0,24	0,23	0,21
Electric PAM Service	0,23	0,21	0,21	0,19	0,19	0,18
Current PAM Service	0,22	0,18	0,20	0,18	0,16	0,14
Grouped Electric PAM Service	0,16	0,15	0,14	0,12	0,13	0,12
Grouped Current PAM Service	0,16	0,13	0,13	0,11	0,11	0,09
Walking	-0,14	-0,11	-0,16	-0,16	-0,13	-0,13
Assistance when using public transportation	-0,28	-0,24	-0,21	-0,16	-0,18	-0,14
Conventional public transportation (bus,train)	-0,32	-0,30	-0,29	-0,27	-0,27	-0,26
Pedicab	-0,36	-0,31	-0,29	-0,25	-0,25	-0,21

Note: PAM = Pour Aider à la Mobilité

Robustness was assessed across six SMAA–PROMETHEE scenarios (Table 4), ranging from strict weights (S1) to flexible priorities with strong evaluation noise (S6). Dynamic on-demand transport consistently ranks first, with electric PAM service as the main challenger and the current PAM service as a conditional third option. Rank acceptability remains concentrated on the two leading alternatives. Overall, the results support a robust short-list composed of dynamic on-demand transport and electric PAM service, while the current PAM service remains a contingent option.

4. DISCUSSION

Mobility research commonly relies on household travel surveys linking socio-demographic characteristics with self-reported travel behavior (Lawson et al., 2023) sometimes complemented by interviews or focus

groups (Mars Aicart et al., 2016). However, for populations with psychiatric disabilities these approaches raise methodological and ethical concerns, as they are resource-intensive and prone to non-response and representativeness biases (Delbosc and Currie, 2010). This study therefore adopts a trip-based analysis to characterize service-use patterns while avoiding additional burden on user.

From a demand-side perspective, mobility segmentation commonly relies on distance-based clustering (e.g., k-means or hierarchical clustering) applied to socio-demographic variables (Salminen et al., 2020). In contrast, this study uses latent class analysis (LCA) to segment trips based on categorical service-use characteristics, allowing probabilistic class membership. The resulting classes reflect observed service-use patterns rather than latent mobility needs or preferences under alternative service configurations.

MCDA methods structure alternatives, criteria, and trade-offs to support transport decision-making (Broniewicz and Ogrodnik, 2025). Deterministic approaches such as PROMETHEE, AHP, or TOPSIS rely on fixed scores and precise weights, implicitly assuming certain evaluations and well-defined stakeholder preferences. In participatory contexts, however, preferences are often incomplete or imprecise. This study therefore applies SMAA-PROMETHEE, allowing the identification of alternatives that remain robust under preference and evaluation uncertainty (Corrente et al., 2014).

5. CONCLUSION

This study identifies mobility solutions suited to people with psychiatric disabilities. We use a three-step protocol combining operational data, qualitative insights, and multi-criteria decision analysis. Results show that the current PAM service ranks among the three most suitable options given both user needs and local authority constraints, though improvements such as vehicle electrification or service optimization remain possible. Lower-ranked solutions may still serve niche or last-mile functions.

Methodologically, linking trip-based personas with SMAA-PROMETHEE supports decision-making under preference and evaluation uncertainty for the design of mobility services tailored to the specific needs of people with disabilities. However, results depend on the specification of admissible weights, and important health-related dimensions remain outside the available data. Future work should integrate these factors and apply the framework to other mobility-constrained populations.

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