BITS&CHIPS
SYSTEM
ARCHITECTING
CONFERENCE

24 SEPTEMBER 2020 • IGLUU • EINDHOVEN

The challenge to define architectures and interfacing standards for an electric Mobility as Service ecosystem

J. Roberto Reyes García & Maarten Bonnema

UNIVERSITY
OF TWENTE.

About us

University of Twente – Department of Design, Production and Management
Systems Engineering and Multidisciplinary Design (SEMD) Group || Electric Mobility Research Team

	Junior Researcher	**J. Roberto Reyes García**	Researcher on Reference Architectures for Data-driven Systems and Electric Mobility Applications
	Associate Professor	**Dr. Ir. Maarten Bonnema**	Chair of SEMD and Project Supervisor

About us

University of Twente – Department of Design, Production and Management
Systems Engineering and Multidisciplinary Design (SEMD) Group || Electric Mobility Research Team

	Junior Researcher	**J. Roberto Reyes García**	Researcher on Reference Architectures for Data-driven Systems and Electric Mobility Applications
	Associate Professor	**Dr. Ir. Maarten Bonnema**	Chair of SEMD and Project Supervisor

Projects (2018-2020)

Electric Mobility Europe

PROMOTING proEME ELECTRIC MOBILITY EUROPE

eMAAS

European Commission

About us

University of Twente – Department of Design, Production and Management
Systems Engineering and Multidisciplinary Design (SEMD) Group || Electric Mobility Research Team

	Junior Researcher	**J. Roberto Reyes García**	Researcher on Reference Architectures for Data-driven Systems and Electric Mobility Applications
	Associate Professor	**Dr. Ir. Maarten Bonnema**	Chair of SEMD and Project Supervisor

Projects (2018-2020)

Electric Mobility Europe

PROMOTING proEME ELECTRIC MOBILITY EUROPE

eMAAS

European Commission

About our project

The eMaaS project:

Develops and stimulates an open ecosystem for eco-friendly Mobility as a Service

Our Goals:

- Support large scale adoption of EVs through new business models
- Connect EV sharing services to other eco-friendly modes of mobility
- Put users at the centre and provides easily accessible solutions

eMaaS project partners

For more info: www.emaas.eu

Sweden

MoveAbout Sweden

Netherlands

GoodMoovs

University of Twente

Germany

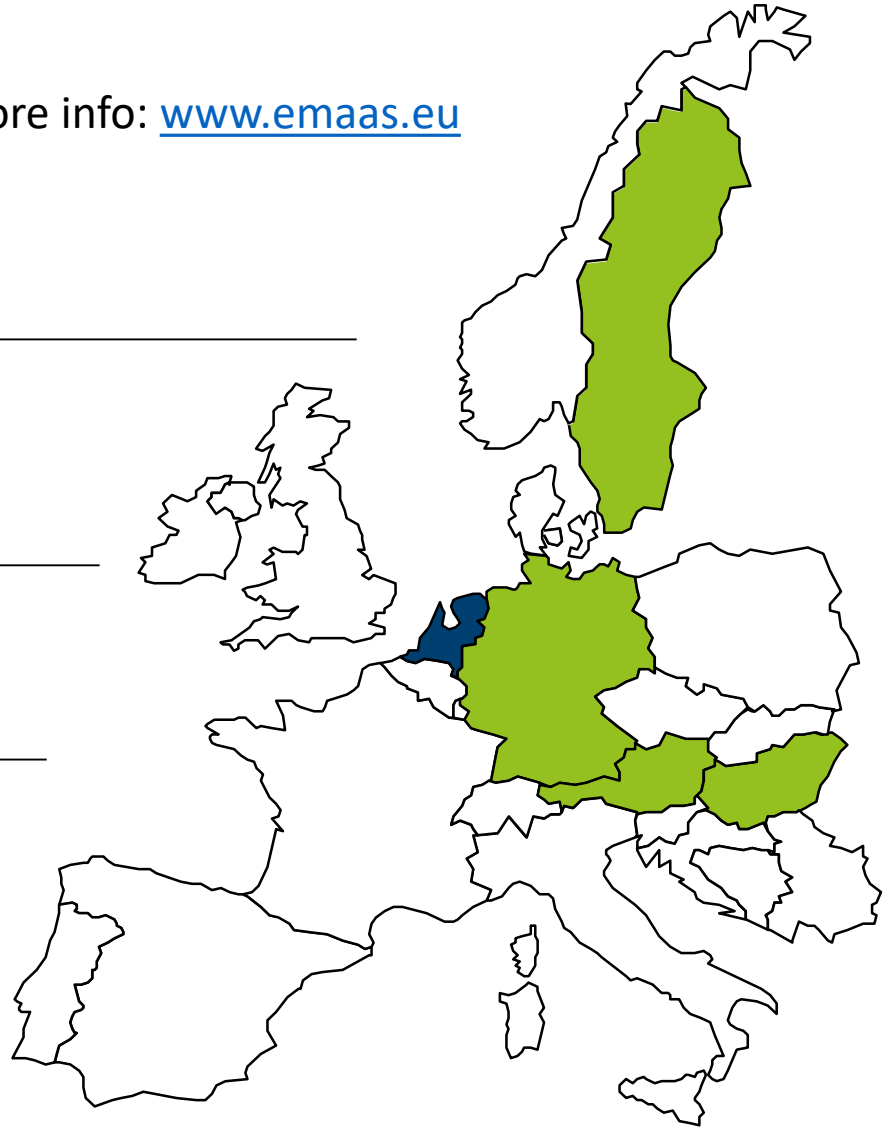
[ui!] urban institute

Austria

MoveAbout Austria

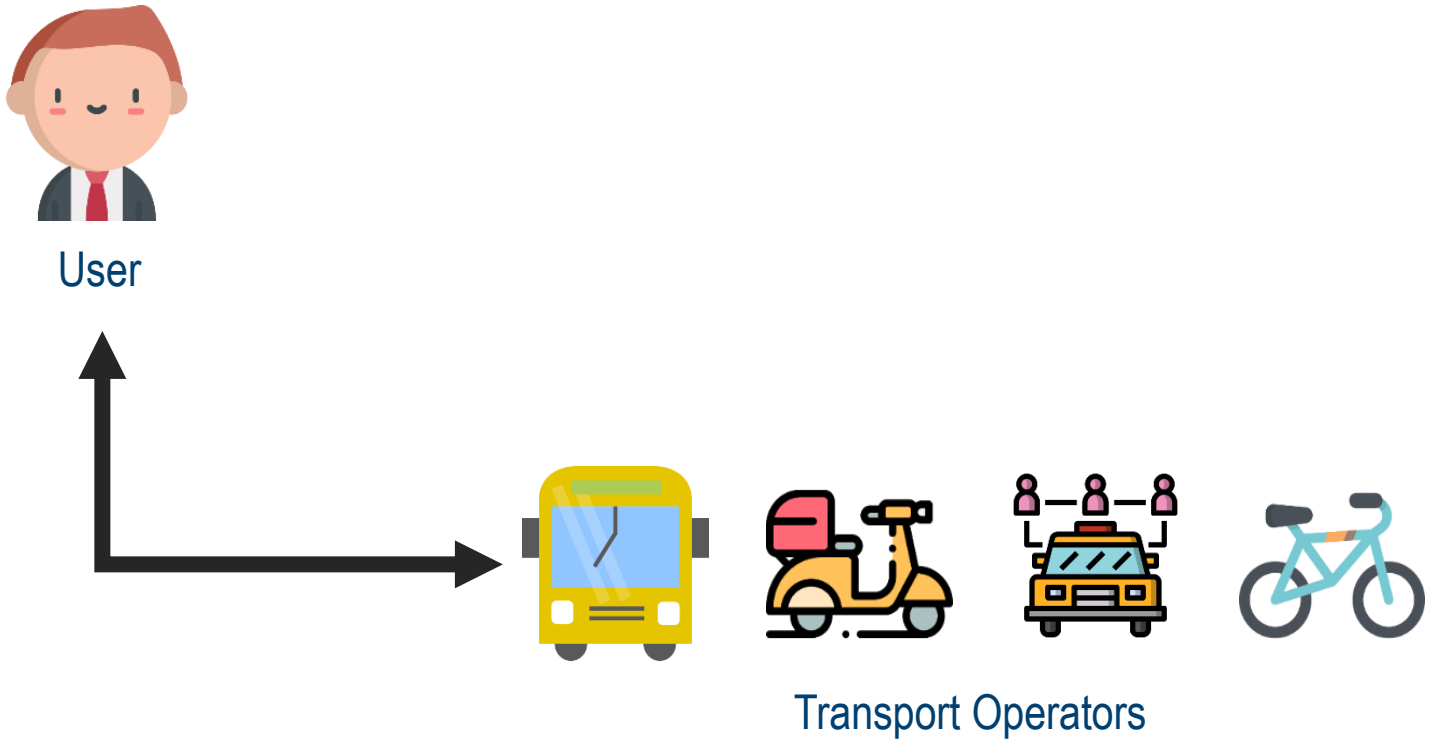
Hungary

[ui!] urban institute Hungary Zrt.



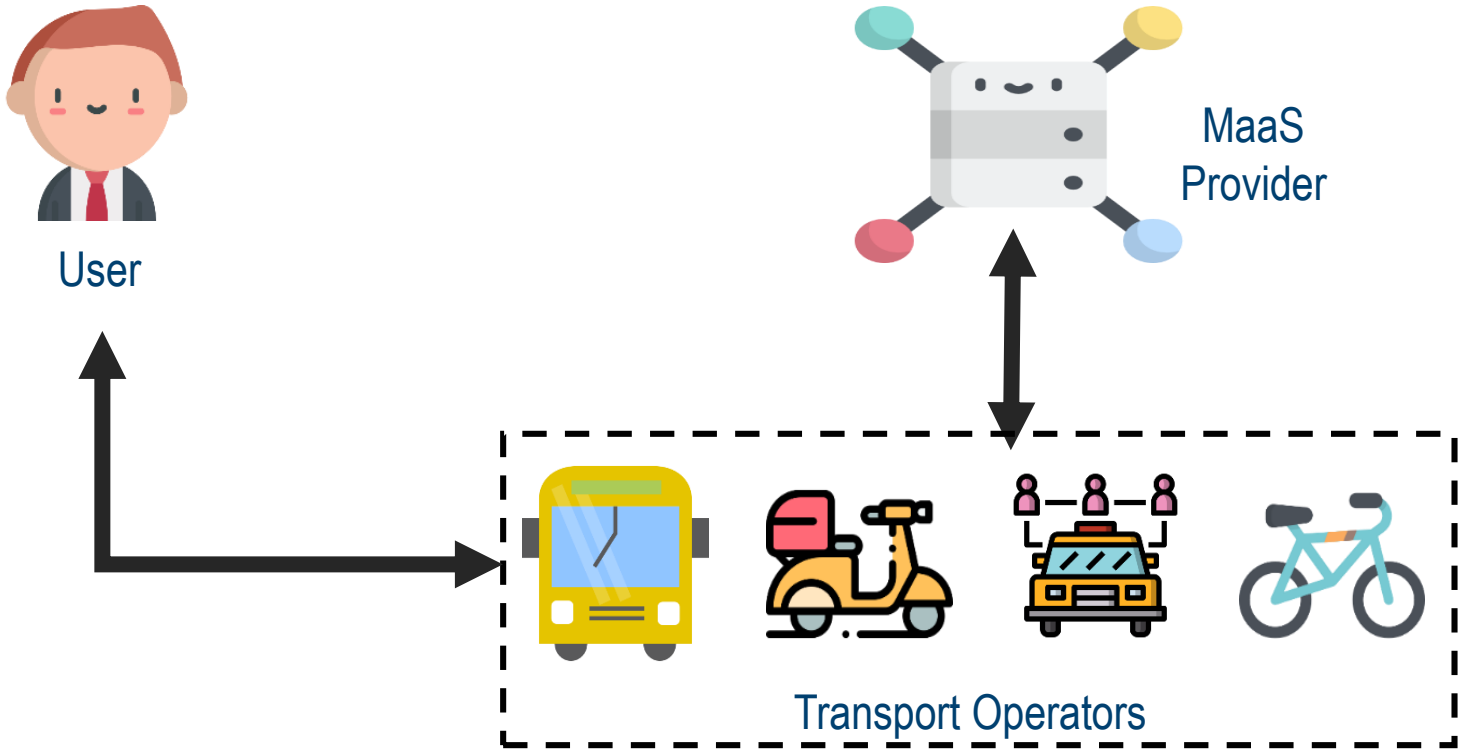
What is (e)MaaS?

What is (e)MaaS?



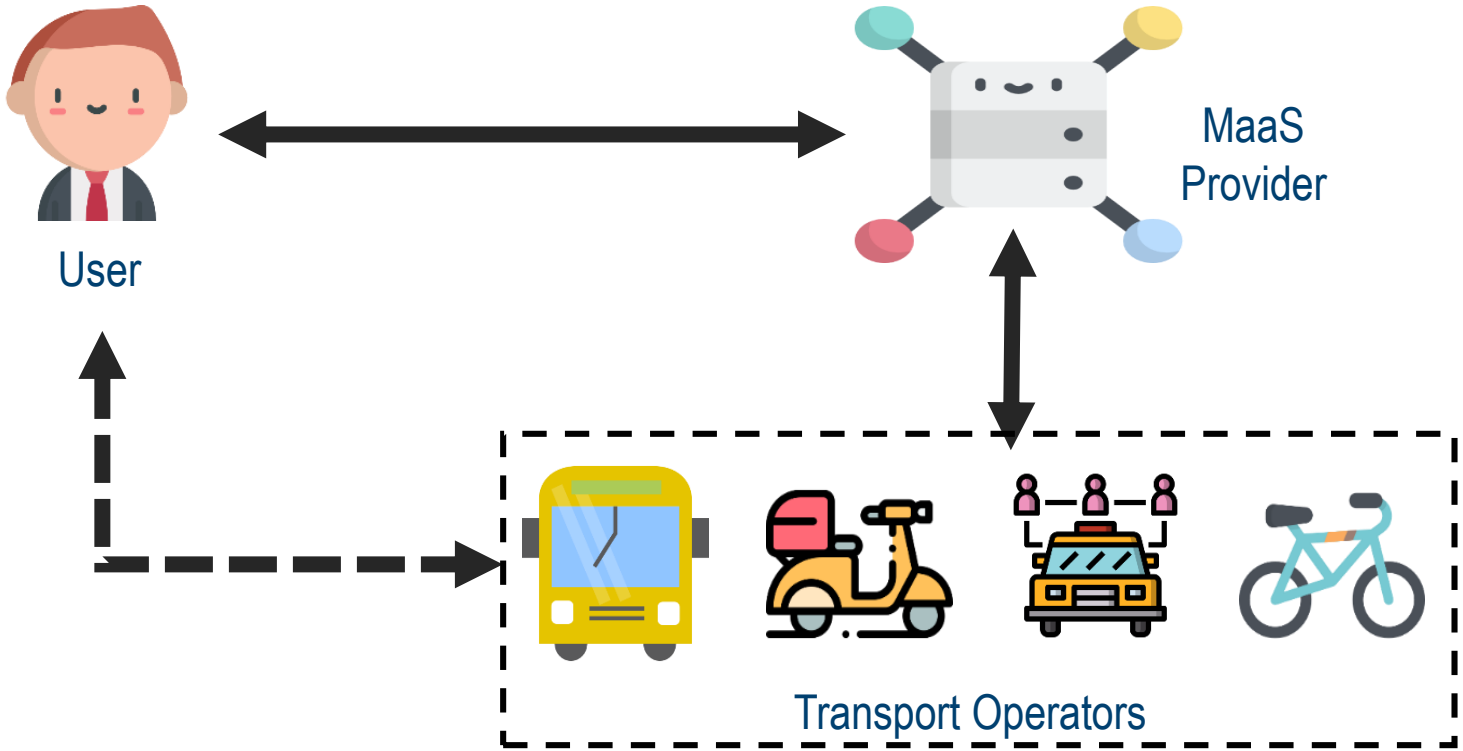
* Icons from *flaticon.com*

What is (e)MaaS?



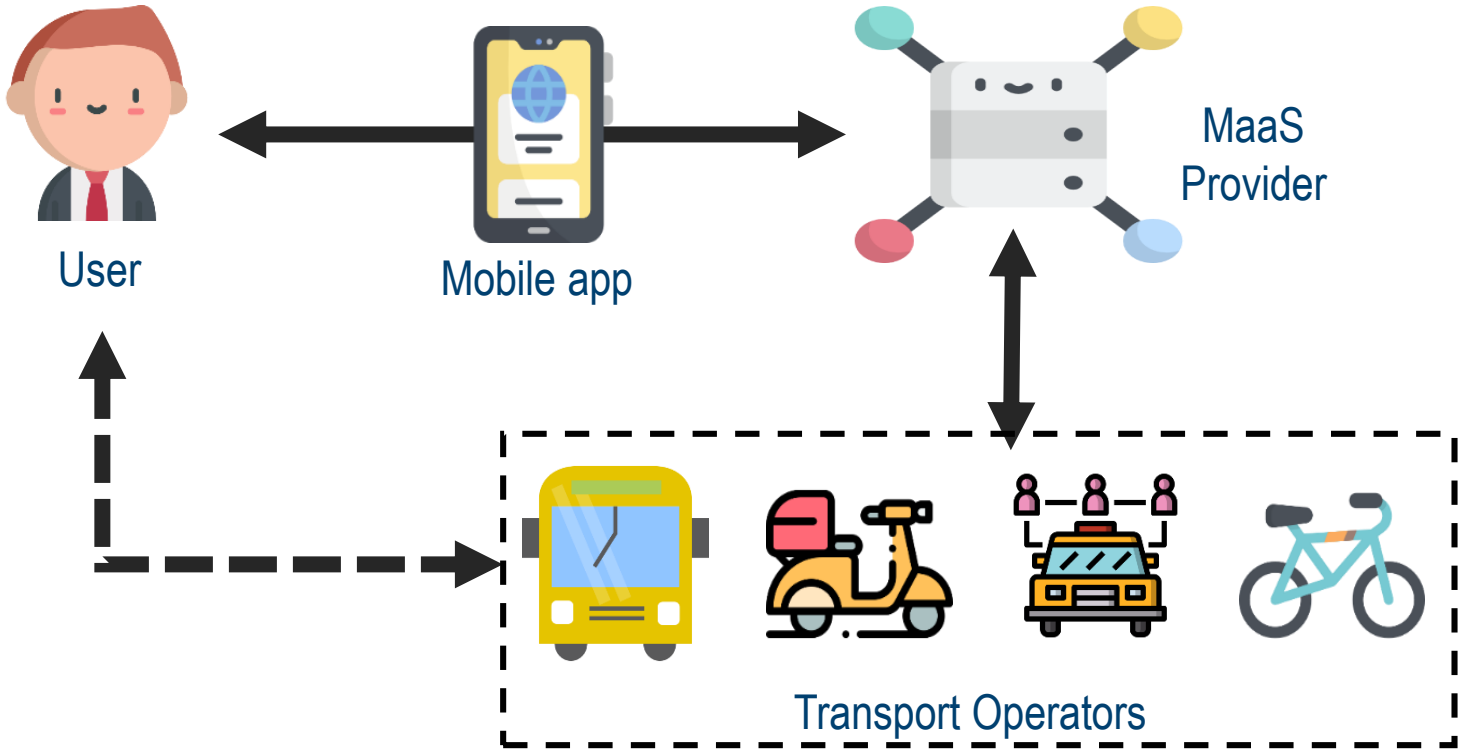
* Icons from *flaticon.com*

What is (e)MaaS?



* Icons from *flaticon.com*

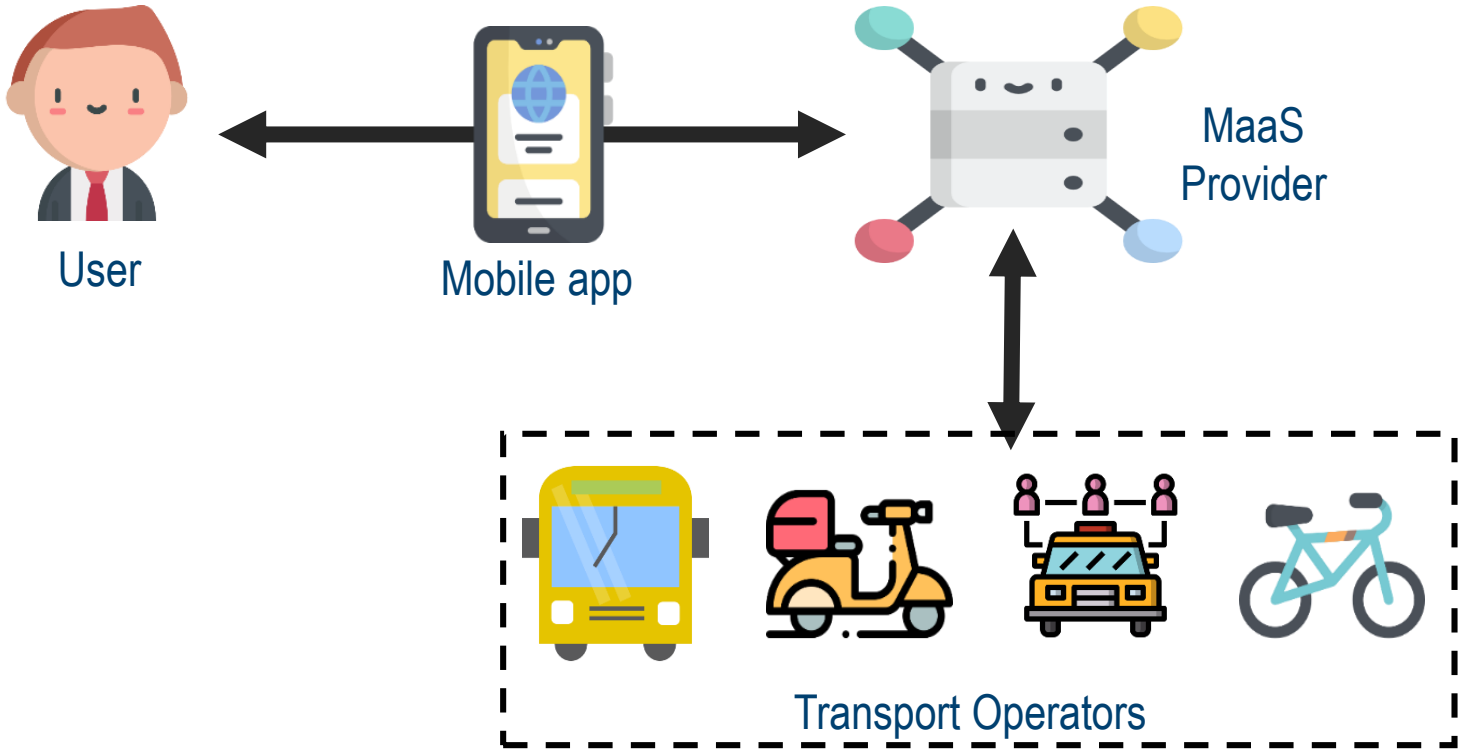
What is (e)MaaS?



* Icons from *flaticon.com*

What is (e)MaaS?

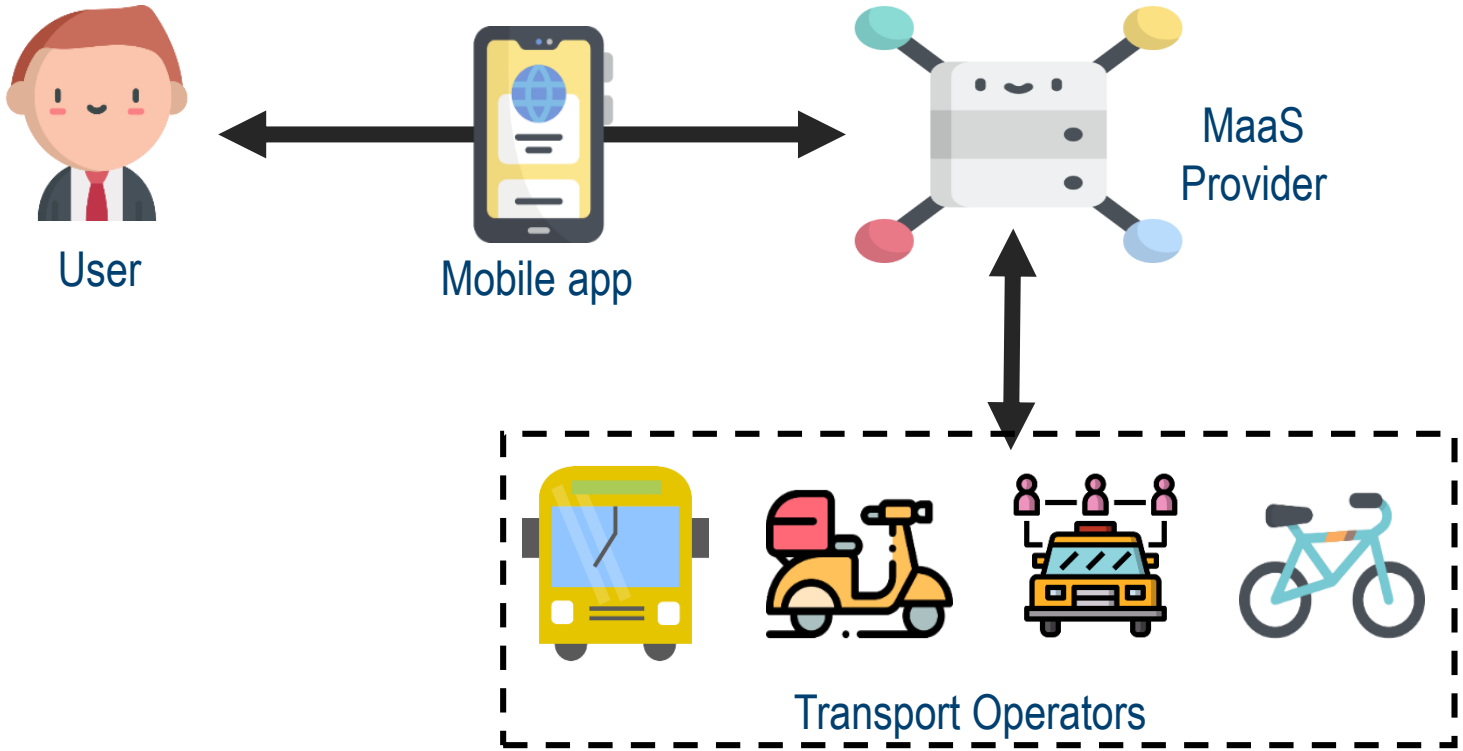
Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

What is (e)MaaS?

Basic Mobility as a Service ecosystem

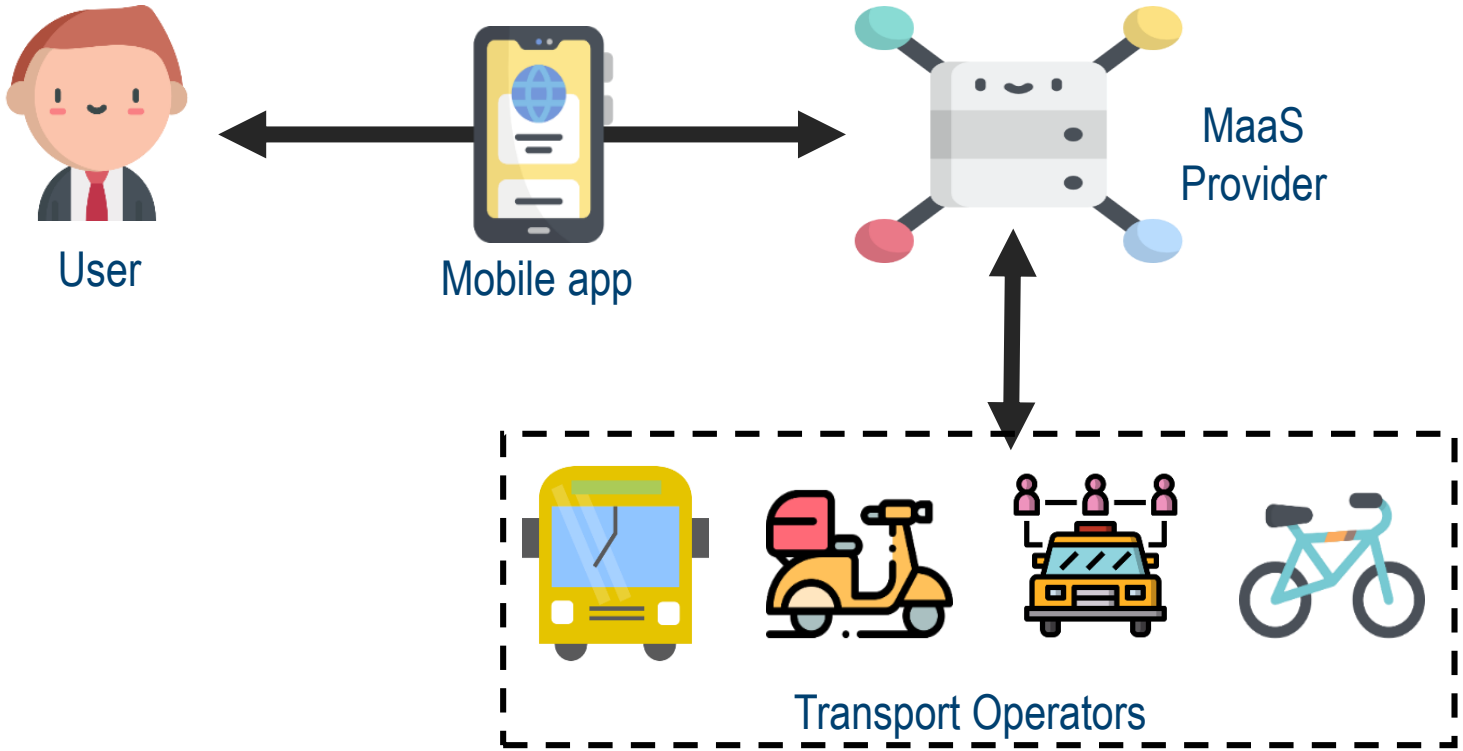


eMaaS = MaaS + EVs ?

* Icons from *flaticon.com*

What is (e)MaaS?

Basic Mobility as a Service ecosystem



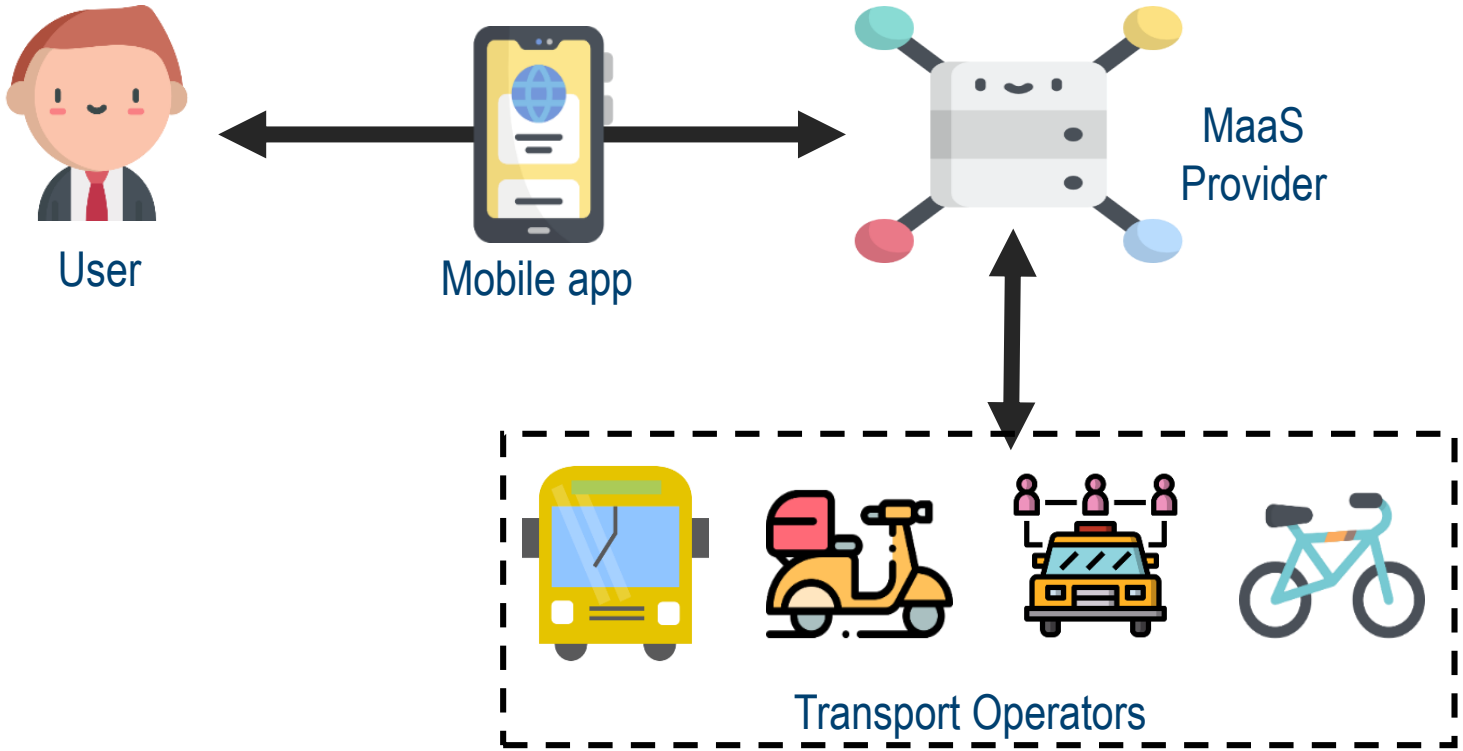
eMaaS = MaaS + EVs ? ✗

The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

* Icons from *flaticon.com*

What is (e)MaaS?

Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

eMaaS = MaaS + EVs ? ✗

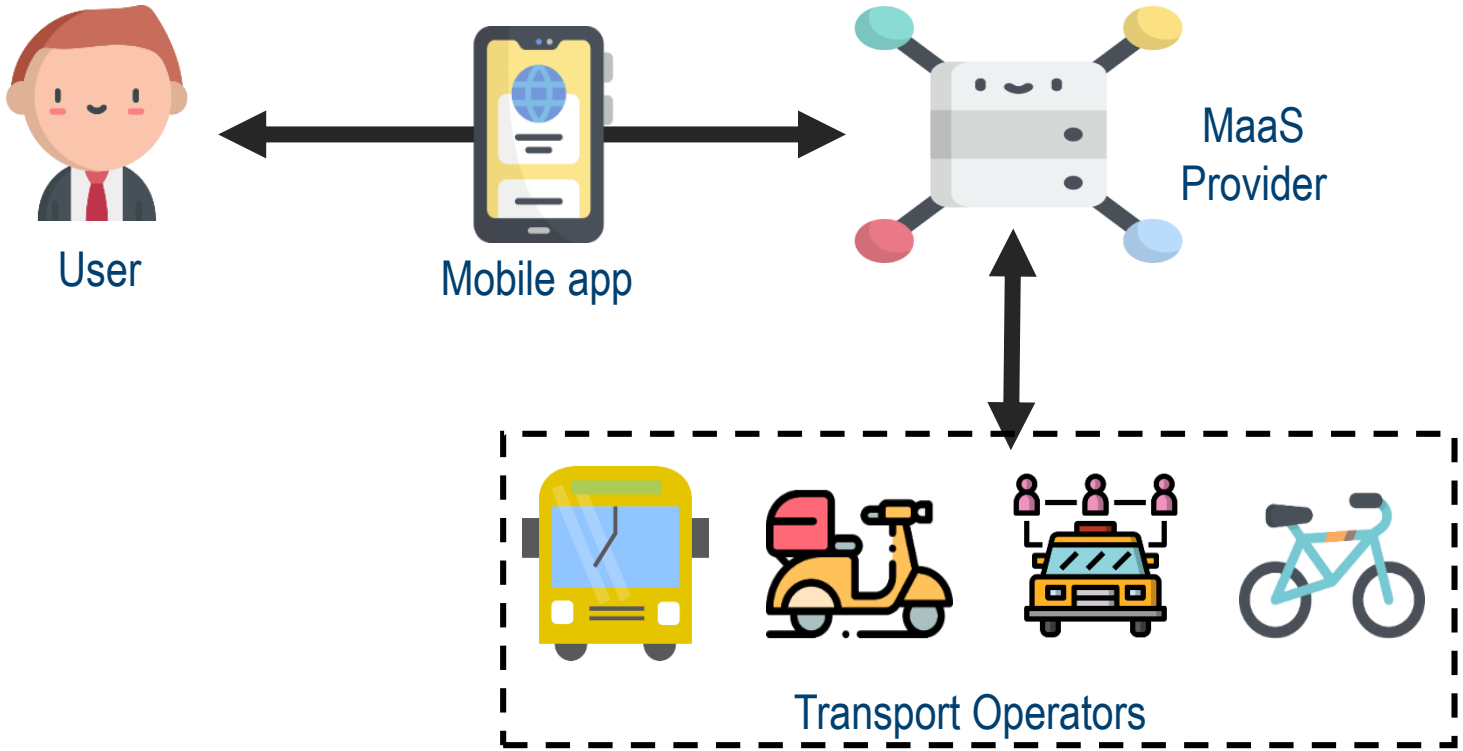
The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

eMaaS = MaaS + SeMS + EMS ✓

eMaaS = electric Mobility as a Service
MaaS = Mobility as a Service
EMS = Electric Mobility Systems
SeMS = Shared electric Mobility Services

What is (e)MaaS?

Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

eMaaS = MaaS + EVs ? ✗

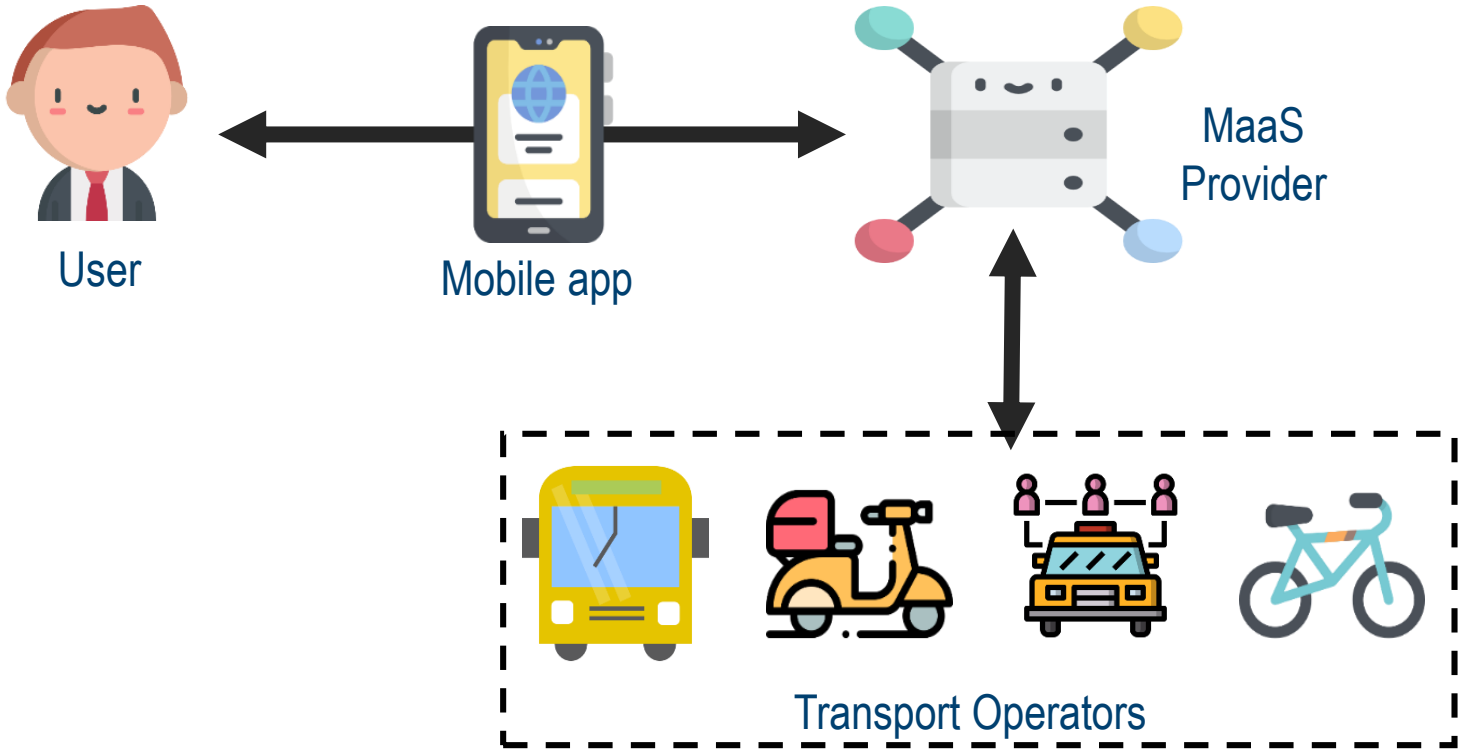
The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

eMaaS = MaaS + SeMS + EMS ✓

eMaaS = electric Mobility as a Service
MaaS = Mobility as a Service
EMS = Electric Mobility Systems
SeMS = Shared electric Mobility Services

What is (e)MaaS?

Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

eMaaS = MaaS + EVs ? ✗

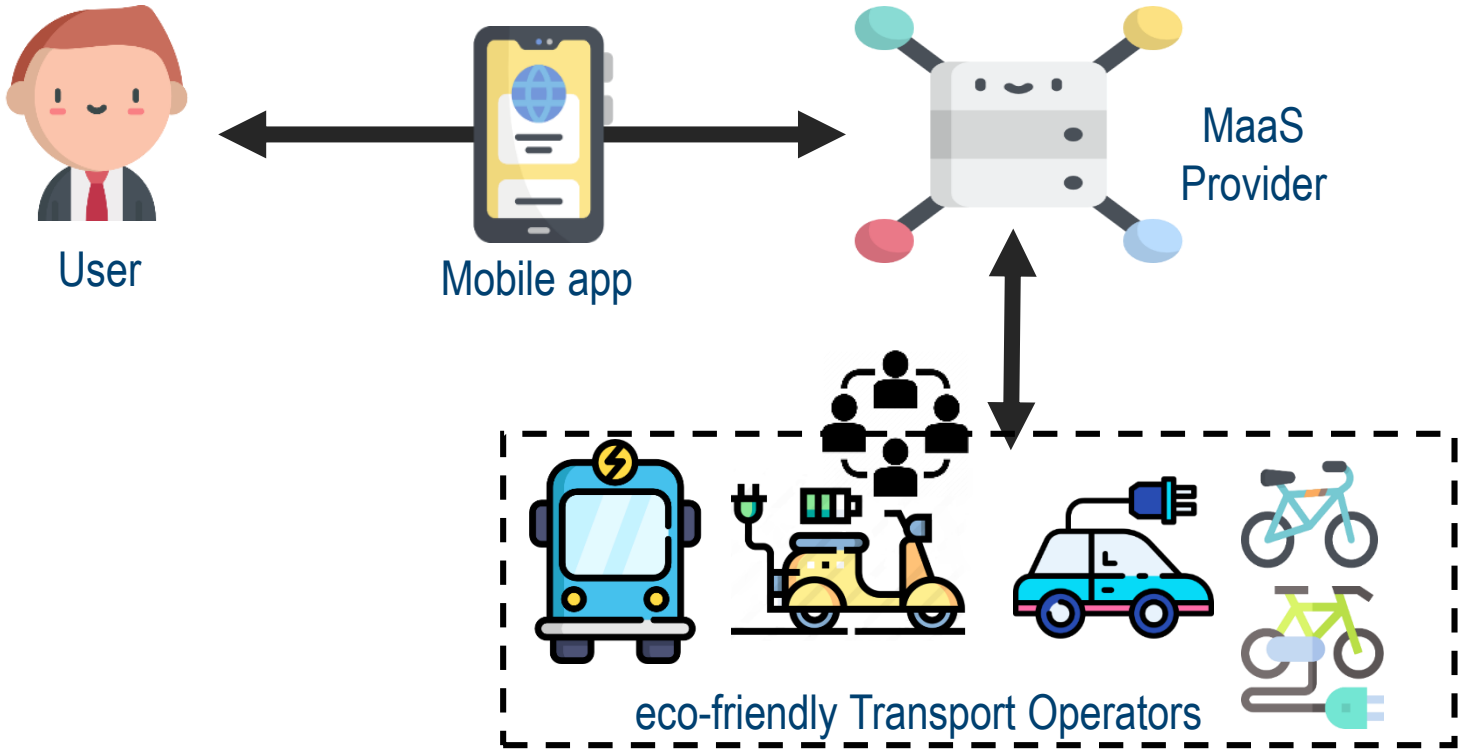
The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

eMaaS = MaaS + SeMS + EMS ✓

eMaaS = electric Mobility as a Service
MaaS = Mobility as a Service
EMS = Electric Mobility Systems
SeMS = Shared electric Mobility Services

What is (e)MaaS?

Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

eMaaS = MaaS + EVs ? ✗

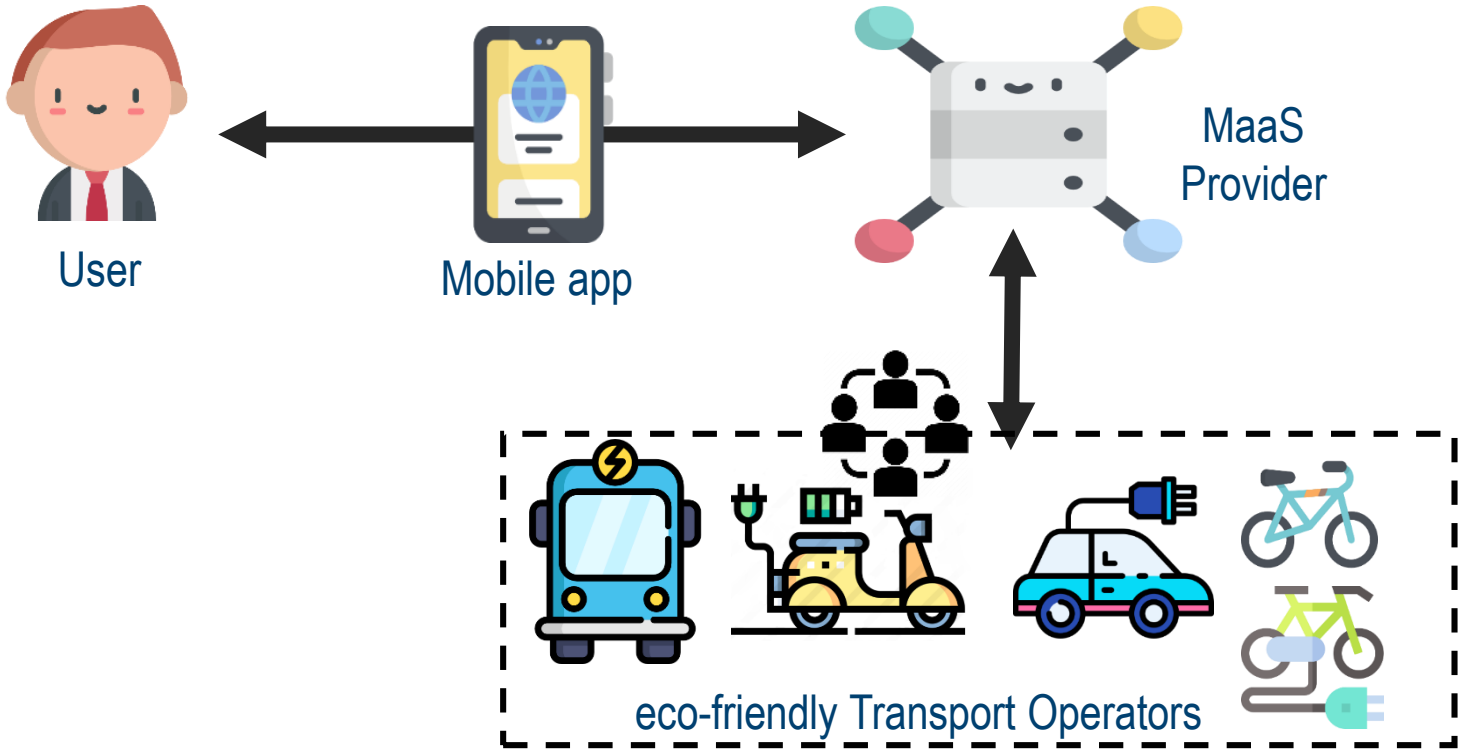
The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

eMaaS = MaaS + SeMS + EMS ✓

eMaaS = electric Mobility as a Service
MaaS = Mobility as a Service
EMS = Electric Mobility Systems
SeMS = Shared electric Mobility Services

What is (e)MaaS?

Basic Mobility as a Service ecosystem



* Icons from *flaticon.com*

eMaaS = MaaS + EVs ? ✗

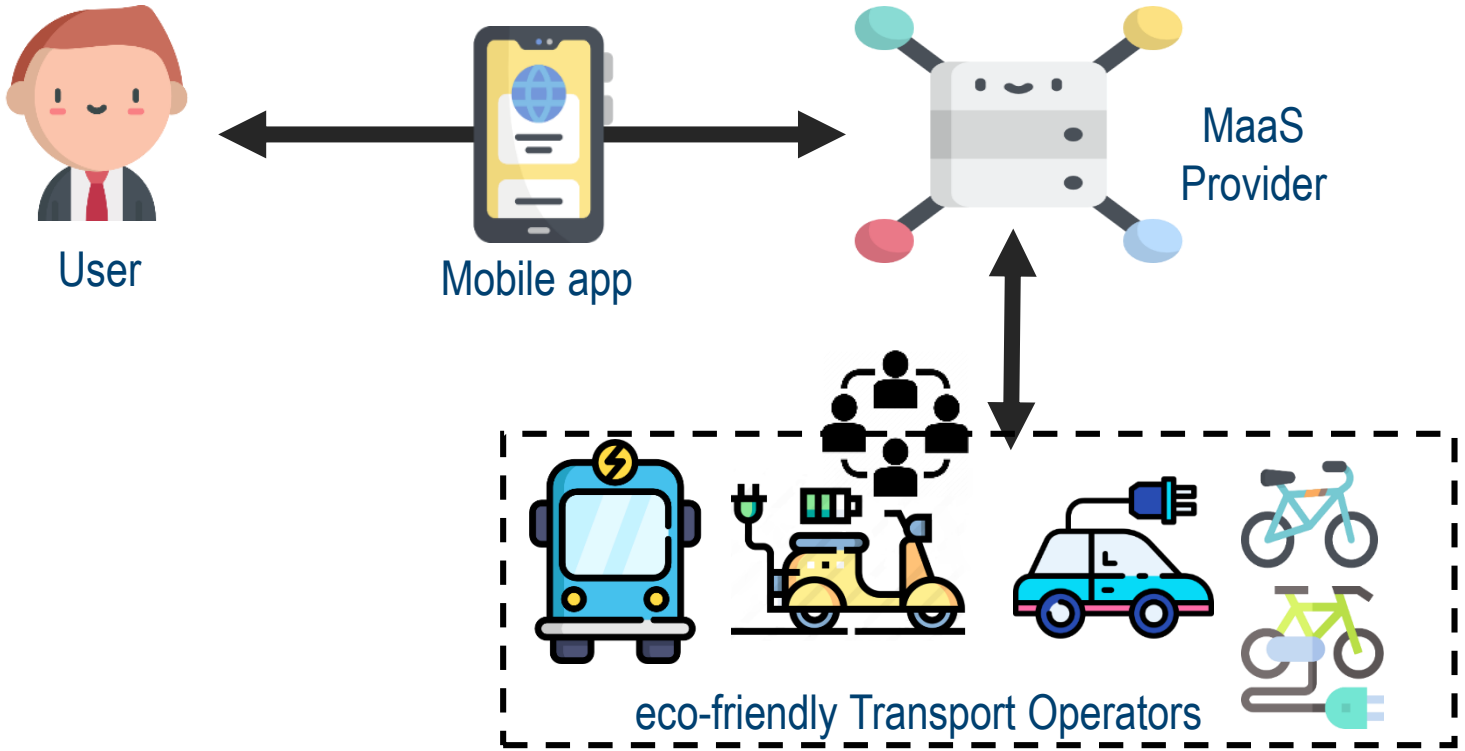
The complementary goal of eMaaS, when compared to MaaS, is to provide users the possibility to go from A to B in an **eco-friendly** way. Therefore, **eMaaS** is meant to be **shared** and **electric**

eMaaS = MaaS + SeMS + EMS ✓

eMaaS = electric Mobility as a Service
MaaS = Mobility as a Service
EMS = Electric Mobility Systems
SeMS = Shared electric Mobility Services

What is (e)MaaS?

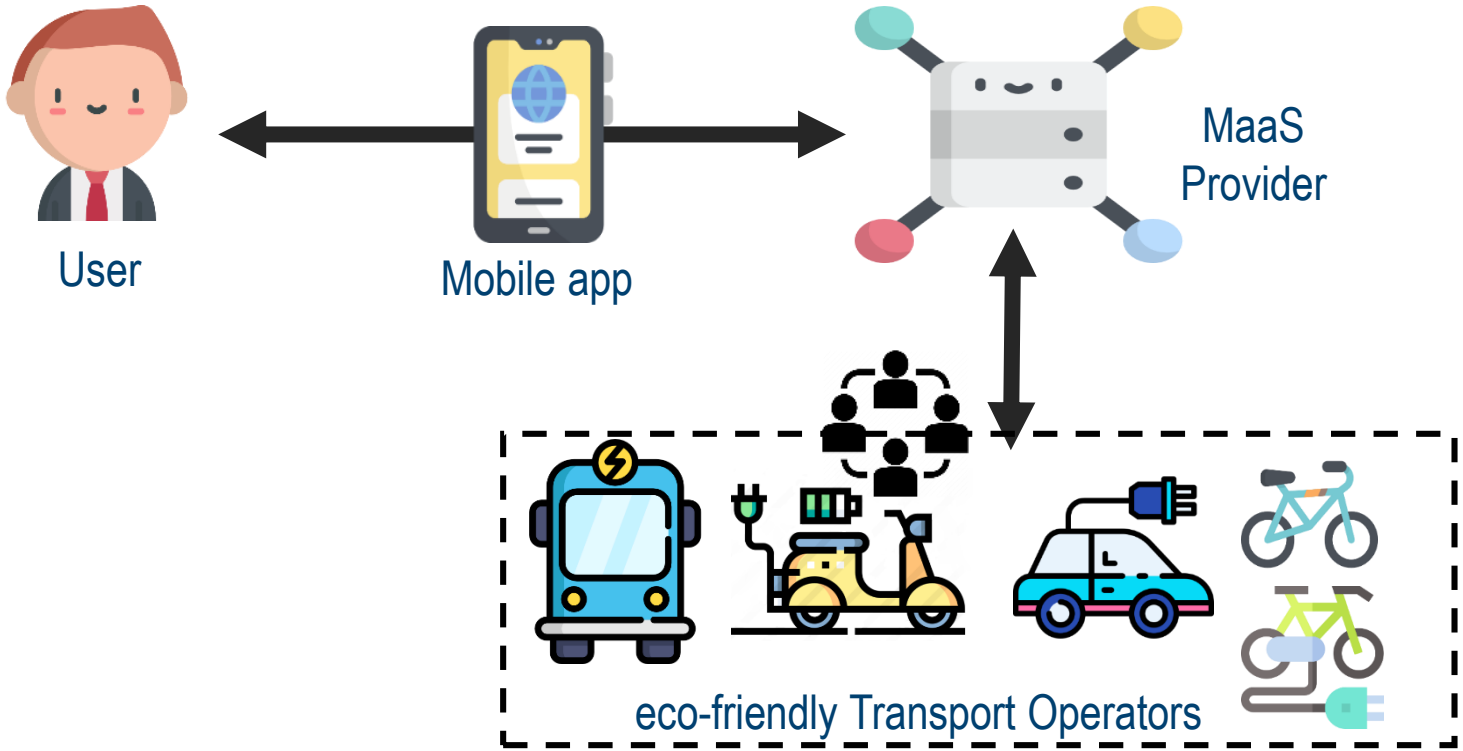
Basic Mobility as a Service ecosystem

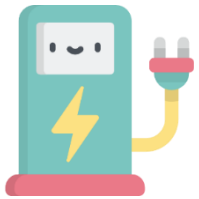


* Icons from *flaticon.com*

What is (e)MaaS?

Basic Mobility as a Service ecosystem



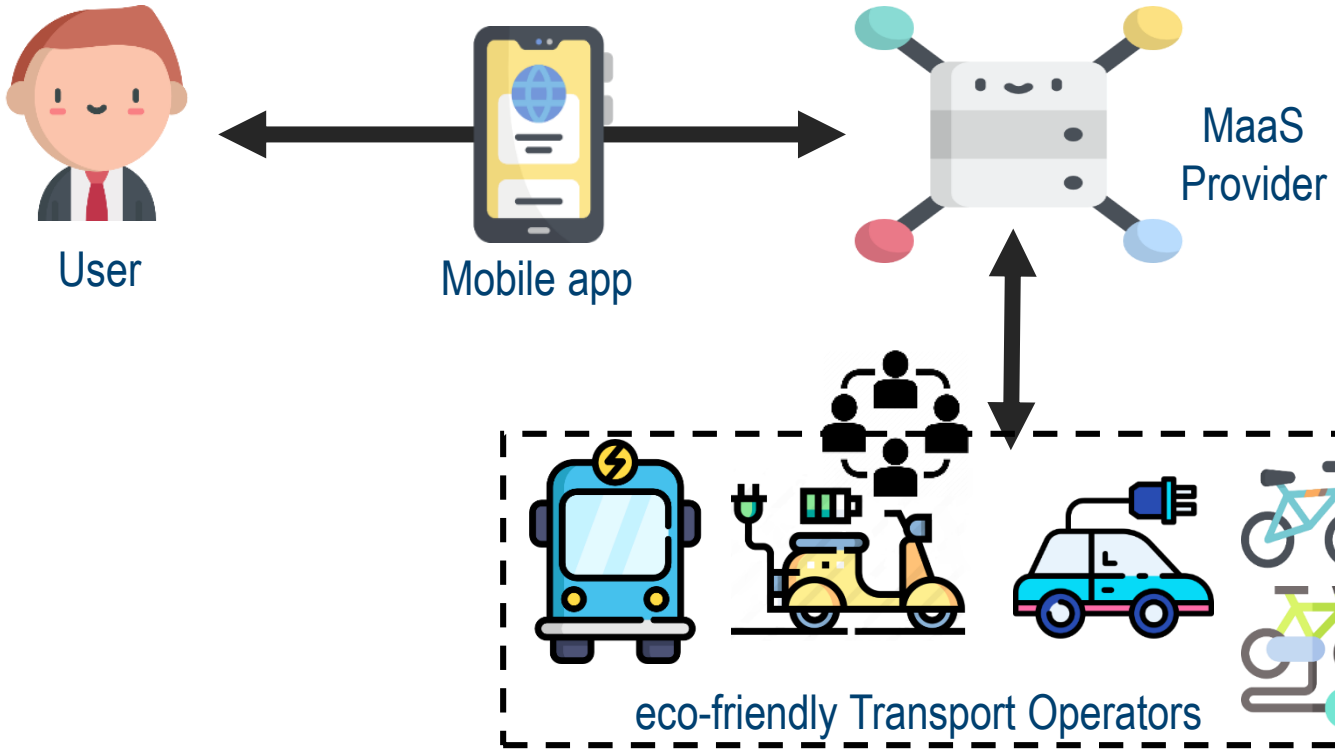


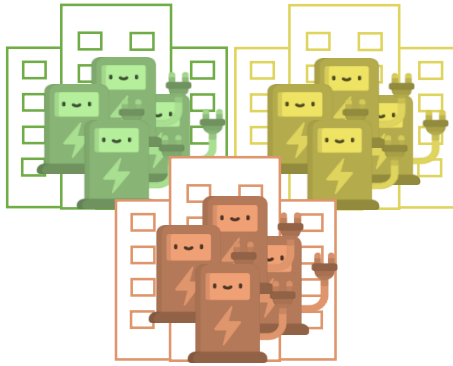
Electric Vehicle Supply Equipment (EVSE)

* Icons from *flaticon.com*

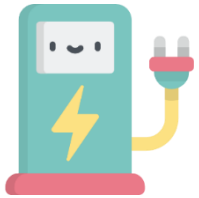
What is (e)MaaS?

Basic Mobility as a Service ecosystem





Charging Point Operators (CPOs)

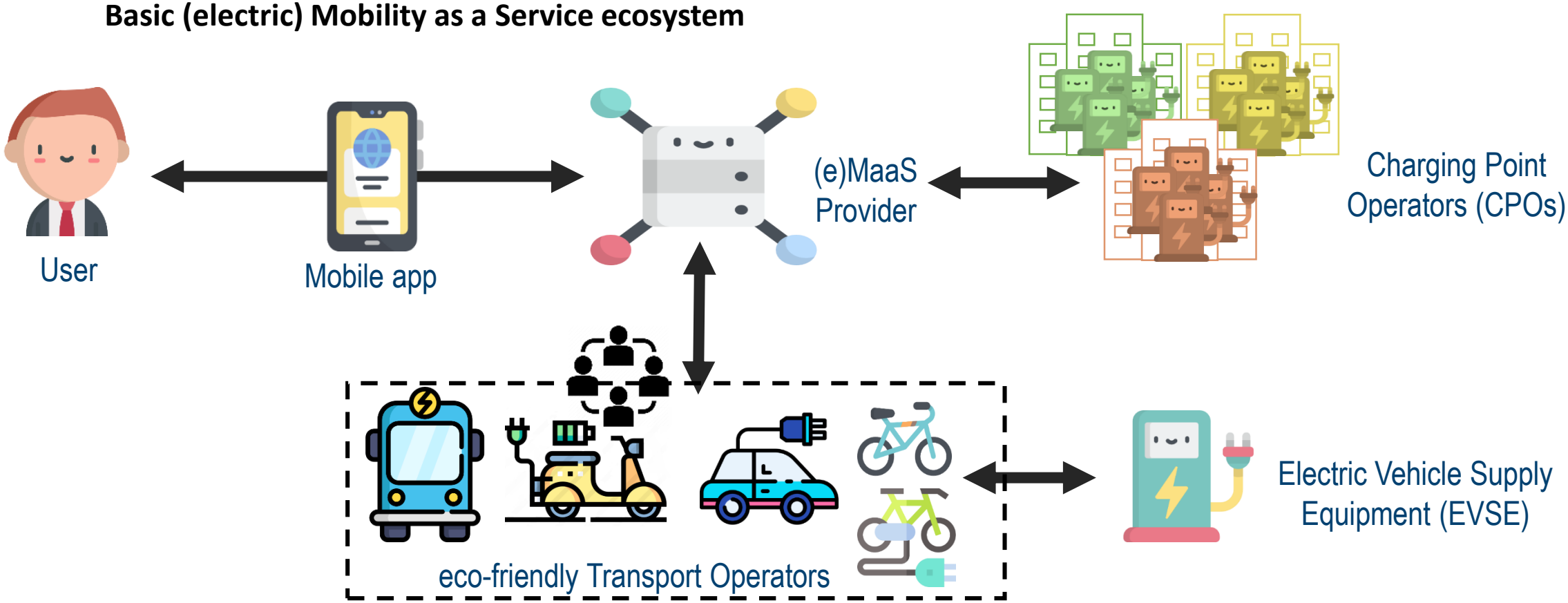


Electric Vehicle Supply Equipment (EVSE)

* Icons from *flaticon.com*

What is (e)MaaS?

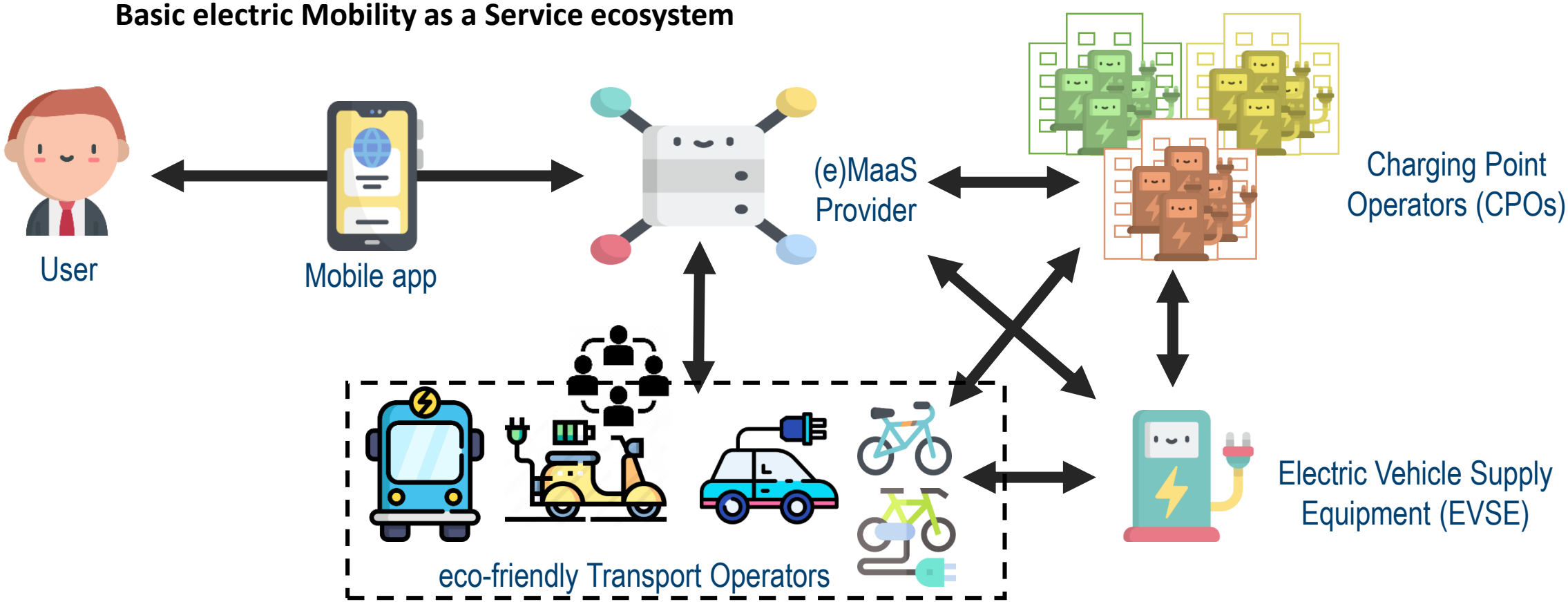
Basic (electric) Mobility as a Service ecosystem



* Icons from *flaticon.com*

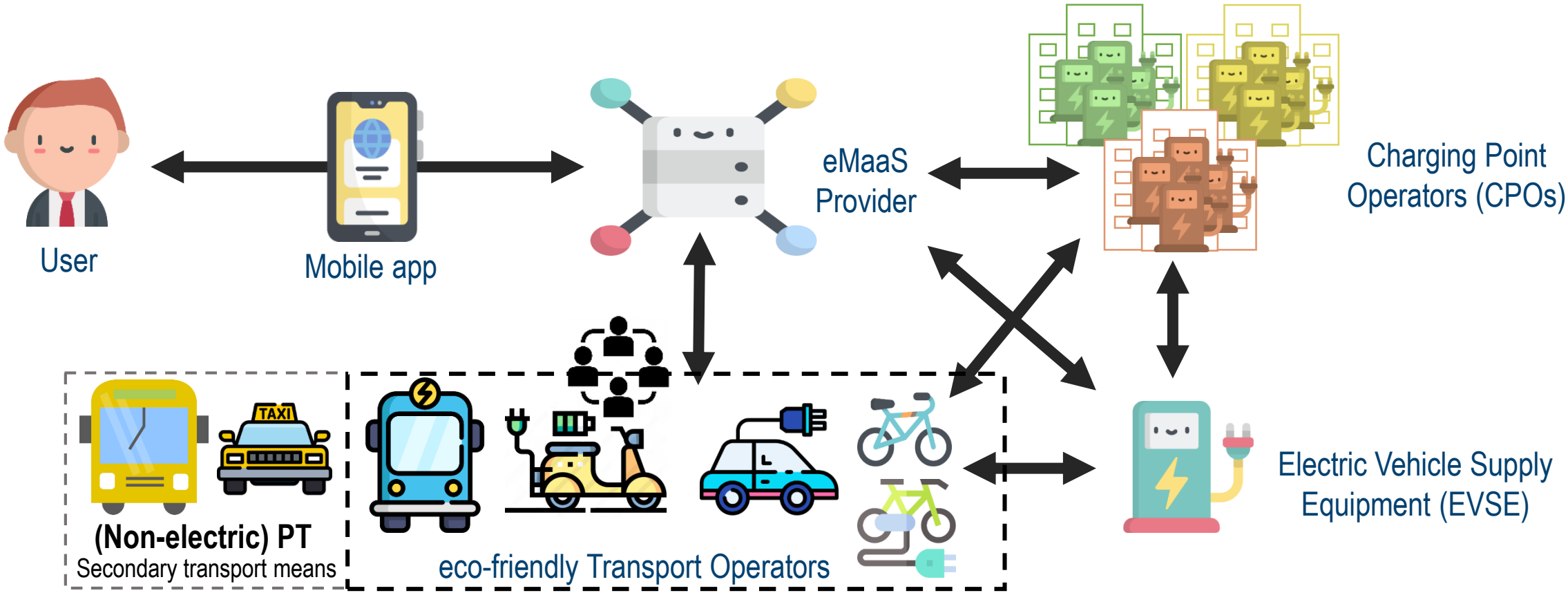
What is (e)MaaS?

Basic electric Mobility as a Service ecosystem



* Icons from *flaticon.com*

The (basic) eMaaS ecosystem



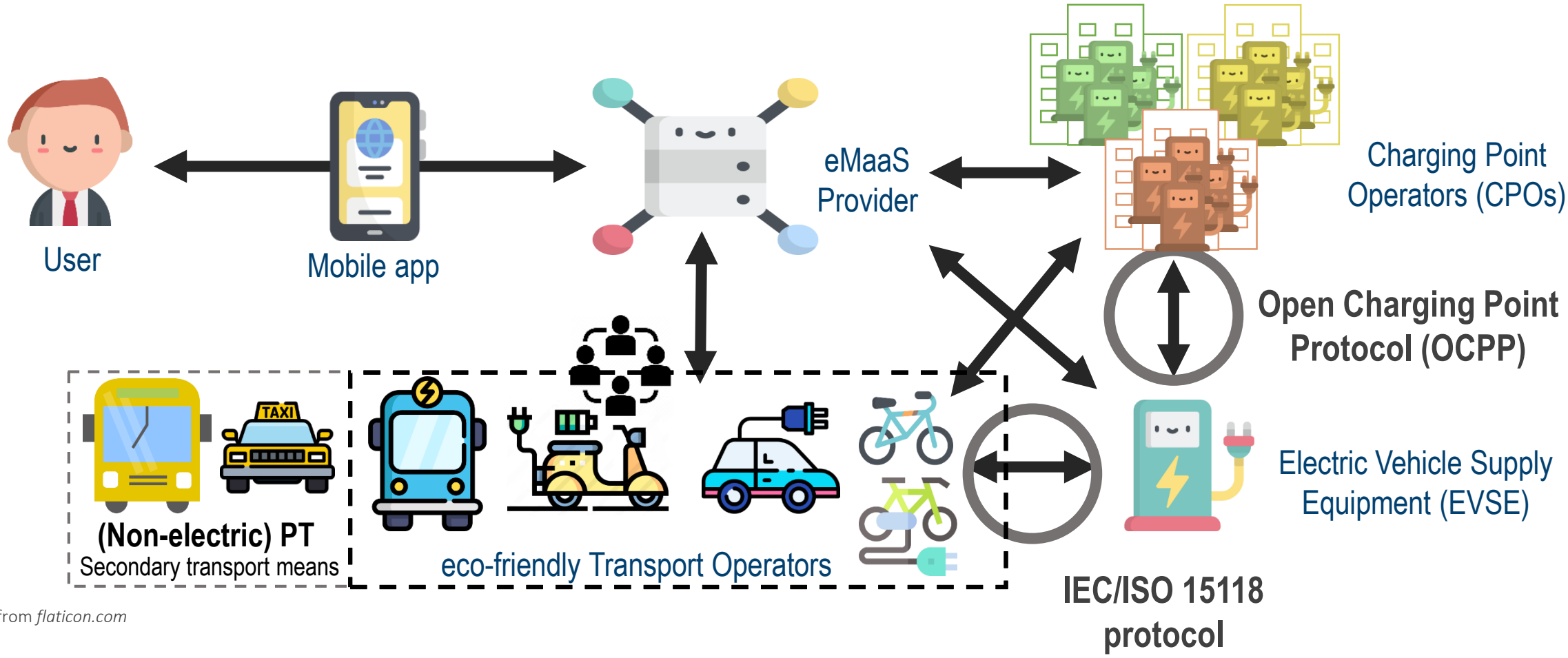
* Icons from *flaticon.com*

How to support the development of eMaaS?

How to support the development of eMaaS?

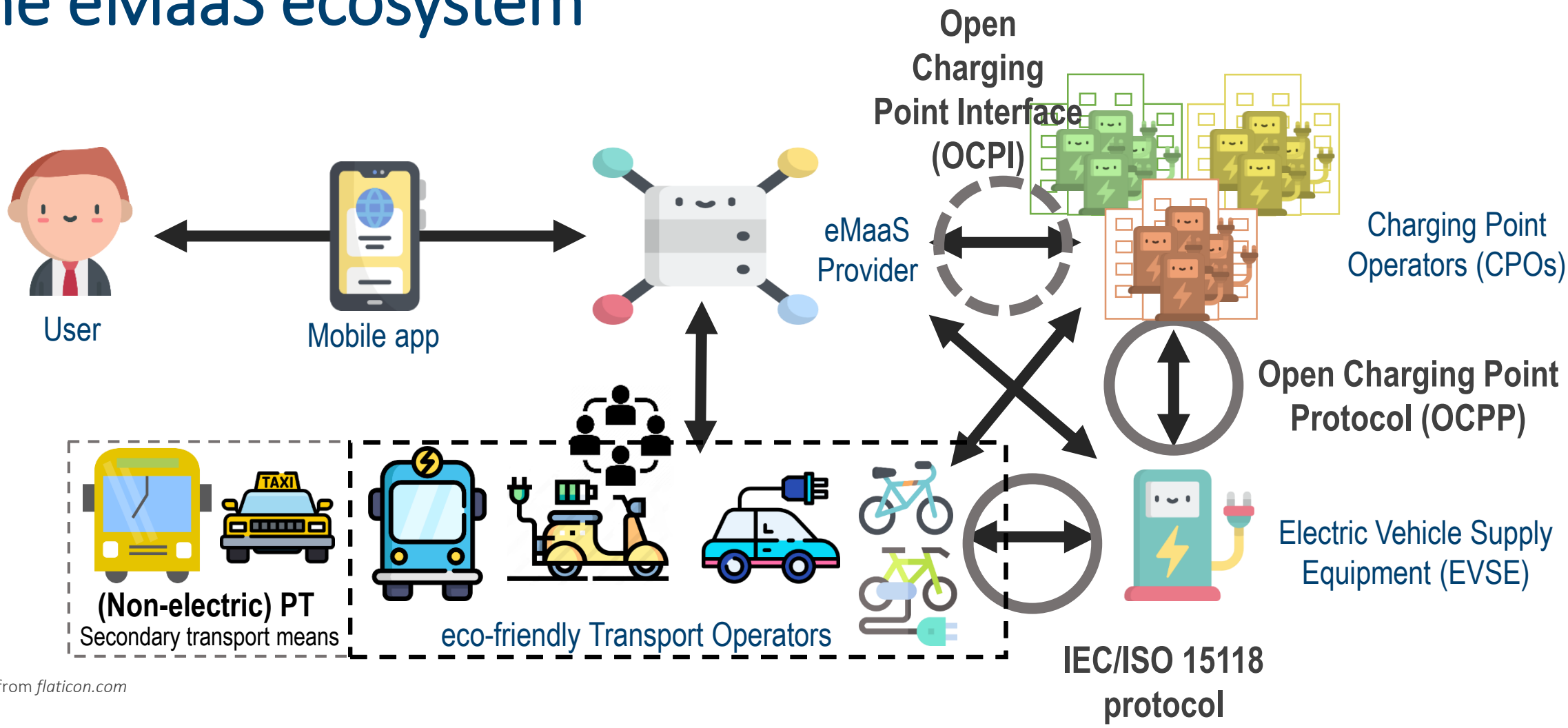
By Architecture and Interfacing Design!

The eMaaS ecosystem



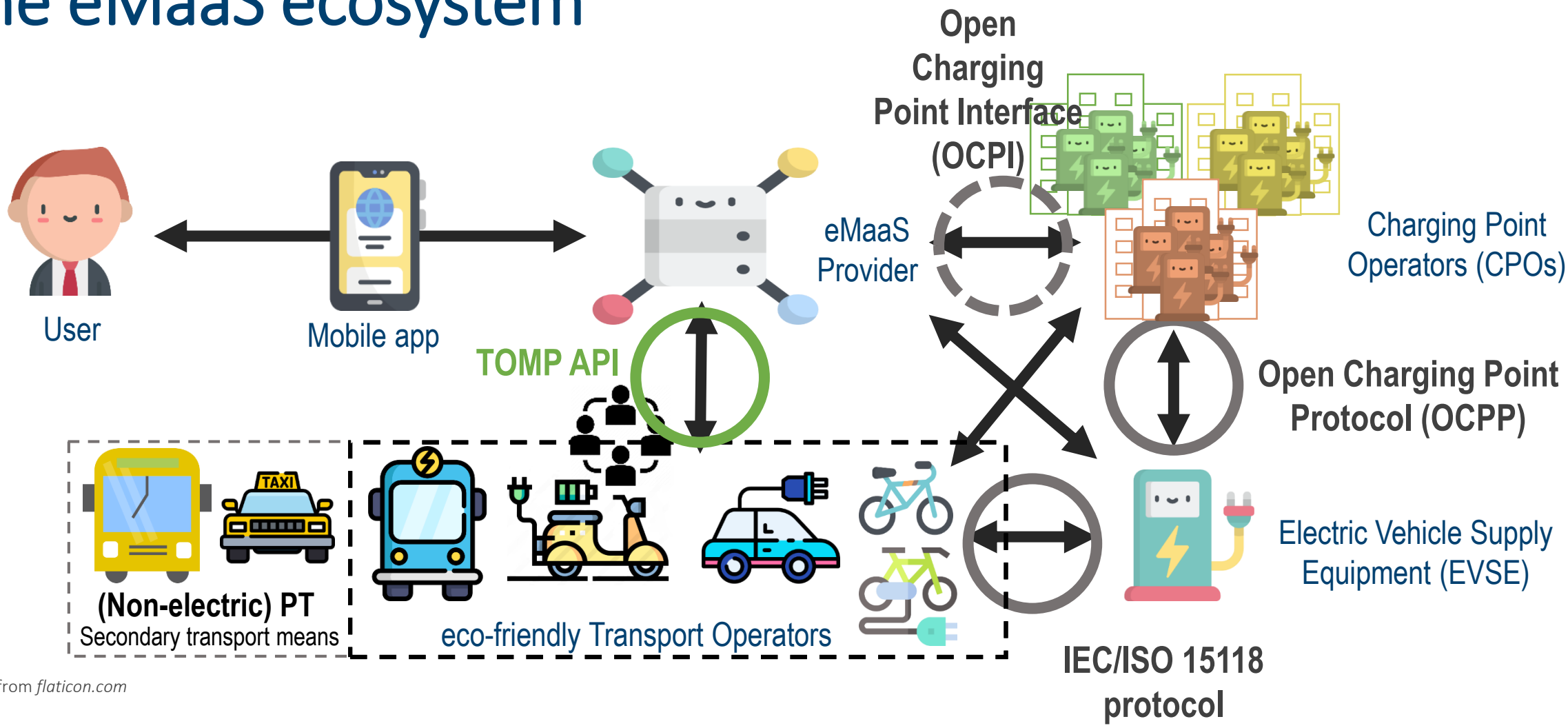
* Icons from *flaticon.com*

The eMaaS ecosystem



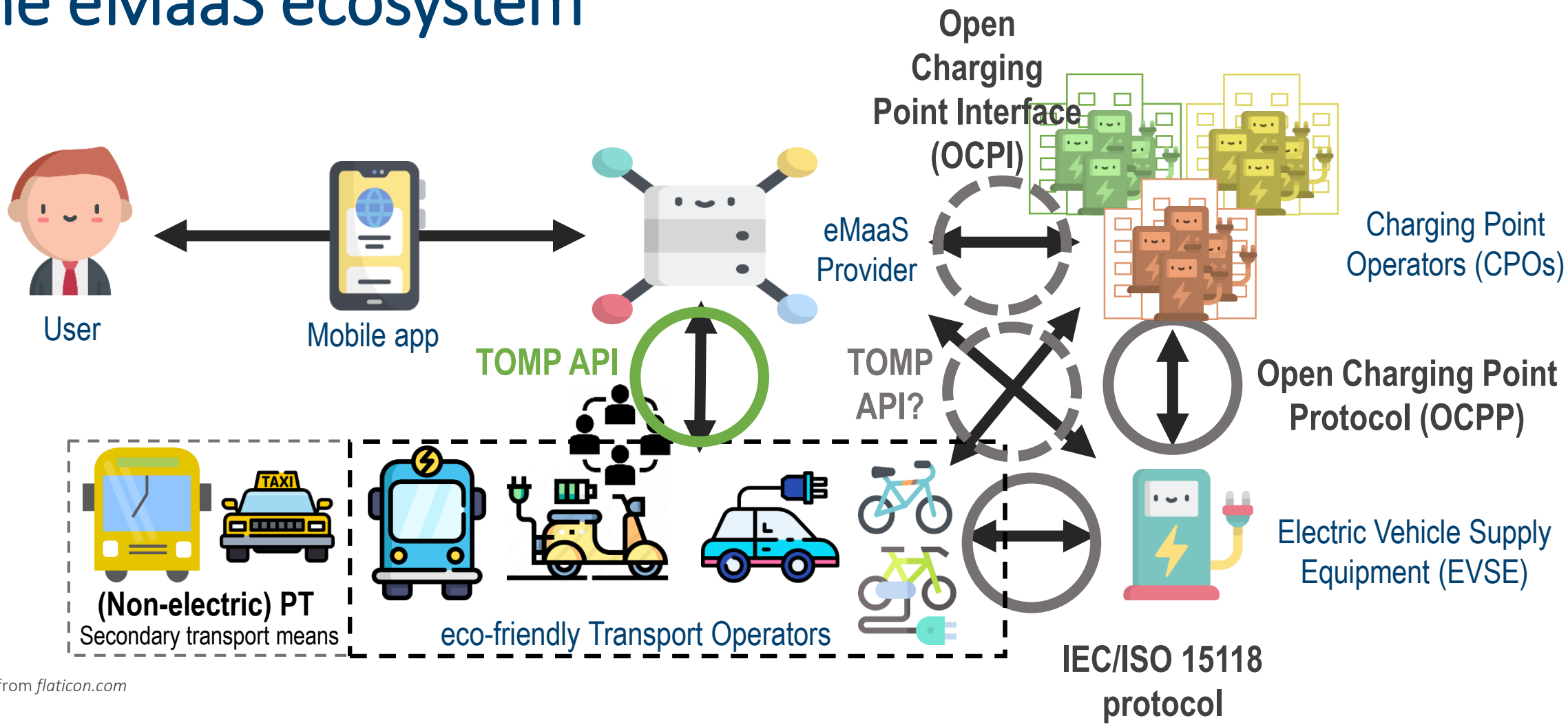
* Icons from *flaticon.com*

The eMaaS ecosystem



* Icons from *flaticon.com*

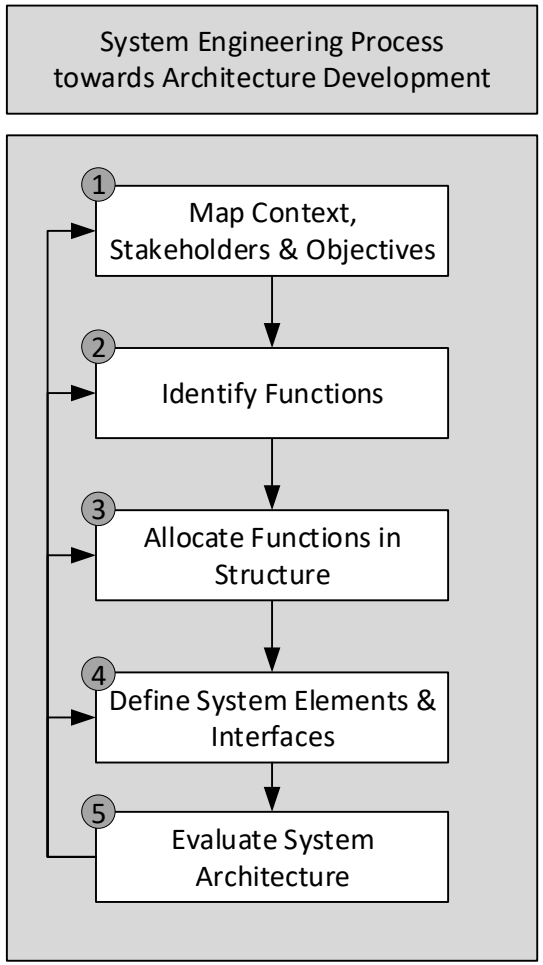
The eMaaS ecosystem



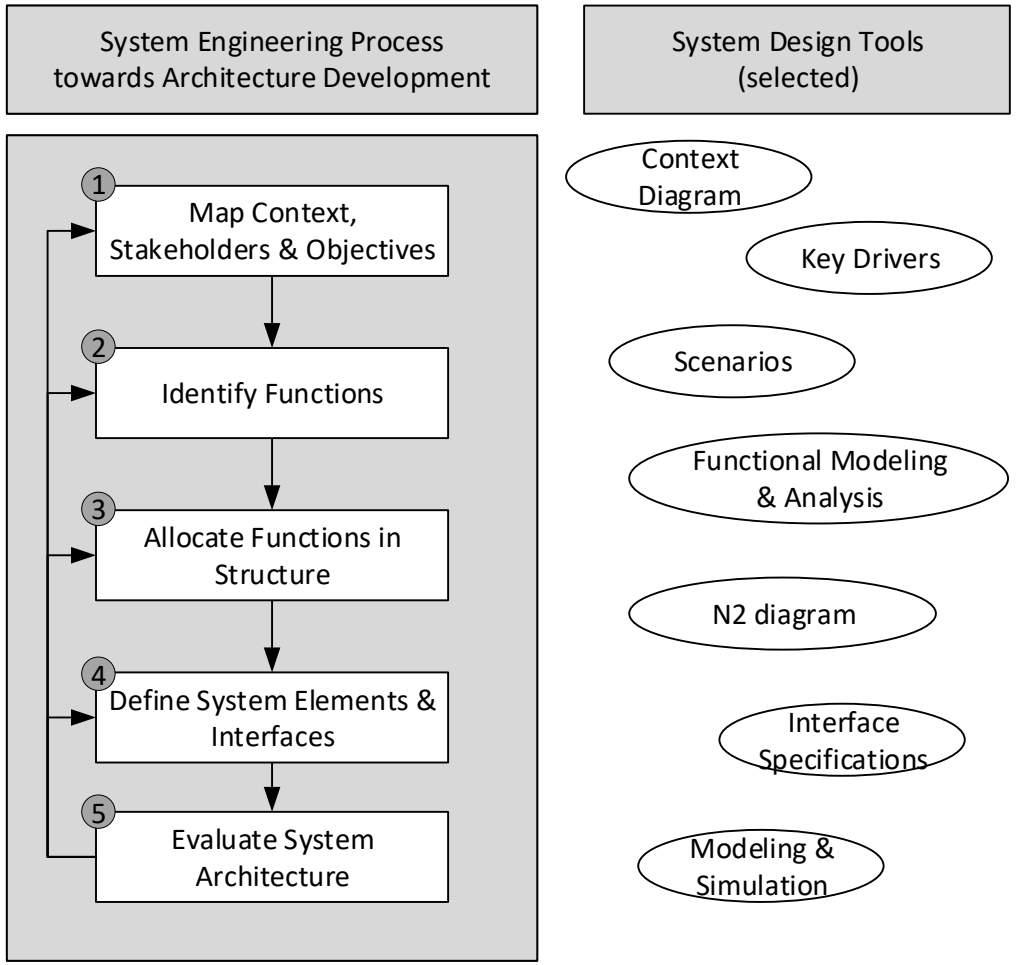
* Icons from *flaticon.com*

The Design Approach – Systems Engineering Principles

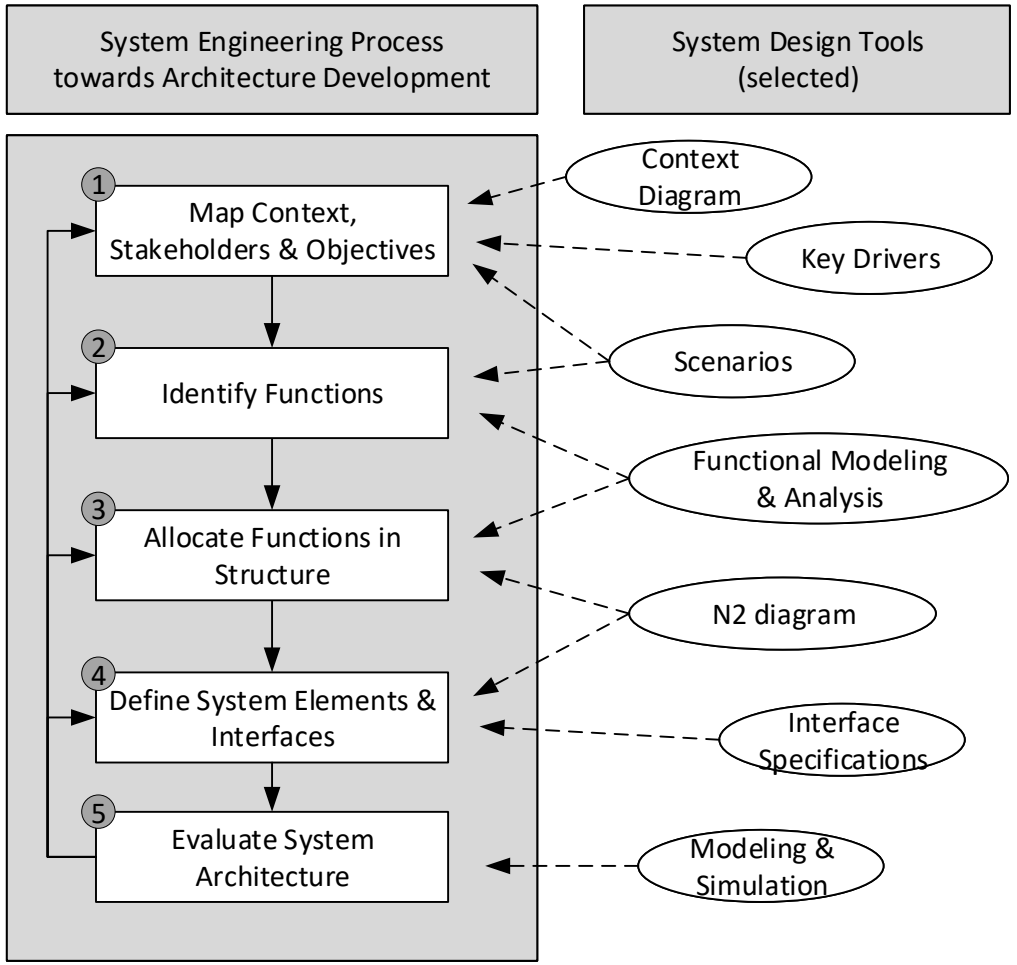
The Design Approach – Systems Engineering Principles



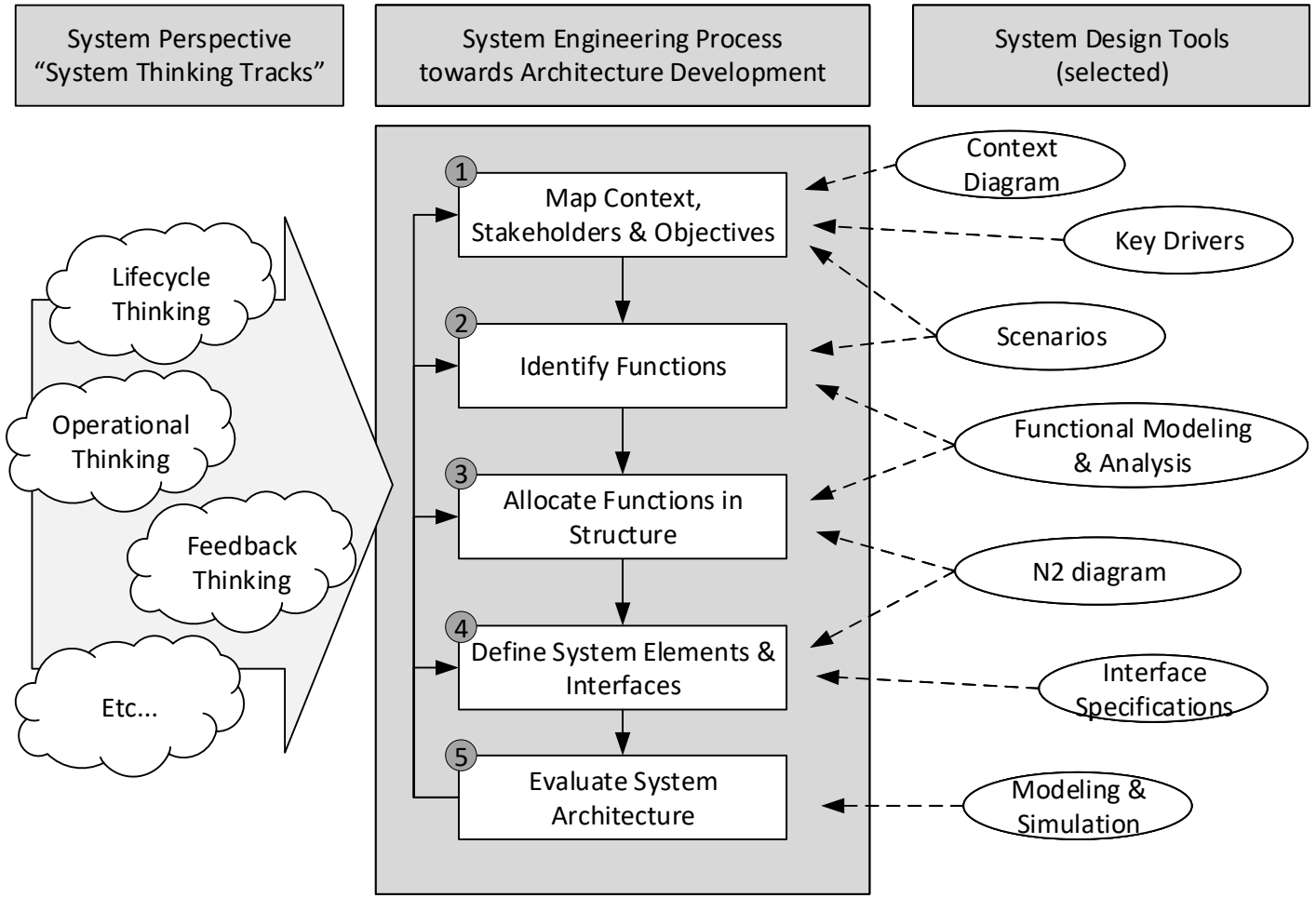
The Design Approach – Systems Engineering Principles



The Design Approach – Systems Engineering Principles



The Design Approach – Systems Engineering Principles



Systems Engineering & eMaaS – Example applications

Systems Engineering & eMaaS – Example applications

Context

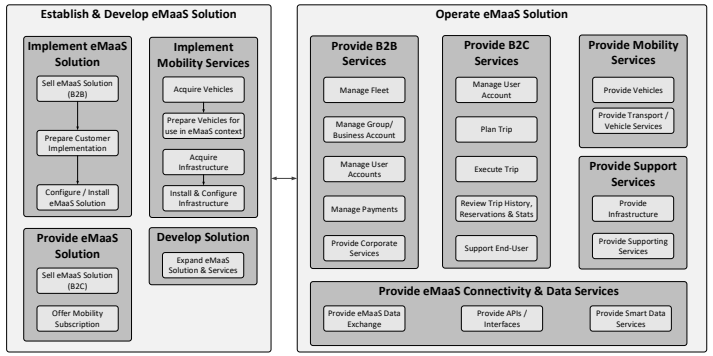
Understand stakeholders, concepts & relations

Systems Engineering & eMaaS – Example applications

Context

Understand stakeholders, concepts & relations

Functional Modeling



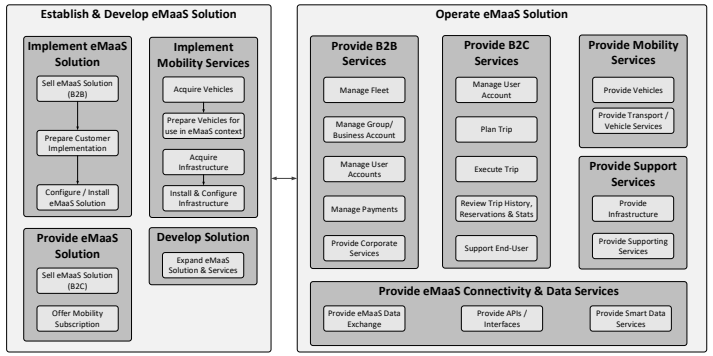
Identify & structure required functions

Systems Engineering & eMaaS – Example applications

Context

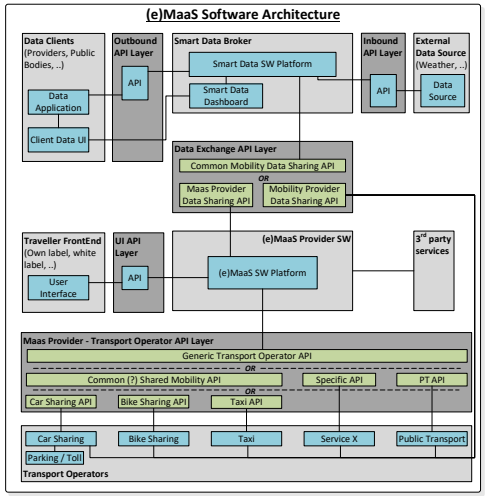
Understand stakeholders, concepts & relations

Functional Modeling



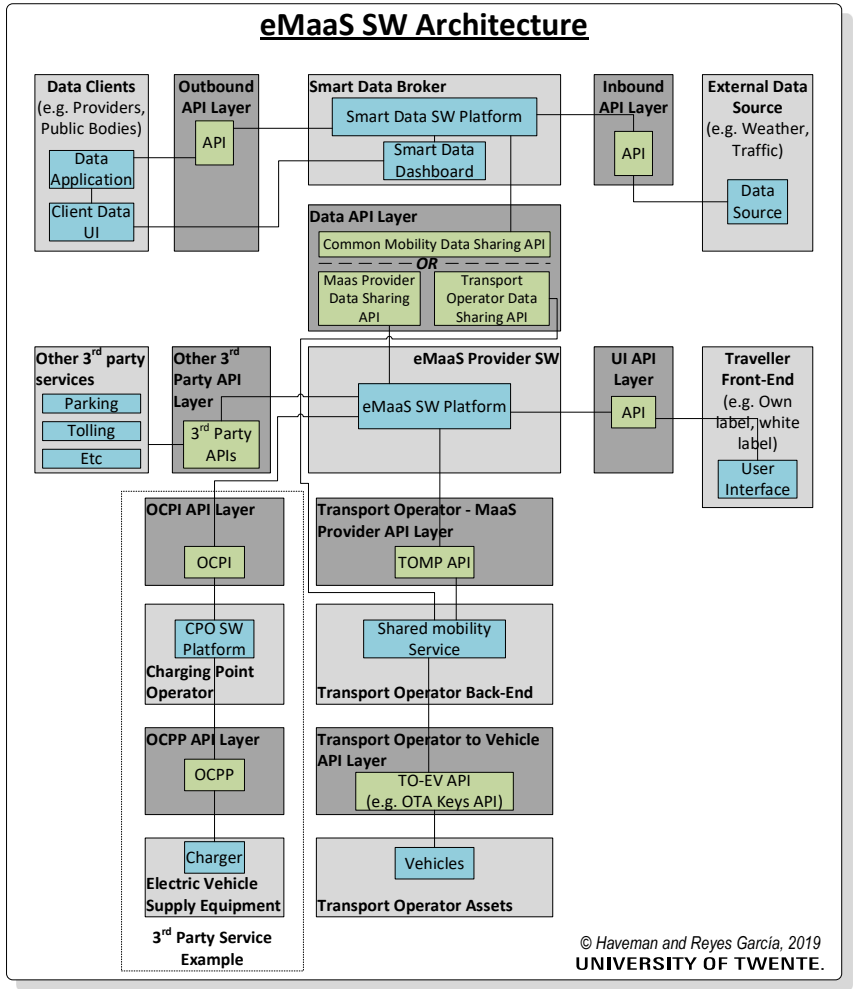
Identify & structure required functions

Architecture

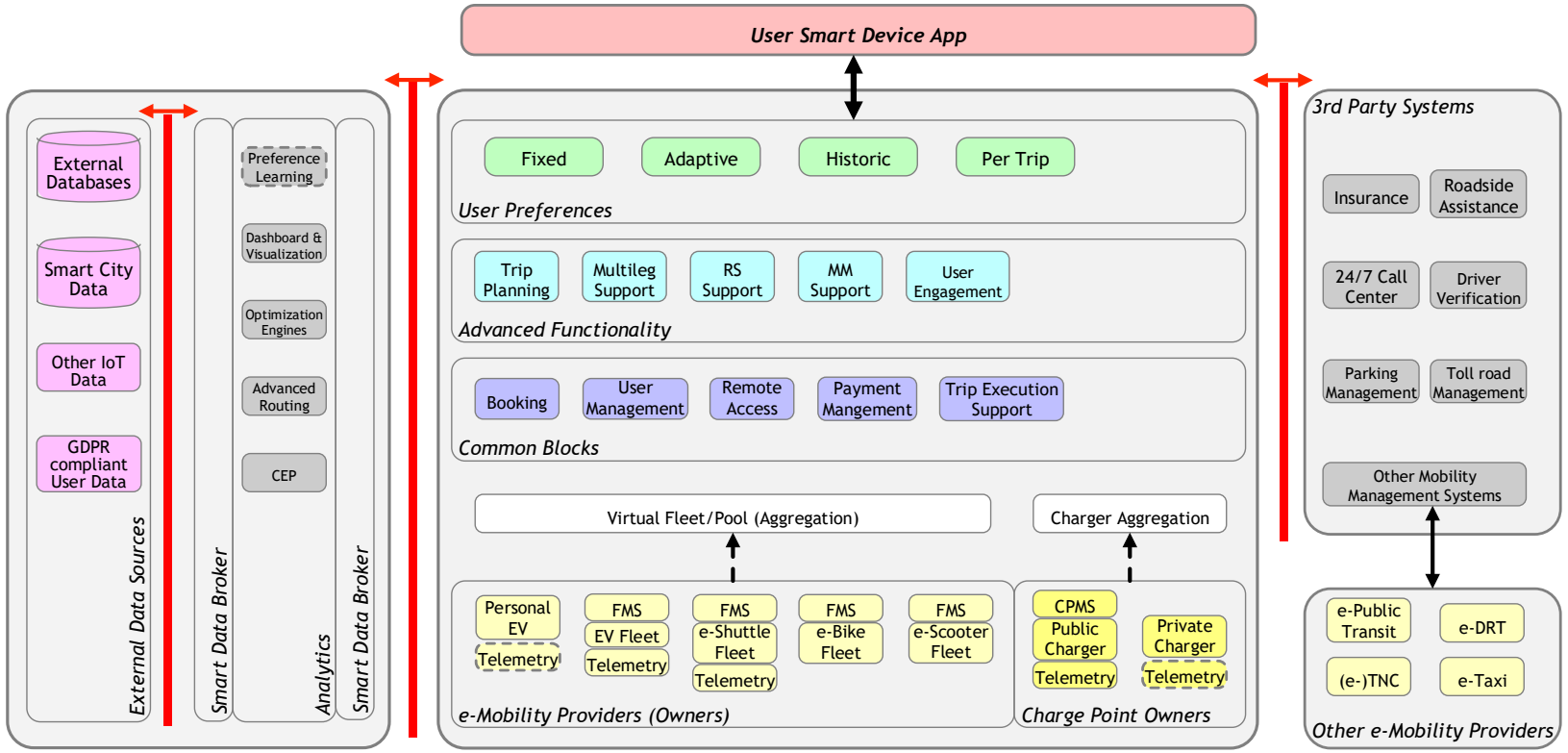


Allocate functions to a structure & identify interfaces

Architecture example: eMaaS Software Architecture



Architecture example: eMaaS Functional Architecture



Data & Analytics extension

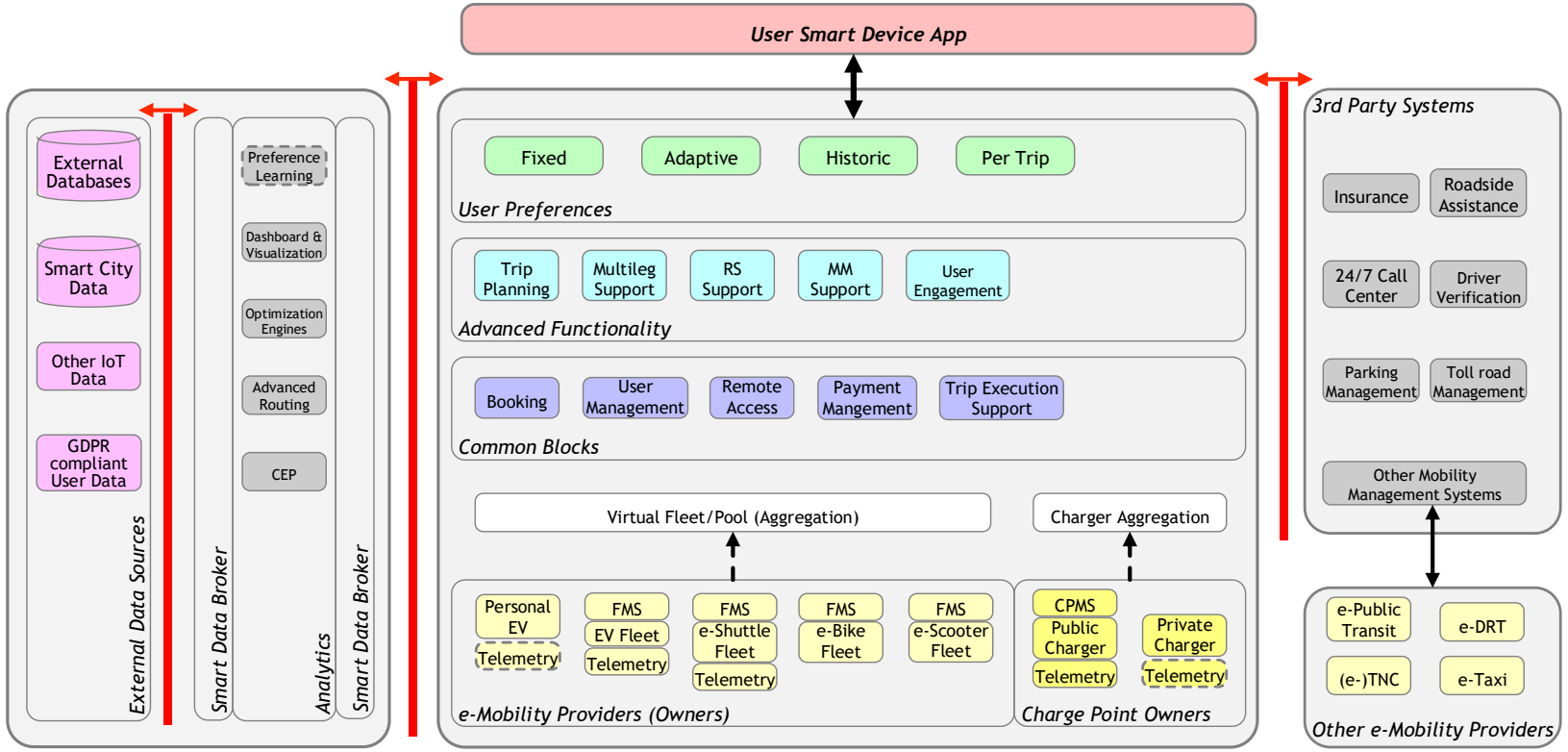
Shared e-Mobility

Other e-mobility & 3rd Party Systems

CEP: Complex Event Processing | CPMS: Charge Point Management System | DRT: Demand Responsive Transport |FMS: Fleet Management System | MM: Multi-Modal
RS: Ride Sharing | TNC: Transportation Network Company (e.g. Uber, Lyft)

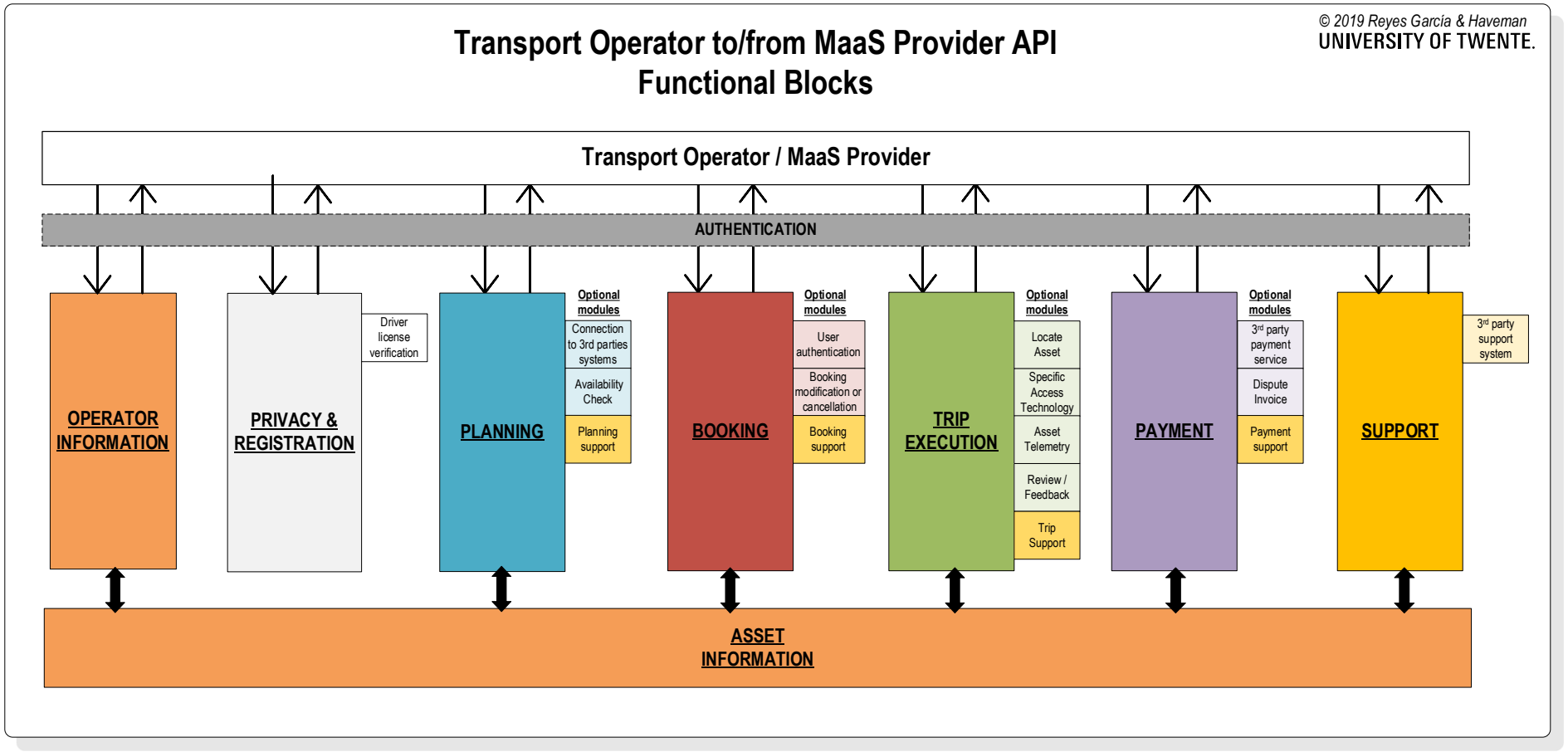
eMaaS Functional Architecture

Source: Reyes García, J.R.; Lenz, G.; Haveman, S.P.; Bonnema, G.M. **State of the Art of Mobility as a Service (MaaS) Ecosystems and Architectures—An Overview of, and a Definition, Ecosystem and System Architecture for Electric Mobility as a Service (eMaaS)**. *World Electr. Veh. J.* 2020, *11*, 7. doi: 10.3390/wevj11010007



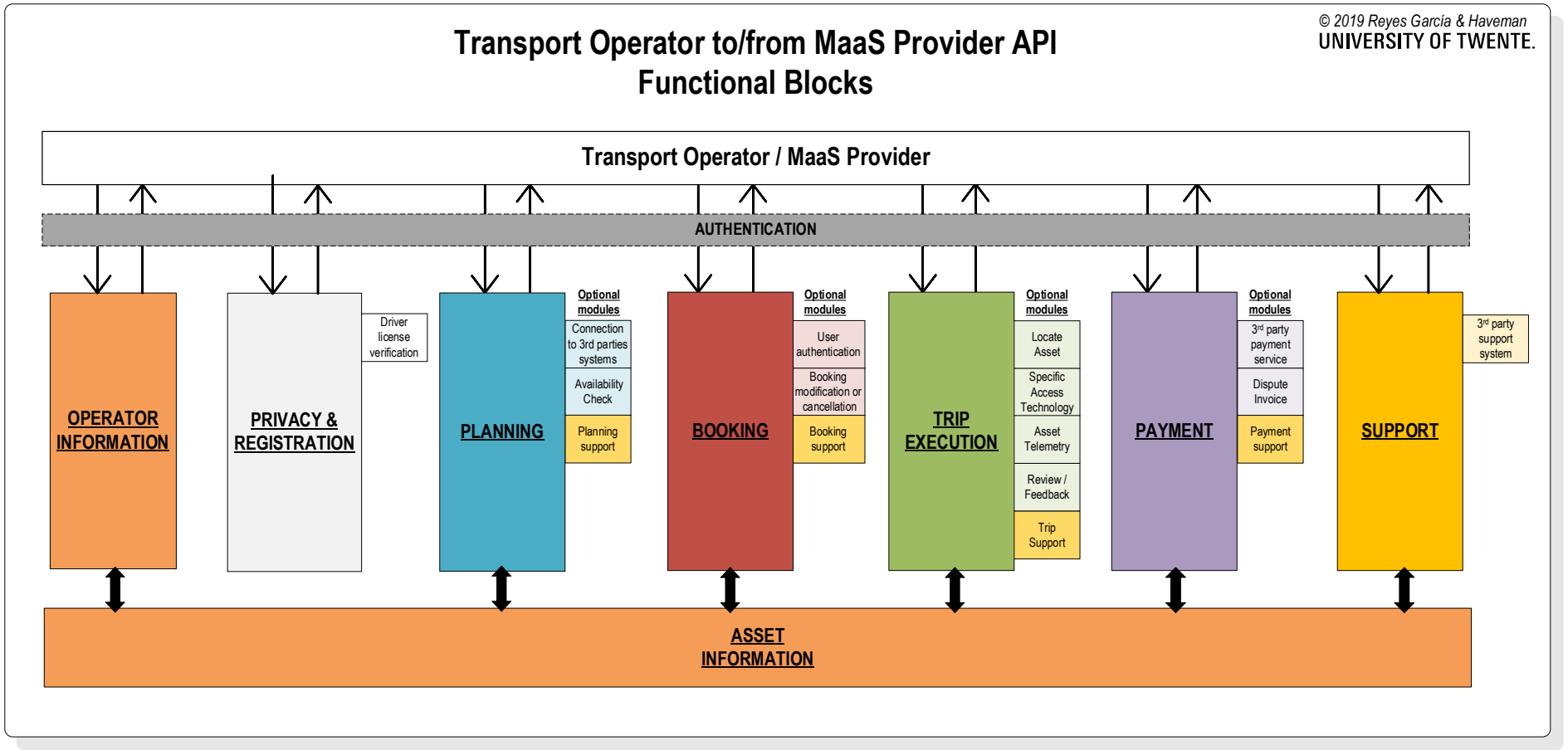
CEP: Complex Event Processing | CPMS: Charge Point Management System | DRT: Demand Responsive Transport |FMS: Fleet Management System | MM: Multi-Modal
RS: Ride Sharing | TNC: Transportation Network Company (e.g. Uber, Lyft)

Interface design: TOMP API Functional Architecture



TOMP API Functional Architecture

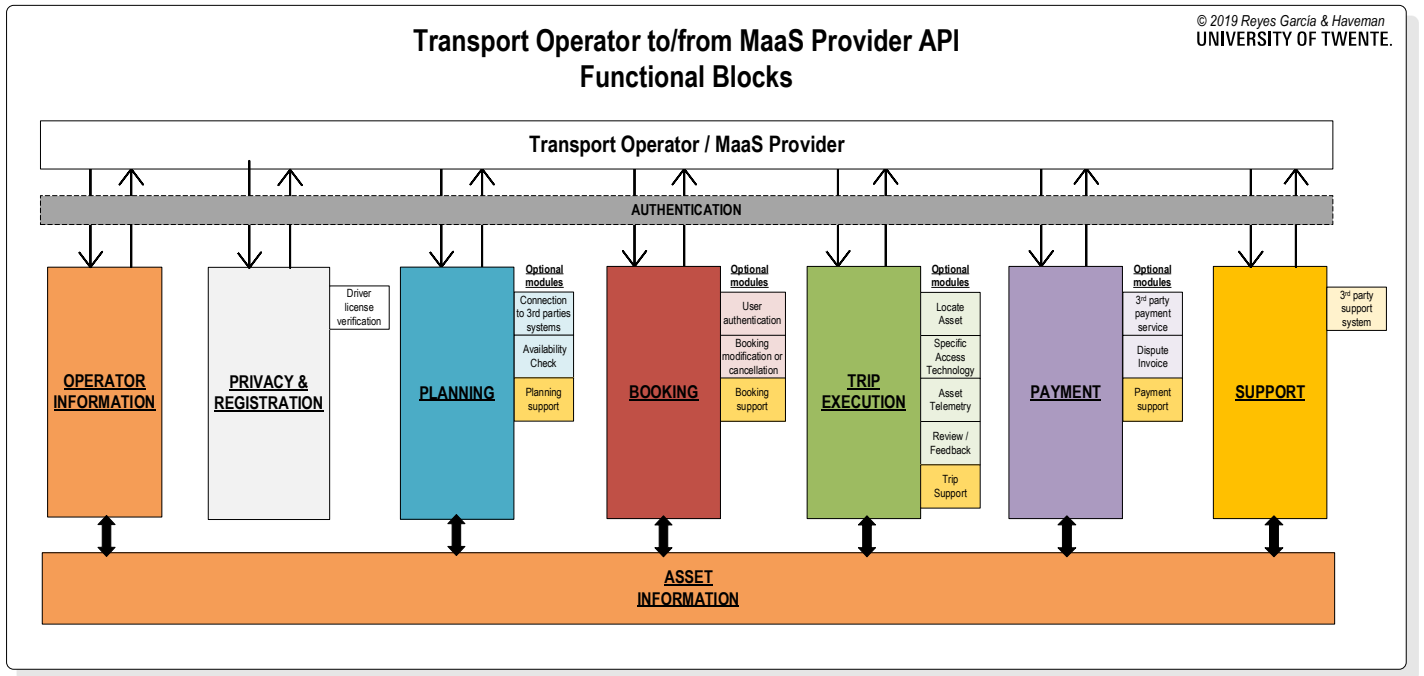
Source: Reyes Garcia, J. R., van den Belt, E., Bakermans, B., & Groen, T. Blueprint for an Application Programming Interface from Transport Operator to MaaS Provider (TOMP-API) – Version Dragonfly. The Netherlands, 2020.



Systems Engineering & eMaaS – Detailed example

The TOMP API:

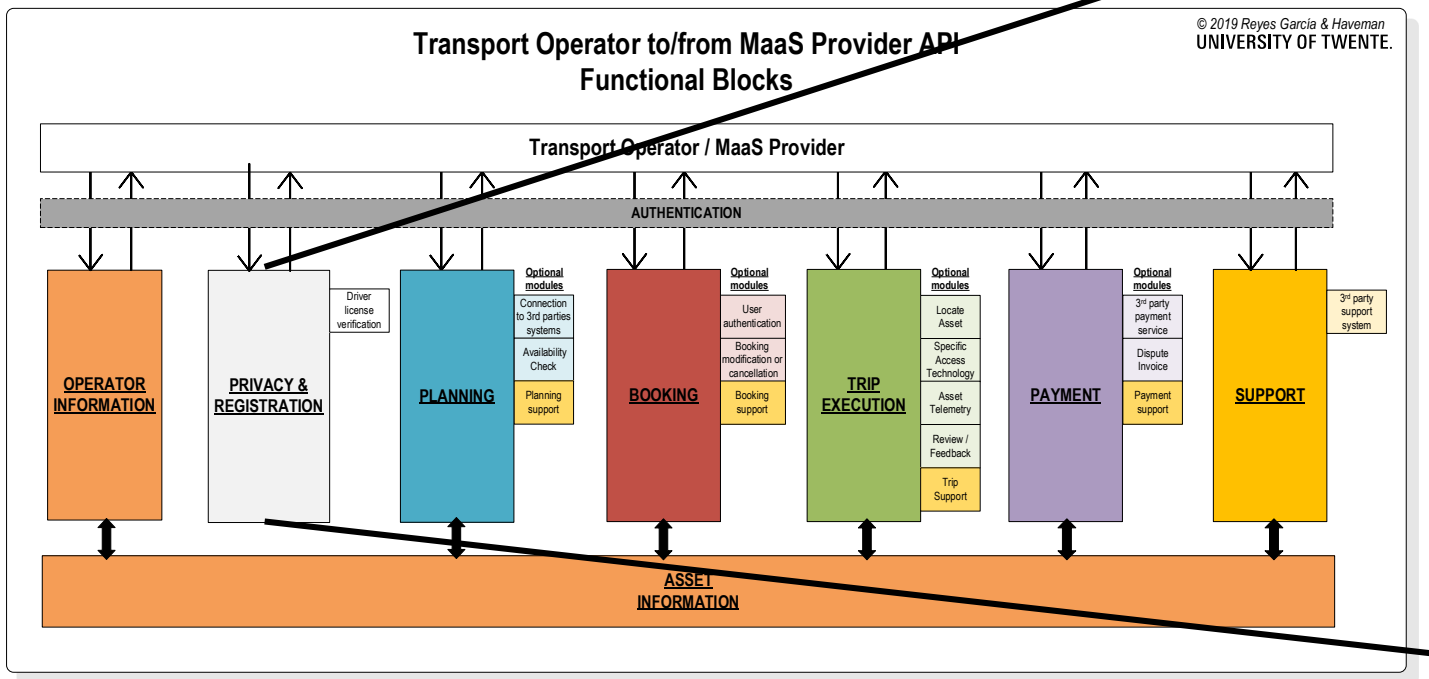
- Standard Interface definition for a(n) (e)MaaS API

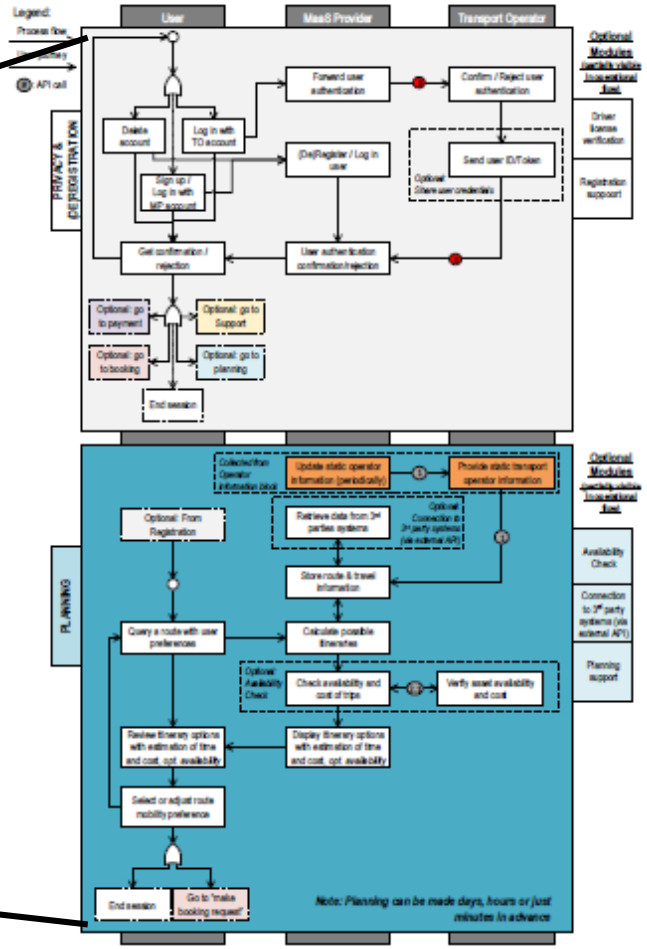


Systems Engineering & eMaaS – Detailed example

The TOMP API:

- Standard Interface definition for a(n) (e)MaaS API





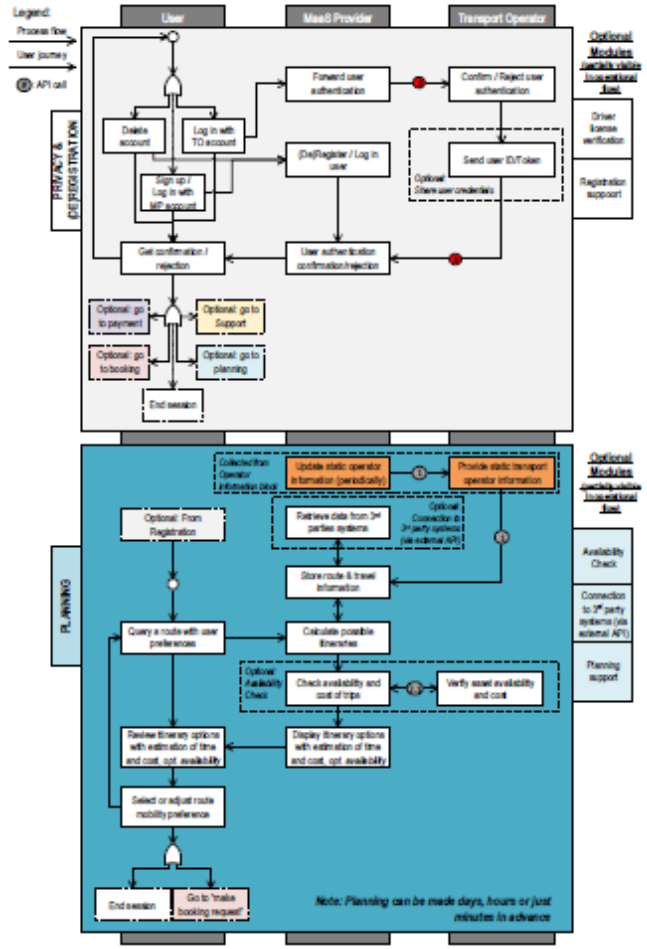
Systems Engineering & eMaaS – Detailed example

The TOMP API:

- Standard Interface definition for a(n) (e)MaaS API

What needs to be in the API?

- Reason functionally, e.g. using “operational thinking”



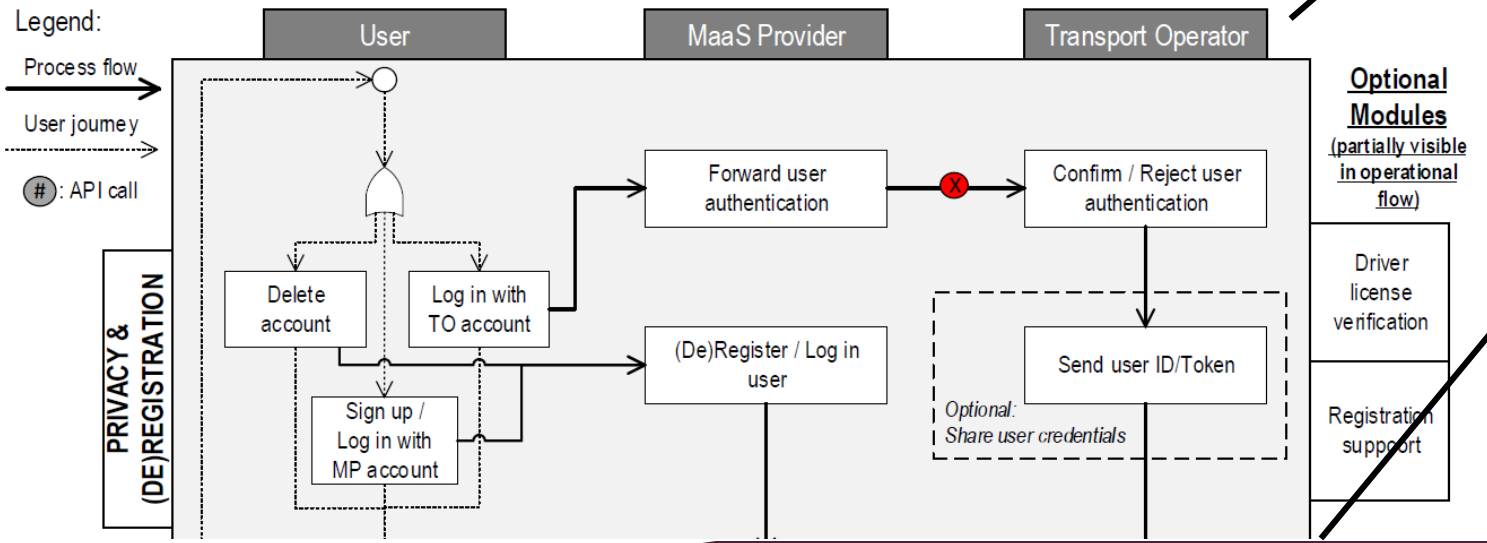
Systems Engineering & eMaaS – Detailed example

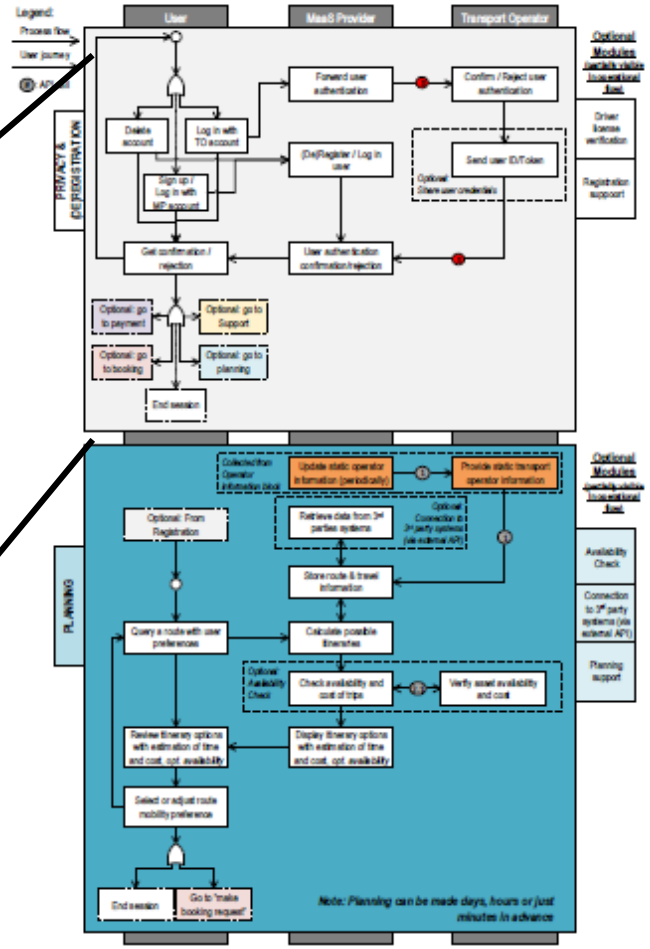
The TOMP API:

- Standard Interface definition for a(n) (e)MaaS API

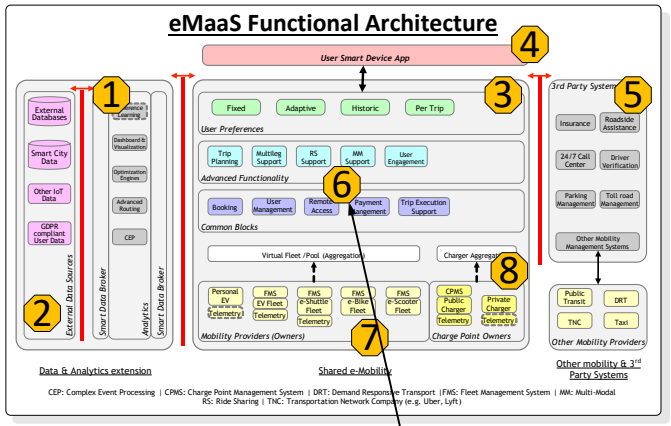
What needs to be in the API?

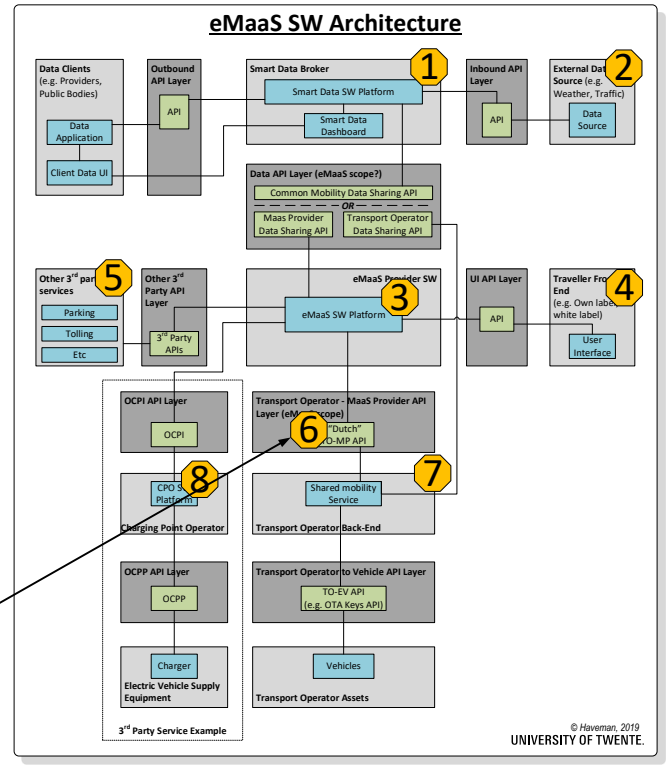
- Reason functionally, e.g. using “operational thinking”

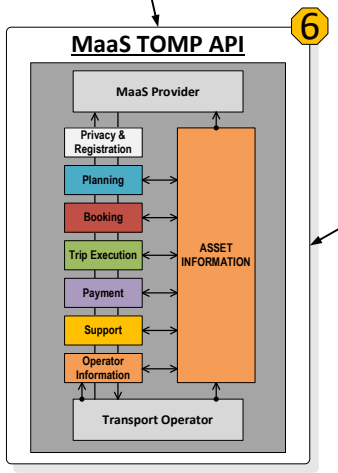




Mapping between Architecture Views







Summary – Takeaways

- **Systems Engineering is a holistic approach for the design of large-scale complex systems**
- **It offers both concrete tools as well as a systems thinking approach**
- **It can and already has been applied to (e)MaaS successfully, see for example the eMaaS Architecture and the TOMP API**

Additional insights from the authors:

- Bonnema, G. M. and Broenink, J.F. "Thinking Tracks for Multidisciplinary System Design," Systems, vol. 4, no. 4, p. 36, Nov. 2016 – doi: 10.3390/systems4040036
- Bonnema, G. M., Veenvliet, K., & Broenink, J. F. (2016). "Systems design and engineering : facilitating multidisciplinary development projects". London: CRC Press. ISBN 9781498751261

Thank you for your attention!

Questions?

Contact:

Dr. ir. Maarten Bonnema: g.m.bonnema@utwente.nl

Roberto Reyes: j.r.reyesgarcia@utwente.nl