INCORPORATING THE MOBILITY AS A SERVICE CONCEPT INTO TRANSPORT MODELLING AND SIMULATION FRAMEWORKS

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Extended Abstract

Technological advancements and the rise of the sharing economy have contributed towards the emergence of new flexible and on-demand mobility services and business models with the potential to greatly impact the current mobility landscape. This changing transport landscape has triggered the development of the Mobility as a Service (MaaS) concept. MaaS implementations could lead to changes of end users' activity and travel patterns (1;2) affecting private vehicle ownership and usage levels, consequently alleviating congested networks. Due to the multi-dimensional effects of MaaS, decision makers (both public authorities and businesses) need tools to capture, quantify and evaluate the impact of MaaS and determine how to implement it. Capturing the impacts of MaaS requires a full representation of demand and supply entities and their interactions through integrated demand and supply modelling and simulation approaches (3). Thus, the objectives of the paper are to first details the MaaS ecosystem before proposing an integrated transport modelling and simulation platform to capture the complex the dynamics of MaaS scenarios and business models. Finally, the approach is conceptualized within an integrated supply and demand activity-based model: SimMobility (4).

"*MaaS is a user-centric, intelligent mobility management and distribution system, in which an integrator – the MaaS Operator - brings together offerings of multiple mobility service providers and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility*" (5). It can be seen as an ecosystem of interacting demand and supply entities with the MaaS Operator (MO) in the middle. On the demand side, MaaS users are provided with a list of travel options to choose from, including public and private transport modes, based on multiple needs, preferences and travel budget, as well as a service which allows them to pursue more activities within the same timeline (3,6). The MaaS users are also provided with real-time mobility guidance via personalized real-time travel planning alternatives and information. On *the supply side*, the MO is responsible for distributing and assigning trip requests among Mobility Service Providers (MSP), while the MSPs are responsible for the efficient operations of their own services. The provision of a seamless mobility experience to end users is accomplished through the integration of ticketing, booking and payment across several modes.

The MO, as the integrator, plays the central role within a MaaS system. Currently, there are three prevailing operator types in the market and literature:

1. A *private company* that owns no supply assets (fleet etc.) and integrates/bundles different mobility services together to provide to end-users.
2. A *private MSP* that owns supply assets or controls the supply assets without owning them and partners with other MSPs to enhance their service promise to customers.
3. A *public transport authority* which integrates multiple forms of public and private transport through integrated payment and ticketing.

Several demonstrations have been initiated to provide insights into MaaS. Commercial implementations have recently been launched. A review of implemented MaaS services revealed that most are offered by private companies not owning a fleet. Multimodal journey planners are converted into MaaS services offering booking and ticketing in addition to planning. MSPs often integrate public transport options in their offerings, but cases where a MSP collaborates with other MSPs (competitors) are rare. Finally, there are some cases where the public transport authority acts as the MO.

Since MaaS systems are fundamentally dynamic and complex integrated transport systems, the consistent evaluation of the multidimensional and multiscale impact requires explicit modelling and simulation of the core MaaS actors' roles, functionalities, behaviours and interactions. The utilization of integrated demand and supply modelling and simulation techniques is, thus, deemed necessary to conduct a consistent analysis and evaluation of different MaaS business models, MO types and MaaS operations in urban environments. This paper presents a strategic roadmap to model and evaluate the MaaS concept by proposing an Integrated Transportation Modelling and Simulation (ITMS) framework that is envisioned explicitly to replicate all the daily operations, behaviours and interactions of the MaaS system's components.

The proposed ITMS incorporates five major components:

1. The *MaaS Market Model,* responsible for setting the ground of the MaaS scenario simulation, establishing MaaS system-related features and configurations as well as evaluating the MaaS system's performance.
2. The *Demand Modelling framework,* which is a system of econometric demand models responsible for capturing MaaS user's (referred to as agents within the simulation) long-term and short-term choices.
3. The *Multi-modal network model,* which handles aggregated or disaggregated vehicle movements in public and private transport networks.
4. The *MaaS Integration Controller,* which is a module that replicates the MaaS platform's daily operations.
5. The *Mobility Service Controllers*, which are dedicated modules that replicate the individual service management operations performed by public or private MSPs.

The MaaS Market Model represents the MaaS business ecosystem within the ITMS framework, providing the basis for simulating MaaS and evaluating its performance. Specifically, the MaaS Market Model will configure specific attributes of MaaS scenarios including MO types, objectives, functionalities, partnerships and commercial agreements with other MSPs. It will further define the MaaS products that will be offered as well as the static and dynamic pricing strategies performed by a MO for the Maas product prices. Simulation results will be further utilized from the MaaS Market Model to evaluate the performance of a simulated MaaS system by capturing key performance indicators such as the MO's profitability, revenues and costs, the MSPs' demand shares and revenues in and out of a MaaS system as well as the system's impact on traffic congestion and environmental pollution.

The MaaS Integration Controller is envisaged as a new experimental research platform, which emulates a MO's role and, thus, a MaaS platform's functionalities in a MaaS system, and allows to test algorithms and operational strategies for integrating, managing and offering the proposed MaaS system's mobility services. It will be a detachable (platform-independent) and simulation-based model designed explicitly to interact with the demand (MaaS users) and supply (MSPs) agents of the integrated agent-based transport simulation framework. The controller's framework will be modular to allow testing different scenarios and management algorithms. Each module will be responsible for a different task, such as personalized MaaS menu generation, MaaS menu provision, dynamic pricing, trip request handling and booking communications, etc. The MIC is mainly composed of two sub-modules, the *MaaS Integration Optimizer,* which is responsible for the optimization of the demand and supply management operations such as menu optimization/personalization and dynamic pricing and the *MaaS Integration Interface,* which is responsible for interfacing with the demand and supply agents of the system and monitoring their performance and decisions *(Figure 1)*.

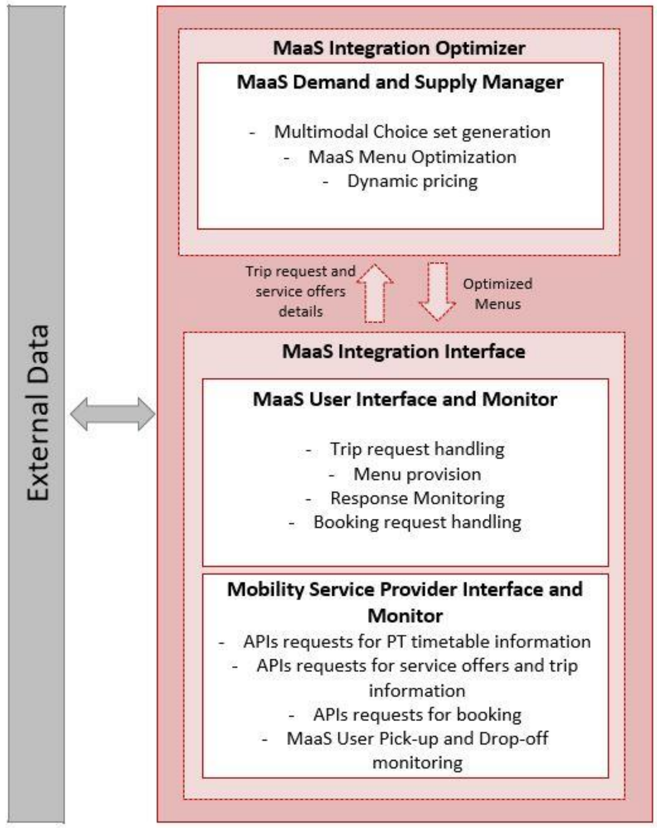

Figure 1: MaaS Integration Controller Architecture

The proposed Demand Modelling framework is agent-based so that capture long-term and short-term individual's decisions can be captured. Several behavioural models will be incorporated to capture individuals' choices on different scales such as subscribing to MaaS, product selection, and dynamic multiservice menu choices. These models will further allow us to capture the cumulative impact of MaaS on vehicle ownership, residential and work locations, daily activity and travel patterns and accessibility.

The Multimodal Network Model represents and emulates vehicle trajectories and traffic conditions of the simulated system by modelling either vehicle movements and traffic propagation. The network model is an important component of the ITMS, as it allows us to capture the impact of MaaS on traffic congestion and the environment.

Finally, the mobility service controllers represent the control centers of the different mobility services, being mainly responsible for operating and managing different services such as PT (Bus, Train), taxis, carsharing, ridesharing, ride-hailing, bike-sharing and even autonomous mobility on-demand services. The controllers will be modelled based on optimization and simulation-based approaches focusing on operations such as station locations, fleet sizing, static and dynamic pricing, assignment, routing, vehicle relocation, etc.

Finally, based on the integrated demand and supply modelling requirements addressed above, the paper proposes the integration of the proposed MaaS modelling framework in an ITMS, namely SimMobility (4), that consists of the fundamental design and agent-based demand and supply modelling approaches needed to consistently model and evaluate MaaS. SimMobility is an agent-based, activity-based, multi-modal simulation platform that models individual travel decision-making and the transportation systems operations at different time-scales. It comprises three fully integrated simulation levels: Long-Term (LT), Mid-Term (MT), and Short-Term (ST) corresponding approximately to the traditional land-use (LT), travel demand and mesoscopic network (MT) and microscopic traffic (ST) simulation models.

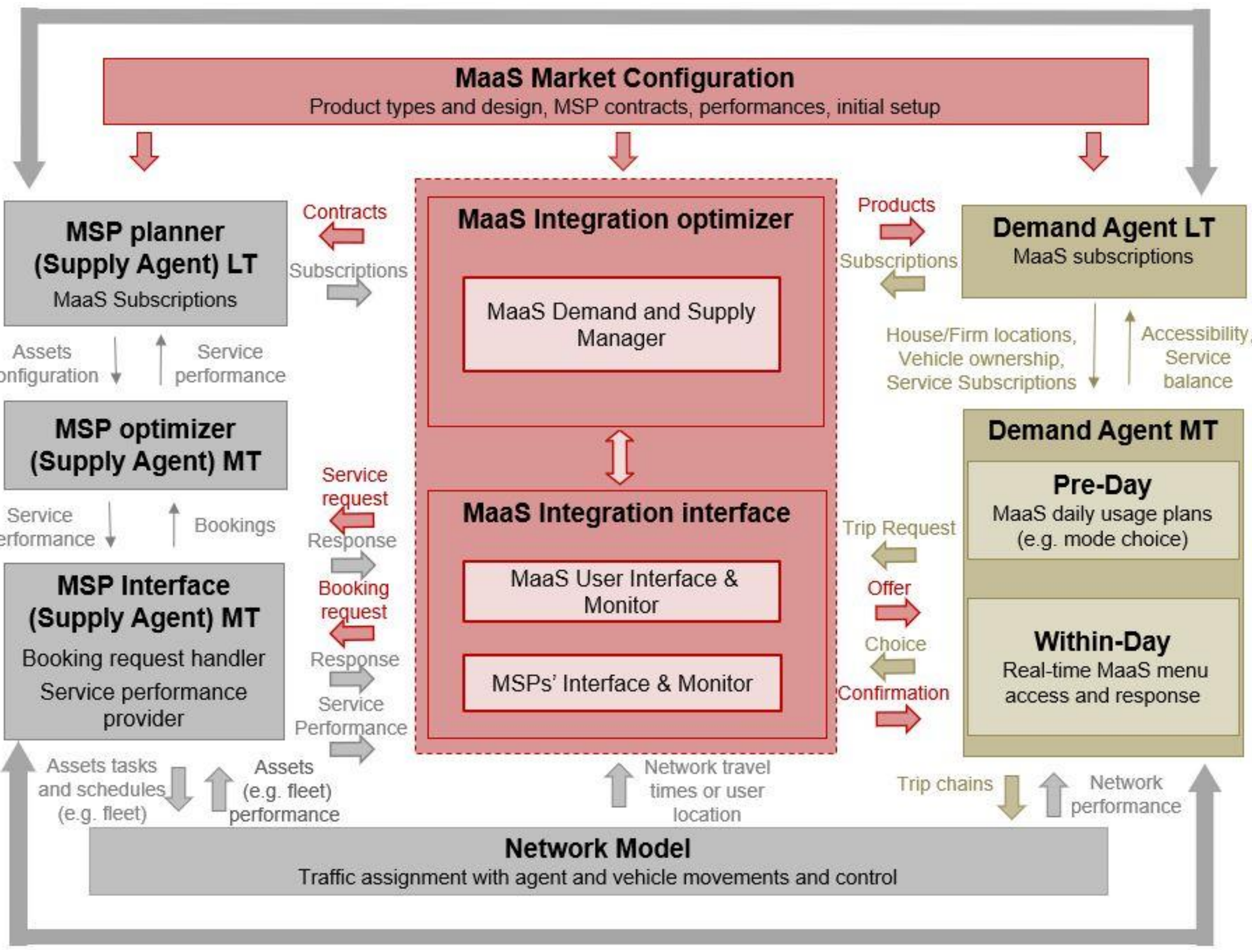

Figure 2: Integrated SimMobility and MaaS modelling framework

Figure 2 presents the overall integration framework and can be categorized into two modelling layers. The first modelling layer covers the long-term decision making of demand and supply agents, including:

- Individuals' subscriptions, product, vehicle ownership and residential locations in the presence of MaaS or not:
- MSPs and MOs making long-term decisions on partnerships, changing service agreement details (e.g. price or capacity levels available to MaaS) and general rules of daily operation

The second layer of modelling interactions happens on the daily decision making and supply simulation, i.e. the SimMobility-MT model. On the demand side, the Pre-Day model plans the daily activity schedule for each agent through a sequence of choice models, which is a key demand input for the within-day simulation, where demand in terms of actions and schedule revisions are carried out by agents as they interact with the supply models. Demand agents that have subscribed in MaaS interface with the MaaS Integration Controller making trip requests. The MaaS Integration Controller communicates the requests to the MSPs and generates an optimized menu of service alternatives. The pre-trip models capture the demand agents' choices through a behavioural model and the bookings are communicated with the MSPs through the interfaces. Finally, the network model emulates traffic conditions and handles vehicle movements.

The proposed integrated framework is conceptualized as a strategic roadmap to model MaaS in ITMS frameworks, enabling researchers, policy makers, transportation planners, decision makers and MOs to understand the complex nature of MaaS, test different MaaS business models with different organizational, structural and behavioural settings and evaluate the potential multi-scale and multi-dimensional impacts of MaaS on both demand and supply. In future work, we plan to test and evaluate different MaaS business models with different configurations settings by developing the required MaaS-oriented extensions in SimMobility and applying the integrated modelling and simulation framework to Greater London.

References:

1. Kamargianni, M., Matyas, M., Li, W., and Muscat, J. 2018. Londoners' attitudes towards car-ownership and Mobility-as-a-Service: Impact assessment and opportunities that lie ahead. MaaSLab - UCL Energy Institute Report, Prepared for Transport for London
2. Sochor, J., Strömberg, H., & Karlsson, I. C. M. (2015). Implementing Mobility as a Service challenges in integrating user, commercial, and societal perspectives. Transportation Research Record, 4(2536), pp1–9.
3. Jittrapirom, P., Caiati, V., Feneri, A.M., Ebrahimigharehbaghi, S., González, M.J.A.,Narayan, J., 2017. Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. Urban Plann. 2 (2), pp13–25
4. Adnan, M., Pereira, F.C., Azevedo, C.M.L., Basak, K., Lovric, M., Raveau, S., Zhu, Y., Ferreira, J., Zegras, C. and Ben-Akiva, M. Simmobility: A multi-scale integrated agent-based simulation platform. *95th Annual Meeting of the Transportation Research Board (TRB 2016).* Washington D.C., US, January 10-14, 2016.
5. MaaSLab. The MaaS Dictionary. MaaSLab, UCL, London. https://docs.wixstatic.com/ugd/a2135d_accc1c84f69d437bb89844e660a0ca26.pdf Accessed Jul. 20, 2018
6. Nikitas, A., Kougias, I., Alyavina, E. and Njoya Tchouamou, E., 2017. How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context of Smart Cities? Urban Science, 1(4), p.36.