Dragonfly

Blueprint for an API
From Transport Operator to MaaS Provider

15/07/2020

TOMPAPI

MaaS
Mobility as a Service

Blueprint for an

Application Programming Interface (API)

from Transport Operator to MaaS Provider

a technical milestone towards Mobility as a Service

TOMPAPI

Version Dragonfly
15-07-2020

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1   Introduction

With Mobility as a Service (MaaS) travelers can plan, book, execute their trips using any available transport mode and pay for all of them via integrated apps. For MaaS to be successful, transport operators are required to share their transport services and availability of their assets in a digital form. To facilitate MaaS providers and thus enable the deployment of MaaS services, transport operators are also required to standardize the digital form to facilitate access to their information. The TOMP API (Transport Operator to MaaS Provider - Application Programming Interface) is a standardized and technical interface between MaaS providers and transport operators.

Fig. 1 below depicts the concept of having a standard-based Application Programming Interface (API) from Transport Operators (TO) to or from MaaS Providers (MP). It allows all participating companies to communicate about planning, booking, execution, support, general information and payments of multimodal, end user specific trips. Using the TOMP API enhances the interoperability between parties in the MaaS ecosystem.
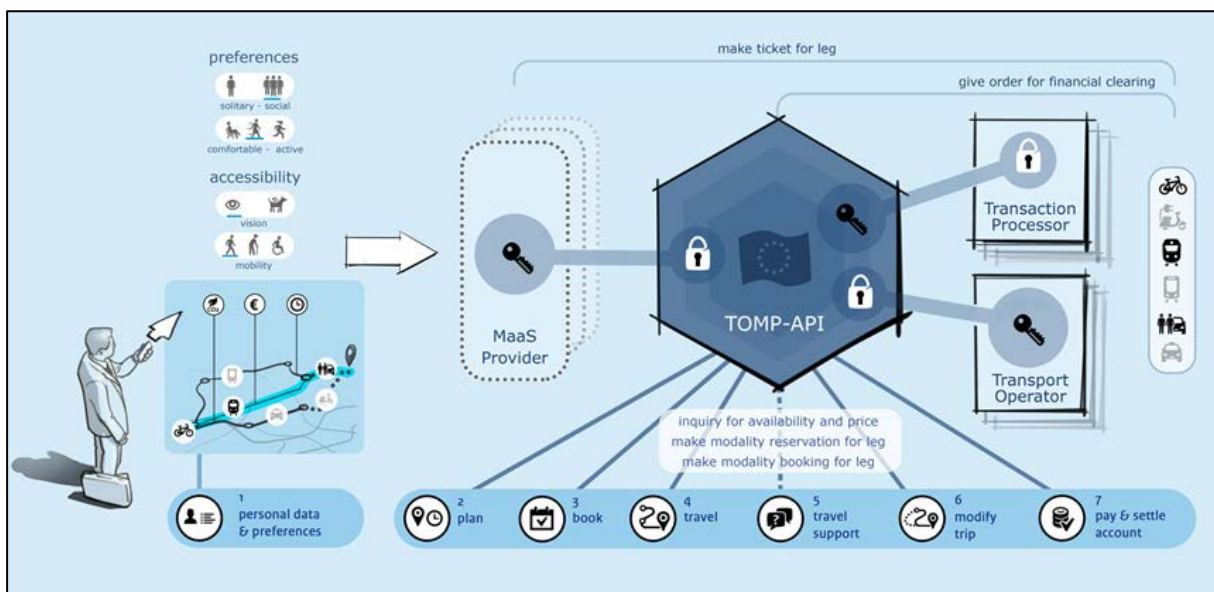
Fig. 1: The standard-based API for Transport Operators to/from MaaS providers
(Source: MaaS program of Dutch Ministry of Infrastructure and Water Management)

Goal of this document

In this Blueprint for an API for TOs and MPs (the TOMP API) we look into the necessary functional requirements for the interoperability between transport operators. The goal of this document is to:

- Define the necessary scope for full interoperability between TOs for the deployment of MaaS services, always keeping the customer journey in mind to determine which API calls are needed between TOs and MPs.
- Define the necessary parameters and values to fulfill this scope.
- Define the available parameters in various already available APIs and propose amendments where applicable.

Who is involved

This document has been written to consolidate the work of the Transport Operators and MaaS Providers - Working Group (TOMP-WG). The TOMP-WG is an initiative started in the Netherlands by the Ministry of Infrastructure and Water Management in 2018. The goal of

the group is to provide standardised APIs to facilitate the development of the MaaS ecosystem. Since 2020 the TOMP-WG has been moved to become an open source foundation with an international scope. A list with all collaborators, companies and stakeholders involved in the current design and development of the TOMP API is provided in the Appendix.

2 What is in this version

In the release candidate for Dragonfly a few major changes have been made. The internal goal was to review the support module, which was successfully achieved. On the other hand, some first implementations of the TOMP API took place in the last couple of months which allowed to improve the API based on the lessons learned.

These results are specially reflected in a simplified object model in the planning phase (flattened the object structure of the leg) and a new endpoint with self-describing facilities was created. This last one is needed for (inter)national scale up, to be informed of what the addressed TO is capable of.

There are also quite a few minor changes, they can be found in our WIKI page:
https://github.com/TOMP-WG/TOMP-API/wiki

The digital version of the API is available for consultation at:
https://app.swaggerhub.com/apis/TOMP-API-WG/transport-operator_maas_provider_api/0.9.0

3 To be added after this version

In no particular order, the following developments are envisioned for future versions:
- Further (continuous) refinement after testing and implementation.
- Express the flow of the API in the self-describing part.
- Standardization of enumerations, like driver license types.
- Addition of infrastructure assets (e.g., EV charging stations, parking).
- Determine pagination and rate limiting requirements.
- Define and describe authentication.
- Integrate other modalities (e.g., air planes).

A high-level roadmap with the future developments of the TOMP WG has also been created, can be consulted at:
https://www.linkedin.com/feed/update/urn:li:activity:6630048414732300288

4 User Stories

To facilitate the definition of parameters and values that are required for full interoperability in MaaS, user stories have been defined from three different perspectives: the User, Transport Operator (TO) and MaaS Provider (MP).
By using these three perspectives, the chances are increased that all necessary functionalities for MaaS are taken into account. These functionalities can then be related to the necessary interface specifications between the TO and MP. This document does not set up any requirements for the human-machine-interface (HMI) between Users and MPs.

The table below presents an overview that summarises the user stories used as a basis for the functionalities included in the TOMP-API. For details about the users stories see Appendix A.4.

Nr.	User Story	Category	Existing API description used in this document	Required for MaaS
1.1	As a USER, I want to depart from STARTLOCATION and arrive at DESTINATION, To define from where to where I need mobility services for my trip	PLANNING	GBFS MaaS-API	Yes
1.2	As a USER, I want to know the PRICING of my trip, To determine how expensive my trip will be	PRICING	GBFS	Yes
1.3	As a USER, I want to receive a single INVOICE for my entire trip, To simplify my cost overview	PRICING	No	Yes
1.4	As a USER, I want to give a RATING and see other ratings of a transport operator, To leave my feedback or determine if I want to use a certain transport operator	TRIP EXECUTION	No	No
1.5	As a USER, I want to be able to REPORT an issue, In case the asset I want to use has a problem/damage/issue	TRIP EXECUTION	No	Yes
1.6	As a USER, I want to be able to select an asset based on COMPETENCES of the vehicle, To fit with the criteria for my trip	PLANNING	GBFS+	Yes
2.1	As a MAAS PROVIDER, I want to know which travel means are available around STARTLOCATION which allow to reach DESTINATION, To give travel advice to the USER	PLANNING	GBFS MaaS-API	Yes
2.2	As a MAAS PROVIDER, I want to know if the trip starts at STARTLOCATION and ends at DESTINATION,	PLANNING	GBFS MaaS-API	Yes
2.3	As a MAAS PROVIDER, I want to know the ACCEPTABLE DISTANCE for the USER from LOCATION X to STARTLOCATION , To define the travel options to the USER	PLANNING	GBFS+?	No
2.4	As a MAAS PROVIDER, I want to know the CONDITIONS of a transport operator, To define the travel options to the USER	PLANNING	GBFS MaaS-API	Yes
2.5	As a MAAS PROVIDER, I want to be able to place a BOOKING with a TRANSPORT OPERATOR , To book an asset beforehand	BOOKING	MaaS-API	Conditional
2.6	As a MAAS PROVIDER, I want the USER to be able to OPEN/CLOSE/PAUSE the asset through my interface, To make the use of the asset as easy as possible	TRIP EXECUTION	GBFS+?	Conditional
2.7	As a MAAS PROVIDER, I want to give my USER on-the-fly USAGE INFORMATION about the asset usage and the booking from the TRANSPORT OPERATOR, To avoid having to keep and update all the information myself	TRIP EXECUTION	No	Optional
2.8	As a MAAS PROVIDER, I want to patch my USER through to the HELPDESK of the TRANSPORT OPERATOR in case of issues, To deliver the best support possible	TRIP EXECUTION	No	Yes
2.9	As a MAAS PROVIDER, I want to be able to CANCEL/MODIFY a transaction or booking , To inform the TRANSPORT OPERATOR about any changes	BOOKING	MaaS-API	Yes
2.10	I want to know if my USER can share a journey or booking with a USER from another MAAS PROVIDER	PLANNING	No	No
3.1	As a TRANSPORT OPERATOR , I want to know from when to when (TIME T1 to TIME T2) the USER,	PLANNING	GBFS MaaS-API	Conditional
3.2	As a TRANSPORT OPERATOR , I want to know the DESTINATION of the USER, To determine if my assets are suitable or available	PLANNING	GBFS MaaS-API	Conditional
3.3	As a TRANSPORT OPERATOR , I want to know if the USER has the right USER COMPETENCE, To determine if the USER is allowed to use my assets	PLANNING	No	Yes
3.4	As a TRANSPORT OPERATOR , I want to know if the USER complies with my USER CONDITIONS before ,	PLANNING	No	Yes
3.5	As a TRANSPORT OPERATOR , I want to give a RATING and see other ratings of a USER, To leave my feedback about and determine if USER can use my asset	TRIP EXECUTION	No	Optional
3.6	As a TRANSPORT OPERATOR , I want to be able to receive USER AUTHENTICATION, To determine if and how USER may use my asset	PLANNING	MaaS-API	Yes
3.7	As a TRANSPORT OPERATOR , I want to be able to CONTACT the USER, In case of problems, emergencies or other issues	TRIP EXECUTION	No	Conditional
3.8	As a TRANSPORT OPERATOR, I want to be able to CANCEL/MODIFY a transaction or booking , To inform the MAAS PROVIDER about any changes	PLANNING	MaaS-API	Yes

5 Process Flows

Together with the eMaaS project team from the University of Twente, process flows for the customer journey have been defined. This helps to scope the necessary functions required in the API building blocks. The goal is to accommodate different business models within these functional flows. Since the focus lies on sharing asset information, both, the asset information from free-floating systems (bike sharing, car sharing, ride sharing, taxi) and the information from (virtual) station- or fixed-route- based systems (such as public transport, (virtual)mobility hubs, or station-dependent transportation) can be shared through the functional descriptions provided in this chapter.

Functional Blocks

The TOMP API is composed of 8 functional blocks. Fig. 2 below aims at giving a general overview of the different functional modules within the TOMP API.
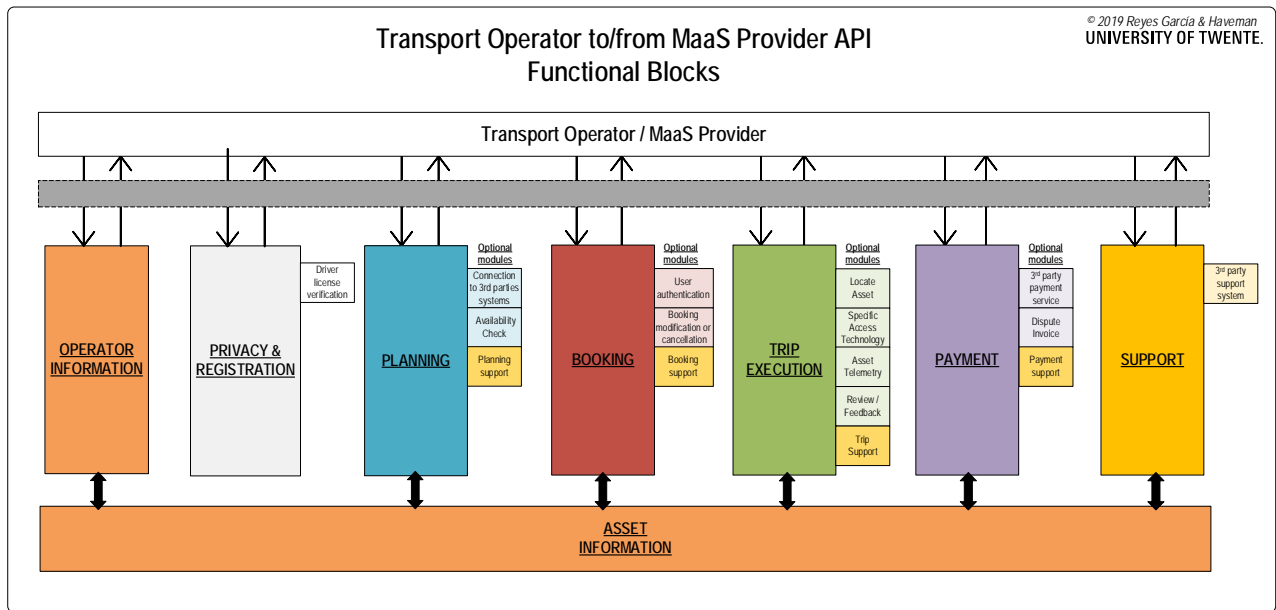

Fig. 2: Functional blocks of the TOMP API

The different functions for the interface between MPs and TOs are described as follows:

- ➢ Operator Information/General Information: Gives static information on the operator according to the General Bikeshare Feed Specification+ (GBFS+) standard.
- ➢ Privacy & Registration: Although the focus of the TOMP API is not on this block, because it impacts not only TOs and MPs but the complete MaaS ecosystem, it is included here as future point for investigation and possible integration in this API.
- ➢ Planning: Gives information about availability, estimated travel time and costs.
- ➢ Booking: Allows reservation of specific assets for a specific place, time and date.
- ➢ Trip Execution: Allows access to the asset(s) and travel during the booked period.
- ➢ Payment: Allows settlement between TOs and MPs. Supports different business models (i.e., pay-as-you-go or subscription-based).
- ➢ Support: Assists users in the solution of operational troubles encountered during any part of the process. Connects with optional support modules.
- ➢ Asset Information: Is defined as a separate module that can be used by other modules to supplement API calls with specific asset information where applicable. Assets can be vehicles or for example infrastructural assets.
- ➢ Optional modules: The more dynamic functional blocks have additional optional modules which are used for execution of sub-processes derived from the main functions which might not be desired or required depending on scope of the MaaS implementation and Business Models.

API Authentication

The TOMP-WG is currently exploring different forms of authentication. For example, via external certificates or via JSON web tokens (JWT). Fig. 3 below shows that the API features authentication for each call to allow secure communication and exchange of information between MPs and TOs.
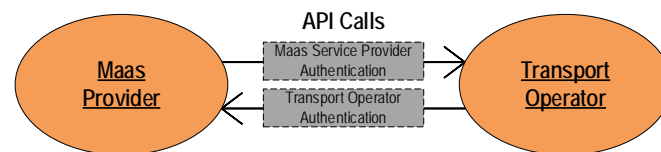

Fig. 3: API calls and authentication

MaaS Provider authentication and authorization should take place following the process below:

- *Authorization code* – The most common flow, mostly used for server-side and mobile web applications. This flow is similar to how users sign up into a web application using their Facebook or Google account.
- *Resource owner password credentials* (or just *password*) – Requires logging in with a username and password. Since in that case the credentials will be a part of the request, this flow is suitable only for trusted clients (for example, official applications released by the API provider).

A Transport Operator might require authentication to communicate with a MaaS Provider, for example to manage (update/cancel) a booking or to send a call-back request. That makes bidirectional authentication necessary.

Operational view of the API

As a summary of the data exchanged provided by the TOMP API calls, Fig. 4 shows an overview of the data sets' blocks and units exchanged between the TOs and MPs.
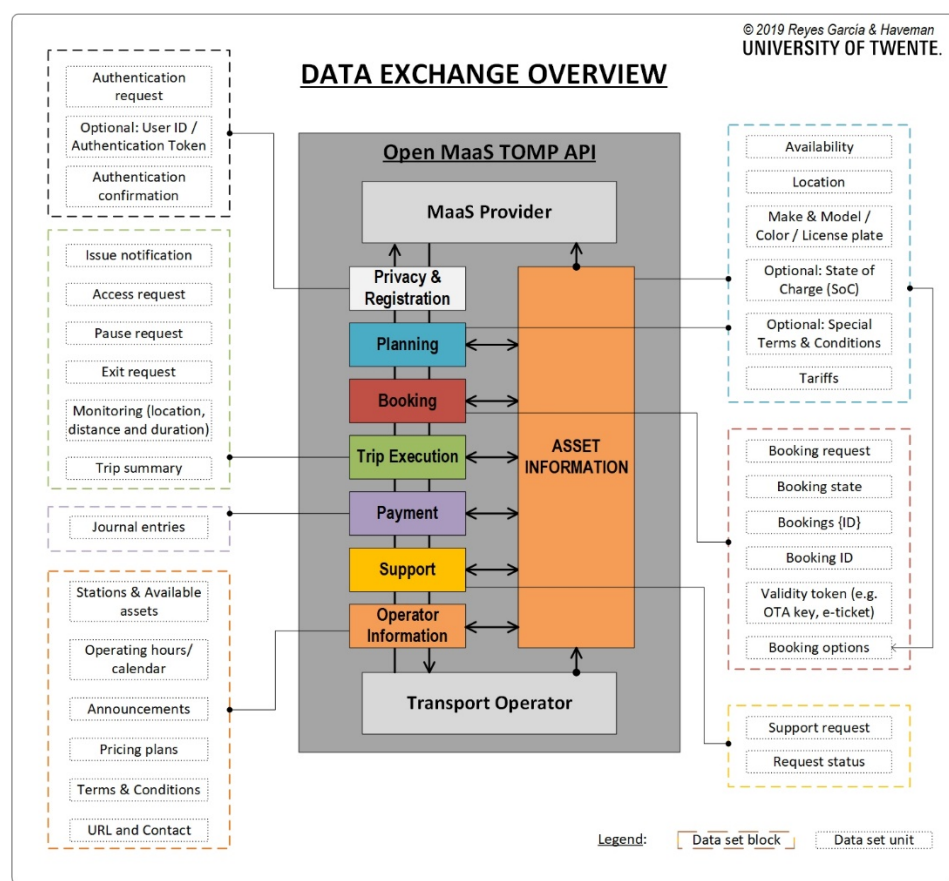

Fig. 4: Data exchange overview of TOMP API

Privacy & Registration and Planning

The first operational block in the TOMP API is the *Privacy & Registration* or deregistration block. This block offers the possibility for users to either delete, sign-up or log-in into their account with the MP. The TOMP API would enable the possibility to use the costumer account with a specific TO to log-in into the MP system.

Planning forms the exploration phase of a trip, where options are explored by the User through the MP. The MP has an archive of (semi-)static general information which is periodically retrieved from the TO. Thus, the MP can check real-time availability of assets to give different travel options to the User. Table 1 presents the functions between the MP and TOs within the planning process, which relate to the user stories presented earlier in §4 and to available API calls from similar API specifications.

Table 1. Functions between the MaaS Provider and Transport Operator within the planning process

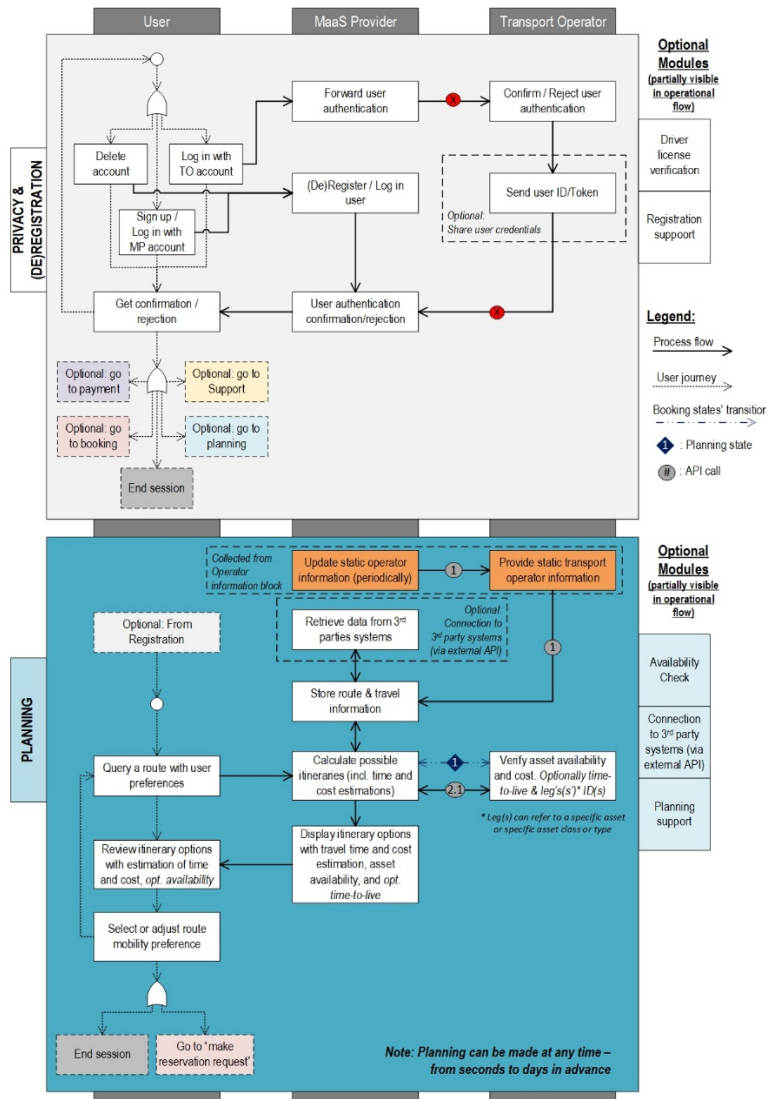| Category	Function	User Story (See Appendix A.4)	Reference
Planning	Update static operator information > provide static operator information	1.2; 1.6; 2.1; 2.2; 2.3; 2.4; 3.4	General Information [from GBFS]
Planning	Check availability of trips > Verify availability and temporarily reserve asset	1.1; 1.2; 2.1; 2.2; 2.3; 3.2	Asset availability and competences [from GBFS and amended]

Fig. 5: Operational view of the Registration & Planning modules

Booking

Booking is the phase where the User will commit to a certain travel option offered by the MaaS Provider (MP). This can be a result of the *Planning* phase, or in case Users know exactly which ticket or booking they want, the result of a new booking request directly. Table 2 presents the functions between MPs and TOs within this process, which relate to the user stories presented earlier in §4 and to available API calls from similar API specifications.

Table 2. Functions between the MaaS Provider and Transport Operator within the booking process

Category	Function	User Story (See Appendix A.4)	Reference
Booking	Make booking request > Process booking	1.6; 2.5; 3.1; 3.2	Booking > POST/bookings/
Booking	Provide User Authentication > Request User Authentication	3.3; 3.4; 3.6	Components/securityschemes [from MaaS Alliance API]
Booking	Cancel / Modify Booking	1.5; 2.9; 3.8	Booking > PUT/bookings/{id}

In addition, Table 3 describes the transition states that take place during the *Booking* process. All these states are helpful to understand the steps and actions within the process of making a reservation. The *Booking* states are also indicated in the operational flow presented in Fig. 6.

Table 3. Transition states of the Booking process

Phase	#	State	
Planning	1	Availability check	In the planning phase, a MP can check the real-time **availability of assets** from a TO. In this way, a MP can offer their Users an overview of which assets and options are currently available following the User's request (for a specific mode, a specific location or other User conditions). A time-to-live can optionally be added to the response to show the User how long the information will be valid for. Just before presenting the results to the user add `provideIds = true` to get booking ids.
Booking	2	Pending	Once the User has narrowed down their selection, the MP can send a booking request to the TO for a specific asset (or asset type) selection, using the id provided in the previous step. This creates a booking with the state **PENDING** and temporarily 'freezes' an asset while the User is finalizing the selection (i.e., while the User is having to choose multiple options for multiple legs of a journey). A time-to-live in the availability confirmation response is mandatory.
	3	Released	If a User decides to go for other options than the one(s) narrowed down, the PENDING state can be cancelled by the MP. The Booking State is changed to **RELEASED**. This frees up the asset for other Users.
	4	Expired	If the expiry time for the PENDING state is reached (as defined in the time-to-live in the availability confirmation), because the User has not (yet) made a selection, the booking state changes to **EXPIRED** and the corresponding asset(s) are no longer 'frozen' for the specific request and the asset is released for other Users.
	5	Confirmed	If a User confirms the selection of a given option, the asset (or asset type) is requested from the MP to the TO and the Booking State changes to either CONFIRMED (in case the "authentication" and payment conditions are met) or to REJECTED (in case the "authentication" and/or "payment" conditions haven't been met).
	6	Rejected	
Trip Execution	7	Started	Once the confirmed asset is in use, the Booking State is changed to **STARTED**.
	8	Paused	If a User wants to pause a ride (fe. park a bike) the Booking Stage can be changed to **PAUSED**.
	9	Finished	Once the asset is returned, the leg is considered completed and the booking state is changed to **FINISHED**.

| Phase	#	State	
Additional States	C	Cancelled	If the asset confirmation is cancelled by the MP (which could also happen upon request from the User), the Booking State changes to **CANCELLED**, and the corresponding terms and conditions for cancellations between TOs and MPs apply. If the asset confirmation is cancelled by the TO (in case of a broken-down vehicle, late return etc.), the booking state changes to **CANCELLED**, and the corresponding terms and conditions for cancellations between TOs and MPs apply.
	CC	Conditional-Confirmed	Optional booking state for parties acting as a _"broker"_ between TOs and MPs. This state supports a postponed commitment by the broker (which would act as a TO) and originated by its sub-TOs. The **CONDITIONAL-CONFIRMED** state can be set by the TO to inform that a reservation it's not yet completely confirmed. Whenever the subcontractor confirms, the booking state will change to CONFIRMED. The **CONDITIONAL-CONFIRMED** stated is also limited by a time-to-postponed-commitment, if the time has expired, the booking state will become EXPIRED.
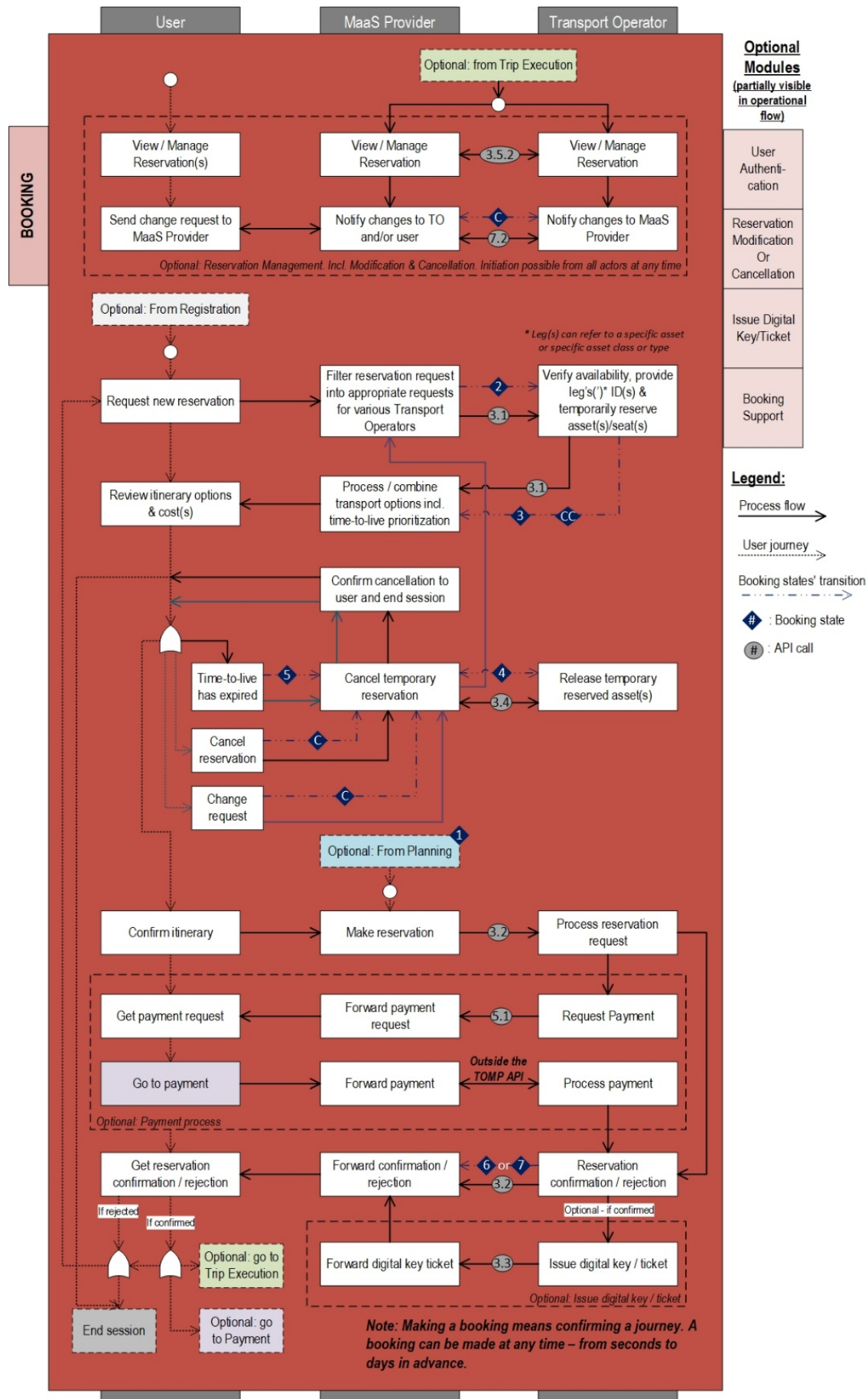
Fig. 6: Operational view of the Booking module

Trip Execution

The *Trip Execution* module offers all functionalities for the User during the trip. This includes breakdown into different legs, access to the asset, ending a leg and monitoring a trip. When all legs are concluded, summaries of the specific legs are exchanged to offer the User a complete overview of the executed trip. Table 4 presents the functions between the MPs and TOs within this process, which relate to the User stories presented earlier in §4.

Table 4. Functions between the MaaS Provider and Transport Operators within the Trip Execution process

Category	Function	User Story (See Appendix A.4)	Reference
Trip Execution	Forward location request > provide location	1.1; 2.1	Asset availability and competences > free_asset_status [from GBFS] New proposal: GET/legs/{id}/progress
Trip Execution	Forward access request > grant / reject access	2.6; 3.6	New proposal: PUT/legs/{id}/events
Trip Execution	Monitor trip <> monitor use of asset	2.7	New proposal: POST/legs/{id}/progress
Trip Execution	Forward exit request > grant / reject exit	2.6	New proposal: PUT/legs/{id}/events
Trip Execution	Generate Trip Summary > Provide Leg Summary	1.3	New proposal: GET/legs/{id}
Trip Execution	Manage Review / Feedback <> Review / Feedback with respect to user	1.4; 2.8; 3.5	New proposal: POST/bookings/{id}/notifications
Trip Execution	Trip support (optional)	2.8; 3.7	New proposal: POST/bookings/{id}/notifications

In addition, Table 5 describes the transition states that take place during the *Trip Execution* process. All these states are helpful to understand the steps and actions within the process of executing a trip. The *Trip Execution* states are also indicated in the operational flow presented in Fig. 7.

Table 5. Transition states of the Trip Execution process

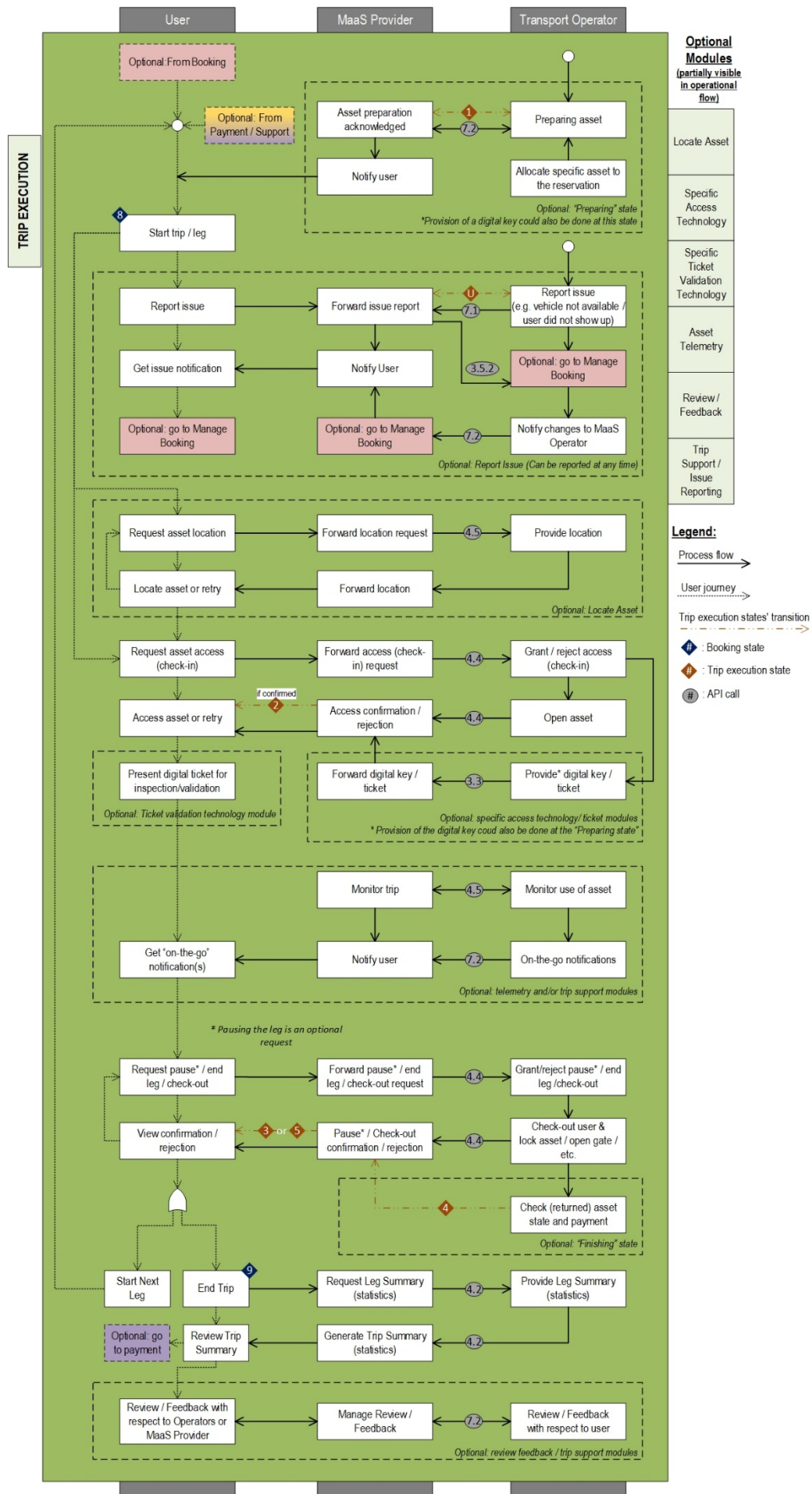|		Trip Execution states
#	State	Description
1	Preparing	When an asset is not being used yet by the user, but is being prepared (e.g., a taxi is coming towards the user, or a rental car is being cleaned before start of the rental).
2	In use	The user has started to use the asset. This can be acknowledged or confirmed either by the TO or MP, depending on the type of asset.
3	Paused	If possible, an asset that is in use can be paused in order to apply a lower rate (e.g., when parked).
4	Finishing	When the asset is no longer being used by the user, but the Trip execution is not yet finished (e.g., during verification of damages, cleaning of asset, payment check). At this time the user could have continued with another leg of their trip.
5	Finished	The asset has been returned and the trip/leg is confirmed to be finished.
U	Issue	An issue has arisen during the trip execution, reported by the user through the MP to the TO.

Fig. 7: Operational view of the Trip Execution module

Payment

The scope of the *Payment* module is limited to the communication between TOs and MPs concerning settlement and clearing, not about ticketing or the actual payment process. The *Payment* module offers two alternative payment models that can also be used in conjunction: a prepayment model and a postpayment model. A prepayment model can be used to exchange payment information regarding fares for the legs booked, deposit, subscriptions, etc. A postpayment model can be used to exchange payment information after a trip has been completed regarding fares for the legs travelled, reimbursements, fines, etc. Table 6 presents the functions between MPs and TOs within this process, which relate to the User stories presented earlier in §4.

Currently the payment module supports only the reporting and requesting of payments. The TO can enlist all the trip costs and 'other costs', like fines, extra usages etc. The MP can request the 'journal items' to find out how much has to be paid to the TO. In the journal items there is also a precise description of the executed leg: distance, time etc. All different scenarios (prepaid, postpaid, subscription, deposits, fines, etc) can be implemented with the current setup.

Table 6. Functions between the MPs and TOs within the Payment process

Functions between MaaS-provider and Transport Operator			
Category	*Function*	*User Story (See Appendix A.4)*	*Reference*
Payment/PrePay	Request / receive payment <> Request / receive payment	1.2; 1.3	-
Payment/PostPay	Request / receive payment <> Request / receive payment	1.2; 1.3	-

In addition, Table 7 describes the transition states that take place during the *Payment* process. These states are helpful to understand the steps and actions within the process of making a reservation. The booking states are also indicated in the operational flow presented in Fig. 8.

Table 7. Transition states of the Payment process

Payment states		
#	State	Description
T	To invoice	TO requests payment from MP
I	Invoiced	TO has confirmed payment from MP

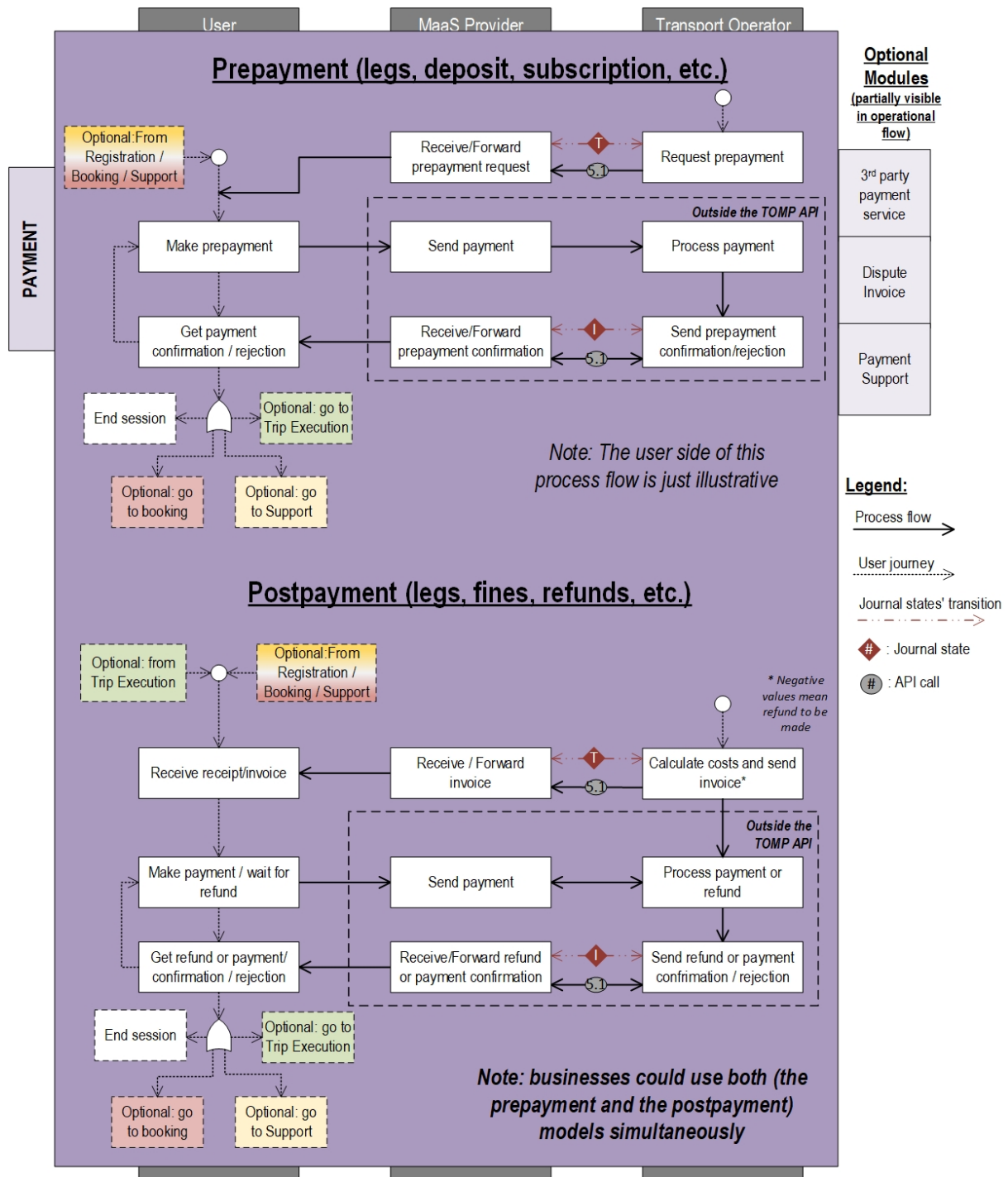*Fig. 8: Operational view of the Payment module*

Support

The support module offers functional blocks that refer to the technical assistance to the User in case of an issue experienced during any of the other modules. Within this module, optionally, 3rd party systems could be used to solve the User problems. Fig. 9 shows the process flow of the *Support* module.
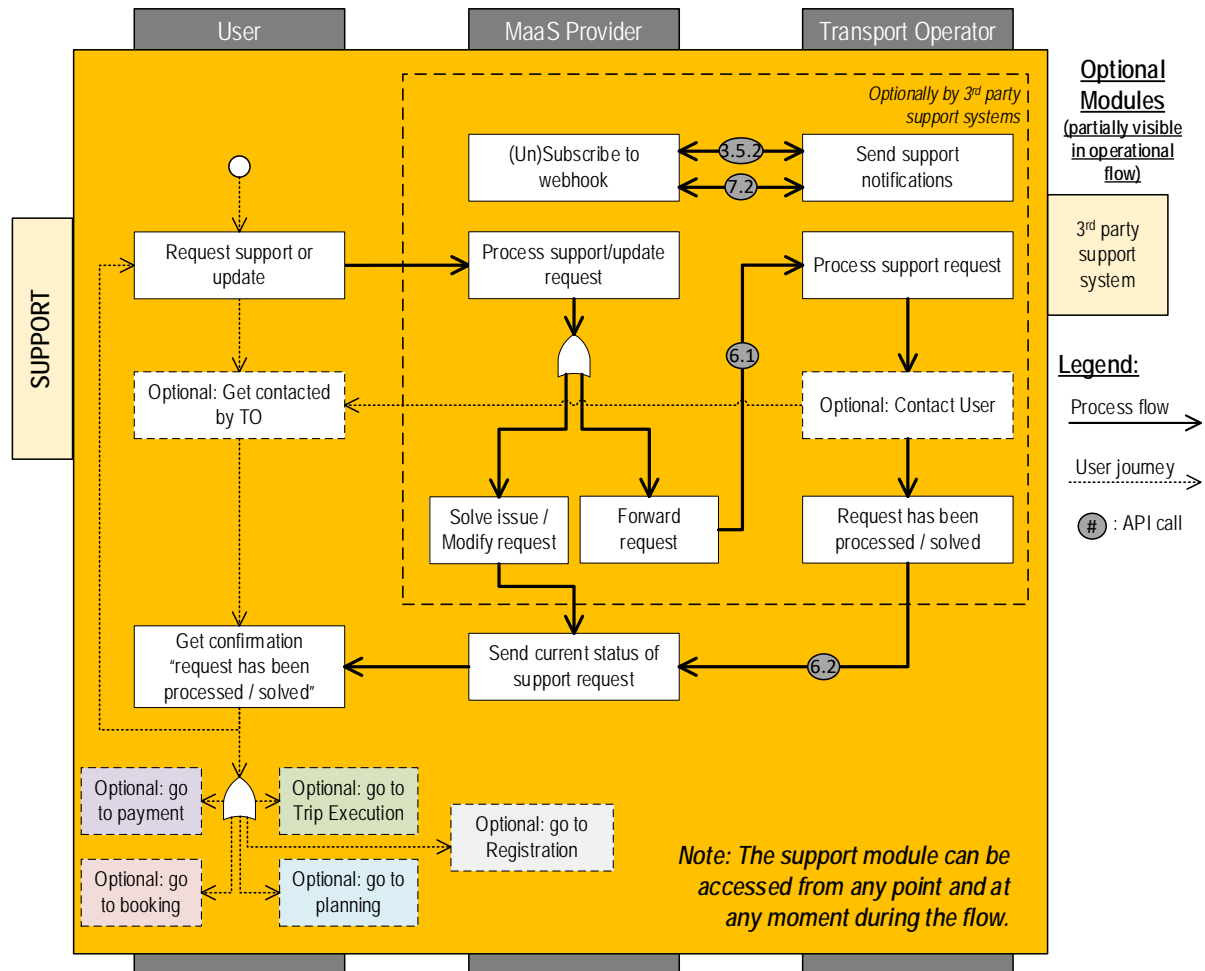

Fig. 9: Operational view of the Support module

6 Reference implementations

To facilitate a quick and smooth implementation, several examples, explanations and step-by-step guidelines are provided in the TOMP API wiki page:

https://github.com/TOMP-WG/TOMP-API/wiki

As a result, during the past few months several parties (both TOs and MPs) have started to implement the TOMP API. These implementations however, have been in most cases limited in scope and/or adaptations of the intended standard. On the other hand, none of the implementers has encountered major impediments with the implementation of the TOMP API.

To have an overview of the latest implementations, the TOMP Working Group conducted an internal survey to explore the level of implementation among members of the group. A summary of the results of such survey are presented in the table below:

Type of implementer	Bike Rental	3
	Car Rental	4
	Public Transport	3
	MaaS Provider	4
MP vs TO	Nr. of TOs	7
	Nr. of MPs	4
Type of project	Commercial Pilot	70%
	Reference Implementation	20%
	Other	10%
Multiple TOs behind a single API		40%
Communication	Peer-to-peer	90%
	Router	30%
	Unclear	10%
Security	Custom	70%
	None	30%

7 GBFS+ recommendations

The following additions to GBFS have been proposed by the TOMP-WG to the GBFS community. The acceptance of these suggestions and future phasing is still to be defined. A national GBFS+ standard can be implemented to speed up developments in the Netherlands.

1. Deep links, Add rental_url to free bikes and stations
There is already a change-requests (from others) for an extension of the standard, covering exactly our wishes. So we include request #25 in GBFS+, which enables deep links.

2. Type_of_system
We will add type_of_system in the "system info" file. Allowed values are [free_floating, station_based, virtual_station_based]

3. Type_of_bike

We add a file "Types_of_bikes" which describes the different bike types (type_id, name, gears, electric, description, img_url). In free-bike-status file we add the field type_of_bike (our first proposal on OpenBikeShare Github)

4. TTL

The time to live (TTL) for real-time data feeds will be at most 30s, so that traveller has always the most actual information about the availability of bicycles.

There are some other topics to cover to make an awesome bike standard in the future, but more research has to be done. Possible topics are:

- Which fields should be compulsory?
- Operation area: For a free-floating system we would like to indicate where you can return your bike (for example you are only allowed to return the bike within the city). In this https://github.com/NABSA/gbfs/issues/65 thread there is already a discussion about this idea.
- Virtual stations: We would like to introduce virtual stations (a virtual location where you allowed to park your bike) within GBFS so operators comparable with Donkey Republic are supported as well. We created a proposal. The exact location of a virtual zone should be presented as GeoJSON polygon in station_information.json.
- Option to define a radius around a bike or bikesharing station for location-specific API-calls.
- Option to OPEN/CLOSE/PAUSE an asset.

8 Technical Specifications

The technical working group suggests to implement this interface using REST-APIs. Other quality specifications are:

Criteria	Value
Time To Live	Max. 30 seconds
Reliability	95%
API-call max radius around asset	500 meters
API-call min radius around asset	10 meters
Pagination of API-responses	t.b.d. after testing of v. 1.1/1.2
Rate limiting	t.b.d. after testing of v. 1.1/1.2

9 To-do's and risks

- Opening and closing of assets can vary greatly between different transport operators. Some regard this technology as their own intellectual property and are not willing to offer external access. This is a risk for common API development and might require further harmonization in the future.
- Which service/helpdesk functions are required for the User?
- Options for ticketing and payment of legs/trips
- Central registry of available stations/hubs/operators and assets, with unique ID's

10 **Appendix**

A.1 - List of terms and definitions

This appendix presents the terms and definitions that served as a reference for the development of the functionalities covered by the TOMP API.

TERM	DEFINITION	SOURCE
Availability	The ability of an asset to perform a required function under given conditions at a given instant in time, or over a given time interval, assuming that the required external resources are provided.	Adapted from UNISIG (2016)
Booking	The process of making a reservation for space on a means of transport for the movement of people or goods.	Adapted from EC 1305/2014
Booking Process	The process involving those steps necessary to make a reservation, possibly including: - Query of route - Select preferred option - Request reservation - Accept terms and conditions (incl. payment) - Get reservation confirmation	
Booking State	The situation at a particular time during the booking process.	TOMP WG (2019)
- Started	User requested the usage or reservation of an asset(s) or a seat(s).	
- Pending	The requested seat(s) or asset(s) is/are temporary reserved for the user. Reservation is pending for payment.	
- Released	If a User decides to go for other options than the one(s) narrowed down, the PENDING state can be cancelled by the MP. Then the booking state is changed to RELEASED.	
- Confirmed	Reservation has been paid and the seat(s) or vehicle(s) has/have been granted for the user	
- Cancelled	The reservations has been cancelled by one of the parties involved	
- Changed	If a reservation needs to be changed after it has been CONFIRMED by the User or TO (e.g., different asset has been assigned, different starting time), the MP will indicate it to the other party and the booking state will change to CHANGED.	
- Finished	Reservation period has ended and the utilization of the asset or seat is no longer valid.	
(passenger) Journey	A collection of segments which satisfies transportation of a passenger for a given origin and destination.	IATA (2018)
Mass transit	Large-scale public transportation with high carrying capacity, such as buses, subways, and trains.	
Motor vehicle	A road vehicle propelled by an engine or motor (internal combustion engine, or electric motor, or some combination of the two) and used for the transportation of passengers, property, or freight	Byars, M., Wei, A., & Handy, S. (2017)
Multi-modal travel	Travel using more than one travel mode.	
Multimodal access	A system that meets the needs of bicyclists, pedestrians, transit users, passenger vehicles, and other motor vehicle users. A system providing multimodal access integrates different transportation modes to allow co-existence and easy switching between modes	California State Bicycle and Pedestrian Plan in Byars et al. (2017)
Multimodal connectivity	The ease with which people can switch between modes on the same trip. For example, pedestrian and bicycling access to transit stops and stations	Byars et. al (2017)
Passenger vehicle	A motor vehicle with at least four wheels, used for the transport of passengers, and comprising no more than eight seats in addition to the driver's seat.	Organisation Internationale des Constructeurs d'Automobiles (OICA)

TERM	DEFINITION	SOURCE
Private transportation	Transport services owned and operated by private entities, such as privately-owned shuttles	Adapted from Byars, M., Wei, A., & Handy, S. (2017)
Public transportation	Transport services owned and operated by state, regional, or local public agencies.	
Rebooking	A change of reservation and/or other changes which do not require ticket reissuance or exchange	IATA (2018)
Reservation	The allotment in advance of seating or sleeping accommodation for a passenger or of space or weight capacity for baggage, cargo or mail. This term is also applied to hotel, car and other types of travel services.	
Rideshare	When a driver, or a passenger, shares an open seat(s) in a vehicle with one or more passengers that have similar travel paths and schedules. Traditional forms of ridesharing include carpooling and vanpooling and current use includes sharing space in a ride sourced vehicle.	Byars et. al (2017)
Ride sourcing	A rideshare service that connects passengers to drivers, typically through a digital application and typically for a fee. Drivers and companies work for-profit and typically offer rides that are not incidental to their own trips.	
Shared Mobility	When a transportation mode, such as an automobile or bicycle, is used by more than one person either for moving a person or personal goods. Mode-usage typically occurs at the same time, but may also refer to sequential use, i.e. a leasing a shared bicycle. Although it can reduce miles travelled per person, it may or may not be efficient in terms of mode used or emissions per person. *This includes*: public transit options, car sharing; personal vehicle sharing (peer-to-peer car sharing and fractional ownership); car-pooling; van-pooling; ride-splitting, bike sharing; scooter sharing; shuttle services; micro transit; ridesharing; e-Hail (taxis); shuttle services; neighbourhood jitneys; ride sourcing; transportation network companies; ride-hailing; paratransit; and more. It can also include courier network services or flexible goods delivery, which provide for-hire delivery services using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with freight (e.g., packages, food), and commercial delivery vehicles providing flexible goods movement.	
Station	Location or facility where air or surface transportation originates, stops and/or terminates, and where passengers and/or cargo can be taken on or off.	
Traffic	The vehicles, pedestrians, ships, or planes moving through an area or along a route.	
Transport	Take or carry (people or goods) from one place to another by means of a vehicle, aircraft, or ship.	Oxford Dictionary
Transportation	The action of transporting someone or something or the process of being transported	
Transit	Public or private transportation service that moves passengers in mass and usually has fixed routes, stops, and fares. Operates within cities or regions rather than between cities or regions.	Byars et. al (2017)
Travel	The action of going from one location to the other, from origin to destination.	
Travel mode	The means by which travel is done. Common travel modes for people include passenger car (driving alone or shared ride), public transit (bus, subway, or train), walking, and bicycling. Common travel modes for freight include land (road, rail, and pipelines), maritime, and air transportation.	

TERM	DEFINITION	SOURCE
Vehicle sharing	Provides short-term, on-demand access to a transportation mode without sole, direct ownership, thus reducing the overall number of vehicles including automobiles, bicycles, and scooters.	

References

Byars, M., Wei, A., & Handy, S. (2017)	Sustainable Transportation Terms: A Glossary	Retrieved from https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2759
EC 1305/2014	COMMISSION REGULATION (EU) No 1305/2014 – Annex II, Glossary	Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1305&from=EN
EC 62/2006	COMMISSION REGULATION (EU) No 1305/2014 – Annex B, Glossary	Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R0062&from=EN
IATA (2007)	International Air Transport Association (IATA) — Ticketing Handbook 39th Ed.	Retrieved from https://www.travelready.org/PDF%20Files/IATA%20-%20Ticketing%20Handbook.pdf
IATA (2018)	International Air Transport Association (IATA) — Passenger Glossary of Terms	Retrieved from https://www.iata.org/whatwedo/passenger/Documents/IATA-Passenger-Glossary-of-Terms.xlsx
OICA	OICA statistics web page	Retrieved from http://oica.net/wp-content/uploads/stats-definition1.pdf
Oxford Dictionary	Online	https://www.lexico.com. Accessed on 30 July 2019
TOMP WG	Dutch working group for a Transport Operator to MaaS Provider	https://www.linkedin.com/company/tomp-wg
UNISIG (2016)	Glossary of Terms and Definitions - SUBSET-023 v.3.3.0	Retrieved from https://www.era.europa.eu/filebrowser/download/1091982_en

A.2 – Passenger characteristics' dictionary

This appendix presents the main classification of the corresponding codes for passenger characteristics as defined in the (Dutch) dictionary of passenger characteristics (*woordenboek reizigerskenmerken*) by the Traffic and Transport Knowledge Platform (CROW-KpVV, 2019). By using these codes, it is possible to clearly establish what are the passengers' needs to successfully complete a (multi-leg) journey. For a full description of the codes and terms please consult the original source at:

https://github.com/efel85/TOMP-API/blob/master/documents/Woordenboek%20Reizigerskenmerken%20CROW.pdf

Category	Code	Name
Passenger's assistance tool	HR-01	Standard wheelchair
	HR-02	Electric wheelchair
	HR-03	Foldable wheelchair
	HR-04	Wheelchair - not securely fixed
	HR-05	Wheelchair - self-balancing two-wheeler
	HR-06	Wheelchair - Different
	HR-07	Rollator – or walker
	HR-08	Rollator - different
	HR-09	Mobility scooter - Standard
	HR-10	Mobility Scooter - Different
	HR-11	Variable assistance tool
	HR-12	Dog
Vehicle tool	HV-01	Belt – exemption seatbelt duty
	HV-02	Belt - extension
	HV-03	Seat - booster seat
	HV-04	Seat - child seat category 1
Additional requirement - transport	AV-01	Transportation – individual
	AV-02	Transportation - in (wheelchair) bus
	AV-03	Transportation - last in / first out
	AV-04	Transport – if passenger car, then in the front
	AV-05	Transport – in passenger car
	AV-06	Transport - in the front and in passenger car
	AV-07	Transport - in the front, regardless of type vehicle
	AV-08	Transport – low entry
	AV-09	Transport - combi with others except …
	AV-10	Transportation - no combi other target group
	AV-11	Transport – shortened travel time
Additional requirement - guidance	AB-01	Guidance - room-room transfer
	AB-02	Guidance - door-to-door
	AB-03	Counselling - necessary / medical counsellor
	AB-04	Guidance - variable companion
Additional requirement - extra passenger	AER-01	Shared travel – for free
	AER-02	Shared travel – reduced fee
	AER-03	Housemate
Characteristics	K-01	Characteristic - blind / visually impaired
	K-02	Characteristic - deaf / poor hearing
	K-03	Characteristic – cognitively limited
(Guided) Independent travel	ZR-01	Public transport advice
	ZR-02	Public transport stop at max 100 meters
	ZR-03	Public transport stop at max 250 meters
	ZR-04	Public transport stop at max 500 meters
	ZR-05	Public transport stop at max 1000 meters
	ZR-06	public transport stop at (variable) meters

Category	Code	Name
	ZR-07	Public transport stop: required - accessible by motor
	ZR-08	Public transport stop: required - non-visual
	ZR-09	Transfers: max 0 times
	ZR-10	Transfers: max 1 times
	ZR-11	Transfers: max 2 times
	ZR-12	Transfers: max 3 times
	ZR-13	Multimodal trip
	ZR-14	Night-blind
	ZR-15	Use of bicycle - partly
	ZR-16	Use of bicycle - fully
	ZR-17	Use of train - partly
	ZR-18	Use of train - fully
	ZR-19	Use of bus - partly
	ZR-20	Use of bus - fully
	ZR-21	Use of own transport - partly
	ZR-22	Use of own transport - fully
	ZR-23	Use of the boarding place/platform
Travel rights	RR-01	Kilometre budget
	RR-02	Mobility budget
	RR-03	Transboundary transport - Valys

A.3 – APIs available on the transportation ecosystem

This appendix provides and overview of available commercial and non-commercial APIs on the market.

Name	Website	Service	License
BoMaaS / FLOU.io	https://tapahtumat.tekes.fi/event/bomaas2310 https://app.swaggerhub.com/apis/FLOU	Ticket sales (example) Service registry catalogue	Creative commons 4.0
SUTI	http://www.suti.se/	Exchange of demand responsive traffic information between clients and providers	Membership
GTFS	General Transit Feed Specification https://developers.google.com/transit/gtfs/	Public transportation schedules and associated geographic information	Google - Apache 2.0
GBFS	General Bikeshare Feed Specification https://github.com/NABSA/gbfs	Bike sharing system, service and status information	Open standard, community on Github
MaaS-API	http://www.maas-api.org/	Booking and listing	MIT license / Alliance Membership
Uber API	https://developer.uber.com/docs/riders/ride-requests/introduction	Uber ride requests	Developer dashboard membership
IPSI	Interoperable Product Service Interface https://oepnv.eticket-deutschland.de/en/fachpublikationen/themenportal-ipsi/	Mobile ticketing, ticket purchase, conditions for sale of tickets	License with VDV
Wiener API	http://akirk.github.io/Wiener-Linien-API/	Public transport schedules	Open government data Wien (OGD)
OTP	Open Trip Planner http://www.opentripplanner.org/	Multimodal trip planner Passenger information and transportation network analysis	Open source
OTM	Open Trip Model www.opentripmodel.org	Exchange real-time logistics data	Creative Commons 4.0
TripGo API	https://developer.tripgo.com/ https://developer.tripgo.com/specs/#	Plan door-to-door trips using a large variety of public and private transport. It integrates real-time information and, for selected providers, allows users to book and pay for transport.	Apache License 2.0 Free testing below a threshold of API calls
Combitrip	https://www.combitrip.com/combitrip-api.php	APIs for maps, autocomplete an journey planning.	For small non-commercial use it is free for the first 500 daily requests.

A.4 – Overview of the User stories used as parameters for the MaaS functionalities applicable to the TOMP API

Definitions within the User Stories

Definition	Meaning
API	Application Programming Interface, using REST-APIs as architectural style
User	Customer wanting to make a journey
Maas Provider	Provider of travel advice, information, booking and invoicing
Transport Operator	Owner of (any) transport assets. This can be a bike sharing or car sharing platform, public transport operators, taxi companies, ferry operators etc.
Required for MaaS	Yes = mandatory Conditional = mandatory for some operators Optional = mandatory for no operators
User	Competence = is the user able Conditions = is the user compliant Authentication = confirmation of identity/profile/token

Part 1: From a USER perspective

Item	1.1
Who	As a USER
What	I want to depart from STARTLOCATION and arrive at DESTINATION
Why	To define from where to where I need mobility services for my trip
Required for MaaS	STARTLOCATION=yes DESTINATION=conditional
Comments	*Some transport operators require the asset to be brought back to a specific station or zone. This requires knowledge about the desired destination or trip (single, return, multi-leg).*

Item	1.2
Who	As a USER
What	I want to know the PRICING of my trip
Why	To determine how expensive my trip will be
Required for MaaS	PRICING=yes
Comments	

Item	1.3
Who	As a USER
What	I want to receive a single INVOICE for my entire trip
Why	To simplify my cost overview
Required for MaaS	INVOICE=yes
Comments	

Item	1.4
Who	As a USER
What	I want to give a RATING and see other ratings of a transport operator
Why	To leave my feedback or determine if I want to use a certain transport operator
Required for MaaS	RATING=optional
Comments	

Item	1.5
Who	As a USER
What	I want to be able to REPORT an issue
Why	In case the asset I want to use has a problem/damage/issue
Required for MaaS	REPORT=yes
Comments	*Maybe this doesn't have to be available in an API, but needs to be covered by B2B arrangements. A User want the MaaS Provider to solve any issues, as this is their travel interface. A booking should only be made if an asset has no known technical issues, a transport operator should facilitate this.*

Item	1.6
Who	As a USER
What	I want to be able to select an asset based on COMPETENCES of the vehicle
Why	To fit with the criteria for my trip
Required for MaaS	COMPETENCES=yes
Comments	*E.g., selection of number of seats, type of vehicle, range, fuel type etc.* • *Proposals:* o *No of passengers* o *Propulsion (e.g., hydrogen)* o *Vehicle class* o *Brand* o *Type* o *Bicycle type (men, women, tandem)* o *Steering wheel on left or right* o *Colour* o *State of charge (%)* o *Exclusive yes/no (in case of ridesharing)* o *Type of access/key* o *Towing hook* o *Airconditioning* o *Cabrio* o *Child's seat* o *Winter tires* o *Allowed to travel abroad* o *Pets allowed* o *Smoking allowed* o *Underground parking allowed* o *Easy accessibility to location (lift, escalator)*

Item	1.7
Who	As a USER
What	I want to receive SUPPORT during my trip
Why	In case I want to be guided along my travel, get additional suggestions or need any kind of support.
Required for MaaS	SUPPORT=yes
Comments	*Added in v0.9*

Part 2: From a MaaS Provider perspective

Item	2.1
Who	As a MAAS PROVIDER
What	I want to know which travel means are available around STARTLOCATION which allow to reach DESTINATION
Why	To give travel advice to the USER
Required for MaaS	STARTLOCATION=yes DESTINATION=conditional
Comments	*The destination is not always relevant, but some assets need to be brought back to their specific station or zone or even if a one way trip is possible, to a specific zone or station at destination location*

Item	2.2
Who	As a MAAS PROVIDER
What	I want to know if the trip starts at STARTLOCATION and ends at DESTINATION Or will end at the STARTLOCATION
Why	To define my travel options to the USER
Required for MaaS	STARTLOCATION=yes DESTINATION=conditional

Item	2.2
Comments	Covered by user story 2.1
	The destination is not always relevant, but some shared bikes need to be brought back to their specific station or zone or even if a one way trip is possible, to a specific zone or station at destination location

Item	2.3
Who	As a MAAS PROVIDER
What	I want to know the ACCEPTABLE DISTANCE for the USER from LOCATION X to STARTLOCATION
Why	To define the travel options to the USER
Required for MaaS	ACCEPTABLE DISTANCE=optional
	LOCATION X=optional
Comments	*A user can have a preference for maximum distance he/she wants to walk to reach a bicycle. Proposed standard value = 500 meters*

Item	2.4
Who	As a MAAS PROVIDER
What	I want to know the CONDITIONS of a transport operator
Why	To define the travel options to the USER
Required for MaaS	CONDITIONS=yes (but can be periodical)
Comments	*E.g., business conditions, user conditions for the rental of the asset etc. These can be updated every week or month (t.b.d.), and do not necessarily have to be requested with each query*

Item	2.5
Who	As a MAAS PROVIDER
What	I want to be able to place a BOOKING with a TRANSPORT OPERATOR
Why	To book an asset beforehand
Required for MaaS	BOOKING=conditional
Comments	*This could also be done without a USER requesting a booking. In this case the booking risk lies with the MAAS PROVIDER instead of the TRANSPORT OPERATOR. In this case, the TO's own clients might not have access to the assets if the MP books everything in advance.*

Item	2.6
Who	As a MAAS PROVIDER
What	I want the USER to be able to OPEN/CLOSE/PAUSE the asset through my interface
Why	To make the use of the asset as easy as possible
Required for MaaS	OPEN=conditional
	CLOSE=conditional
	PAUSE=optional
Comments	*Requires information on the locking systems of operators. Pausing is an optional function to allow different pricing models when asset is temporarily parked by user*

Item	2.7
Who	As a MAAS PROVIDER
What	I want to give my USER on-the-fly USAGE INFORMATION about the asset usage and the booking from the TRANSPORT OPERATOR
Why	To avoid having to keep and update all the information myself
Required for MaaS	USAGE INFORMATION=conditional
Comments	*A transport operator could like to send real-time usage instructions (e.g., "please unlock the bike now using the QR-code") to the User through the MaaS-provider interface.*

Item	2.8
Who	As a MAAS PROVIDER
What	I want to patch my USER through to the HELPDESK of the TRANSPORT OPERATOR in case of issues
Why	To deliver the best support possible
Required for MaaS	HELPDESK=yes
Comments	*A Transport Operator can give specific support about the asset in case of issues. A direct link between User and Transport Operator is required, the MaaS Provider can facilitate this link through*

Item	2.8
	their service. As a reference, insurance companies offer similar assistance, where a neutral helpdesk can take on the 'image' of the insurance provider that manages the specific contract of the User.

Item	2.9
Who	As a MAAS PROVIDER
What	I want to be able to CANCEL/MODIFY a transaction or booking
Why	To inform the TRANSPORT OPERATOR about any changes
Required for MaaS	CANCEL=yes MODIFY=yes
Comments	*MaaS providers need to be able to cancel or modify transactions or bookings on behalf of their users.*

Item	2.10
Who	As a MAAS PROVIDER
What	I want to know if my USER can share a journey or booking with a USER from another MAAS PROVIDER
Why	To efficiently make use of available transportation through carpooling or ridesharing
Required for MaaS	No
Comments	*This allows higher occupancy of available assets through ridesharing and carpooling*

Item	2.11
Who	As a MAAS PROVIDER
What	I want to receive information on public transport USER stops and line information
Why	To plan an efficient route for my USER and give the necessary SUPPORT along the journey
Required for MaaS	No
Comments	*For planning purposes, e.g., information on kerbs, ramps, lights, displays, linetype and transport operator*

Part 3: From a Transport Operator perspective

Item	3.1
Who	As a TRANSPORT OPERATOR
What	I want to know from when to when (TIME T1 to TIME T2) the USER wants to use my assets
Why	To define if this fits my offer of assets
Required for MaaS	TIME T1(START TIME/DAY)=conditional TIME T2(END TIME/DAY)=conditional
Comments	*This is optional, only required in case of usage restrictions of the Transport Operator or to implement the option to book an asset beforehand (long-term).*

Item	3.2
Who	As a TRANSPORT OPERATOR
What	I want to know the DESTINATION of the USER
Why	To determine if my assets are suitable or available
Required for MaaS	DESTINATION=conditional
Comments	*The destination is not always relevant, but some shared bikes need to be brought back to their specific station or zone or even if a one way trip is possible, to a specific zone or station at destination location*

Item	3.3
Who	As a TRANSPORT OPERATOR
What	I want to know if the USER has the right USER COMPETENCE
Why	To determine if the USER is allowed to use my assets
Required for MaaS	USER COMPETENCE=yes
Existing API's	Not available/necessary in GBFS, use other MaaS-API specs.
Comments	*E.g., the user should have a driving license, correct contact details, a membership etc. This could be a liability issue that needs to be covered with insurance providers.*

Item	3.4
Who	As a TRANSPORT OPERATOR
What	I want to know if the USER complies with my USER CONDITIONS before starting a trip
Why	To determine if the USER is allowed to use my assets
Required for MaaS	USER CONDITIONS=yes
Comments	*E.g., user is not on a blacklist, registered member*

Item	3.5
Who	As a TRANSPORT OPERATOR
What	I want to give a RATING and see other ratings of a USER
Why	To leave my feedback about and determine if USER can use my asset
Required for MaaS	RATING=optional
Comments	*A transport operator might want to rate a user or determine if a user is allowed to use an asset based on their rating*

Item	3.6
Who	As a TRANSPORT OPERATOR
What	I want to be able to receive USER AUTHENTICATION
Why	To confirm the identity of the USER using my asset
Required for MaaS	USER AUTHENTICATION=yes
Comments	*Authentication provides the transport operator with a confirmation of a user's identity, profile or token.*

Item	3.7
Who	As a TRANSPORT OPERATOR
What	I want to be able to notify the MaaS provider to CONTACT the USER
Why	In case of problems, emergencies or other issues
Required for MaaS	CONTACT=yes
Comments	*A transport operator can give specific support about the asset in case of issues. A direct link between user and transport operator is required, the MaaS Provider can facilitate this link through their service (see also item 2.8).*

Item	3.8
Who	As a TRANSPORT OPERATOR
What	I want to be able to CANCEL/MODIFY a transaction or booking
Why	To inform the MAAS PROVIDER about any changes
Required for MaaS	CANCEL=yes MODIFY=yes
Comments	*Transport operators need to be able to cancel or modify transactions or bookings in case an asset is unavailable or delayed.*

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A.7 – Adoption and Implementation of the TOMP API

This section shows examples of parties and transport operators that have adopted and/or implemented the TOMP API.

<u>Working on implementation and/or realization:</u>

<u>Adopted by:</u>

Supported by: