Reyes Madrigal *et al.*
European Transport Research Review 2023, **15**(1):13
https://doi.org/10.1186/s12544-023-00585-2

European Transport
Research Review

ORIGINAL PAPER **Open Access**

Pedestrian mobility in Mobility as a Service (MaaS): sustainable value potential and policy implications in the Paris region case

Laura Mariana Reyes Madrigal[1,2*], Isabelle Nicolaï[1] and Jakob Puchinger[3,1]

Abstract
Pedestrian mobility remains neglected in MaaS solutions, yet it has the potential to become a tool for promoting public policies and more sustainable lifestyles away from excessive private car use. This research identifies the potential for sustainable value creation and the transversal implications for policymakers and other MaaS stakeholders of overlooking walking in innovations like MaaS. To do so, we explore how walking is currently integrated into four MaaS solutions in the Paris region. Our main findings show heterogeneity in the hierarchy given to walking in the user interfaces and the determinant roles of governance and policy in supporting the prioritization of pedestrian mobility in MaaS.

Keywords Mobility as a service, MaaS, Walking, Pedestrian mobility, Sustainable mobility, Inclusion, Active mobility, Sustainable value, Public policies, Governance

1 Introduction

In the context of global social, energy, and health crises aggravated by climate disruptions, joint efforts towards encouraging and prioritizing sustainable mobility practices have become a matter of preserving life on earth. Only in France, transportation represents a third of the overall production of greenhouse gas (GHG) emissions. 54% of those emissions are due to private cars [29]. Additionally, 13% of the French household's total consumption budget goes to transport expenditures [56]. Currently, several strategies are being undertaken to transition from our present mobility schemes to more sustainable practices that enable fair access to opportunities for everyone through social, environmental, and economic enhancements [54, 88]. Walking, cycling and other human-powered travel modes have the potential to counterbalance inequitable mobility dynamics, mostly car-based, currently reinforcing global warming and the crises mentioned above. As of 2020, active modes represented 42% of the total number of trips in the Île de France (ÎdF) region (18 of more than 43 million daily trips), 40% of which were walking trips [47].

Around 2014, Mobility as a service (MaaS) arrived to propose a radical shift in mobility practices away from the private car. In this research, we define MaaS as a human-centered technological and organizational innovation aiming to improve mobility access and management by integrating data from different mobility-related services and providing users with real-time information, navigation, booking, and payment features [41, 49, 51, 82, 91]. This innovation was rapidly considered as a potential solution for more sustainable urban mobility practices by simplifying and facilitating access to different mobility services and enabling a modal shift from private cars toward shared and less pollutant mobility [5, 13, 36, 67, 78, 86].

*Correspondence:
Laura Mariana Reyes Madrigal
mariana.reyes@centralesupelec.fr
[1] Laboratoire Génie Industriel (LGI), Université Paris-Saclay, CentraleSupélec, 91190 Gif-sur-Yvette, France
[2] Anthropolis Chair, IRT SystemX, 91120 Palaiseau, France
[3] Present Address: EM Normandie Business School, Métis Lab, 92110 Clichy, France

Nonetheless, many challenges are still ahead for MaaS solutions to become drivers of sustainable mobility. Some of them are the implications brought by different governance configurations in the MaaS ecosystems [8, 34, 44, 100]; the access, sharing and ownership of data [31, 39, 74]; the effects on modal share distribution [3, 6, 90]; the potential of walking in MaaS [63, 77, 82), the link with the built environment and its role on individual perceptions [26, 38, 97], and the lack of tailormade frameworks to evaluate MaaS impacts [14, 57, 106, 107].

We approach sustainable mobility through the lens of MaaS and propose to advance knowledge on walking as a key enabler of sustainability and sustainable value creation. Our research builds upon the work of Lyons [63], who first illustrated the concept of "Walking as a Service," where the author described the economic and non-economic potentials of digital navigation aids for pedestrians. The originality of our work lies in the comparative case study focused on the analysis of User Interfaces of MaaS in the Paris region and the transversal analysis perspective of interrelated implications for policy and sustainability. We depict the current status of walking in MaaS as a utilitarian active travel mode that does not require significant resources and could catalyze more sustainable mobility practices [32, 69]. In addition, we highlight walking as the basis of intermodal travel chains, which we identified as highly relevant, considering that an average of 94% of users in urban cores join public transport (PT) by foot [43]. Our research answers the following research questions:

- *What is the status quo of walking in MaaS in the Paris region?*
- *How is walking in MaaS relevant to create sustainable value?*

To address these questions, the article is organized as follows: First, we provide a research background to identify the opportunities and knowledge gaps for the inclusion and appraisal of walking in MaaS. We do this by looking into the role that walking has in the context of sustainable mobility, its place in digital tools, and its potential for sustainable value creation in MaaS. Second, we present the research design and method choices. Then, we delve into the analysis of the empirical data and compare the walking features and information provided by four MaaS solutions in the Paris region. Finally, we interpret the results and discuss the transversal sustainability implications of our findings at a macro level, leading to the paper's conclusions, where we provide future research perspectives.

2 The role of active modes in MaaS for sustainable mobility

There are different drivers for MaaS to become an ally of social well-being, health, the environment, and everyone's pocket; two of these drivers are walking and cycling. Fast-paced urban lifestyles like sedentariness linked to car-based transportation, new home office practices, and access to processed junk food at low costs, especially in urban environments, are some of the factors provoking a widespread health emergency [101]. Active mobility has been historically carried out by modes requiring human energy [59] and "trained bodily movement" to function [87, p. 289]. However, the definition of "active modes" is under debate since the upsurge of micromobility engines such as e-kick scooters or e-unicycles. These motorized micromobilities, also referred to as "electric-powered micro personal mobility vehicles (e-PMVs)" [19, p. 1] could, or not, be considered active modes since they require balance and strength while providing impulse through an electric engine. In 2020 Paris launched a call for candidates where shared e-kick scooter operators participated to be among the three only providers of these services, putting micromobility services at the same level as shared bikes [95]. Now, five years later, the ongoing discussion is banning their use, mainly due to the elevated friction between other modes and infrastructure uses [96].

2.1 The importance of walking in MaaS

A lack of attention in scientific discussions to the role of walking and cycling in MaaS has been identified [63, 65, 93]. Nevertheless, the vast majority of trips made by PT require walking to start, connect, and finish the journey, as shown by Hillnhütter [42]. At least 22% of the PT journeys in the Paris region require reliable information on pedestrian navigation [46]. From a financial point of view, walking and cycling represent the cheapest mobility options. It has been recognized that walking is the least expensive transport mode and the least pollutant, followed by cycling, PT, and other shared modes [86].

Mulley [73] identified active travel as a way to counterbalance the population's unhealthy life routines and demonstrated how improving health has a positive impact on public expenses and productivity. Positive impacts are also to be found from the environmental perspective since walking and cycling are low-carbon modes that release no tailpipe emissions and enable most travel chains [12]. Active mobility also boosts social well-being, as emphasized by Biehl and Stathopoulos [16], who found a link between active mobility and "neighborhood cohesion and life satisfaction". The positive impacts were found not only at a micro-level but also at a macro-level. One of the main factors for the success of active modes in MaaS is the "seamless integration" of modes, ensuring travel quality and becoming an aspect of competitiveness face to the private car and the comfort it offers.

Lyons et al. [64] developed the term "Combo travel" to reinforce the existing links between active travel (e.g., walking, jogging, running, cycling) and the rest of the modes in the transport system through better information and tailored policies. The lack of innovation concerning the health-related functionalities of "physical activity trackers" and the integration of active travel and private car trips are recognized as research gaps.

2.2 The presence of walking in digital tools

Digital applications are only the interface of different human needs decoded into new tools, where users "dialogue with an informatic system to obtain responses, solve problems or needs and make choices" ([75], p. 180). The importance of digital mobility solutions like MaaS lies in creating awareness among users and encouraging more sustainable mobility practices. Objectively, it has been found that using these digital tools to promote sustainable travel could lead to increases of up to 14% in sustainable mobility choices [37]. Pangbourne et al. [77] classified digital tools incorporating walking incentives based on health, economic, environmental consciousness, and emotional responses. Authors found in the literature three types of solutions [37, 50, 77, 105]: "Digital travel assistants," "Gamification systems" and "Self-monitoring systems." MaaS belongs to "digital travel assistants" since it provides information, travel features, global positioning system (GPS) navigation assistance, and the possibility to choose between transport modes. Gamification strategies, like group challenges and objectives, are among the most common strategies applied to digital transport solutions [98] and digital health applications [9] and could be integrated into MaaS to promote walking. In 2020, Lyons developed the concept of Walking as a Service (WaaS), where he defines that the main differences between MaaS and WaaS are based on their business models (BM). For WaaS, BM is based on selling access to places and "geography," whereas for MaaS, it is access to integrated mobility services that is being sold. The author illustrates the "WaaS circle of virtue," conformed by five main elements: investment in walkability, improvement in navigability, increase in walking, increase in profit, and economic growth. The presence of walking in digital tools illustrates the potential for MaaS to integrate extra functionalities to improve users' travel experience and contribute to sustainable value creation.

2.3 Sustainable value creation potential

Little scientific production has focused on analyzing the role of walking in the creation of MaaS' sustainable value and sustainable business models (SBM). However, previous research approaching sustainable value creation could help to build a framework to measure the sustainable value brought by walking in MaaS. Sarasini et al. [86] explored how MaaS could bring sustainable value. *Sustainable value* is defined as value created beyond direct economic profits. Bocken et al. [18] defined business models for sustainability as innovations facilitating the reduction of adverse environmental impacts built by shifting value creation paradigms towards creating multiple types of value. Another perspective by Maas [65], recommends "(…) healthy behavior through credits or the avoidance of journeys" to tackle the question of mobility sufficiency [65, p. 21], also discussed by Vaddadi et al. [94]. This could work as a mechanism to control the induced demand of PT for short trips that MaaS could generate and create a state of mobility awareness where trips are made not because there is unlimited access but because of an informed choice helping solve a human need.

Value creation from the appraisal of active modes can have several direct and indirect positive impacts in multiple sectors. Litman [58] described a set of indicators to measure the economic impacts from improved "walking conditions" like accessibility, cost savings for individuals and for public authorities, efficiency in land use, livability, public health, equity, and economic development [58, p. 3]. Still, public health impacts are among the most discussed in the literature since they are a current global concern [33, 52, 53, 71]. The consequences of sedentary lifestyles cost not only lives but also amounts of money that go from 0.8 to 2.4% of the gross domestic product of Australia, Brazil, India, Mexico, Saudi Arabia, South Africa, Spain, and Thailand [76].

The strategy of the region of Brussels is an exciting example of approaching sustainable value creation through active modes. Firstly, they recognize the risk of new mobility services substituting active modes and PT [22]. Secondly, Brussels Mobility has set specific strategies like communicating the "excellent cost-effectiveness ratio" of walking and cycling infrastructure, the economic benefits for local commerce, and the health benefits that translate to social security savings (Ib., p. 55).

Even though walking is perceived as a seemingly non-monetizable mode, finding a BM has been the focus of applications that target incentive features like local coins in exchange for a certain number of daily steps. This model includes monetary incentives in partnership with local shops, increasing value capture for commerce, the app operator, and the users [9]. These are some leads towards developing a sustainable value-creation model for walking in Maas.

3 Methodology

We use a qualitative inductive approach [99] to explore the form in which pedestrian mobility is currently offered and integrated through MaaS. We carried out an embedded single case comparative study collecting primary data and using secondary data to set the bases of the research objects [102]. We addressed the main results through an analysis of the comparative case study results using the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis matrix [15]. This allowed us to gain insights on the main "opportunity spaces" or potentials ([70], p. 28) to tackle through the improved presence of walking in MaaS. Lastly, we analyzed the results with a STEEPL-based (Social, Technological, Economic, Environmental, Political, and Legal model that also guided the discussion and the transversal implications and potentials [24, 103, 104].

3.1 Method

We conducted a case study to identify the current presence of walking information in MaaS in the Paris region (ÎdF). Four MaaS solutions were chosen as multiple embedded units of analysis. A test itinerary request was effectuated, and the presence of walking in the itinerary suggestions retrieved was analyzed based on the disposition of features offered through the UI of MaaS. The test trip was effectuated the same day in all the apps, using the Android Operative System (OS) version, and it was illustrated using a trip in Paris, where PT is available. The itinerary requests were set at a fixed departure date and time at 18 h the next day for standardization of the search results.

3.2 Selection of MaaS solutions

The MaaS solutions were selected from the database of 28 identified MaaS available in the territory of ÎdF according to the benchmark made by the CEREMA's observatory of MaaS. The observatory of MaaS is a strategic partnership for building knowledge on MaaS coordinated by the French National Center for Studies and Expertise on Risks, the Environment, Mobility, and Development [25]. In the benchmark done by the observatory, three types of service integration were identified: (1) non-identified, Multimodal Information Systems (MIS), and MaaS. Under our approach, MIS is equivalent to level 1 MaaS on the scale of Sochor et al. [91], meaning that at least basic or advanced navigation features of mobility services for more than one mode. Based on the benchmark made by the observatory, we chose four MaaS solutions among the ones available in the region of ÎdF. We considered the nature of the project owner to classify the solutions as public or private, independently of the system operators sub-hired. Two of the selected MaaS are run by private companies, "Google Maps" and "Citymapper". The other two are "IDFM App," carried by the region's Public Transport Authority (PTA), and "Bonjour RATP" operated by the Public Transport Operator (PTO) "RATP" and developed by the subsidiary company "RATP Smart Systems".

3.3 Analysis framework

We identify how information is offered through the apps' when an itinerary is requested. We look at information offered for fully walking trips and PT trips to and from Paris. We analyzed the layout of menus and buttons to access the modes and itineraries. This first step of our analysis is based on universal design principles [21, 66, 92]. *Universal design* is defined by [62, p. 12] as a "design that meets broad needs". We also integrate basic design principles for the user experience, which are used for communicating structure and hierarchy and recommend to adapt placement to communicate priority to the analysis [10, 17, 62, 75]. We synthesize our results with a SWOT model [15]. Lastly, we organize our discussion with a STEEPL-based model to analyze the sustainability and policy implications for the construction of sustainable MaaS through the improvement of the walking offer. We consider that the six dimensions in the STEEPL framework help provide a transversal panorama of the social, environmental, and economic sustainability dimensions [35], incorporating technological and political dimensions as well.

4 Case study results

In this section, we identify the main characteristics of the MaaS studied (Table 1). We observed two key stakeholders for the creation and implementation of MaaS which also impact the overall MaaS objectives: the system operator and the project owner.

4.1 Governance and main characteristics of the studied MaaS

Governance dynamics differ across MaaS solutions, where governance models are still being designed or tested. Understanding the configurations and dynamics between stakeholders is essential to identify their roles in the service design and deployment of the MaaS solutions [89]. The way these processes are approached tends to

Table 1 MaaS solutions characteristics

MAAS PLATFORM/ INDICATORS	A. Bonjour RATP	B. IDFM app	C. Google Maps	D. Citymapper
COMMERCIAL LOGOTYPE				
PROJECT OWNER[1]	RATP (Paris PTO)	IDFM (Regional PTA)	Google (Alphabet Inc).	Citymapper Ltd
GOVERNANCE[1]	Semi-public	Public	Private	Private
JURIDIC STATUS	Industrial or Commercial Public Establishment (fr. EPIC, FR.)	Public Administrative Establishment (fr.EPA, FR.)	Limited liability company (LLC, US)	Private limited company (Ldt., UK)[4]
GLOBAL DEPLOYMENT SCOPE	Local–Regional	Regional	International, + 200 countries	International, + 80 cities worldwide
DEPLOYMENT IN FRANCE[1]	ÎdF	ÎdF	France	ÎdF and other 7 French metropolitan regions
SYSTEM OPERATOR[1]	RATP Smart Systems	Instant Systems and Capgemini	Google Maps LLC	Citymapper Limited
LEVEL IN SOCHOR'S SCALE[2]	MaaS level 2	Maas level 2	MaaS level 1 (France) MaaS level 2 (USA)	MaaS level 1 (France) MaaS level 3 (UK)
TYPE OF PLATFORM	Smartphone app: Android and iOS	Smartphone app: Android and iOS	Website and Smartphone app: Android and iOS	Website and Smartphone app: Android and iOS
DOWNLOADS[3]	+ 5 M (09/2022)	+ 1 M (09/2022)	+ 10 000 M (09/2022)	+ 10 M (09/2022)

Adapted from [82]

[1] Data from [25]

[2] Classification from [91]

[3] Data from Google Play Store

[4] Data from Companies House (n.d.) [30]

reflect the objectives and interests of the project carrier [81].

For Bonjour RATP (A), the project owner is the Paris Autonomous Public Transport Operator (fr. Régie Autonome des Transports Publics), an "Industrial or Commercial Public Establishment" owned by the French State and financed by state subventions, user fees and other income sources [79]. The system operator of this MaaS solution is the company branch named "RATP Smart Systems," which focuses on developing innovations for intelligent mobility management, ticketing, and travel information.

In the case of IDFM App (B), the project owner is the regional PTA in charge of organizing and financing mobility in IDFM. As a Public Administrative Establishment governed under public law, IDFM receives funding from the region that charges the enterprises of more than 11 agents in the territory of ÎdF a tax for this purpose. The system operator is Instant System, which sells the white brand technological platform [25].

Google Maps (C) is owned by Google (Alphabet, Inc), a private company from USA (LLC). In late 2007, Google Maps launched a smartphone version of Google Maps for Android OS and iOS. The possibility to pay for PT trips in the application started recently in some cities in the United States. Google Maps generates profit by offering services based on suggesting activities and places; these revenues are produced in exchange for user data and commercial partner subscriptions (listings). The provision of maps and navigation tools at no apparent cost for users has generated enormous audiences that generate "advertisement revenue" and become a key component of data updating [68, p. 9].

Citymapper (D) is a United Kingdom-based private limited company (Ltd.), project owner, and system operator simultaneously. Its deployment scope is international, and in France, it offers information for the transport networks of eight metropolitan regions, including the ÎdF.

4.2 Available functionalities in the main screen

Our analysis starts at the home screen of the MaaS UI, where navigation functionalities are provided in the four applications. All four apps (A. Bonjour RATP, B. IDFM App, C. Google Maps, and D. Citymapper) display a navigation map and a retractable tab where an itinerary search text field is found, as well as fast-access buttons to favorite addresses, saved trips, and access to account parameters to set up user preferences as shown in Fig. 1.

Specific functionalities not common to all the interfaces were identified; these included a main screen access button (A, B, C), crowdsourced contributions (A, B, C), safety contact (B), advertisement of nearby places, and recommendations of point of interest (C), access to static

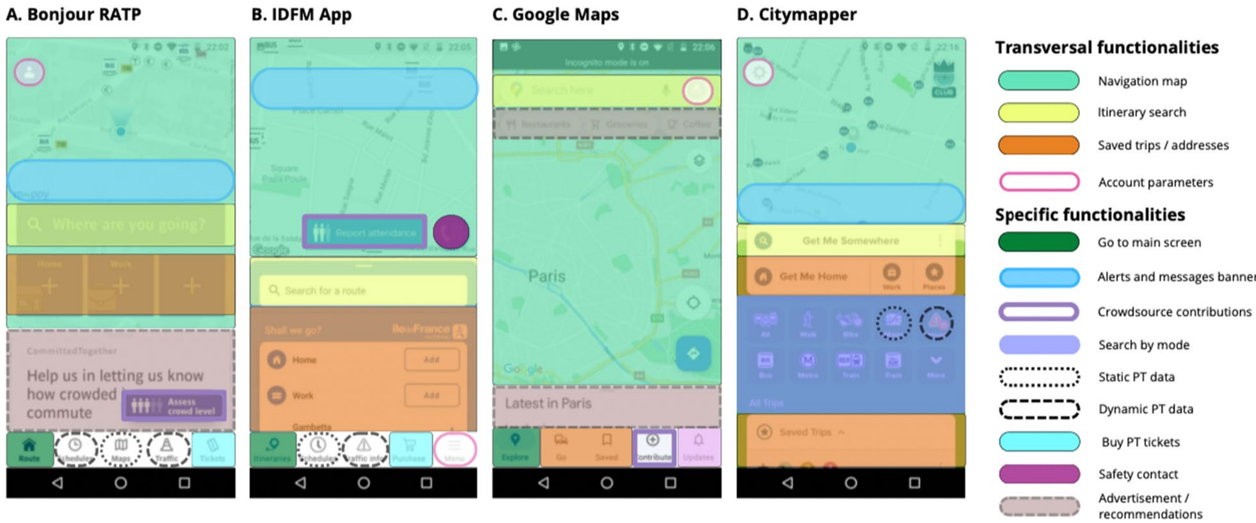


Fig. 1 Main screen: Transversal and specific functionalities. Adapted from [83]

data (transport maps and schedule tables) (A, B, D) and dynamic PT information (real-time frequencies and routes) (A, B, D), search by mode (D) and provision of alerts and special messages through ephemeral banners (A, B, D) (Fig. 1). Only (D) Citymapper provides the overview of all available modes on the first screen through a checkerboard menu, where walking is the second mode displayed (Fig. 1).

4.3 Hierarchization of modes and trip customization parameters

The next step in the user journey leads the user to a second screen where under the origin–destination text fields, a horizontal menu displays available transport modes (referred to as "modes menu" from here onwards) and, according to the mode selected, a list menu with the trip options available is displayed underneath (Fig. 2).

In the test itinerary, we looked at the information delivered for walking itineraries and the walking-related information offered for PT itineraries. All the analyzed MaaS solutions provided different levels of information and customization of travel preferences.

We illustrate the hierarchies given to each mode in the itinerary request screen's UI in Table 2 and describe the results in the following paragraphs. Table 4 with details on the functionalities in each app is available in the "Appendix".

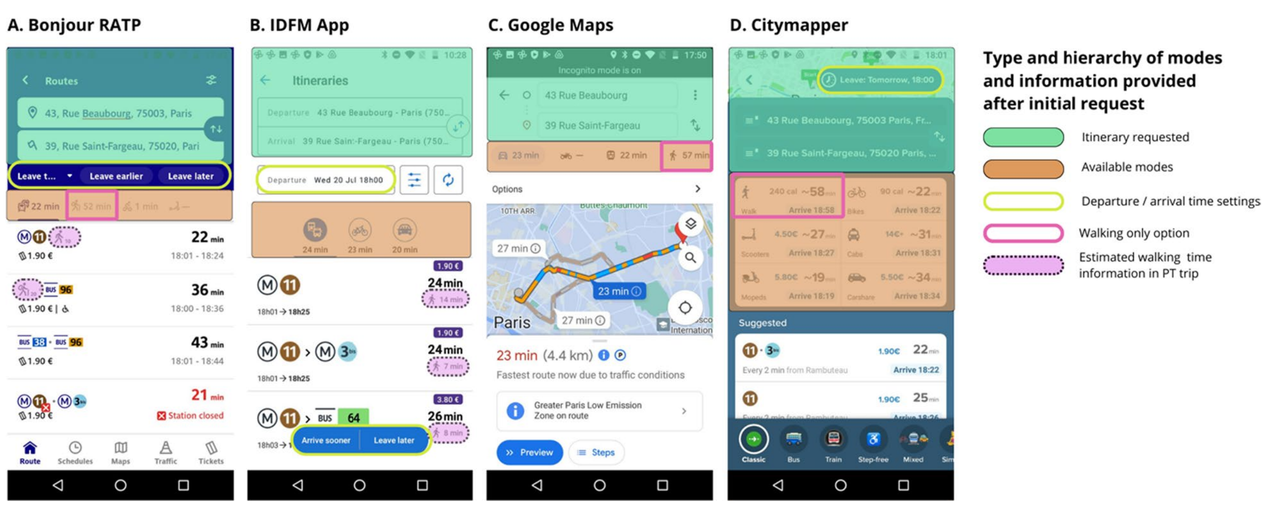
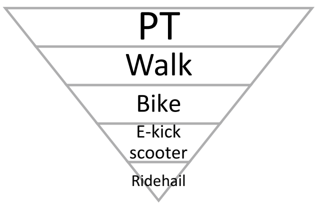
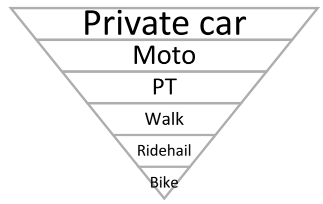
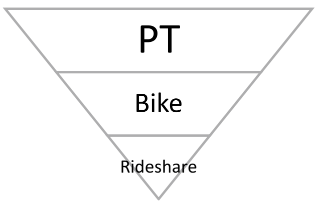
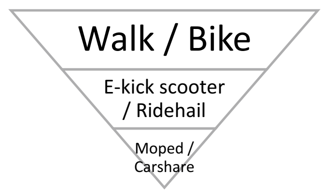


Fig. 2 Second screen: Modes displayed after itinerary request. Adapted from [83]

Table 2 Governance type and displayed hierarchy of modes in the apps' UI[1]

Semi-Public (A)/Public (B)-Led MaaS	Private-Led MaaS (C, D)
(A) Bonjour RATP 	**(C) Google Maps** 
(B) IDFM App 	**(D) Citymapper** [2] 

Source: The authors

[1] In the horizontal menu in the second screen after itinerary request (Fig. 2, in orange)

[2] Menu shown as a checkerboard and not a horizontally scrollable menu

Bonjour RATP offers dedicated buttons for PT, walking, cycling, e-kick scooters, and ridehailing (Table 2). In the test journey, ridehailing was seemingly dismissed due to the programmed departure. For PT itineraries, walking travel times before and after the PT connection appear on the list menu but only for some itineraries (Fig. 4). This seems to be due to the algorithm filtering connections of under 5 min of walking, but this needs further tests. The trip customization options allow users to switch on/off accessible journey results and preferred modes (Fig. 5). While testing this app, a promotional pop-up window offering to participate at a contest to win ridehailing trips by using e-kick scooters was found (Fig. 6).

In contrast, IDFM App provides dedicated buttons in the "modes" menu only for PT, cycling, and carsharing (Table 2). Information on walking itineraries is found at the bottom of the PT itinerary suggestions (Fig. 7). In the test trip, the walking itinerary option appears only if the "Good walker" parameter was previously selected. Total walking time shows for all the PT itinerary suggestions, not specifying if it is before or after PT access. Trip customization options offer to switch on itineraries for wheelchair users and to select a walker type between "Good walker," "Normal walker," or "Walker with difficulties," without specifying the characteristics of each (Fig. 7). IDFM's vision is to use MaaS to reinforce their role as the authority coordinating sustainable regional mobility and the use of PT [46].

Google Maps presents dedicated buttons for car, motorcycle, PT, walking, ridehailing, and cycling itineraries (Table 2). The route options allow users to choose between "best itinerary," "less changes," and "less walking" suggestions, without describing what the elements considered are for the "best itinerary". Other trip options comprise searching for commerce or other facilities along the route and the possibility of adding extra stops (see Table 3). When selecting the itinerary for the test trip, two walking itineraries were offered, along with a trip where shared e-kick scooters (Dott) and shared-bike services (Dott and Lime) were suggested. Other information and features available include step-by-step guidance, photos, and augmented reality. A graphic showing the elevation of the terrain throughout the route is also provided. For PT itineraries, information on the walking time before or/and after the suggested route is provided, as well as three suggestions to effectuate the trip using shared e-bikes or ridehailing instead of PT (Fig. 8).

Citymapper proposes dedicated buttons on a 3×2 grid, where priority is given to walking and cycling according to the row order, then to e-kick scooters and ridehailing, and finally to shared moped scooters and carsharing

Table 3 SWOT synthesis from the results

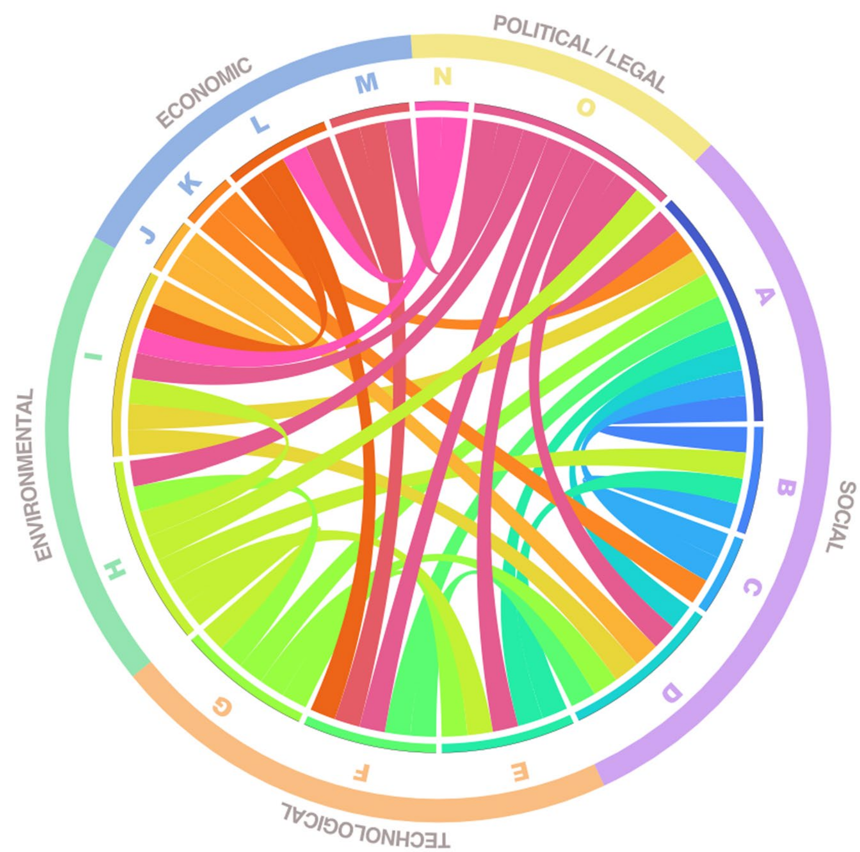
	A. PTO lead MaaS Bonjour RATP	B. PTA led MaaS IDFM App	C. Commercial MaaS 1 Google Maps	D. Commercial MaaS 2 Citymapper
Strengths	Prioritizes walking through dedicated buttons in MaaS UI. Has the knowledge and the capacity to adapt the platform behind MaaS (in-house MaaS development). Provides GPS guidance with precise instructions	Provides customization parameters based on types of pedestrians. Includes information on total walking times for all PT suggestions	Walking itineraries have a dedicated button to facilitate access. Various navigation aids for walking are provided to users at no extra charge. Suggests more than one route for the itinerary requested	Depurated interface and dedicated buttons prioritizing walking and cycling
Weaknesses	Provides only basic features and customization options to enhance the walking travel experience	Access to information on walking itineraries is complex (too many steps to find it)	Prioritizes car itineraries in the menu bar of the UI. Directions might not very accurate at a local scale, especially with small streets or passages	Promotes the use of micromobilities in walking itineraries. Only allows for two types of custom routes for users, this risks not being enough for a larger diversity of users
Opportunities	Potential to promote the use of PT and access to PT services by nudging mobility behavior through their extensive number of users (based on downloads). Increase personalization options (Linked to incentives)	Potential to implement strategies enhancing sustainable objectives in mobility and health policies through MaaS for its role as regional PTA. Authority to set up guidelines to hierarchize walking and cycling to PTOs developing MaaS. (Linked to governance and sustainable value creation)	Potential to continue innovation on walking features and navigation aids, own budget. Nudge car users to more sustainable modes (Linked to incentives and sustainable value creation)	Potential to continue innovation on walking features and navigation aids, own budget. Territorialized approach for the provision of information helps capture more details on the characteristics of mobility and users at a specific scale (Linked to governance)
Threats	Potential to promote less sustainable modes by sending persuasive messages for non-active mobility services, for example with Dott, Lime, and Tier e-kick scooters and ridehailing. Opaque definition of customization criteria	Competition among MaaS solutions developed by PTOs and commercial MaaS operators. Opaque definition of customization criteria	Responding to economic interests and promoting alternative, less sustainable modes instead of walking	Still searching a BM allowing them to thrive. This could lead to promoting alternative, less sustainable modes instead of walking. Opaque definition of customization criteria

(Table 2). By selecting the walking itinerary for our test trip, two options were proposed based on (1) speed and (2) the type of street (main streets). Trip customization options are provided as pre-established travel profiles through the navigation bar at the bottom of the second screen (once the itinerary is requested) (Fig. 9). Access to these functions requires a paid membership to Club+, except for the basic and the accessibility options (classic and steps-free, respectively). There is a "walk-less" paid functionality, promoted to avoid sun and rain. No details for walking connections are given on the list menu for PT itineraries. However, guidance, walking times, and the “best entrance” to the metro are provided once a route is selected (Fig. 9). Advertisement has also been recently included for non-Club + members [28].

4.4 Status quo of walking in MaaS: SWOT-based synthesis of results

In this section, we synthesize the main results answering the first research question regarding the status quo of walking in MaaS in the Paris region case. We classified them using the SWOT model for further analysis (Table 3).

- The empirical test showed that Google Maps and Citymapper offer more features and more information for pedestrian mobility, PT, and walking itineraries compared to the ones provided by Bonjour RATP and IDFM App.
- We observed in Bonjour RATP, Google Maps, and Citymapper heterogeneity in the hierarchy given to walking among all the available modes, and according to the provision and position of dedicated buttons facilitating or hindering users’ access to information on walking itineraries.
- We identified some personalization options for different types of pedestrians in IDFM App and Citymapper. For example, “good” and “normal” walker in the case of IDFM App. In the case of the pre-customed profiles offered for walking trips in City-



Code	Implications
A	Marginalization of disadvantaged population
B	Reinforcement of negative associations and connotations for walking
C	Reinforcement of the lack of visibility for walking
D	Disregard of lifestyle changes & new health needs
E	Limited access due to added complexity
F	Innovations responding to a BM, not to common interests
G	Hindered intermodality
H	Hindered informed, sustainable mobility choices
I	Resilience issues related to climate & energy crises
J	Health impacts with economic consequences
K	Unequal access to opportunities for economic development
L	Missing opportunity for sustainable value creation
M	Missing opportunity of increasing territorial attractivity
N	Falls short achieving national and international climate engagements
O	Fails to integrate innovation to public policy design and implementation

Fig. 3 STEEPL-based transversal implications for sustainability and policy[1]. Source: The authors. 1 Colors of the relationship lines inside the circle are only to facilitate reading the different implications in the Figure

mapper, show "fast route" and "main street". Criteria defining these parameters were not found.
- We found suggestions to use e-kick scooters or e-shared bikes when we requested a walking itinerary Google Maps and e-kick scooters and ridehailing Bonjour RATP. A similar travel suggestion was offered for users to walk less in Google Maps and Citymapper.

4.4.1 Transversal implications: STEEPL-based analysis of results

Our findings allowed us to identify the social, technological, economic, environmental, and political implications of the status quo of pedestrian mobility in MaaS. We then classify them (see Table 5) with a STEEPL-based model that permitted us to find several transversal relationships between the implications and answer the second research question regarding the relevance of walking in MaaS for sustainable value creation (Fig. 3). We consider that a higher amount of connections acts as an indicator to prioritize *hard* and *soft* policy measures and instruments [72].

In the social dimension there are increasing inequalities for pedestrians that undergo walking like women, elders, children, and the unemployed [48]; lack of visibility of walking leading to a detriment in the global *savoir-fare* of walking as a social practice [20], and the disregard of new needs brought by new lifestyles, consequences of different social trends and crises [4, 101]. In the technological dimension (also closely related to the social dimension), there are accessibility issues and barriers to intermodality linked to the complexity of UIs and the lack of data transparency. In the environmental dimension, we identified a link between the MaaS operator's UI and service design choices and the potential to enable or hinder more sustainable mobility practices. In the economic dimension, there are health impacts with economic consequences, as also discussed by [33, 52, 53, 59, 101]; Unequal access to opportunities for economic development [87], and the missing opportunities for sustainable value creation and territorial attractivity [2]. Lastly, in the political/legal dimensions, we placed the barriers to achieving national and international climate engagements and the hurdles to integrating innovations like MaaS into public policy strategies [55].

5 Discussion

This research addressed the initial research questions regarding the status quo of walking in MaaS and its relevance for sustainable value creation. Our main findings allowed us to identify the hierarchy given to walking in four MaaS available in the Paris region, the characteristics of information provided like type, tools, and content structure, and the link to the governance of each MaaS. Throughout this section, we relate the transversal sustainability implications shown in Fig. 3 to existing literature. Our discussion focuses on three axes of potential improvement: Governance, Incentives, and Sustainable Value Creation, according to our research findings and the analyzed implications of Sect. 4.4.

5.1 Hierarchy of walking in MaaS: a governance and regulation issue with deep social implications

Walking is a shared responsibility among various stakeholders. Public authorities at different government levels (national, regional, municipal) partake in setting objectives and creating policy tools and processes to enable urban pedestrian mobility [1, 23, 85]. As our findings showed, the governance issues related to the under-representation of walking in MaaS are, to a great extent, linked to the shortfalls of public stakeholders in assuming or "absorbing" [72] a responsibility role in pedestrian mobility. Additionally, the challenges that walking has historically faced regarding the existence and comfort of infrastructure, the perception of the mode, and its governance [84] are also found as a digitalized version in MaaS. Contrarily to the expected role of public actors in the Paris region and the objectives fixed in the ÎdF Urban Travel Plan (*fr. PDUIF*) aiming at increasing by 10% walking and cycling trips [45], we found that both public and semi-public MaaS provide less information, less digital navigation aids, and fewer customization parameters than private MaaS operators. Multisectoral sustainability policies should be integrated into MaaS operated by public stakeholders, in this case, the MaaS operated by the regional PTA (IDFM and the MaaS provided by the semi-public mobility operator (RATP to implement their envisioned policy objectives. To help frame the roles and actions of regional and local governments, National and European authorities have recently developed and applied legal frameworks like the European Climate Law [80], the French Climate Action Law [60], and the French Mobility Guidelines Law [7, 61]. These juridic instruments officially recognized the role of walking to achieve sustainability objectives and started providing legal bases for the hierarchization and nudging of sustainable modes in digital solutions like MaaS. A more proactive role of public authorities representing the interests of pedestrians and mobilizing the new legal background has the potential to act against unequal mobility dynamics and strengthen the perspective of mobility justice as developed by Sheller [87, 88]. These frameworks will be determinant to counteract the present hierarchization trend for walking in MaaS found in our research (see Table 2) and the social implications it conveys.

5.2 Walking in MaaS solutions' UI: what you see is what you get (to use)

MaaS' UIs have an important role in nudging mobility behaviors. As studied by Gabrielli and Maimone [37], Pangbourne et al. [77], and Wang et al. [98], incentives play a significant role in the user appraisal of sustainable practices and the economic opportunities that pedestrian mobility could have in MaaS solutions. We found that nudging strategies are not being fully exploited in the studied MaaS. Only Citymapper displayed a "content structure" [62, p. 16], prioritizing fully walked trips through UI design and providing walking information first when an itinerary is requested. As developed by Ballard [10], Blair-Early and Zender [17], Lynch and Horton [62], and Nogier [75] in the field of UI design, the visual hierarchy in which content is structured and displayed strategically influences the use. Manley [66] states that walking should be "at the top of the hierarchy" of mobility, following universal design principles like equity, flexibility, simplicity, and intuitiveness [92]. Moreover, transparency in the information provided and the parameters structuring that information is also very relevant to build trust among users. We found that the customization parameters provided for walking trips were behind the vague concepts of "good walker", "normal walker", and "fast/slow route". As Brög et al. [21, p. 18)] stated, "*providing information tailored to individual situations is far more convenient and motivating, than having to filter through and select from multiple possibilities*.". This was also developed by Pangbourne et al. [77], who found that customized messages engage a better response toward sustainable travel.

5.3 Sustainable value creation enabling sustainable mobility paradigms through MaaS

Our results showed that commercial MaaS operators have chosen to develop innovation around pedestrian mobility because there is a business case behind it. For example, by listing shops, restaurants, landmarks, and flagship stores as we found Google Maps does, corroborating what Lyons [63] developed as the "WaaS circle of virtue". Developing this model, MaaS could be a tool for collaboration between public and private stakeholders and add local, sustainable value to their communities. Nowadays, merchants tend to keep a negative perception of the policies reinforcing streets' pedestrianization. Better communication conveying the benefits of walking for economic activity would be beneficial. MaaS could be the tool to implement and measure such strategies, which have been proven positive for economic activities [27, 40]. Listing local economic activities in MaaS and linking them with pedestrian itineraries could act as a nudge to increase the territories' sustainable value and attractivity. This was developed by Banister [11], implemented by [22], and revisited in the 15-min city concept explored by Allam et al. [2]. The authors stress that mixed uses, density, and "neighbourhood quality is central to sustainable mobility" [11, p. 75].

6 Conclusion

Even though currently operational MaaS solutions do not comprehensively integrate pedestrian mobility, our research demonstrates that significant potential can be explored to improve this and that not doing so will have important implications for society, the economy, and the planet.

Disregarding the presence of walking in innovations like MaaS will likely have transversal impacts hindering the opportunity to achieve sustainable development goals [4], mobility justice [87], health goals, and tackling the climate emergency.

Many physical barriers to walking and walkability have been transferred to the digital realm of MaaS. We agree that MaaS alone will only be able to bring the modal change from car-based transportation to active and intermodal transportation with profound socio-technical transitions happening first.

Some limitations must be considered since our study compared only four MaaS solutions in the Paris region using the app in an Android OS device. UI can differ between Operative Systems, and a contrast of the UI of the studied MaaS in Apple OS devices could show slightly different results (although the core content structure discussed in our research does not seem to vary).

Future research should investigate the stakeholder's motivations and levers to appraise walking in MaaS solutions and explore models to evaluate the walkability of MaaS solutions.

Appendix

See Tables 4 and 5, Figs. 4, 5, 6, 7, 8 and 9.

Table 4 Walking information provision in test case throughout the different MaaS[1]

	(A) Bonjour RATP (Figs. 4, 5, 6)	(B) IDFM App (Fig. 7)	(C) Google Maps (Fig. 8)	(D) Citymapper (Fig. 9)
Information for full walking itineraries	GPS guidance, total travel distance and time, emissions of CO2 and equivalent emissions if trip taken by car, and calories burned	Full walking itinerary is shown at the end of the list menu of PT itinerary suggestions, and it appears only if the option "Good walker" has been selected. Other information provided includes GPS guidance, total distance, and travel time, CO2 emitted, and accessibility warnings[2]	Three different walking route options displayed in the map with the total walking time are shown. One option shows the same route offering to take a shared electric bikes and e-kick scooters. Total walking time and distance and step-by-step written instructions. A preview of the trip on the map, and the visualization of the elevation of the terrain throughout the trip. Satellite view	Walking itinerary shown in the dedicated button over the checkerboard menu. Two route possibilities: (1) fast and (2) main roads. Total walking time and distance for each of the options. Button for help for inquiries about problems with the proposed itineraries. GPS navigation guidance
Information for walking in PT itineraries	Total walking travel time before or after the trip. After selection of trip, walking travel times, visual route, and information on the metro entry to take are provided. CO2 and equivalent emitted, equivalent if trip had been taken by car, and calories burned are shown	Total walking time provided for all the PT suggested trips right below the total travel time. Walking route visible in map. Information on the metro entry to take. Other information provided includes GPS guidance, total distance, and travel time, CO2 emitted, and accessibility warnings[2]	Walking time before or after the connection with PT is provided for some itineraries in the suggestions' list menu. Results are shown by the following categories: recommended route, more by subway, more by bus, also consider (shared car-based and micromobility services). Other features include accessibility, temperature, and crowd level user assessment, add trip to calendar, and transport agency info link	PT itineraries are shown on a list menu below the checkerboard "modes" menu. No walking information is provided at this stage. Once the PT itinerary is selected, walking time is provided for before, during (changes between platforms) and after the trip. GPS guidance. Button to activate the visualization of the traffic layer on the map, to save the trip as favorite, and to share the trip
General app settings and trip customization options	(a) Accessible journeys[3] (yes/no switch) (b) Transport modes: RER / Transilien, Metro, Bus / Noctilien, Tram (yes/no switch)	(a) My travel profile[3]: Walk speed (Good, Normal walker or walker with difficulties) Biking level (beginner, intermediate, experienced) Wheelchair traveler (yes/no switch) (b) PT: RER, Train, Metro, Funicular, Rail shuttle, Tramway, Bus (yes/no switch) (c) Other Modes: Personal bike, bike sharing station, bike sharing, ride sharing (yes/no switch)	(a) Walking route[3]: Route options: Avoid ferries. Other options: Add stop, Search services along route (Gas station, restaurant, café, fast food, groceries, ATMs) (b) PT route: Preferred modes: Bus, Tram, Subway, Tram, and Light rail. Route options: best route, fewer transfers, less walking, wheelchair accessible, lowest cost. Connections to transit: drive, ride service, bicycle (c) General settings (main screen): Accessibility for wheelchair users. Navigation settings: Sound and voice: mute, guidance volume, voice settings. Route options: Avoid highways / tolls / ferries. Map display: Color scheme, and distance units. Driving options: Speedometer, driving notifications	Nine options available[4], classic and step-free are free, and Bus +, Train +, Walk less, Mixed, Simple, Turbo, Price-based, require a Club membership. General app settings (main screen) show statistics on calories burned, total CO2 saved with transport choices made, and economies made

[1] Data retrieved from the apps by the authors

[2] A list of accessibility warnings based on the presence of sounds, lights, assistance, elevators is offered. A phone number for travelers with disabilities, and the amount of CO2 emitted during the trip, this information is also shown for PT itineraries

[3] Custom options are available through a "parameters" icon button

[4] The custom options are shown in the navigation bar at the bottom of the screen

Table 5 STEEPL-based analysis: transversality of implications

Implications	Source	Social	Social	Social	Social	Technological	Technological	Technological	Environmental	Environmental	Economic	Economic	Economic	Economic	Politic/Legal	Politic/Legal	Contacts
	Target	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
Social	1 Marginalization of "captive pedestrians"	0	1	1	1	1	1	1	0	1	0	1	0	0	0	1	9
Social	2 Reinforcement of the lack of visibility of walking	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	4
Social	3 Reinforcement of injust paradigms	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	3
Social	4 Disregard of lifestyle changes & new **health** needs	1	0	0	0	0	1	1	0	1	1	0	0	0	0	1	6
Technological	5 Limited access due to added complexity	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	5
Technological	6 Innovations responding to a BM, not to common interests	1	0	0	1	0	0	0	0	0	0	0	1	1	0	1	5
Technological	7 Hindered intermodality	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	4
Environmental	8 Hindered informed, sustainable mobility choices	0	1	0	0	1	0	1	0	1	0	0	0	0	0	1	5
Environmental	9 Resilience issues related to climate & energy crises	1	0	0	1	0	0	0	0	1	1	0	1	0	1	1	7
Economic	10 Health impacts with economical consequences	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2
Economic	11 Unequal access to opportunities for economic development	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Economic	12 Missing opportunity for sustainable value creation	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	4
Economic	13 Missing opportunity of increasing territorial attractivity	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	3
Politic/Legal	14 Falls short achieving national and international climate engagements	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2
Politic/Legal	15 Fails to integrate innovation to public policy design and implementation	1	0	0	1	1	1	0	1	1	0	0	0	1	0	0	7

See Fig. 3

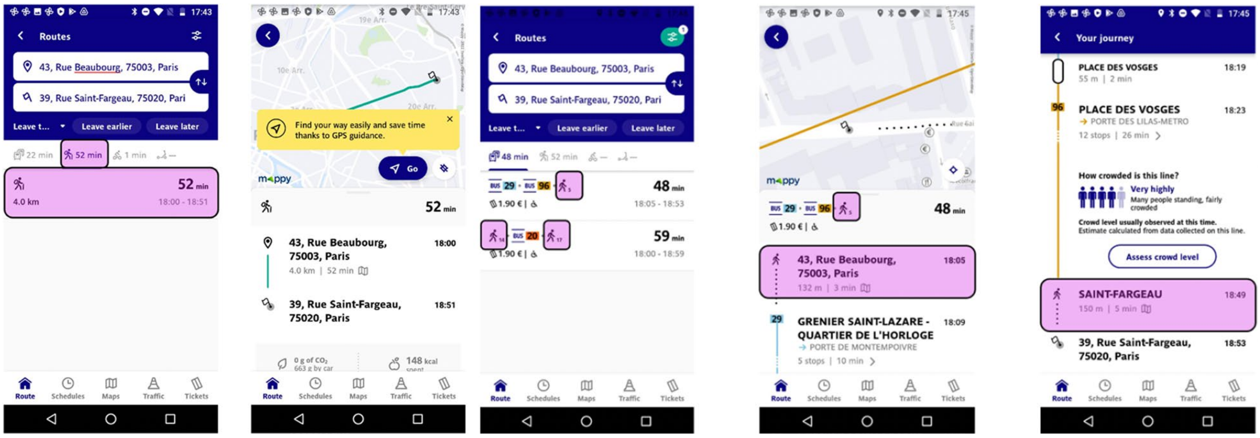


Fig. 4 Bonjour RATP: Walking itinerary and walking information provided in PT itinerary

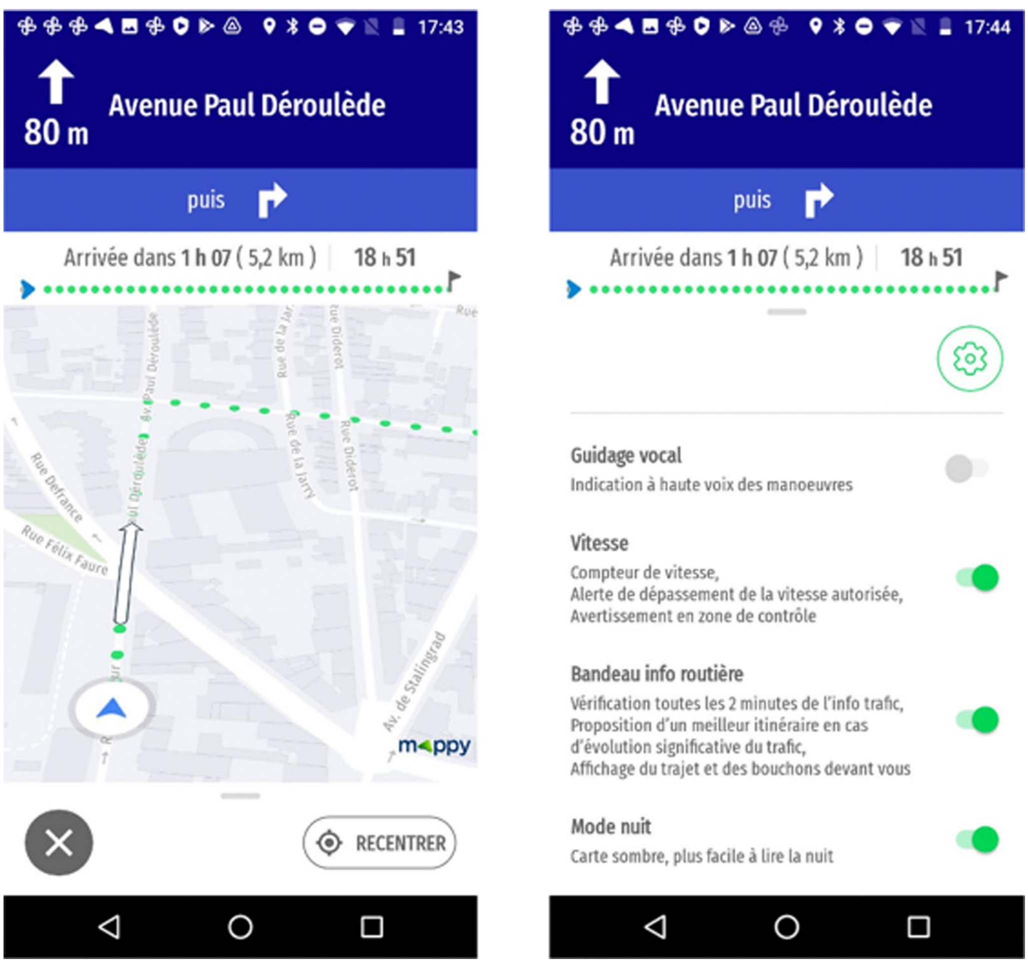


Fig. 5 Bonjour RATP: Navigation guidance display and accessibility parameters for walking itinerary

Fig. 6 Bonjour RATP: Advertisement promoting micromobility and ridehailing

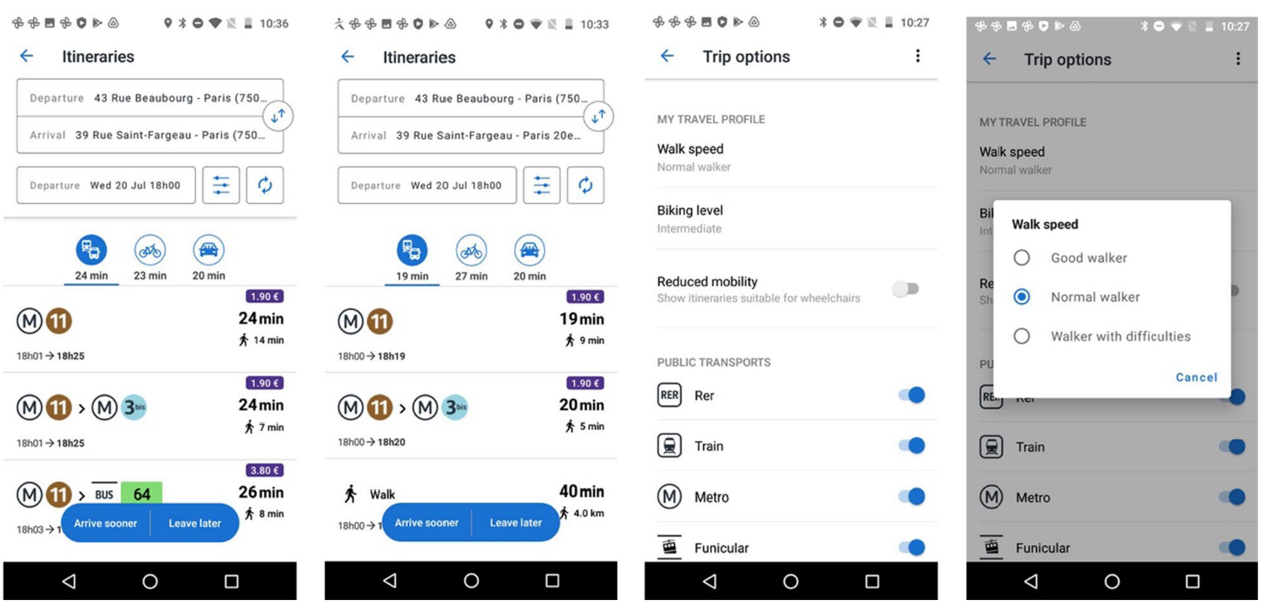


Fig. 7 IDFM App: Walking itinerary and walking information provided in PT itinerary

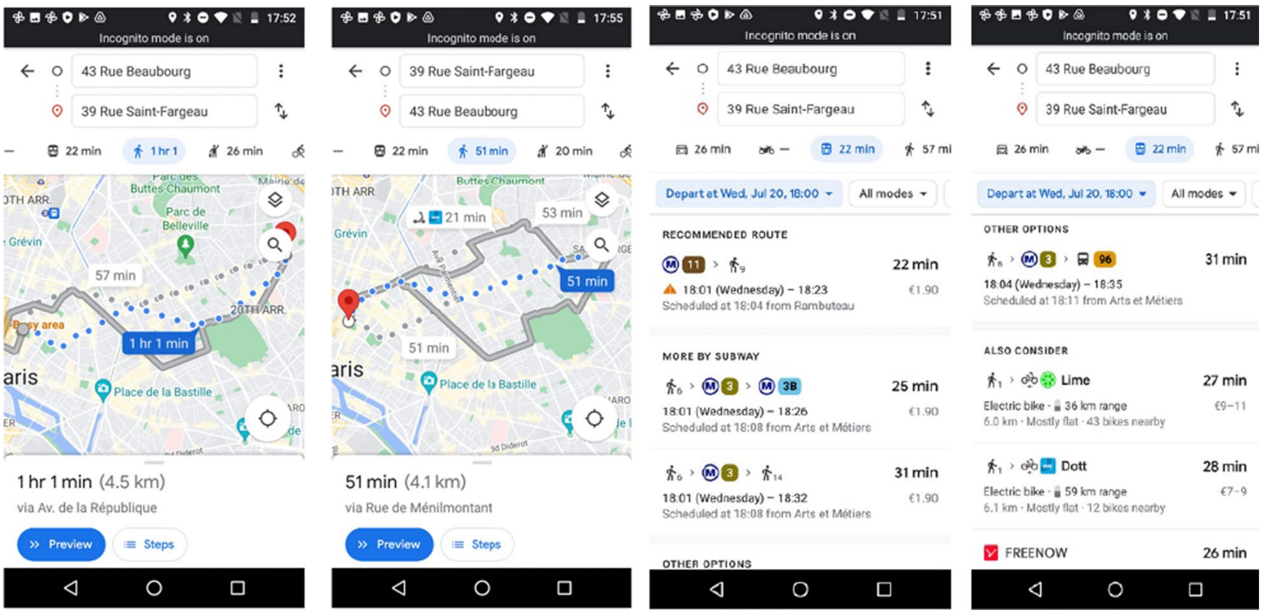


Fig. 8 Google Maps: Walking itinerary and walking information provided in PT itinerary

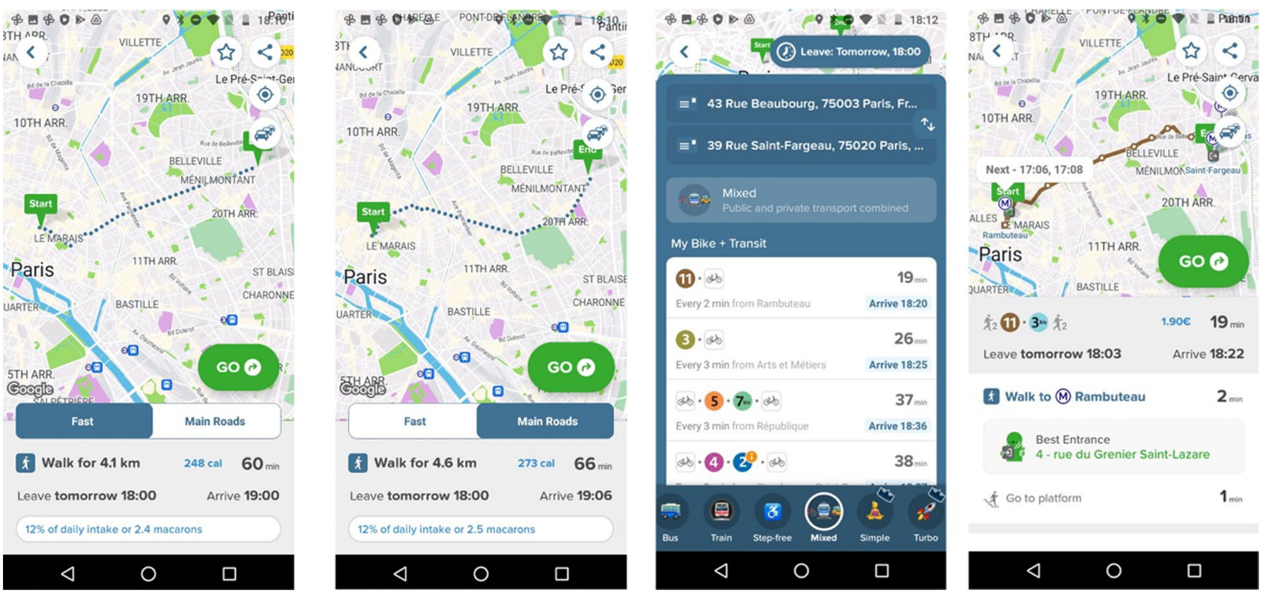


Fig. 9 Citymapper: Walking itinerary and walking information provided in PT itinerary

Abbreviations

App	Application
BM	Business model
CO2	Carbon dioxide
GHG	Greenhouse gases
GPS	Global Positioning System
IDFM	Île de France Mobilités
ÎdF	Île de France
MaaS	Mobility as a Service
MIS	Multimodal Information System
PTA	Public Transport Authority
PTO	Public Transport Operator
PT	Public Transport
RATP	Régie Autonome des Transports Parisiens
SBM	Sustainable Business Models
UI	User Interface
UX	User Experience
WaaS	Walking as a Service

Acknowledgements
The authors wish to thank the colleagues who helped in the proof-reading process and with the visuals. Also, a sincere acknowledgement to the anonymous reviewers of the paper for their time, and their useful detailed comments.

Author contributions
All the Authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by LMRM. The first draft and the reviewed version of the manuscript were written by LMRM and all the Authors commented on previous versions and the final version of the manuscript. All authors read and approved the final manuscript.

Funding
This research work has been carried out in the framework of the Technological Research Institute SystemX under the Anthropolis Chair, and therefore granted with public funds within the scope of the French Program 'France 2030'.

Availability of data and materials
For access to the data supporting our findings please contact mariana.reyes@centralesupelec.fr

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors have no conflicts of interest to declare that are relevant to the content of this article.

Received: 26 October 2022 Accepted: 6 April 2023
Published: 28 April 2023

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