- ABSTRACT -

*32nd Electric Vehicle Symposium (EVS32)*
*Lyon, France, May 19 - 22, 2019*

# State of the art of electric Mobility as a Service (eMaaS): an overview of ecosystems and system architectures

J. Roberto Reyes García[1,2], Gadi Lenz[3], Steven Haveman[2], G. Maarten Bonnema[2,4]

[1]*Corresponding author. University of Twente. Drienerlolaan 5, 7522 NB, Enschede, The Netherlands. email: j.r.reyesgarcia@utwente.nl*

[2] *University of Twente, Faculty of Engineering Technology. Department of Design, Production and Management*

[3] *Urban Software Institute GmbH, Fasanenstraße 3, 10623 Berlin, Germany*

[4] *University of South-Eastern Norway, Norwegian Industrial Systems Engineering group, Kongsberg, Norway*

**Summary**

Mobility as a Service (MaaS) is a concept that aligns with both current and future mobility demands of users, namely intermodal, personalized, on-demand and seamless. Although the number of shared mobility, electric mobility and multimodal passenger transport users is rapidly growing, until now, the list of MaaS and electric Mobility as Service (eMaaS) providers is quite short. This could partly be explained by the lack of a common architecture that facilitates the complex integration of all actors involved in the (e)MaaS ecosystem. In this paper we first review the state of the art of (e)MaaS ecosystems and architectures. Secondly, we propose an eMaaS ecosystem and an innovative eMaaS architecture that focuses on the integration of MaaS and electric mobility systems. With this work, we aim to support the further development of eMaaS.

*Keywords: MaaS (mobility as a service), mobility system, research*

## 1 Introduction

With both the growing adoption of electric mobility and the expanding development of MaaS, electric Mobility as a Service (eMaaS) has the perfect opportunity to become one of the foremost solutions for today's mobility challenges. eMaaS expands on the MaaS concept having as a complementary goal to provide users the possibility to go from A to B not only in a multimodal and seamless way but also in an even more eco-friendly way than just reducing car ownership as intended by MaaS.

The eMaaS concept is built upon the MaaS model. Its proposition is that to achieve multimodal, seamless and eco-friendly mobility, MaaS should be combined with Electric Mobility Systems (EMS) and Shared Electric Mobility Services (SEMS). Connecting these three concepts leads to our working definition of eMaaS:

> electric Mobility as a Service (eMaaS) refers to the integration of multiple forms of (electric) transportation modes –including public transport– and shared electric mobility services (e.g. e-car sharing, e-bike sharing, e-scooter sharing, e-bus, e-taxi) into a single mobility service that allows travelers to plan and go from A to B (and/or from B to C and/or vice versa) in an eco-friendly and seamless way. The service is offered through a single customer-centred interface and it also involves the prearrangement of electric mobility technologies and infrastructure (e.g. charging stations, energy contracts).

### 1.1 Goal and research question

The goal of this publication is to give an overview of the state of the art regarding (e)MaaS' ecosystems and architectures. Moreover, it aims to support the further development of eMaaS by proposing a novel system architecture. The research questions that lead this paper are:

1. What are existing (e)MaaS ecosystems and architectures?
2. What elements and functions should an eMaaS architecture include to facilitate the integration and interaction of all actors within the eMaaS ecosystem?
3. How does a system architecture support the further development of eMaaS?

## 2 MaaS ecosystems

The MaaS ecosystem has already been described by some transport specialists, researchers and MaaS developers. However, most of the first (e)MaaS ventures are still under development or at a pilot phase. On a high-level, the MaaS ecosystem consists of: transport infrastructure, transportation services, transport information and payment services [1]. Within the ecosystem, all different modes of transport and actors share the common objective of delivering a seamless mobility experience [1] and aim at improving the transportation network by exploiting the benefits of each service. Moreover, other actors such as local authorities or data management companies can also cooperate to enable the operation of the services and improve their efficiency [2], [3].

Fig. 1 below shows one of the most used (and probably the first) examples of the MaaS framework [10]. The framework was presented by the Finish Ministry of Transport and Communications in December 2014 as an overview of the envisioned scenario for MaaS operators. A remarkable observation given by the MaaS-Alliance on the MaaS framework is that, although the framework includes the main services of the MaaS ecosystem, in a mature ecosystem some of the services could, and most probably be, non-mobility related [1].

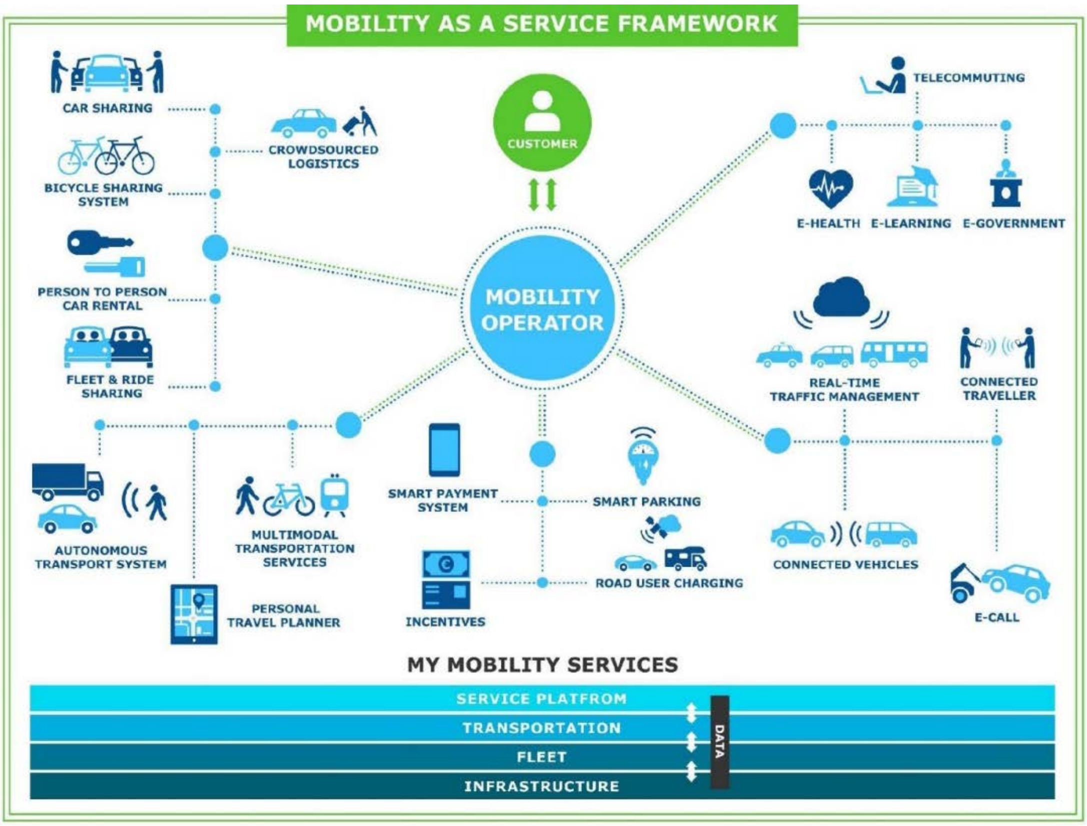


Figure 1: The Mobility as a Service framework. Source: [4]

### 2.1 The eMaaS ecosystem

All in all, the MaaS ecosystems found in the literature seem to take all relevant factors into account to guarantee the mobility of users from A to B in a seamless way. However, as explained before, the proposition of eMaaS is to offer users the possibility to travel in an eco-friendly way. Therefore, the eMaaS ecosystem is composed of the combination of Mobility as a Service (MaaS), Electric Mobility Systems (EMS) and Shared Electric Mobility Services (SEMS) as shown in Fig. 2.

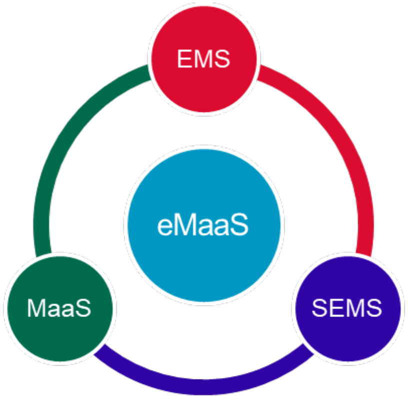


Figure 2: The electric Mobility as a Service (eMaaS) ecosystem

Within the eMaaS ecosystem all three modules (MaaS, EMS and SEMS) are complementary. This means that, even when each of the modules offer mobility options for the user, eMaaS cannot be achieved by means of only one or two modules. An important reminder here is that eMaaS is built upon the MaaS model, therefore the actors taking place in the MaaS ecosystem are also playing a role in the eMaaS ecosystem. In this paper we will expand and explain all the components of the eMaaS ecosystems.

## 3 MaaS architectures

As with MaaS ecosystems, some MaaS architectures have already been proposed by MaaS practitioners and researchers. A system architecture “defines the parts constituting a system and allocates the system’s functions and performance over its parts, its user, its super system and the environment in order to meet system requirements” [5] (p.5). MaaS system architectures such as the ones presented by Siemens [6], König et al. [7], Datson [8], García Hernández [9], Ambrosino et al. [10], or Pflügler et al. [11] are useful conceptual references to describe the requirements, functions and capabilities of the components within the MaaS ecosystem.

One of the most common examples referred in literature of a successful MaaS pilot is the SMILE project run in Austria. The goal of the project was to create a mobility platform that not only allowed users to be informed about all available means of transport but to let them book, pay and use them [12]. The goal of the SMILE project architecture was to provide standardized and easy to integrate connectors that enable even smaller partners to use the full range of high quality services offered in the MaaS environment [13].

Although the existing conceptual architecture references offer an overview of the elements in a system architecture, there is not yet an open architecture that can be used as a base for the further development of (e)MaaS [1], [14], [15]. Taking this into account, in this paper we will present an innovative system architecture that aims to be a supporting pillar for the further development of (e)MaaS.

### 3.1 The eMaaS architecture

The system architecture proposed here is composed of functional blocks and elements that cover all elements within the eMaaS ecosystem. The eMaaS system architecture can be explained by dividing it in three main blocks, namely (1) Shared e-mobility, (2) Data & Analytics extension, and (3) Other mobility & 3rd Party Systems. One of the distinctive characteristics of this architecture is that it is more extensive than the ones intended for MaaS systems. It not only covers electric mobility requirements such as charging points management and EV fleet management, but also combines elements that not all architectures take into account (e.g. smart data brokers integration and advanced analytics).

## 4 First conclusions

The current state of the art regarding MaaS ecosystems and systems architectures is fairly limited, although some examples can be found in literature which are useful conceptual references for the understanding of the MaaS model and its context. Moreover, some MaaS architectures have been used in practice and have brought the first examples of functional MaaS models (e.g. SMILE).

eMaaS is a concept that builds upon the MaaS model. As such, the MaaS ecosystem and MaaS system architectures serve as a foundation for the development of eMaaS and its system architecture. The addition of the eMaaS concept over MaaS is that the former guarantees eco-friendly mobility while offering the same benefits as the latter. Furthermore, eMaaS can even mitigate some of the downsides of MaaS, like the underutilisation of public transport, by only offering shared mobility services (including public transport).

Having a clear overview of the elements in the eMaaS ecosystem and in the system architecture helps in the development of eMaaS by identifying the requirements, functions, stakeholders and interfaces that need to be covered when developing the eMaaS services. With the eMaaS architecture proposed in this paper, all the required capabilities of eMaaS are covered. The architecture takes into account the additional elements of Electric Mobility Systems (such as EV fleets and charging points, etc.) and Shared Electric Mobility Services (such as e-car sharing, e-bike sharing or e-scooter sharing, and even extra mobility modes such as e-public transport or demand responsive transport).

## Acknowledgments

The eMaaS project has received funding from the ERA NET COFUND Electric Mobility Europe (EMEurope). Participating project partners are Move About GmbH from Austria, Urban Software Institute GmbH from Germany, the Urban Institute Zrt. from Hungary, Move About AB from Sweden, GoodMoovs (trademark of eMobilityToolBox B.V.) and the University of Twente from the Netherlands.

## References

[1] MaaS Alliance, “Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem,” 2017.

[2] P. Jittrapirom, V. Caiati, A.-M. Feneri, S. Ebrahimigharehbaghi, M. J. A. González, and J. Narayan, “Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges,” *Urban Plan.*, vol. 2, no. 2, pp. 13–25, 2017.

[3] A. Kawasaki, “Fujitsu’s Approach to Smart Mobility,” *FUJITSU Sci. Tech. J*, vol. 51, no. 4, pp. 3–7, 2015.

[4] M. Kivimäki, “MaaS - Finland on the leading edge,” in *Mobility as a Service seminar and networking event* , 2014.

[5] G. M. Bonnema, “FunKey Architecting: an integrated approach to system architecting using functions, key drivers and system budgets,” University of Twente, 2008.

[6] SIEMENS, “MaaS operation and integration with demand-responsive transport in Tampere.” Siemens Mobility Division, 2016.

[7] D. König, E. Piri, M. Karlsson, J. Sochor, and I. Heino, “MaaSiFiE: Technology for MaaS (Deliverable nr. 5),” 2017.

[8] J. Datson, “MOBILITY AS A SERVICE EXPLORING THE OPPORTUNITY FOR MOBILITY AS A SERVICE IN THE UK,” Milton Keynes, 2016.

[9] J. García Hernández, Ed., *Holistic Personal public Eco-mobility - Deliverable 2.3 - HoPE Architecture Analysis*. 2014.

[10] G. Ambrosino, J. D. Nelson, M. Boero, and I. Pettinelli, “Enabling intermodal urban transport through complementary services: From Flexible Mobility Services to the Shared Use Mobility Agency: Workshop 4. Developing inter-modal transport systems,” *Res. Transp. Econ.*, vol. 59, pp. 179–184, 2016.

[11] C. Pflügler, M. Schreieck, G. Hernandez, M. Wiesche, and H. Krcmar, “A Concept for the Architecture of an Open Platform for Modular Mobility Services in the Smart City,” *Transp. Res. Procedia*, vol. 19, pp. 199–206, Jan. 2016.

[12] “smile – simply mobile,” 2015. [Online]. Available: http://smile-einfachmobil.at/index_en.html. [Accessed: 20-Feb-2019].

[13] “Smile Projeckt.” [Online]. Available: http://at.nttdata.com/fileadmin/web_data/country/at/Archiv_2013_2014/Downloads/Reinhard_Birke__Wr._Stadtwerke_-_SMILE.pdf. [Accessed: 30-Jan-2019].

[14] W. Goodall, T. Fishman Dovey, J. Bornstein, and B. Bonthron, “The rise of mobility as a service - Reshaping how urbanites get around,” *Deloitte Rev.*, no. 20, p. 20, 2017.

[15] J. Eckhardt, A. Aapaoja, L. Nykänen, J. Sochor, M. Karlsson, and D. König, “The European Roadmap 2025 for Mobility as a Service,” in *Proceedings of 7th Transport Research Arena TRA 2018*, 2018.

## Authors

J. Roberto Reyes García holds a Bachelor degree in Mechatronics, a Master degree in Industrial Engineering, both by the Instituto Politécnico Nacional (IPN) in Mexico, and a Professional Doctorate in Engineering (PDEng) by the University of Twente. Roberto currently works as a Junior researcher at the Systems Engineering and Multidisciplinary Design group at the University of Twente. His research focuses on data-driven models for the promotion of electric mobility in Europe and on data-driven architectures and business models for the development of electric Mobility as a Service (eMaaS).

Gadi Lenz holds a Doctoral Degree in Electrical Engineering from the Massachusetts Institute of Technology (MIT). He started his career as a research scientist at Bell Labs in the field of optical communications. He has held CTO and Chief Scientist positions over the last two decades. In this capacity, he participated and led complex systems engineering projects in various domains including public safety and security, Intelligent Transportation Systems (ITS), Smart Energy and Smart infrastructure. Most recently, he has been working on IoT centric solutions, platforms and architectures for Smart Cities with a focus on mobility and electric vehicles.

Dr. Ir. Steven Haveman holds a Doctoral Degree as well as a Master's degree in Industrial Engineering, both achieved at the University of Twente in the Netherlands. His doctoral research, titled "COMBOS: Communicating Behaviour of Systems", established a method to communicate system behaviour of large and complex systems towards multiple stakeholders during conceptual systems design. Steven has worked as a technical Systems Engineering lead responsible for developing Automated Guided Vehicle Systems for applications in warehouses and factories. His current research focuses on clarifying the complex electric and smart mobility ecosystems by capturing these in usable models and architectures for various stakeholders.

Maarten Bonnema is an Associate Professor at the Department of Design, Production and Management at the University of Twente, and at the Norwegian Industrial Systems Engineering group of the University of South-Eastern Norway. His background lies in Electrical, Mechatronic and Systems Design. His main focus is on design of complex systems. One of those complex systems that has his particular attention is electric mobility. Here, he researches the shift to electric mobility from a systems perspective, including technology, infrastructure, facilities, regulations and most importantly, the user.