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Towards improving personalisation of MaaS tools

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Abstract

Over the past few years, Mobility-as-a-Service (MaaS) has become an alternative to owning a private car, integrating various public and shared travel modes in a single platform. Despite its attractiveness in meeting everyday travel needs, it has not seen high penetration rates within the urban population. A solution to increase its acceptability is to improve its personalisation so that it can better cater to the needs of each user. In this paper, we propose the global architecture of a MaaS tool under development for the city of Toulouse and its surroundings. The proposed architecture combines the information about users' mobility patterns and their individual preferences along with real-time traffic updates to proactively recommend personalised routes. Within the application, users' probability of choosing a particular transport mode, calculated using discrete choice models, as well as various gamification-based elements are integrated in order to understand users' travel behaviour and promote sustainable transportation.

Keywords:

Mobility-as-a-Service, Personalisation, Gamification, Transport Mode Choice Modelling, Macroscopic Mathematical Traffic Modelling, Mobility Assistant

Introduction

In World Economic Forum's (WEF) annual meeting held in Davos in 2021, the founder of WEF launched his book entitled "Stakeholder Capitalism: A Global Economy that Works for Progress, People and Planet". In a nutshell, stakeholder capitalism calls for a company to take into account the long-term effects of its businesses on all the stakeholders affected by its decisions and functioning. These stakeholders can be the employees of the company, its customers, the government and, most importantly, the planet and the environment. Although the concept of stakeholder capitalism has existed since 1970s, with the discussion at WEF's annual event in 2021, one can see the willingness of the policy makers from around the world to gradually move towards more inclusive socio-economic models which would result in a sustainable growth in different sectors of the global economy while keeping the environment preservation at the forefront.

In the mobility and transportation sector, the concept of Mobility-as-a-Service (MaaS) shares this vision and follows the guidelines for urban mobility [1] laid out by WEF for providing

environment-friendly user-centric mobility services, by integrating various modes of transport, managed by distinct Mobility Service Providers (MSP), through a single digital platform [2]. The concept of MaaS was introduced by Sampo Hietanen as *a mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider* [3].

MaaS has become a hypernym, over the past few years, for mobility partners proposing multi-modal integration and payment services. Due to the variety of existing services, it is not easy to define, in concrete terms, what constitutes MaaS. However, there is a general consensus on its core characteristics, as noted in [4], which should be taken into consideration. One of the core characteristics of MaaS is *personalisation* [4] where the objective is to provide individualised and tailor-made recommendations to each user based on his/her past behaviour and preferences. The significance of personalisation has been noted by other researchers as well. Sochor et. al. [5] discuss several definitions of MaaS out of which more than half describe it as a *personalised service, catering to the needs of the customer* for planning, booking, paying and executing their journeys.

In a recently published book [6], various MaaS trials and pilot projects are presented. The authors note that MaaS has the ability to change travel behaviour of the general population towards opting for more sustainable modes of transport. However, they argue that motivating people to change their travel behaviour is not an easy task and requires the MaaS service to be attractive, convenient and flexible for its large-scale adoption. In order to promote sustainable modes of transport and understand people's daily travel habits, Andersson et. al. [7] investigated different behaviour change theories and found that the incorporation of *users' needs* for the development of mobility services has a positive effect on the acceptability of such services. When the users' preferences and habits are taken into account and personalised service is provided, their confidence in the service increases which, in turn, helps in changing their travel behaviour [8].

In this paper, we present the global architecture of a multi-modal MaaS tool under development within the framework of Vilagil project [9]. Launched in 2020 and funded by the French government and Toulouse Métropole, this project aims to promote new modes of transportation such as car-pooling and bike- and car-sharing, and integrate them in a MaaS platform in order to provide door-to-door mobility solutions to the residents of Toulouse (France) and its surrounding areas. This project brings together multiple private and academic partners to collaborate with Toulouse Métropole and Tisséo Collectivités (local state-owned mobility operator). This paper discusses various modules of the global architecture and highlights their role in improving personalisation within MaaS.

Related Work

Ever since its inception in 2014 [3], MaaS has seen an increasing interest, both from private and public entities, for its successful development, deployment and acceptance on large scale. In this section, we discuss some of the notable MaaS tools and focus on the aspect of personalisation within the existing research. The list of the MaaS tools considered is not at all exhaustive and the reader is

referred to [2, 4, 5, 6] for a review and comparison of various MaaS schemes.

Table 1 lists some of the MaaS tools deployed in different cities in Europe and Asia. Some of the listed tools are still operational while others were limited to a pilot project. It is noteworthy that all the listed MaaS tools integrate multiple modes of transport and provide multiple payment options (Pay-As-You-Go, monthly and annual subscriptions, family subscriptions in UbiGo etc.) as well.

Table 1: Some notable MaaS tools

Name	Place(s)	Year	Status	Modes	Personalisation
Whim	Helsinki, Birmingham, Vienna, Tokyo, Switzerland, Turku, Antwerp	2016 - present	Operational	Public transport, Rental car, Rail, Taxi, Bike and car sharing	Synchronization with user's agenda, Weather information
WienMobil	Vienna	2017 - present	Operational	Public transport, Bike and car sharing, Taxi, Rental car, E-moped sharing, Rail	User's mobility profile
UbiGo	Gothenburg, Stockholm	2013 - 2014; 2019 - present	Pilot; Operational	Public transport, Bike and car sharing, Rental car, Taxi, Parking	Family subscriptions
NaviGoGo	Scotland	2017 - 2018	Pilot	Public transport, Rail, Taxi, Bike sharing	Personalised journey planner, User's profile, Incentive points for sustainable choices, Deal matcher
Optymod'Lyon	Lyon	2012 - present	Operational	Public transport, Bike and car sharing, Rental car, Rail, Taxi, Airplane, Parking	Real-time traffic prediction and updates, User's preferences, Bike and car ownership

In order to provide a personalised user experience, existing tools take different approaches. Whim has the option to synchronize the user's calendar in order to find trips which respect the scheduling constraints of the user's daily meetings and appointments. Various applications, like WienMobil, NaviGoGo and Optymod'Lyon, create a user profile. At the time of registration, users are asked if they own a bicycle, a car etc. and/or how far they are willing to walk in order to take a public/shared mode of transport. This information is stored in the user profile and is utilized when the user searches for a trip between an origin and a destination. In addition, user's preferred locations and routes are also stored in the profile. Furthermore, some tools like Optymod'Lyon take into account real-time traffic updates while calculating possible routes. Real-time traffic information is also useful in calculating alternative routes in case there is a problem during the journey. Since the promotion of sustainable transport modes is one of the objectives of MaaS, tools like NaviGoGo incentivize their

users with reward points if and when they make sustainable choices.

Within the framework of MaaS4EU project [10], a personalised multi-modal journey planner has been developed which can be integrated in MaaS tools in order to recommend routes based on the user's query [11]. The proposed journey planner integrates third-party data from various mobility service providers to include services such as bike- and car-sharing, ride-hailing and the information about parking spaces. It uses a scenario-based heuristic to combine multiple modes of transport. To promote sustainable transportation, within the same project, [12] uses "persuadability profiles" developed by taking into account the user's personality type, and attaches persuasive messages with recommended multi-modal routes to nudge user's choice towards sustainable modes.

In a recently published review [13], the authors compared around 30 MaaS tools from 14 countries and concluded that given the importance of personalisation for increasing the acceptability of MaaS and promoting sustainable travel behaviour, future MaaS tools should be developed with the vision to improve this aspect for route recommendations. In this regard, the objective of this paper is to propose an approach which combines real-time traffic information with the user's profile containing his/her movement habits, preferences and daily schedule along with contextual information to proactively provide personalised recommendations. Various existing tools use such data separately, however, to the best of our knowledge, there does not exist a MaaS tool which incorporates all this information in a single platform. Our proposed approach is discussed in the next section.

Proposed System

In this section, we present the global architecture of the multi-modal MaaS tool. The architecture is divided into four sub-modules identified as critical in promoting large-scale acceptance of MaaS and sustainable mode choices as well as providing personalised mobility recommendations before and during the journey. The sub-modules are currently under development and their integration will bring together four academic partners - IRIT-UT3, ENAC, CLLE-UT2J, ONERA - and local public entities (Toulouse Métropole and Tisséo Collectivités).

Global Architecture

Figure 1 presents the proposed global architecture. The four sub-modules which make-up the architecture are: **Citizen Participation** that focuses on the development of a gamification-inspired user interface, **Transport Mode Choice Model** responsible for calculating the preferred travel mode for a given user based on his/her age, gender, level of education etc., **Mathematical Model for Urban Traffic** used to calculate travel time and cost (both financial and environmental) of a trip based on real-time traffic updates, and **Personalised Virtual Mobility Assistant** which combines the information about the user (like his/her preferred mode of transport) stored in the user profile and real-time traffic information along with user's past movement habits and the current context (like the weather or if the user has a car) in order to rank various route propositions calculated using unimodal and multi-modal itineraries generator. Each of these sub-modules provide complementary information

useful for improving the personalisation of MaaS.

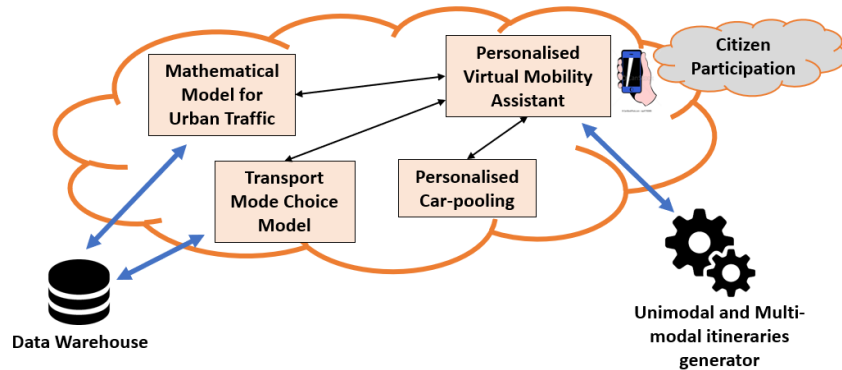


Figure 1. Global architecture of the MaaS tool combining various sub-modules

The objective of these sub-modules is to proactively recommend unimodal and/or multi-modal trips based on the user’s needs without requiring him/her to explicitly search for them. To protect user privacy, data about the movement habits and preferences of the user is stored and processed locally within the smartphone application using an “Edge Computing” based approach. However, the data required for mathematical modeling of traffic and transport mode choice model is stored in an external data warehouse since it is provided by our public partners. In addition to public and shared transport modes, integrating car-pooling within the MaaS tool is one of the major objectives of Vilagil project. For this, users receive personalised recommendations depending on their type i.e., whether they are drivers or passengers. Each sub-module is discussed in detail in the following.

User Interface – “Citizen Participation”

“Citizen participation (CP)” is another research group involved in the Vilagil project which intervenes in the MaaS group, to help on issues of citizen participation of users. The purpose of CP group is to understand the acceptability of all future mobility systems. Concerning the MaaS application, this group conducts research on users and their cognitive functioning when faced with these types of applications and tools. The recommendations concern the characteristics of the application and the interface of the tool through the integration of gamified elements.

Gamification is an emerging practice inspired by video games and is increasingly used in the field of human-computer interaction. It consists of inserting game elements and mechanics into an activity whose context is not initially related to the game [14]. The objective is to influence users' engagement and play on their motivation to perform an activity, but above all increase users' satisfaction and pleasure. This approach can be implemented through a multitude of elements borrowed from games: for example, the attribution of rewards and prizes, points, challenges, leaderboards, levels or steps, etc.

Designers of a MaaS application can implement gamification to meet specific needs, such as

to encourage users to change their mode of transportation to reduce road congestion. Gamification can be thought in a collective way or personalized to each individual. Personalized gamification is gaining interest due to the expectation that it can improve its success compared to *one-size-fits-all approaches*. Different types of users can be attracted by specific elements of gamification which can be adapted to each user's personality traits. Customization of game elements to the participant's profile can increase the effect of gamification on the participant's behavior [15]. The Hexad model [16] proposed six user types that differ by either intrinsic (e.g., self-realization) or extrinsic (e.g., rewards) motivational factors. Each type of user can be motivated by different elements of gamification. For example, *socializers* will be motivated by relatedness, so leaderboard will be an optimized element of gamification, while *achievers* will be motivated by competition, so challenge and quest will be the best element. Moreover, game elements can also be adapted to users' characteristics such as age, gender, culture, susceptibility to specific persuasive strategies or simply by the preferences that the users have specified.

Pragmatically, the process of gamification is defined in six steps [17]: 1) Define the designer's objectives, especially, the goals of the gamified system 2) Delineate the target behaviors, especially what users will do and how the user outcomes will be measured; 3) Describe the user's motivations and characteristics. 4) Create activity cycles: the designer has to develop two types of activity cycles: engagement loops in which user actions produce feedback from the system, which in turn motivate the user to take further actions (dynamics of the system) and progression stairs which concerns the user journey, especially, how the goals and activities will evolve in the future; 5) the fun that will keep the user engaged and optimize user experiences; 6) Deploy the appropriate tools, especially a selection and implementation of the appropriate game mechanics to create the designed activity cycles.

Finally, whether they are children or adults, pedestrians, drivers, cyclists or using public transport, all citizens can be involved in using mobility applications. Understanding their needs and constraints is a first central point. Hence, gamification, a promising new approach not well studied in the context of MaaS applications, is interesting to explore.

Econometrics-based Transport Mode Choice Model

Like any market, the transportation market has its own particularities. Users - who represent the demand - make a choice of transport mode for a given trip (train, metro, tram, bus, car, carpooling, cab etc.). This places us in transport economics in the context of modal choice, as defined by De Witte et al. (2013) [18]: *A decision process that leads to a choice between several transport alternatives, that is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors*. The combination of these factors forms the inputs of the user's utility function, and his/her choice is then determined by the maximization of this utility under constraints. Modelling consumer choice then amounts to calculating the probability of using a particular mode of transport and is done using a classic econometric tool: discrete choice models.

Discrete choice models have long been used to explain why a proportion of consumers

choose one product over another. In economics literature [19], these are models where consumers have a random component in their preferences, are statistically identical and their choices are often described by logit-multinomial models [20]. The utility of the consumer is determined by his/her own characteristics as well as those of the products, and the demand for each product is obtained by aggregating the demand of all consumers who prefer this particular product to all others. In the transportation market, this demand embodies the market share of modes and can therefore be estimated from a set of variables. De Witte et al. (2013) [18] propose a comprehensive set of those explanatory variables, classified into three groups: 1) **Supply attributes**: network density, diversity, parking, frequency, proximity, time, cost, 2) **Individual characteristics**: age, gender, income, household, education, trip purpose, weather, and 3) **Preferences**: experiences, familiarity, lifestyle, perception.

Among these determinants, the authors show that the most studied in the literature are travel time and cost, age, gender, network density and motorization. In many cases, these determinants influence each other, which explains the many links between them. For example, there is a positive relationship between income and car use and an inverse relationship with public transport use [21]. Some of the determinants of modal choice are observable, such as supply-side attributes or certain individual characteristics, such as age or gender, and others are unobservable, such as perception or environmental awareness. As transport mode choice is a multi-parametric decision process, it is determined by the characteristics of the transport alternatives and a combination of individual socio-economic, psychological and spatial factors [22].

The estimation of our model allows us to explain the choice of individuals according to the factors discussed above and to calculate the probability of using each mode of transport. It helps in initializing the personalisation process within the MaaS tool and improves the route recommendations for different user categories.

Mathematical Model for Urban Traffic

Decision-making is a data-driven process, and in order to motivate the users to maximize the use of public and shared transportation, we need realistic and reliable data about each possible choice. Mathematical traffic models can provide these data to help in making the final decision. The research towards mathematical modelling of traffic flow started gaining interest in the middle of the twentieth century, due to a sudden increase in the use of cars and buses for urban transportation. Part of the appeal towards modelling traffic flow has been the sheer complexity of the problem, where one may need to account for the complexity of road networks, the dynamics of traffic congestion, the heterogeneity of vehicle sizes and performances, drivers' behaviour and the large number of vehicles. Additionally, modelling and accurate prediction of traffic has a significant environmental impact as it helps in reducing congestion and vehicular pollution [23].

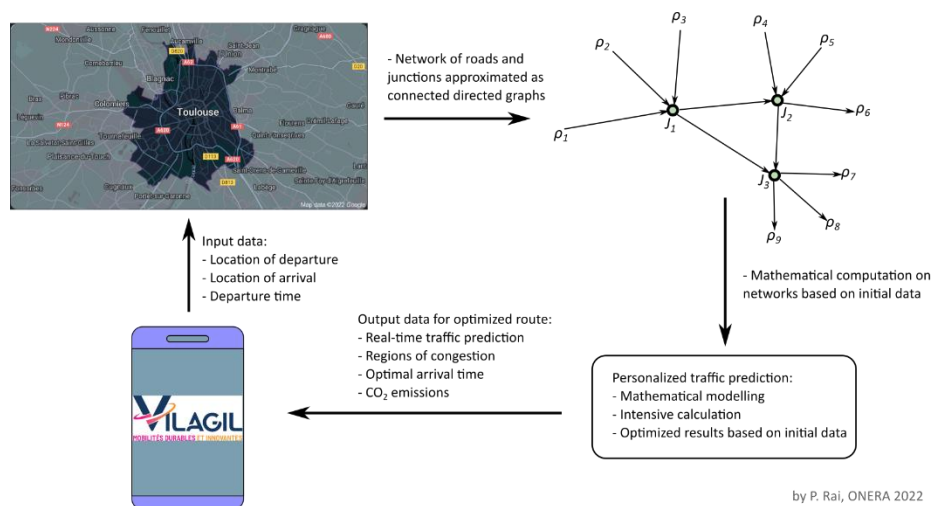
In our work, we treat traffic flow as a continuum (macroscopic point of view). Macroscopic mathematical models rely on a description of the local density of cars, whose dynamics can be

characterized by the following scalar conservation law:

$$\frac{\partial}{\partial t} \rho_i + \frac{\partial}{\partial x} f(\rho_i) = 0, \quad \rho_i(0, x) = \rho_{i,0}(x), \quad x \in [a_i, b_i], \quad i = 1, \dots, N$$

Here, i , denotes any road, with extremities at a_i and b_i , that can be numbered as $1, \dots, N$, ρ_i is the local traffic density on road i and $f(\rho_i)$ is the local flow of vehicles, inferred from the local traffic conditions. Solving these equations is computationally lighter than describing the dynamics of each individual car which allows for fast predictions of the traffic state in the near future, a key point in the MaaS concept. Additionally, the development of a fast and light numerical solver is of prime interest. The numerical solver must also be flexible enough to work with a number of decentralized mobility requests. In this context, part of our work focuses on ways to adapt automatically between these different traffic flow models to aid mobility within Toulouse Métropole. We base our work on existing models such as LWR models [28] or phase-transition models [24, 26] which are able to capture accurately the congestion states.

The mathematical models are part of MaaS application that runs a series of computation in the background, to provide real-time information on the state of traffic on a given road segment. As a set of input data, departure and arrival locations and departure time will be used. The application then selects the part of road network that can facilitate the journey, and approximates it as a connected directed graph. The numerical solver receives the graph as a computational mesh, along with the time of departure and computes an approximated arrival time based on the current traffic conditions. Along with the latest traffic information, the numerical solver provides details on the areas of congestion and bottlenecks, and the carbon emissions. The output, for each user, is an optimized trip which is tagged with its environmental cost and travel time (see Figure 2 for a schematic representation).



by P. Rai, ONERA 2022

Figure 2: Schematic representation of the usage of macroscopic traffic flow models

Knowing the (predicted) state of the traffic allows for a sharper estimate of the environmental cost and fuel consumption of a car-only trip. The users benefit from this information, as

it enables them to make prudent choices to navigate through traffic in the most cost effective and environmentally responsible way. Having realistic, i.e., non-optimistic, transit times provides a fairer comparison between the use of personal cars and the use of multi-modal public transportation system.

Personalised Virtual Mobility Assistant

From the plethora of mobility services offered these days, choosing an appropriate travel option and mode combination can be frustrating from the user's point of view. In order to help users to navigate through the process of planning, booking and executing their journeys, mobility applications propose intelligent virtual mobility assistants integrated within the platform [28]. Such mobility assistants combine traffic information with user preferences and travel habits to reduce the complexity of using mobility services. Within the context of Vilagil project, in this section, we discuss the role such virtual mobility assistant, called "Intelligent Assistant for Mobility (IA4M)", plays in improving the personalisation of MaaS.

Within this project, IA4M will be integrated in the MaaS application for smartphones. In order to cater to ever-evolving user needs and preferences, IA4M continuously observes the daily travel habits for each user without explicit human intervention. By continuously monitoring the GPS and accelerometer data gathered from the smartphone, IA4M extracts user's everyday movement patterns along with his/her preferred mode of transport, favourite locations and preferred departure/arrival times. This information, stored locally on the smartphone as a dynamic user mobility profile, is used to proactively recommend optimal routes.

Since car-pooling is a major mode of transportation within the project, we aim to develop the mobility assistant while keeping in mind different types of user needs depending on whether they are drivers or passengers. In the case of drivers, IA4M has to be capable to proactively suggest potential passengers which can car-pool without needing the driver to make a significant detour from his/her original route. On the other hand, in the case of passengers, the mobility assistant will recommend nearby drivers which could help them in completing (in part or in full) their trips.

Furthermore, using the Transport Mode Choice Model discussed above, the probability for a user to choose a particular mode of transport depending on his/her age, gender, occupation, education level etc. is calculated. This probability facilitates the computation of the user's preferred mode of transport using real-time GPS and accelerometer data. IA4M is responsible for combining the information about the preferred mode of transport, real-time traffic updates calculated using the Mathematical Model of Urban Traffic discussed above and the current contextual information to rank possible multi-modal and/or unimodal routes between origin/destination pair according to the user's requirements and preferences. In order to promote sustainable travel behaviour, the environmental cost of each trip is also taken into consideration while ranking the possible routes. Finally, user feedback is used to improve future route propositions.

For the implementation of such a mobility assistant, two important points need to be kept in mind. First and foremost is the user's privacy. Within the Vilagil project, our aim is to follow the

RGPD guidelines to respect data privacy and usage. As a result, the MaaS tool being developed stores and processes all the user's movement (acquired from GPS and accelerometer) as well as personal (such as age, gender, occupation etc.) data locally on the smartphone and only sends the query to find possible routes between origin and destination at a given departure time to a central server maintained by Tisséo Collectivités and Toulouse Métropole. However, as mentioned before, the traffic data required to compute real-time traffic updates and the data required by the Transport Mode Choice Model is stored and processed externally. This is due the fact that both these data are public and common for all the users. Since the user's personal and movement data has to be processed on-device which has limited computing resources, the second important point is the need to develop memory-efficient algorithms capable of working using (ultra) low-powered processors. For this, an "Edge Computing" based approach is currently under consideration.

Conclusion

In this paper, we discussed the global architecture of a MaaS tool under development within the framework of Vilagil project. The proposed architecture comprises four sub-modules which, when integrated, proactively recommend personalised unimodal and/or multi-modal routes taking into account the user's needs, preferences and past movement behaviour along with real-time traffic updates. Gamification elements integrated within the application aim to nudge users towards sustainable mode choices. The sub-modules presented in the paper provide necessary and complementary information useful for improving the personalisation of route recommendations within MaaS. An important aspect for improving the personalisation of mobility services is related to the payment for multiple mobility providers. At the moment, this aspect is out-of-scope of this paper but there exists some research [29] aiming to recommend MaaS payment plans and service bundles according to the user's individual needs which could be an interesting starting point in this direction. The development of the proposed MaaS tool is currently undergoing, thanks to the fruitful collaboration between different academic partners involved in the project.

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