MaaS
Mobility as a Service

Data requirements

from

TOMP-API perspective

A blueprint for facilitating a MaaS ecosystem,

commissioned by Dutch Ministry of Infrastructure & Water management

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Introduction

The goal of this document is to *determine the 'next steps'* to set up a MaaS ecosystem. These next steps are *derived from a gap analysis* of the data that is already available and data that is needed in such an ecosystem.

The available data can in the Netherlands (as much as possible) is enlisted in the attachments, but to find out the demand… To determine that, we have to map the ecosystem: *what is the process*, *who acts in it* (and in which process step), how is it *related to the actual infrastructure* (which is a source of data)?

After this analysis, look at what we have and what is needed. From there on, we can *draw some conclusions and advice actions*.

In the first chapters we describe the roles of the ecosystem, the 7 MaaS steps, the interaction between the roles during the 7 MaaS steps and the infrastructure layer model. These chapters are there to *describe the concepts* we use (chapter 3 – 6); a kind of dictionary.

After these four chapters, we start describing the data types we see in the MaaS ecosystem. Each *data type will be described* briefly (chapter 7).

After this we can relate the data types: what is the *demand* and what is the *supply*. This will be done in chapter 8.

This will lead to conclusions from the *gap* between the *need and availability of the data types* (chapter 9).

These conclusions result in advices for the ecosystem; for quite a few roles we developed *an advice how to implement this in the ecosystem* (chapter 10).

Initially we started with the data that is available at the NAP (NDW), but the scope became bigger when analyzing the gap between the data that is needed by a MaaS ecosystem and what is already available (and should be improved, but that's out of scope).

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1. Management summary

In this document we use a step-by-step approach to discover the demands and supplies of data in a MaaS ecosystem (Dutch context). The discrepancies are exposed, conclusions are drawn, and advices are created.

The main conclusion is:

> *Infrastructural related data is well on its way (NAP), but data that is not directly related to the infrastructure (personal data, travel rights, payments, contracts) need more attention to create a thriving MaaS ecosystem.*

The most important actions are (for I&W):

> *- continue in centralizing and improving data related to the infrastructural layers, starting with the network itself and relate other data to it.*
>
> *- invest in referencing and/or providing standards for:*
>
> - *areas (stations, regions of TOs, EU 2017/1926),*
> - *availability (EU 2017/1926),*
> - *personal data,*
> - *contracts & conditions (EU 2017/1926),*
> - *travel rights and*
> - *payment information (EU 2017/1926)*

There are other issues, but these are the most prominent ones.

Short note:
In this document there is often referred to 'MaaS ecosystem'. We are aware that the term 'MaaS ecosystem' is much wider than the just the data aspects we want to address in this document.

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Attachments

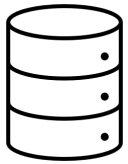
2. Roles in MaaS ecosystem

There are a lot of parties involved in a MaaS ecosystem. Each party can fill in multiple roles, as described in this chapter. ***The roles described are not the current situation***.

A. Traveller

A traveller (end user) is a person who wants to go from A to B (or just starting at A and explore in the neighbourhood of A), optionally in a group of travellers. The traveller has aspects like age, limitations, needs, subscriptions, etc. The traveller can have assets of itself.

B. Personal data store (PDS)



The end user can put his personal information in a personal vault, control the access to his own information and can share it this way with the outer world. Personal data is about a person (age, length, etc) and about his rights (license to drive a car, discount cards, travel budget).

Optionally data can also be posted back from the MaaS ecosystem to inform the end user, store history and intensions.

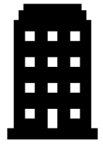
These data stores are currently limited available, nowadays not very common and not all of them are mature.

C. MaaS Service Provider (MP)

A MaaS Service Provider is an organisation that can facilitate the traveller to travel from A to B in the most optimal way for the end user. The MP contacts and uses Transport Operators (TO) to achieve its goal. It has to contact the TOs to find out what is possible to construct trips.

The MP can propose the constructed trip(s) to the traveller. The traveller can book one of the options directly using the MP. The MP also guides the traveller to his destination, takes care of the payments and support.

In short, these are the tasks the MP is responsible for:



- Registering end users (use PDSs)
- Proposing suitable trips to the end user
- Booking legs (=parts of a trip, per asset of a single TO)
- Guide the traveller during the trip
- Incident support
- Handle payments

The MP should aim for providing the best user experience to the traveller, so unique selling points could be:

- knowing traveller best (e.g. take walking/biking speeds during transferring to other assets into account, knowing preferences for modalities),
- durability
- good support during the trip (reactive),
- adjusting the trip if better options will arise (proactive),
- providing cheap trips (arrangements with specific TOs).

D. Transport Operator (TO)

The Transport Operator is an organisation that is able to physically transport travellers from A to B by providing assets (like cars, busses, trains, bikes, scooters, etc.) and they possibly already have a consumer base using these assets. The size of the organisation is very divers, from very small (single taxi) to huge (national train organisations).

E. Discovery service

A MP needs TOs to facilitate travelling the end user to its destination. In a framed environment, the MP can contract TOs in its own area, but when going outside the area, the MP needs a facility to find TOs. This facility is called the discovery service.

The discovery service must be a registration of MaaS ecosystem actors. Only registered members can use the functionality of looking up information about other actors, based on e.g. geographical information.

If possible, most of the data shouldn't be in the discovery service itself, but the discovery service should refer to where the (standardized) data can be found.

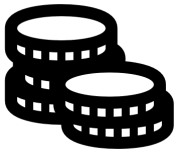
F. Authenticator

The authenticator is a function that can guarantee that, based on some credentials, an organisation is really the organisation that claims it is. In a MaaS ecosystem there should be one preferred way of authentication that can be understood, used and trusted by all parties, otherwise it will be harder to communicate with multiple parties.

The authentication can be done in several, technical ways. Like OAuth2, Open-Id Connect, certificates, etc.

G. Clearing house

A clearing house is an organisation that is responsible for getting the payments done between MaaS Service Provider and Transport Operator.



The MP should be able to registrate the willingness to pay for a certain trip, the TO should be able to check this willingness and register the actual fare (at the end of the trip).

Finally, the clearing house should handle the actual payment at a frequent base.

This role could be implemented by a MP (serving multiple TOs) or another organisation; in public transport environments this role is often already implemented by a transaction processing organisation.

H. Travel right stock

A travel right stock stores travel rights (in public transport terms: tickets, in more generic terms travel rights). The travel right stock might create the ticket, but it is also possible that TOs (or even MPs) can create tickets and store them in the stock.

The stock offers functions for validation (to open/close gates or assets) and inspection by employees of the TO (onboard control).

I. Price calculator

A price calculator has 2 functions: receiving transactions (e.g. 'start of trip', 'ticket validation', 'end of trip') and calculating the actual costs of these trips (over multiple legs of different TOs).

In the current situation this role is often combined with the clearing house function and the travel right stock. For more complex price calculation (e.g. for PTOs) this role is needed and dedicated to that specific (set of) PTO(s). For more simple calculations (like fixed price or price per km or hour), this role is often not delegated, but implemented by the TO itself.

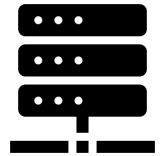
J. Government – maintaining the rules

A governmental organisation wants to manage the TOs in the ecosystem, find out if the TOs act according to their agreements. These governance organisations are mostly local authorities or regional authorities.

National authorities or branch organisations often need other data, to make policy or to proactively react on future events. For that reason, they often will need (private) data analysts. This function can be found under 'Mobility data analyst'.

Another function of the government is to facilitate in setting up an ecosystem for their inhabitants, as well in distributing ideas/guidelines (like describing concepts or APIs) as well in financing initiatives.

K. Common data provider

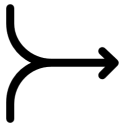


A data supplier is an organisation that is willing to provide data to this ecosystem (payed or open), that can be used in one of the 7 steps of travelling.

The most data suppliers will probably supply data for the 'plan' step, providing information about networks, background information or context information like weather data and real time traffic data.

L. Broker

A broker gets travel/traffic information from other sources, integrates it with other sources and publishes this information again.



It could also facilitate in handling all the seven steps for multiple organisations (TOs).

In the ecosystem there are 2 flavours: integrators (connecting to multiple TOs using propriety communication) and aggregators (connecting to multiple TOs using standardized communication).

M. Certifier

A certifier is an organisation that has the authority to certify a standardized connection, software, contract, etc. All technical parts can be certified whenever it adopts a standard.

N. Mobility data analyst

The data analyst requests data from the MaaS ecosystem to support e.g. governmental organisations in their decision-making process. It analyses data from the ecosystem and creates recommendations.

Often, they will need extra data, like social economic data or other context data like weather conditions, traffic disruption data or accident data.

O. Ontology guard

It is very important that all participants in the ecosystem talk the same language, using the same concepts.

It is needed to have a guard, prescribing and guarding the ontology of the ecosystem.

P. National Access Point

The NAP is requested by the EU (COMMISSION DELEGATED REGULATION (EU) 2017/1926)[4] and should provide static and dynamic travel and traffic data. But it should also provide discovery services.

Actually, a NAP is an organisation, **optionally** implementing several roles: common data provider (for a lot of data to provide a level playing field for MPs), discovery service, authenticator and ontology guard.

In the Netherlands this organisation is the NDW (National Data portal Road traffic). This organisation has nowadays (static) references to sources of mobility data, mainly infrastructure related (like network, usage etc).

Q. Identity provider

And last, but not least, an identity provider, creating a unique ID for each MaaS participant and traveller.

Recap

A lot of roles! No one ever told us it would be easy. And every role has its own place in the MaaS trip of the traveller. Let us find out the steps in the MaaS trip in the next chapter.

3. The seven steps of MaaS trips

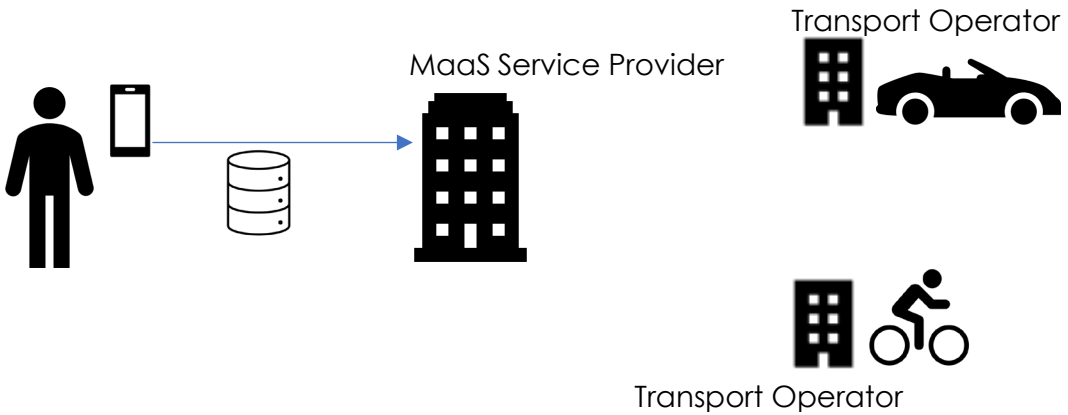
In this chapter we describe briefly the seven steps of MaaS trips. A MaaS trip is a journey of one or several people, initiated in a digital way (app), mostly provided by MaaS Service Providers and - if needed - multi modal.

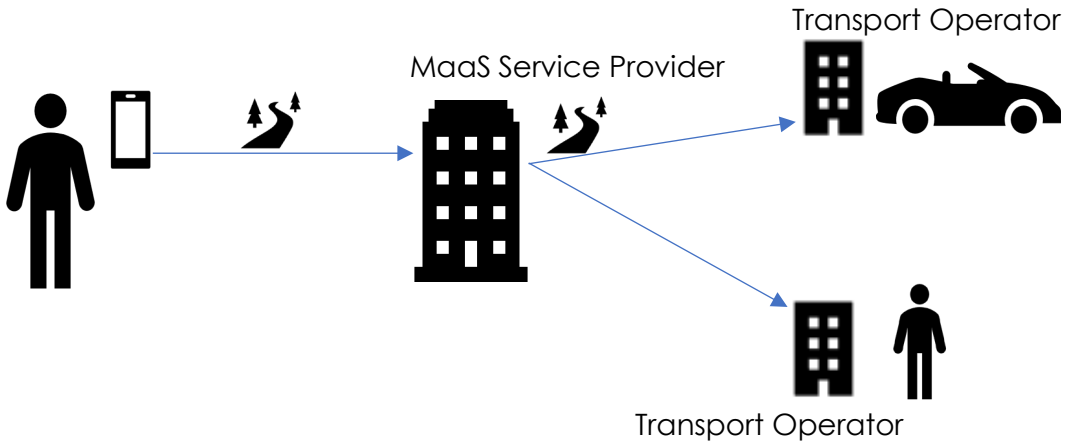
A. Supplying personal data

The end user will have to provide information about his/her (dis)likes, default locations (like home, work), abilities (cannot walk fast or far), etc. Just to make it possible for the MaaS Service Provider to know the endusers preferences and propose the best suitable trip to the end user. This personal data must be registered before any journey can be made. Objects like discount cards, existing memberships and driver licenses can be added.

Other data that can be very relevant to provide to the MaaS Service Provider are own means of transport, like a private car or bike. Historical mobility data (trips in the past) and intentions can be very interesting sources to plan trips in the future.

The ideal situation is of course that the end user has to provide this information only once and in a secure place (PDS), where the end user has full control of. This process should focus on being fully GDPR compliant.





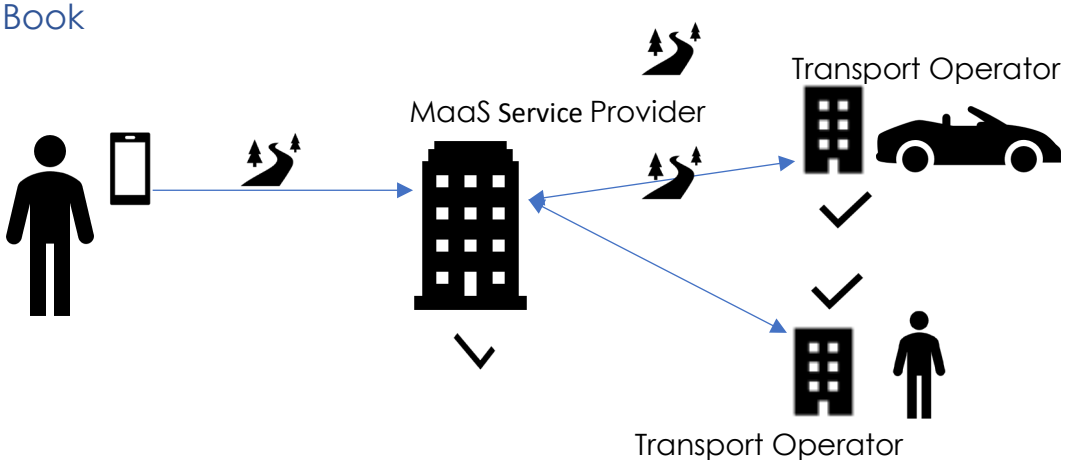
B. Plan

The end user wants to travel and specifies the origin, destination, arrival- and departure times (some might be implicit). It's now up to the MaaS Service Provider to serve the best suitable options for this trip.

Creating these options is a ridiculous complex process. Information about multimodal networks (representing roads, railways, bike paths, etc), the availability, the usage, personal preferences, etc. should be available to create the best suitable trip.

After this 'generic step', Transport Operators can be contacted to give their possibilities to fill in (parts of) the trip, but they all are having their own process (asset-oriented, short- and long term reservation, agreements, deposits, refunds, technical challenges). And we haven't named problems like lack of standardisation, non-matching networks and mapping problems.

C. Book

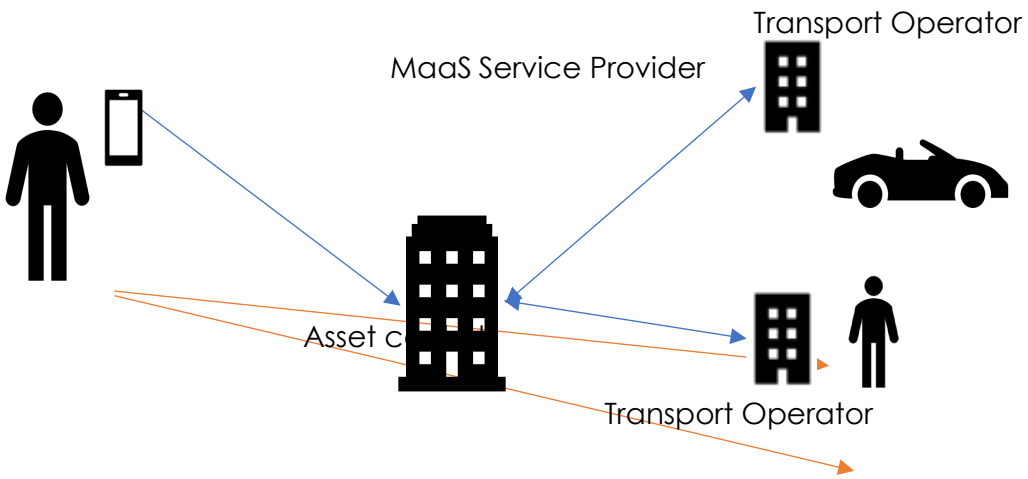


The booking part is actually no more than confirming one of the proposed trips from the planning (offers).

Functional, this looks easy, but technically this is also complex: under the hood the MaaS Service Provider will try to get commitment of all TOs, authentication has to be done, (payment) agreements should be checked, travel permits can be created and access information should be supplied. And if one of the links in the chain doesn't hold, the chain should be reviewed again, and other solutions have to be found. And, until the trip is started, the end user can adjust the trip.

D. Travel

Finally, the end user starts travelling, using the app. The MaaS Service Provider can facilitate the end user in different ways, from take-you-by-the-hand up to just-grant-me-access. The MP must know its end user to provide the best user experience, removing blockades, as much as possible.



During the trip each leg must be started (checking in/out, opening/closing locks, swipe on the app) and finished. But also, functionality as pausing assets, opening lockers or external doors and notifications to help the end user are needed in this part of the trip.

The end user will get access to different assets directly, using its app, but there are also a lot of assets that should be controlled by TOs. The app does communicate with the TOs indirectly through the MP. Nowadays the end user often has to install propriety software of the TO to communicate with the asset (or TO).

E. Support

The end user can have problems during the trip. The MaaS Service Provider has to cope with them. Most of the physical problems can only be solved by the Transport Operator (like a flat tire, lock doesn't open). This means whenever support is needed, the end user and Transport Operator should communicate (indirectly through the MP). And of course, the end user should be informed about the status of the incident.

F. Adjust

If things change during (or just before) the trip, the trip might be impacted (traffic jams, broken equipment, ..), but it is also possible that support issues lead to adjustment of the trip (assigning other assets, proposing alternatives, ..). Other adjustments can be done by the end user, like changed destinations, extend the trip or postpone the usage.

To conclude, the adjustments can be proactive (e.g. to avoid traffic jams, crowded stations) or reactive (e.g. user request another destination, a longer period to rent the bike). These adjustments will need all the functionalities of planning, booking and optionally trip execution. It will reflect in the payment as well (cancellation costs). This part of the MaaS trip is the hardest one (technically seen), but has the most added value to the end user.

G. Payment

The end user should always pay to the MaaS Service Provider. On its turn, it should be paying the Transport Operators. The MaaS Service Provider can have all kinds of contracts with the end user, but this should never impact the payment between MaaS Service Provider & Transport Operator.

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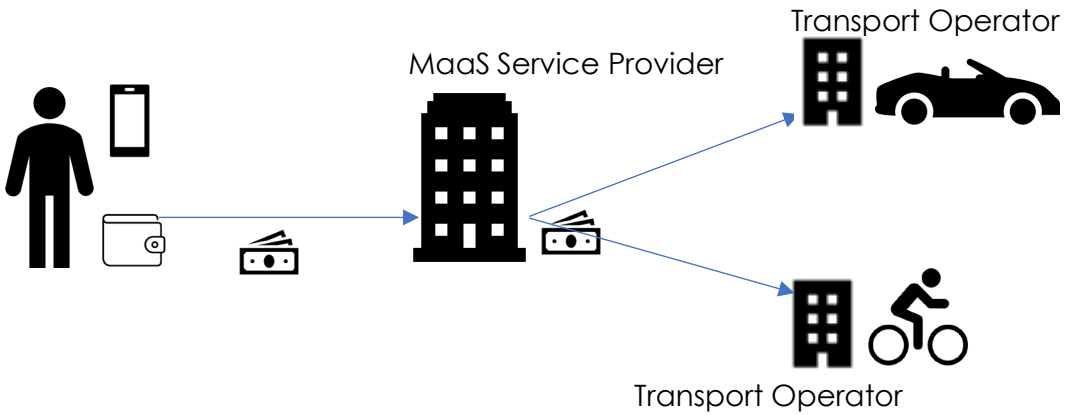
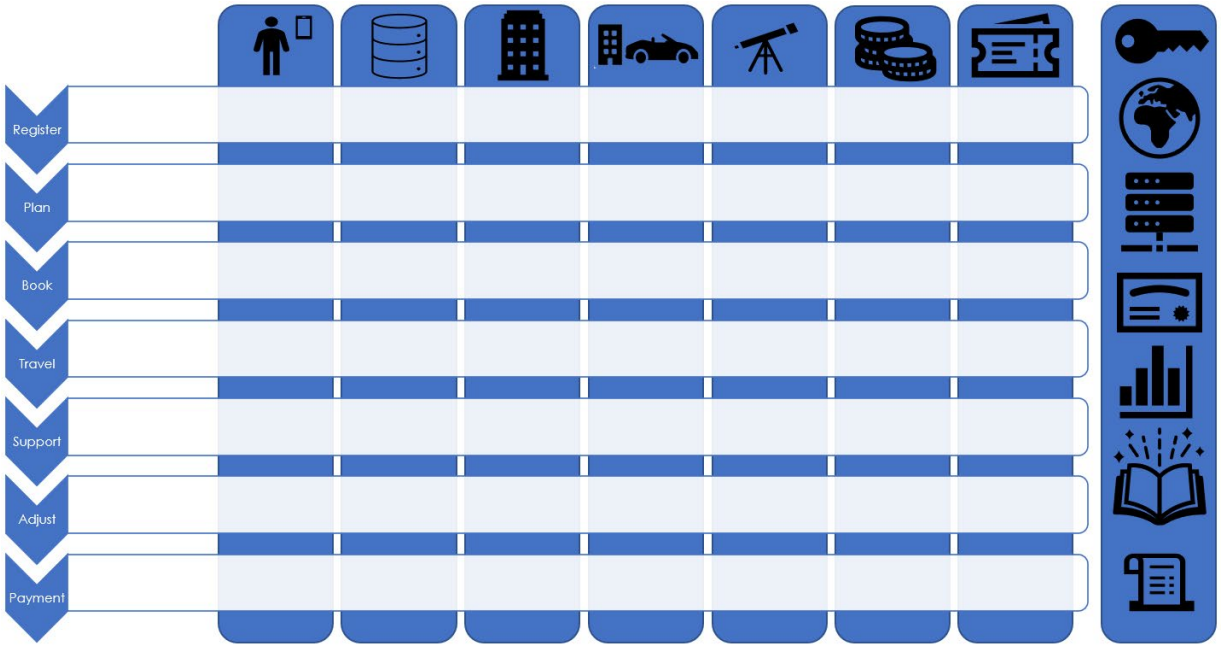


Recap

So, after describing the roles in chapter 3, we've seen now the steps in a MaaS trip. How is every role taking its place in a trip? Time to relate both, in the next chapter.

4. Roles during the 7 steps

To facilitate the end user in a trip from A (to B), most of these roles must be there in the ecosystem. Nowadays a few actors fulfil multiple roles. To facilitate placing the data types in the steps and relate them to the roles, this model is used:

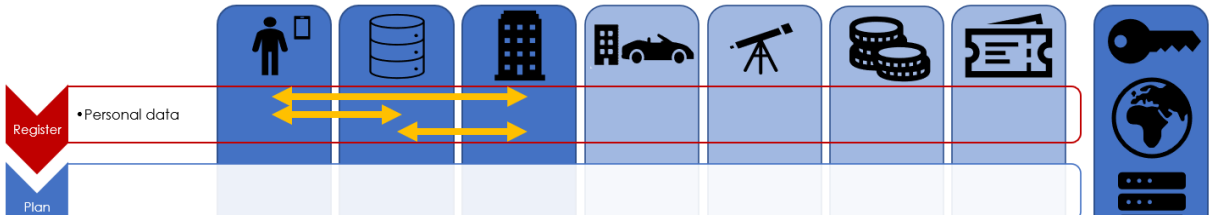


In each step (rows on the left side), some data will be enlisted, but we will explore them in detail in the chapter 'Data types'. The most used roles do have a column: the end user, personal data store (PDS), MP, TO, discovery service, clearing house and travel right stock.

There are also other roles, but these are not active in the journeys (government, certification, ontology guard), mandatory for every step (authentication provider) or less used (common data provider, data analyst, price calculator). In this document they are elaborated upon.

A. Registration

There is a prerequisite for being able to travel on a MaaS style: the end user has to register with a MP.

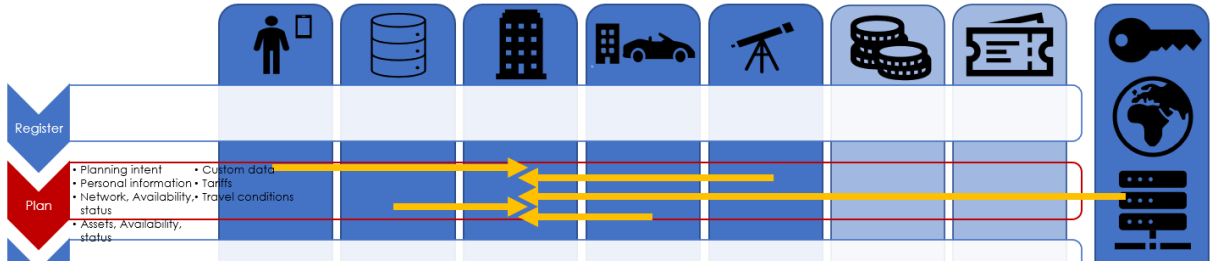


The end user downloads the MP app, fills in registrations and the MP will request to interact with personal data store to get personal information (e.g. name, birthdate, licenses, disabilities).

The personal datastore facilitates to register this information once and at one place; having full control of own information. This personal data can be requested whenever the users wants to plan a trip, so the MP always can use the most accurate personal data.

B. Planning

The MP will continuously refresh a multimodal network with accurate usage information, so route planning in its "covered area" (where most travellers will move around) can be done very quick and in a personalized way. The MP needs to gather data from all kinds of sources, like the networks itself (roads, railways, pedestrian and bike areas), the availability and status of the network(parts), common data like weather etc. Once a rough route set is created -also using personal data-, it's time to find TOs that can fulfil parts of the trip (legs).

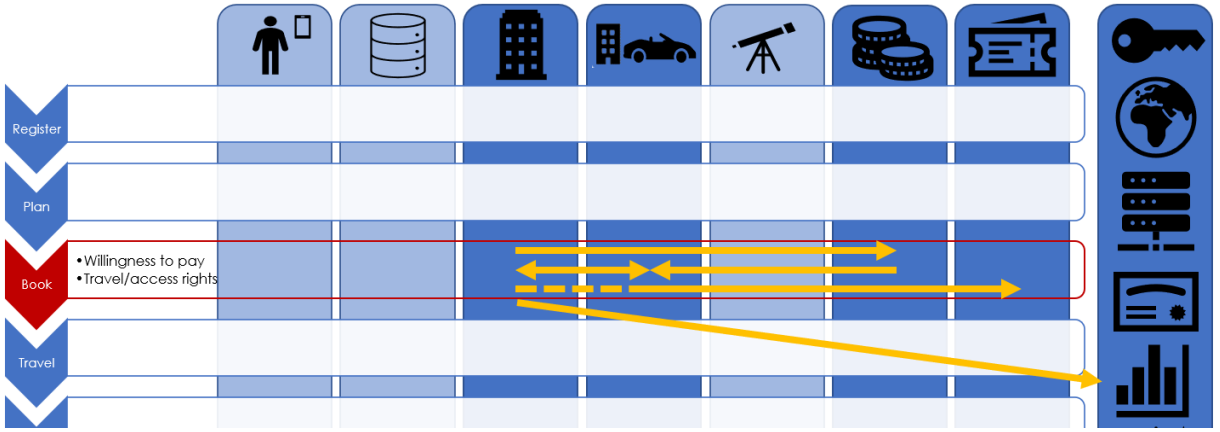


These TOs can be found using a discovery service. The MP gets a list of TOs from the discovery service, using geographical information. The MP uses this information to access the TOs directly for planning purposes, travel conditions, payment arrangements and tariffs.

After selecting the appropriate TOs, the MP can request offers from the TOs ("prebooking"). They can respond with options, the MP can construct various trips out of the returned offered legs. The MP can propose the best options ("know your end user") to the end user. The end user is now able to select one of these options.

C. Booking

The end user selects an option and books it. Now the MP should register the legs in this trip in the clearing house; they actually register willingness to pay for this leg.



All of the TOs receive a booking request. Each TO can validate the booking request against the clearing house, and after a final availability check (and an optional indication of the costs), respond positively. If all the TOs responded positive, the MP can commit the complete trip. The booking is completed.

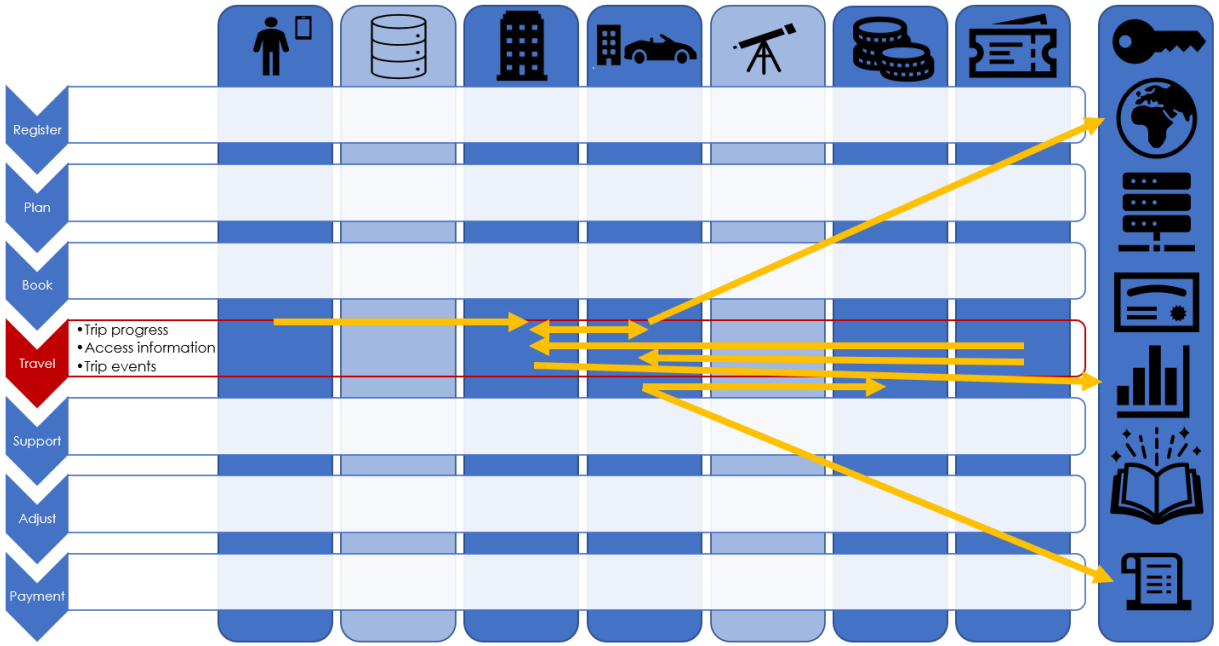
After the commit the TO can register access information in a travel right stock, where the MP can access it to use (e.g. at bus entrance or train gates) or show it during the leg.

These bookings are also valid input for data analysts. The booked trips can be supplied them on a frequent base, but only if needed by law and accepted by the end user (as in the current Learning Environment in the Dutch pilots).

D. Travel

The trip execution starts, the end user travels. Access information can be required and can be available in a travel right stock. This travel rights / access information was already supplied by the TO or can be retrieved from the TO.

During the trip the end user can be asked to show its travel right (mainly in PT). There must be a possibility for the TO to access the travel right as well.

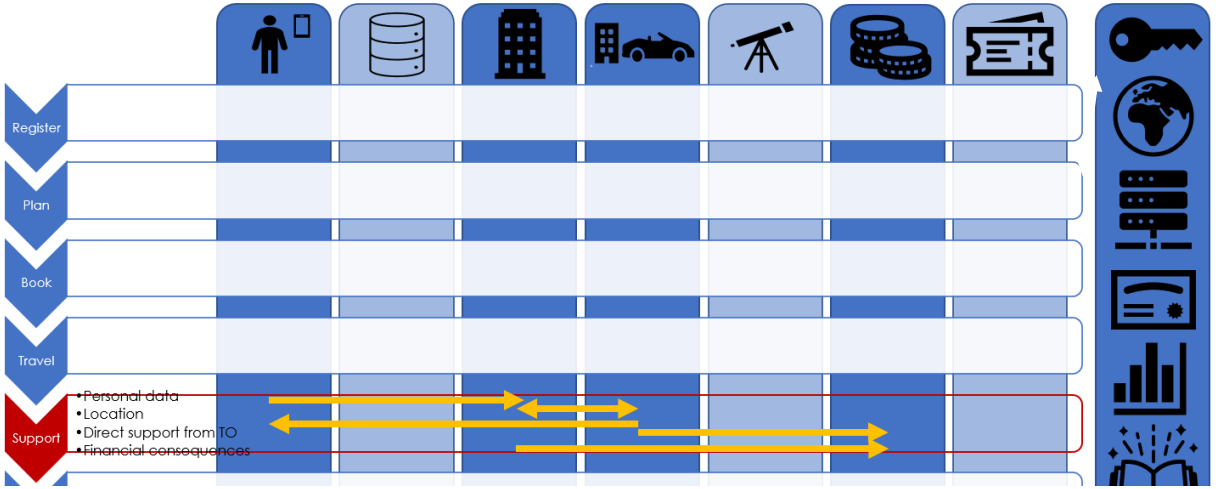


The TO is responsible for sending transactions to its prize calculator (at least applicable for PTOs). During the trip the asset can be paused and started again (in most cases it requires locking the asset).

Finally, the trips end and the prize calculator (if applicable) can calculate the prize. If there is no transaction processor, the TO itself should calculate the prize. As soon the prize is known, it should be sent (indirectly by the TO) to the clearing house. Also, extra payments (fines, refunds etc) should be informed to the MP as well to the clearing house.

E. Support

During the trip all kinds of incidents can happen. The end user must be able to (indirectly) communicate with the TO and -if possible- see the status of the incident. If incidents happen, the MP and TO should be informed / requested to help the end user. Contact information should be supplied to the TO (and vice versa).



As a result of needing support extra payment can be needed; the clearing house should be informed (MP or TO side).

F. Adjust

There are different levels of adjustment: the end user can adjust the (planned) trip or the MP can adjust the trip in case of abnormalities, like blocked railways, etc.

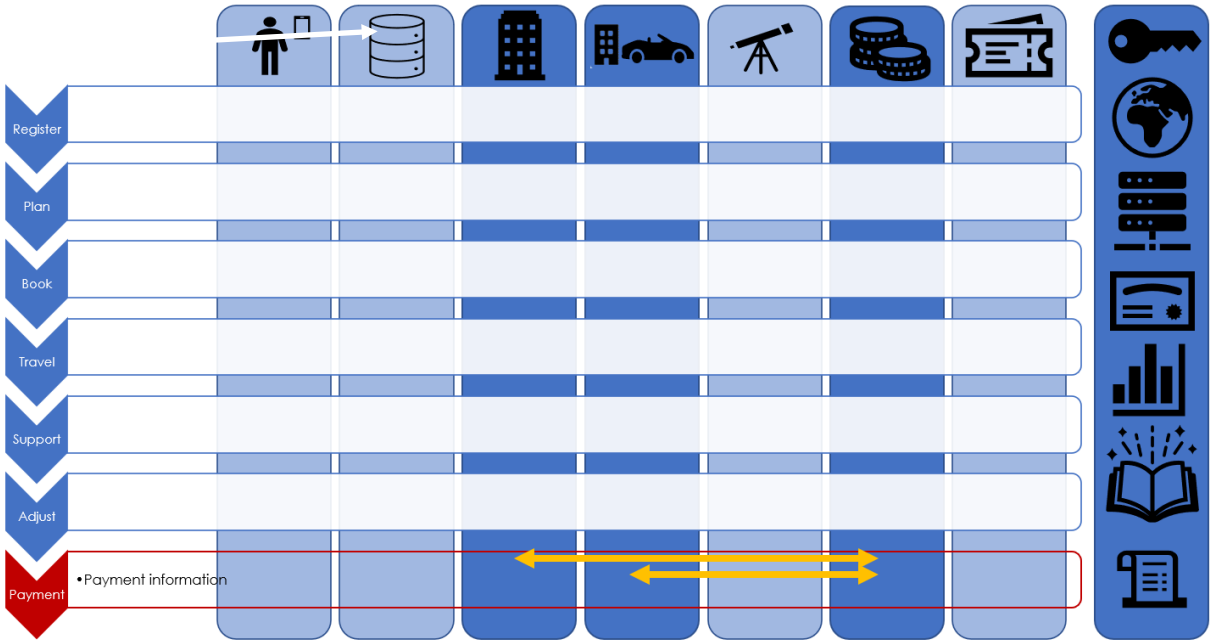
The end user can change the booked legs, e.g. until starting the leg the start location & time can change, the TO is allowed to reject this (e.g. it's outside its operating area, no assets available) and the MP has to solve this problem.

The MP can proactively look for other legs, cancel successive legs, etc. The MP will again need to communicate with the discovery service and optional other TOs. It is repeating the planning and booking process.

The financial consequences of adjustments must be arranged in contracts or standardized.

G. Payment

The end user pays to the MP, book as you go, subscriptions, prepaid or whatever the payment model of the MP is.



The clearing between the MP and TO involves of course the clearing house. This role is responsible to submit the payments from MP to TO (or vice versa). It should also have knowledge about specific arrangements between the combination. Otherwise, it should follow the created payment requests from both sides.

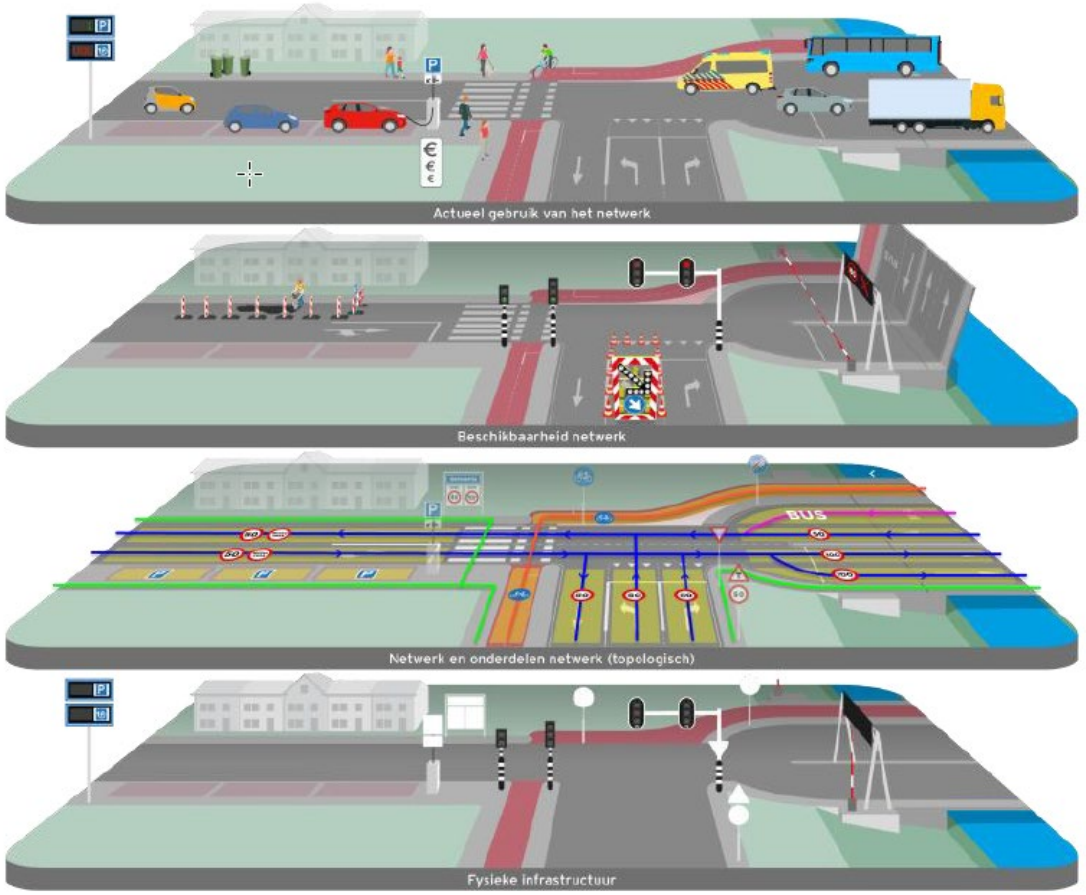
More complex clearing houses can cope with dividing payments for one trip: partial payments by an employer, city, fund or private person, instead of the MP.

Recap

After relating the roles and their place in the steps, it is time to take another point of view: the infrastructural point of view. To find out where a part of data is coming from; its origin.

5. The layer model

All the roles described above can be constructed, but they have one thing in common: they need or produce data for a certain dimension in the ecosystem. Part of the ecosystem is of course physical. There is a model for the physical layers. We describe this model in this chapter and relate data types to it.



A. Physical layer

The layer of physical infrastructure contains all physical, non-movable items, like real estate, roads, bridges, matrix signs, road signs, traffic control signs, bike paths, pedestrian paths, etc, etc. But also, stations, parking lots, bus quays, air fields, waterways, subway tunnels and rails. This layer doesn't contain data, it consists out of real physical items.

B. Network and area layer

This layer can be seen as a model (or models) of the underlying layer. Networks per modality, parking spaces, shopping areas, but also administrative areas like districts, cities, countries are contained in this layer.

For planning purposes all these items should be connected, using interaction locations like bus stops, stations, etc to get from one network to the other.

C. Availability layer

A different dimension on the physical infrastructure is the (limited) availability of the infrastructure. For instance, a bridge is open, a road has been closed due to a road work, parking lots are closed, etc. These aspects are all time related and relate directly to concepts in the first layer, thereby influencing (mostly partly blocking) the network layer.

D. Usage layer

For the best route planning the MP needs also information about the usage of the physical network. If some road segments are flooded by cars, it might be wise to reroute. Information in this layer is mostly expressed in counts, speeds, density rates or travel times.

Recap

This layer model provides a base to relate data types to. Relating data types to these different dimensions (roles, steps and layers) can clarify what data types are already covered, which ones do need attention and what data types are completely absent.

This layer model describes rather accurately the data that currently can be found in the NAP, as we will see in one of the upcoming chapters.

In the next chapter we will describe briefly the known data types.

6. Data types

In this chapter we will describe all types of data that can be found in the ecosystem. We only describe them briefly; the complete information can be found in the attachments.

A. Network

This data type can be split into multiple networks, per modality. For instance, the road network is an important network, but as we speak about multimodal travelling, it is not the only one. Rail networks, bicycle networks, pedestrian networks, water way networks, all kinds of data about networks are available, but hardly integrated.

This data type is the bearer of the network layer; describing the routing possibilities over the physical layer.

Subtypes

Road network, rail network, bicycle network, metro network, bus network, pedestrian network

Location MaaS steps: in planning step and in adjust step
Location layer model: network layer
Status: very relevant but splintered. Needs integration
Current producers: (semi)governmental organisations, market, open source
Consumer: MP
Thoughts: integrated version is very costly, provides more or less a plain level field for MPs
Private/Public: The current situation is that a lot of private organisations distribute networks, related to their own data. Providing one public, (inter)national multimodal network would facilitate a good level playing field for routing.

B. Areas

To provide extra data about areas (e.g. municipalities, parking lots, hubs, operating areas), we have to geographically locate them. Besides the network data type, this data type is the second pillar in the network layer. The network layer concepts like roads should be connected to these areas (otherwise the MP can never route to a parking facility).

Subtypes

Parking facilities, administrative boundaries, (charging) stations, operating regions

Location MaaS steps: in planning step and in adjust step
Location layer model: network layer
Status: relevant but splintered. No overview of availability

Current producers: (semi)governmental organisations, market, open source
Consumer: MP
Thoughts: A central reference place for applicable area sources should make it easier for MPs/analysts. Low costs, some advantages. Except for the operating areas; these are really needed in the discovery service. These areas are mandatory for a real (inter)national MaaS ecosystem.
Private/Public: currently is some data in here public (like PTO stations), but most of it isn't available at all (private part). It should help a MaaS ecosystem when there are references to the private areas.

C. Network/area changes

Changes to the network or area (for a period of time) can have a big impact on traffic. Take this impact into account will enhance routing, especially on longer trips. For instance, if a roadwork is being implemented, busses cannot use that specific lane anymore, or at least the capacity of that road/lane is reduced. But also the opening hours of off street parking areas do have an impact.

What it isn't? It's not 'dynamic data', telling about the status of the network or areas.

Subtypes

Road works, Bridges, Train crossing closures, parking hours, events

Location MaaS steps: in planning step and in adjust step (MP side)
Location layer model: availability layer
Status: very relevant. Most of this data is already published in the NAP (NDW).
Current producers: (semi)governmental organisations, (often based on obligations from licence/concession holders), market
Consumer: MP
Thoughts: This data (except for the train crossing closures) has a high quality in the Netherlands, providing a good base (level playing field) for the MPs.
Private/Public: This data is mainly provided by the government, since it is generated by publicly held assets (bridges, roads, loops etc).

D. Network/area status

This data type gives us information about non-static dimensions of the network. Counts, travel times and speeds are reported using this data type. But alerts are a part of this data type as well.

Subtypes

FCD (floating car data), LDD (loop detector data), travel times, parking area occupancy, departure/arrival alerts, traffic jams, accidents.

Location MaaS steps: in planning step and in adjust step (MP side)
Location layer model: availability layer
Status: relevant but splintered. No overview of availability. History is also splintered available and needed for future predictions.
Current producers: (semi)governmental organisations, (often based on obligations from licence/concession holders), market
Consumer: MP
Thoughts: This data type is necessary for the MPs. Without it, the MP can do route planning, but it is very hard to do accurate route planning, since the current state of the network(s) is not taken into account. Luckily, in most of the cases this data type is already available (although adaptability, the accessibility and accuracy might be diverse). Centralizing references to sources should help a lot to create a better level playing field.
Private/Public: To provide a level playing field, at least a public held organisation should provide references to the available (private) sources.

E. Asset Availability

The asset availability is a real hard item to get; it gives insights in the performance of asset suppliers (TO). This is not only a technical problem, but also a commercial one. Another aspect is the completeness of this data type.

Subtypes

Parking availability, charging station availability, PT schedules, bike availability, …

Location MaaS steps: in planning step and in adjust step (MP side)
Location layer model: availability layer
Status: relevant but splintered. No overview of availability.
Current producers: TOs
Consumer: MP
Thoughts: This data is needed by the MPs and must be supplied by the TOs. Enlisting the TOs (discovery service) should be enough, so

the costs are relatively low. Of course, the MP is completely dependent of the accuracy of the TO.
Private/Public: Most of this data is in (semi)public organisations. To provide a level playing field, at least a public held organisation should provide references to the available sources.

F. Personal data

Personal data is very diverse, not yet standardized and people tend to protect it. The suspicious altitude to provide information and lose control over it, is a burden we have to take away to facilitate real personalized MaaS travelling.

Subtypes

Personal data like birthdate, name(s), addresses, phone numbers, cards, user groups, but also licenses and travel budgets.

Location MaaS steps: in planning step and in adjust step (MP side)
Location layer model: n.a.
Status: No standard yet, but some organisations provide 'Personal Data Stores'. **Current producers**: end users
Consumer: End user, MP, TO (using PDS)
Thoughts: This is one of the few items that is really in favour of the End user. It might influence the embracement of MaaS. It is of course an ethical question if you want to host this as a nation ("Big brother is watching you!").
Private/Public: This data is nowadays not yet archived. Some governments (Belgium) are thinking about storing the data in public hands. The idea behind it is simple: it is sensitive information about their inhabitants.

G. Travel rights / access information

Travel rights and access information can be considered as data. It is information that is stored somewhere and can be accessed when needed (entering/exiting assets, onboard inspections).

Subtypes

Train or other PT tickets, access information for locks (e.g. Bluetooth, but also physical locations),

Location MaaS steps: in trip execution step
Location layer model: not available
Present: very relevant, nowadays often stored by TOs or "Transaction Processors".
Current producers: TOs (delegated to Transaction Processors)
Consumer: MP, TOs

Thoughts: the travel rights/access information can be stored at an independent location and it facilitates "one ticket for one trip".
Private/Public: this data is of private parties. The government doesn't need to act on this data type.

H. Payment information

This data is needed for validation and clearing purposes. MPs can request TOs to supply the details about the trips they have made for the specific MP, the clearing houses can transmit the payments from MP to TO (or sometimes vice versa).

Subtypes

Fares, fines, deposits, credits, etc

Location MaaS steps: in payment step, the clearing between MP and TO
Location layer model: n.a.
Status: only relevant for direct or irregular claims and tax purposes
Current producers: TOs (delegated to Transaction Processors)
Consumer: MP, clearing houses
Thoughts: Facilitates (inter)national scale up, but it takes time to uniformize.
Private/Public: the payment is facilitated nowadays completely by market parties (or at max semi-public organisations). There is no reason for the government to get involved here.

I. Common data

There will always be data that supports this ecosystem and seems not directly relevant, like weather data and 'meta' data like OD matrices and SEG information. But meta data about TOs (like chamber of commerce data, contact information, the cards they accept, etc) are in this data type. The only thing they have in common is that it is not related directly to the layer model.

Subtypes

Weather data, social economic geographical data, OD matrices, payment agreements, travel conditions, payment methods

Location MaaS steps: this data can be relevant in every step, but most likely in the planning step.
Location layer model: n.a.
Status: no overview at all, for all subtypes. Weather data, payment agreements, travel conditions, profiles, SEG
Current producers: market parties
Consumer: MP, TO, ?
Thoughts: some subtypes should be addressed for trust issues (payment agreements), some of them for operational issues (travel

conditions). These 2 subtypes are really needed for an operating ecosystem, other subtypes might be worth wile referencing from a central location, at low costs.
Private/Public: Since this data type is very differs and not completely described, we cannot give a clear overview of this dimension. Weather data, profiles and SEGs are nowadays organised by (semi-)public organisations. A lot of other information is and will be in the private sector.

Recap

So, all needed information about roles, layers and steps is described. It's time to find out who (role) demand these data types and where it needs it (step) and where the supply of this data type is (layer).

7. Supply and demand

The 2 main consumers of the data types in this ecosystem are the roles TO and MP. For this reason, we map the demands of these two ecosystem participants.

After this the supply is described (the current status, October 2020) and placed in an overview. The precise data sources are in the attachments. Each cell in the demand tables contains a character of MoSCoW: Must, Should, Could and Would.

A. Demand: data types in the 7 steps (MP perspective)

	Network	Areas	Network /Area Changes	Network /Area Status	Asset Availa-bility	Personal data	Travel rights/ access	Payment	Context
Supply Personal data						M			W
Plan	M	M	C	S	M	S			W
Book						C	C	S	W
Travel	S				C		M	S	W
Support						M			W
Adjust	M	C	C	S	M	S	M	C	W
Payment								M	W

Explanation:

- The MP MUST gather Personal data when registering an end user. The bank account, email and name are personal data. When it's not fetched from a PDS (situation nowadays), it should be registered by the MP itself.
- During planning, the MP needs at least networks (MUST) and operating regions of the TOs. Network or area changes COULD be used, but the current state of the network is very likely to become a SHOULD (traffic jams or delayed trains). Availability MUST be acquired; the MP cannot propose a trip without knowing it is available. Personal data SHOULD be used to create the best suitable trip.
- Booking requires a valid travel right. The MP has to guarantee to the TOs that he is willing to pay for the travel. The TO can also generate access rights in the booking phase.
  During the booking process the personal data can be supplied to the TO for validation purposes or support (like driver license, name, telephone number).

- Travelling needs probably (SHOULD) functionality to guide the end user. Sometimes the assets cannot be assigned during the planning phase; this information can be added during the travel phase (COULD). Assets must be opened/ closed, and travel information/access information MUST be supplied.
- Support does need personal information: the TO (or MP) must be able to contact the end user.
- Adjust: this complex step is a combination of planning and booking. And optionally has payment consequences.
- Payment: the clearing house can gather payment information needed for the clearing process.

B. Demand: data types in the 7 steps (TO perspective)

	Network	Areas	Network Area Changes	Network Area Status	Asset Availa-bility	Personal data	Travel rights/ access	Payment	Context
Supply Personal data									
Plan	C	M			M	C			W
Book						M	C		W
Travel					C		M	S	W
Support						M			W
Adjust									
Payment								M	W

Explanation:

- Supply Personal data is done completely by the MP (so, no demands in this row).
- During planning, the availability of assets and the operating regions MUST be supplied. Personal data (like disabilities) COULD also been considered.
- If personal data is required (e.g. for creating user accounts), it MUST be supplied during the booking process. Travel rights can be controlled at the travel right stock, access information COULD be generated
- Travelling might require assigning an available asset as first step; the availability COULD be requested. Also, the access information is needed here to open gates, open locks or for visual inspection (MUST). The events during the trip (start, pause, finish) SHOULD result in payment information.
- If incidents occur and support is needed, contact information MUST be supplied to the TO (can already be done during booking).

- Adjustment is handled by the MP.
- The TO must supply information about its trips for a specific MP to facilitate clearing. Historic overview SHOULD be there, but it's not mandatory.
-

C. Location: data types in the infrastructural layers

	Net-work	Areas	Network Area Changes	Network Area Status	Asset Availa-bility	Personal data	Travel rights/ access	Payment	Context
Physical									
Network	X	X							
Availability			X	X					
Usage				X	X				

Explanation:

There is only a small overlap between the layer model and the data types, but these data types represent the largest amount of data: personal data, travel rights, access information and payment information are -compared to the other data types- very limited in size.

We shouldn't forget that without the data types related to the layer model the possibilities to let people travel are limited. More and better data about the areas (operating regions, stations) and the availability will contribute in better, more efficient ways of travelling.

We should stress out that putting effort in the infrastructure related data is very valuable, but there are already programmes that facilitate increasing the coverage or quality of the data sources related to the infrastructural layers.

D. Supply: sub data types per modality

In the table below we try to put every data subtype in a relevant cell. The colour of the data subtype indicates the status of this data at this moment. Green means good usable (availability, coverage, quality & accessibility), dark red means complete absence/usability of this data subtype. In the attachments we will describe this matrix in more detail.

Btw: the left 4 columns are more or less in public hands (NAP), the right 5 columns mostly in private hands. The government should take supportive roles here (legal, control, facilities).

	Network	Areas	Network Area Changes	Network Area Status	Asset Availa-bility	Personal data	Travel rights/ access	Payment	Context
Car	Road networks	Parking areas	Roadworks, parking opening hours	Loop detector, FCD, VRI, travel times, charging status, parking occupancy	-	-	-	-	Weather, OD matrices, profiles
Bus	Bus networks	Bus stops	Road works, line info	Progress info	Availability / occupation	-	Access info	Clearing info	OD matrices, profiles, payment agreem
Train	rail network	Stations	Train works	Delays, occupation, congestion at stations	Availability / occupation	-	Access info	Clearing info	OD matrices, payment agreem.
Bike	Bike network	Bike parking areas	Roadworks, opening hours parking areas	Counts (VRI), parking occupancy	-	-	-	-	Weather, OD matrices, profiles
Shared bike	Bike network	Stations / hubs	Roadworks, Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Scooter	Bike network	Stations / hubs	Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.

Step 	Bike network	Stations / hubs	Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Taxi	Road networks	Taxi stands	Operating hours	Taxi stand occupancy	Availability	Name, telephone	-	Clearing info	OD matrices, profiles, payment agreem.
Shared car	Road networks	Stations / HUBS	Station opening hours	Station occupancy	Availability	Driver licenses	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Metro	Metro network	Metro stations	Station opening hours, metro works	Delays, congestion at stations	Availability / occupation	-	Access info	Clearing info	OD matrices, profiles, payment agreem.
Pede-strian	Pedestrian network	-	-	-	-	-	-	-	Weather, OD matrices, profiles

* This table presents data that is used in a MaaS ecosystem, but it is wishful thinking to believe that everything is in there.

8. Conclusions

In the previous chapter we tried to give an overview of the supply and demand. While writing, it became clear that a lot of 'MUSTs' are mostly not related to the infrastructural layers (except for stations and regions of micro mobility and taxis), but more or less in the corner of Availability, Personal data, Travel/access rights and payment information.

	Network	Areas	Network Area Changes	Network Area Status	Asset Availa-bility	Personal data	Travel rights/ access	Payment	Context
Car	Road networks	Parking areas	Roadworks, parking opening hours	Loop detector, FCD, VRI, travel times, parking occupancy	-	-	-	-	Weather, OD matrices, profiles
Bus	Bus networks	Bus stops	Road works, line info	Progress info	Availability / occupation	-	Access info	Clearing info	OD matrices, profiles, payment agreem.
Train	rail network	Stations	Train works	Delays, congestion at stations	Availability / occupation	-	Access info	Clearing info	OD matrices, payment agreem.
Bike	Bike network	Bike parking areas	Roadworks, opening hours parking areas	Counts (VRI), parking occupancy	-	-	-	-	Weather, OD matrices, profiles
Shared bike	Bike network	Stations / hubs	Roadworks, Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Scooter	Bike network	Stations / hubs	Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Step	Bike network	Stations / hubs	Station opening hours	Station occupancy	Availability	(driver license)	Access info	Clearing info	Weather, OD matrices, profiles, payment agreem.
Taxi	Road networks	Taxi stands	Operating hours	Taxi stand occupancy	Availability	Name, telephone	-	Clearing info	OD matrices, profiles, payment agreem.
Shared car	Road networks	Stations / HUBS	Station opening hours	Station occupancy	Availability	Driver licenses	Access info	Clearing info	Weather, OD matrices, profiles,

									payment agreem.
Metro	Metro network	Metro stations	Station opening hours, metro works	Delays, congestion at stations	Availability / occupation	-	Access info	Clearing info	OD matrices, profiles, payment agreem.
Pede-strian	Pedestrian network	-	-	-	-	-	-	-	Weather, OD matrices, profiles

Of course, agreements and travel conditions are also very important, but they are now more or less in the 'Context' column. We must not lose sight of these 2 categories.

Improving data availability or quality about networks, areas, changes and status will facilitate the MP to upgrade its planning, thereby creating a better level playing field. A lot of effort is needed there to centralize these sources (or refer to these sources), make them 'open' and - where possible – standardize them. But these efforts are well spent money.

On the other hand, facilitating in providing data about the 'MUSTs' will make it possible to make real steps to get an operational ecosystem. Without these, it will stay in the current status, with peer-to-peer connections between MPs and TOs. A situation that's hard to scale up.

Recap

In other words: put effort in areas (stations, regions of TOs), availability, personal data, contracts, travel rights and payment information, but continue in centralizing and improving data related to the infrastructural layers.

9. Actions

As we look at the table in the previous chapter, we see gaps in areas (stations, regions of TOs), availability, personal data, contracts, travel rights and payment information.

Each of these gaps can be filled by (some of the) roles. For instance, the location of the TOs (stations/regions) can be found using a Discovery service. The personal data can of course be found in PDSs, the generic payment must be done using clearing houses, and so on. Some roles are required to let an (inter)national MaaS ecosystem thrive, or even start up: the discovery service, the authentication and clearing houses.

The described actions, however, are not all directly related to the conclusions. Some are not related to the data, like the authentication, the certifier, the ontology guard and the TOMP workgroup. The actions for these roles will create more or less a foundation for the ecosystem. They don't have to be there in the first setup, but to facilitate in robust operations in the future ecosystem, they are necessary.

The roles of Discovery service, authentication and clearing houses should be in the first setup, providing the required data: location of Transport Operators, authentication (and authorization) of participants and payment information for clearance.

PDSs need attention and travel right stock must be standardized, but these are less urgent. To take steps, we need to focus. The advised actions are in order of importance, although the first 3 are both mandatory for (inter)national scale up.

These actions can only be taken in a joint venture with market parties and the government(s). Each of the actions need further exploration, cooperation and alignment with TOs and MPs, but also with other countries, if the international scope is maintained.

A. Discovery service

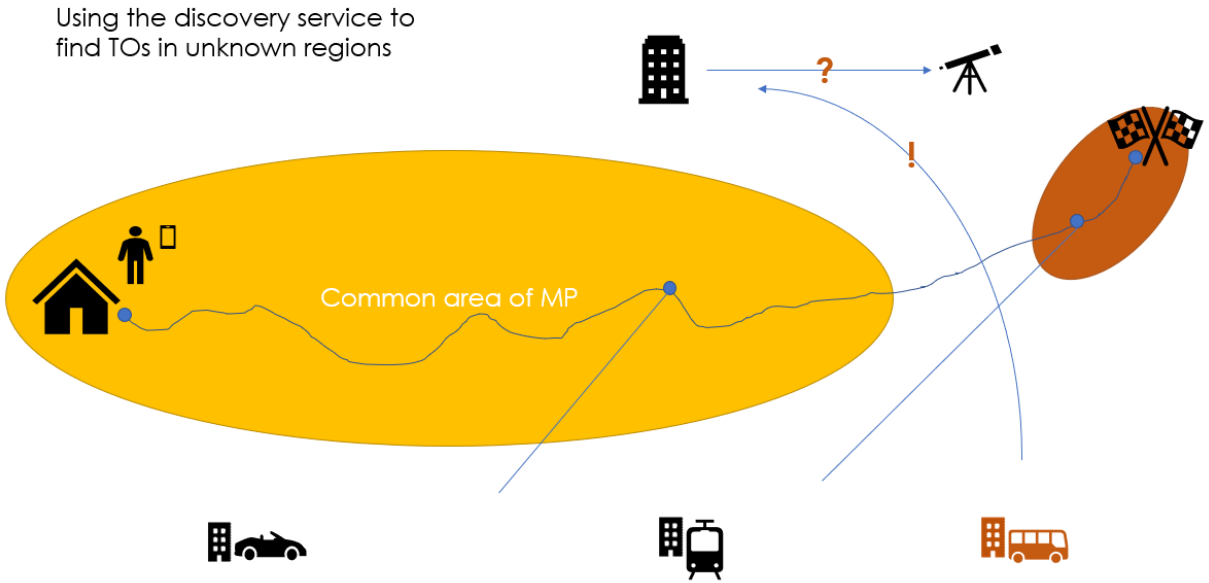
A discovery service must be implemented; TOs must be discoverable using regions and other specifications. This is an EU legislation (2017/1926).

E.g.

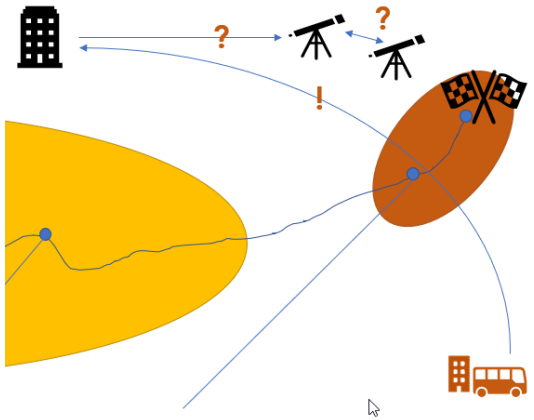
GET /to/?region=[[1,2],[2,3],[3,4],[1,2]]&assetClass=TRAIN.

The corresponding TOs should be returned. The discovery service could be a part of the NAP.

The discovery service can have a distributed nature; requesting a bike operator with the region Berlin to any discovery service should relay the query to the discovery service covering Berlin. Technical international cooperation between the NAPs is mandatory on the longer term.



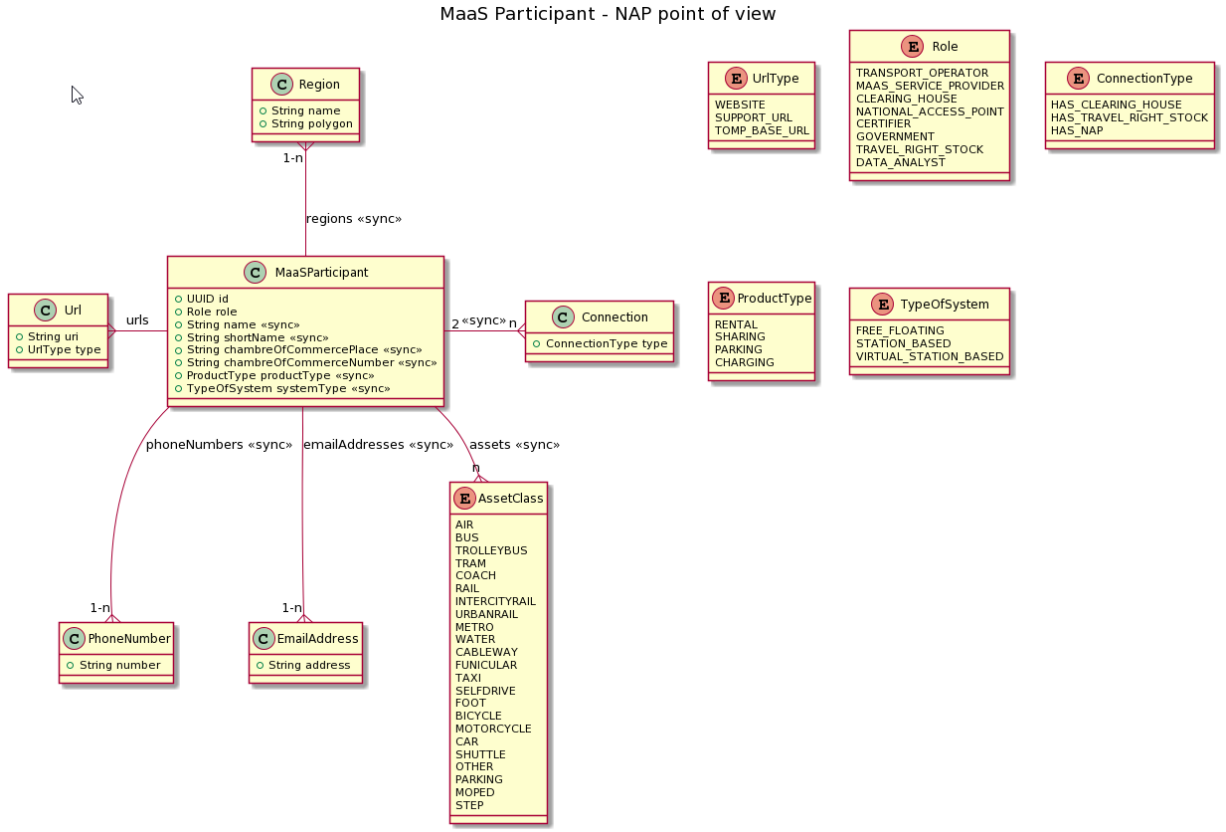
To do so, other discovery services (NAPs) must be registered as well to each other discovery service. It must of course not be possible to establish an own NAP as criminal organisation and inject TOs and MPs with evil intentions in the ecosystem.



The other alternative is of course one central discovery service. This will remove national dependencies but has other disadvantages like governance and funding.

Registering to the discovery service could also work together with the governance. Being listed in the discovery service should also guarantee trustworthiness.

A possible data model for the discovery service (<<synch>> relations or attributes can be registered but should be synchronised whenever possible in an automated way).



Beside the id, name, role and list of URLs, the region is needed for the geographical search. Whenever in the URL list a TOMP_BASE_URL is found, the other data can be refreshed on a frequent base, since the source is standardized and can be interpreted. This information should be stored. Webservices (24x7 available) should be on top of it, implementing a discovery service API.

Actions:

a) find a few NAPs (or other parties that are willing to setup the discovery service) who are willing to cooperate (I&W),
b) describe an API that will serve the MPs in finding TOs, including the connected parties like clearing houses (I&W, willing parties, TOMP WG),
c) create one functional/technical design together (I&W, willing parties, TOMP WG),
d) these discovery services should be implemented in a uniform way, operating together.

Result: the parties in the ecosystem can find each other (hopefully the most on a secure and technical way). This functionality serves finding sources that supply data about areas and availability, since this data types are covered by the TOMP-API. Maybe even later even contract data.

B. Authenticator

The authenticator must be implemented in the ecosystem to guarantee a TO, MP or any other role that -if it is called- that the caller is really the one who is telling it is.

This is not only between TO and MP, but also in the relation TO-MP-Clearing house, TO-MP-Travel right stock, and even in the relation TO-government. And to create a really open ecosystem, it must be possible to communicate between any MP and any TO (of any country). Technically a difficult thing, because it should be a) secure, b) uniform used and c) not manually pre-set.

The technical number of options is very limited to archive this, for instance using certificates issued by the authenticator. Another option is that the authenticator can be requested to find out if the caller is a valid MaaS party using OAuth2.

Actions:

a) propose OAuth2 for the near future (peer-2-peer) and one for later on (N:M), since the second one will require more effort.
b) promote this authentication type to all ecosystem participants (I&W), so authentication will become uniform.
c) Implement an OAuth2 server (at the NAP), allowing data provisioning to parties that are allowed to get this data.
d) Keep looking at IDS/Gaia-X. Don't close this path.

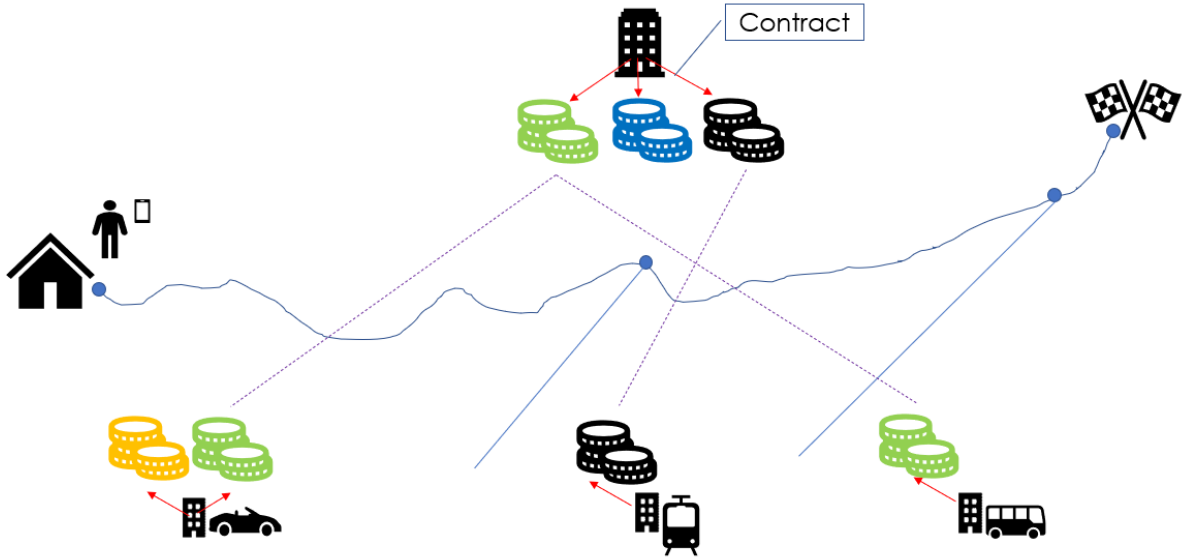
Result: less costs when connecting to other ecosystem participants. It doesn't directly serve a data type, but it is a mandatory infrastructure.

C. Clearing house

To facilitate guaranteed payments, TOs and MPs can set up contracts with Clearing Houses. In this contract the frequency of clearing can be arranged. Of course, this will rise the costs, but facilitates travelling outside the known area of the MP.

As soon a MP wants to use a TO it should be able to find out what the contracted Clearing Houses of the TO are. If there is a Clearing House they both contracted, the MP can 'show willingness' by registering the leg at the Clearing House, where the TO can validate this before committing the leg.

Booking with clearing houses



To make this setup work, the interface of the Clear House must be standardized (in other words, an API has to be constructed). E.g. for registering the willingness to pay for a specific leg:

POST /payment/{mpId}/{legId} { "TOId": "….", "price": … }

And the TO can check this willingness:

GET /payment/{MPId}/{legId}

At the end of a trip, the TO must be able to tell the exact price of the fare:

PATCH /payment/{mpId}/{legId} { "price" : …. }

And - last but not least – custom payments must be added to the payment:

POST /payment/{MPId}/{legId}/extra-costs/ { "category": "FINE", … }

An addition is to work with digital contracts. The TO has to specify the terms and conditions and the pricing conditions on a standardized way and registrate them on a central place, immutable. Technically the block chain could be such a place. The MP can have a look at this and whenever it wants to book a trip, it has to supply the contract id with the willingness, thereby telling the TO the booking can be made under these conditions.

Actions:

a) find willing clearing houses, like TLS, VDV, BMC, BillingHouse, Visa (I&W?)
b) facilitate in formalizing the digital contracts
c) construct together an API for the MaaS ecosystem (I&W, clearing houses, TOMP WG)
d) Keep looking at IDS/Gaia-X. Don't close this path.

Result: payments can be handled in a uniform way and interoperability is guaranteed since these clearing houses are a) standardized, b) published (discovery service) and c) searchable. This serves the data types in the 'Payment' column.

D. Personal Data Store

The personal data store is needed to facilitate in two things:

a) one source of truth (means ease of use for the end user) and
b) trust (the end user chooses its own PDS, still having control of his own data).

To make this a reusable concept, the ontology inside the PDS must be exactly described and the API to use from the MP perspective, should also be described. The end user can authorize the MP to get access to specific items and allow the access using secure authentication techniques, like OpenID Connect or OAuth2.

This allows also the end user to switch to another MP without the need to registrate all the personal data again. Just allowing access to the PDS – with the right restrictions – should be sufficient.

E.g.

GET /pds/{travellerId}

could return { "travellerId": "…", "birthdate": "…", "licenses": […] }.

Actions:

a) find wiling parties to implement & support (MyData, iShare, IRMA) (I&W)
b) create a uniform API for getting this data (I&W, willing parties & TOMP WG)
c) setup an ontology, prescribing exactly the content of the Stores (OSLO?)

Result: This serves the data types in the 'Personal data' column.

E. Certifier

The certifier role needs to be implemented to guarantee a high level of interoperability. Once a TO is certified, MPs must be able to connect easily to them on a technical level (regarding TOMP-API). Other API's should as well be certifiable.

Actions:

a) find a party willing to implement the certifying process (?)
b) create certification requirements (TOMP WG or other API institutes)
c) certify manually OR
d) automate certification.

Result: high level of interoperability.

F. Travel right stock

As soon the TO commits a leg, the access information or travel rights can be distributed from a trusted, central place. Here this information can be fetched by the MP to show it in their app or inspectors on board of trains, busses or trams can inspect and validate them.

E.g.

POST /travel-right/{TOId}/{legId}/ results in { "QR": "…." }

Actions:

a) find appropriate parties that will implement this functionality like TLS, VDV, BMC, Ximedes (I&W)
b) create together one API for the MaaS ecosystem as described (willing parties, TOMP WG, I&W)
c) implement the API.

Result: This serves the data types in the 'Travel right' column.

G. Government

The governments need relevant data in order to make policy choices. This data can be collected (indirectly) from TOs (local) and MPs (regional/national). The governmental entities can be directly connected to the TOs, but they can also use the data analysts as a façade.

The maintenance departments need insights in the real operations (e.g. are they confirming the made agreements about emission, operating areas, operating hours, usage numbers etc), the planning departments are interested in (future) developments and trends (e.g. OD matrices, usage profiles). This means that data has to be delivered from TO to the government, mostly directly related to geographical concepts, like areas, roads etc. The data can be aggregated to prevent GDPR problems, but these can also be covered by contracts ('verwerkers-overeenkomsten').

Data of this type is highly GDPR sensitive, because the travelling number of assets per hour can be very low. The data should be anonymized as much as possible and reported on a high aggregation level (e.g. profiles over at least a month, per asset type).

Actions:

a) continue with the CDS-M initiative (City Data Standard for Mobility, by the G5 in the Netherlands)
b) continue with the investing in the NAP / "krachtenbundeling" programme
c) cooperate with "neighbouring" programmes, like logistics

d) support (and invest) in initiatives setting up role(s) in the ecosystem

Result: serve the analyst and government roles by supplying items like OD matrices and ways to maintain order in the cities.

H. Ontology guard

The ontology guard should be an (open source) organisation, preferably not paid by any of the ecosystem roles (except for the government). The ontology guard should maintain the list of used concepts and see to it that used standards are applied correctly, validating them against the registered concepts.

Actions:

a) support the OSLO initiative in Belgium
b) make the ontology an international one

Result: make the ecosystem data also exposable to other domains.

I. National Access Point

The NAP isn't a role, but an organisation that can fulfil quite a few roles in the ecosystem.

They should (regarding the EU legislation) implement at least the discovery service, but this service overlaps possibly the authenticator.

There are a lot of data types that can be facilitated by the NAP, but these are mostly used by the MPs only. Improving the quality or facilitating (monitored) access to these data types will of course make the operations of the ecosystem better, but to get a real interoperable ecosystem, the discovery service and the authenticator are more important.

Actions:

a) implement the discovery service,
b) implement an OAuth2 server, using the discovery service as source
c) continue centralizing references to other data (related to the infrastructural layers),
d) stay creating a level playing field for MPs, gathering (of referring) to datatypes like networks, areas, their status or changes and asset availabilities. The latter one can be done using the discovery service (2 birds with one blow); using the discovery service, referring to the standardized endpoints, containing assets, but also the areas and alerts.

J. TOMP Workgroup

This workgroup (http://tomp-wg.org/) should take into account that the TOMP-API is operating in an ecosystem. Not only TOs and MPs are involved, but the concepts of discovery service, clearing houses and travel right stocks should be taken into account. And these other participants should also be incorporated in the ecosystem in an interoperable way.

Actions:

a) inform the TOMP WG members about these concepts and let them embrace the concepts and initiatives
b) extend the working group to facilitate the other APIs in this document as well (the clearing house API, the PDS API, the travel right stock API, ..), orchestrating the API versions and their compatibility.
c) Formalize 'digital contracts', in which all aspects are covered. These contracts can be signed from both sides to create a by contracts covered, interoperable way of communicating between TOs and MPs.

Result: support for the ecosystem in the long term and making it possible to give a complete solution for MaaS ecosystems, instead of (non-matching) small pieces that can be found nowadays.

Attachments

1. Status

A. Current situation

In the current situation (pilot phases), the TOs and MPs have bilateral agreements. Every minimal required role is assigned to one of the partners. Most roles land at the MP side, for instance the discovery service. It is obvious that the MP will take this role, it is the only one who has to find his partner TOs.

Traveller: present
MaaS Service Provider: present
Transport Operator: present
Discovery service: if not "hard coded" (peer-2-peer), implemented by MP
Authenticator: absent, bilateral agreements (OAuth, tokens, …)
Clearing house: non-PTO: mostly implemented by MP, pragmatic approach
PTO: centralized at Translink, not open.
Travel right stock: non-PTO: absent, TO supplies travel rights directly to MP
PTO: centralized at Translink, not open.
Price calculator: non-PTO: TO implements the final price
PTO: centralized at Translink, not open.
Government – maintaining the rules: not applicable
Common data provider: diverse, not standardized
Broker: concept op creating TO on top of multiple propriety connections is often seen
Certifier: absent
Analyst: Learning environment
Ontology guard: absent

B. Future situation

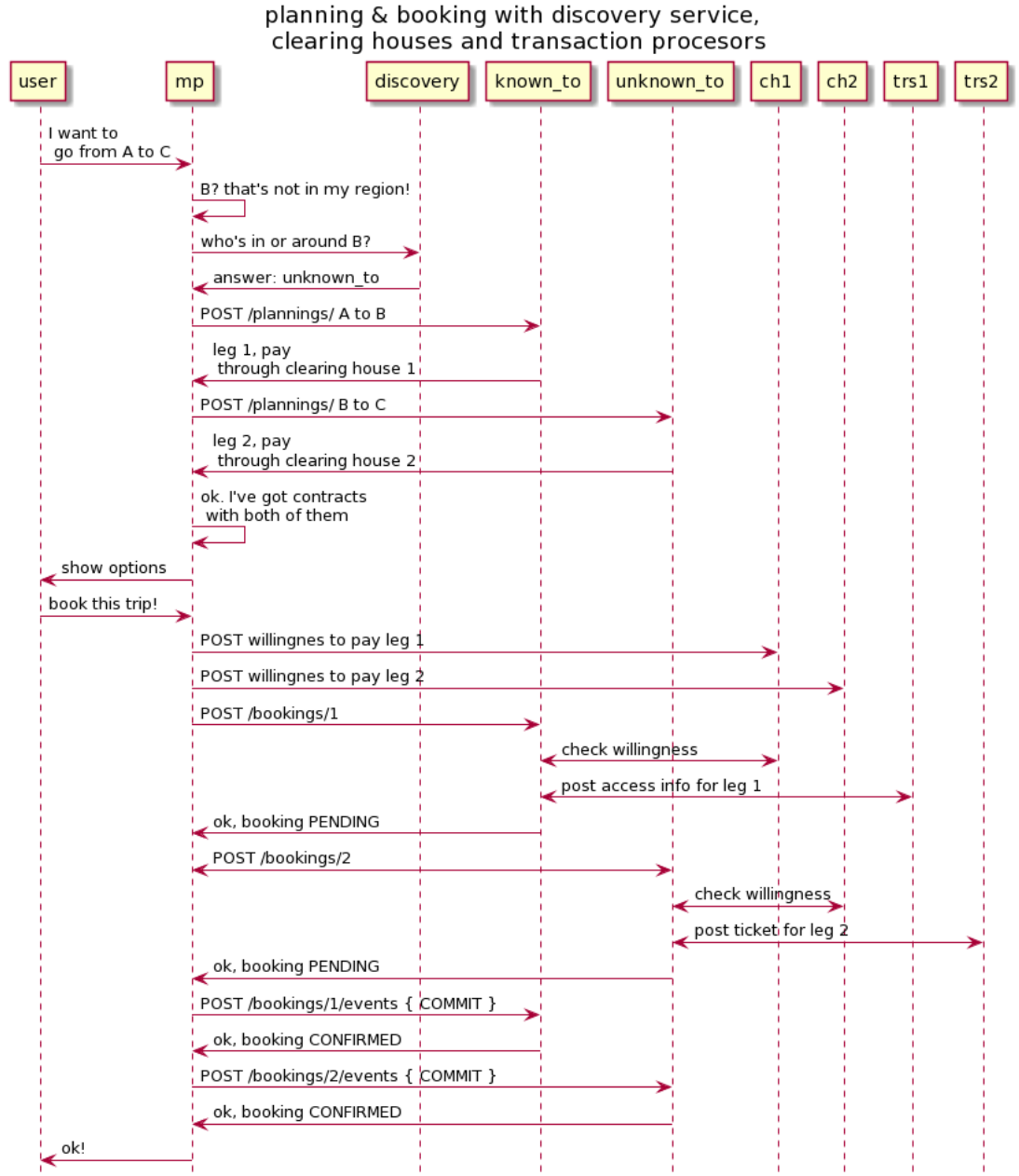
In the future situation roles should be standardized and separated from these MPs. To create a real interoperable ecosystem, the lookup service should be standardized and privatized, the clearing houses should provide clearing between more or less independent organisations, authentication must be set up. All the interactions as described above, should be in place and implemented correctly, on a standardized way.

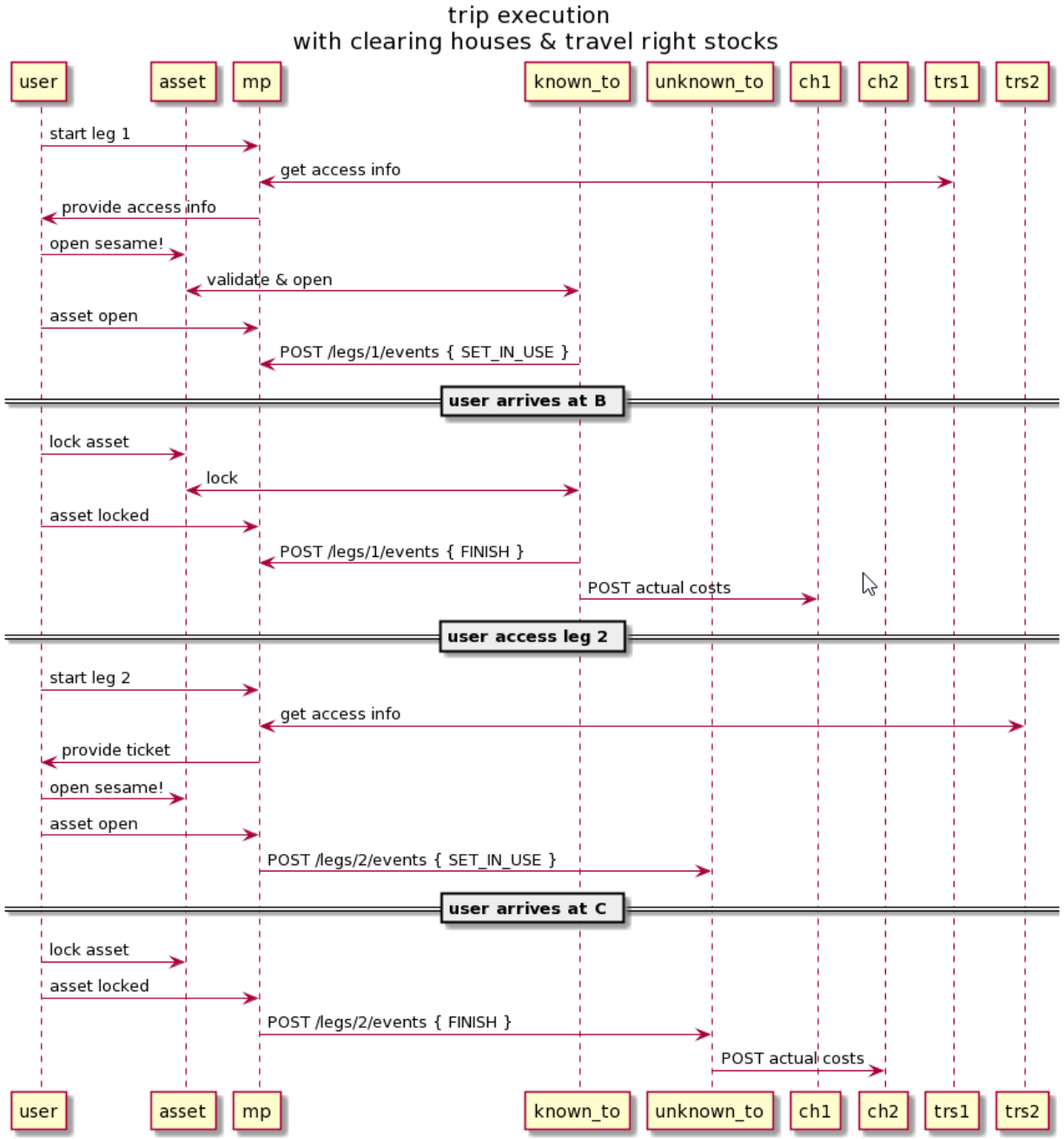
2. Process description

In the sequence diagrams below the process of planning & booking is described, with discovery service ('discovery'), clearing houses ('ch1' and 'ch2') and travel right stocks ('trs1' and 'trs2').

In general, the discovery service returns registered TOs, including their contracted clearing houses and optional travel right stocks (the TO might have implemented this feature themselves as well).

After the booking is completed, the trip can be made. The travel right stocks contains the access information or tickets already; the MP can get the travel rights from there.


planning & booking with discovery service,
clearing houses and transaction procesors
user
mp
discovery
known_to
unknown_to
ch1
ch2
trs1
trs2
I want to
go from A to C
B? that's not in my region!
who's in or around B?
answer: unknown_to
POST /plannings/ A to B
leg 1, pay
through clearing house 1
POST /plannings/ B to C
leg 2, pay
through clearing house 2
ok. I've got contracts
with both of them
show options
book this trip!
POST willingnes to pay leg 1
POST willingnes to pay leg 2
POST /bookings/1
check willingness
post access info for leg 1
ok, booking PENDING
POST /bookings/2
check willingness
post ticket for leg 2
ok, booking PENDING
POST /bookings/1/events { COMMIT }
ok, booking CONFIRMED
POST /bookings/2/events { COMMIT }
ok, booking CONFIRMED
ok!



3. Data sources

A. Networks and areas

Every movement made by travellers needs infrastructure. A road, a path, a railway, a waterway, airports etc. These physical infrastructure can be modelled as digital networks, with a lot of aspects attached to it (e.g. the surface of the road, the capacity of a highway). These networks are needed for creating (multimodal) routes. Nowadays it's very common that networks are covering only parts of our planet and most of the time they cope with one or a few modalities. For real multimodal planning multimodal networks are needed.

Subtypes

Road networks

NWB – Dutch road networks, maintained by the government. To get from the NAP (NDW) or PDOK. Usable for routing, having a lot of details about every road segment.

> https://ndw.nu
> https://www.pdok.nl/introductie/-/article/nationaal-wegen-bestand-nwb-

OSM – Open Street Map, maintained by open source community. To get from www.geofabrik.de, complete, good routable, although there are gaps in the network. It has license consequences: whenever someone adds extra information to this source, he has to publish the enhanced network under the same conditions as the original one. And since it's maintained by the public, there is no guarantee that it is correct and stable.

HERE, INRIX, BeMobile – Paid versions, maintained by market parties. They use their own propriety networks to communicate f.i. FCD or travel times. BeMobile delivers also data through the NAP (NDW).

> https://geofabrik.de
> https://here.com
> https://inrix.com
> https://ndw.nu

Rail networks

ProRail – Dutch maintainer of the railways. No public download.

OSM – Open Street Map, maintained by open source community. ProRail also publishes also their network in OSM. It has license consequences: whenever someone adds extra information to this source, he has to publish the enhanced network under the same conditions as the original one.

https://geofabrik.de

Bicycle networks

Fietsersbond – good routable network for bicycles, not open. Maintained by members of the fietsersbond. No public download.

Routedatabank.nl – maintained by Fietsplatform, WMS/WFS service, no network download.

Fietsknooppunten (regional bicyclenetworks) – WMS service.

OSM – Open Street Map, maintained by open source community. Rather good (quality/coverage), but has license consequences and is maintained by the public: no guarantees on quality and it can change every minute.

https://geofabrik.de
https://routedatabank.nl
https://geodata.nationaalgeoregister.nl/regionale-fietsnetwerken/wms?request=getcapabilities&service=wms

Pedestrian networks

Routedatabank.nl – maintained by Fietsplatform, only contains routes.

OSM – Open Street Map, maintained by open source community. Quality and coverage not complete. Has license consequences and is maintained by the public: no guarantees on quality and it can change every minute.

Regionale wandelnetwerken – WFS service containing regional hiking routes

https://geofabrik.de
https://routedatabank.nl
https://geodata.nationaalgeoregister.nl/regionale-wandelnetwerken/wms?request=getcapabilities&service=wms

Parking areas

NPR – Nationaalparkeerregister.nl provides information about the location and – if available – the availability of parking lots.

OSM – Open Street Map, maintained by open source community. Higher coverage than NPR, no availability. Has license consequences and is maintained by the public: no guarantees on quality and it can change every minute.

https://geofabrik.de
https://nationaalparkeerregister.nl

Charging stations/areas

Eco-movement: an European project, where all charging stations should be available.

Oplaadpalen.nl. A non-open data source with a growing number of charging locations in the Netherlands.

Oplaadpunten.nl – Also a non-open data source (from chargepoints.com). Covering also other countries.

Dataset laadpalen - Overheid.nl. Some static datasets, not maintained, very low coverage.

OSM – Open Street Map, maintained by open source community. Good coverage, but no availability. Has license consequences and is maintained by the public: no guarantees on quality and it can change every minute.

https://eco-movement.com/
https://geofabrik.de
https://oplaadpalen.nl
https://oplaadpunten.nl

Bike stations, scooter stations

These stations can be found using the GBFS implementations (public), but there are quite a lot not enlisted in the GBFS systems.csv. Another source is again the OSM.

https://github.com/NABSA/gbfs/blob/master/systems.csv
https://geofabrik.de

Train stations, bus stops

The 'Centraal Halte Bestand' is a central file, containing all train stations and bus stops in the Netherlands, inclusive a lot of details. It is open data; the coverage is high and the quality is also trustable.

http://data.ndovloket.nl/haltes.

Administrative boundaries

Data.overheid.nl – Maintained by the government, published in PDOK.

OSM – Open Street Map, maintained by open source community. Good coverage, sometimes lacks uniformity. Has license consequences and is maintained by the public: no guarantees on quality and it can change every minute.

https://data.overheid.nl
https://geodata.nationaalgeoregister.nl/spoorwegen/wms?request=getcapabilities&service=wms

Time dimensions

For the MaaS ecosystem the history of networks is not really interesting since it doesn't say anything about the current state and the future state.

Future predictions about how the network will be, neither. Planned changes in the near future will. The only thing that is necessary is an integrated set of data about networks for all modalities for the present.

Supply/demand of TOMP

Networks are essential for routing and should be mandatory for MPs. Networks for most modalities are available (road networks, busses, railways, etc), but these are not complete. Other networks like bike networks or pedestrian networks are harder to get and they are hardly integrated.

These networks are created by governments, by open source communities or market parties, who need networks to deliver their data (mainly floating car data (FCD)).

The networks are only limited requested by the other TOMP parties. In case of governmental and market parties, the ownership and quality assurance are of course at the delivering party. In case of the open source community (Open Street Map), there is no real "owner" and the quality is not stable [1,2,3].

Challenges

Integration: to facilitate routing (in the planning step), the planner needs to 'hop' from one network to the other (e.g. walk to a bus station, hop on the bus). It is needed to merge these networks and add intersections where the routing algorithms can 'hop' from one network to another.

Limitations: Some modalities share the majority of a network, although not completely (like bus and car, or bike and moped). And each network has his own implementation and map projection; how should the different segments from one network 'map' to another?

Discrepancies: while merging networks, one will always find discrepancies: widths, maximum speeds, etc. What network source is trustworthy? How to determine what's the best?

Availability: not every source is centralized available or not covering the whole of the Netherlands.

Added value

Facilitating a real, routable multimodal network and publish it centrally (as open data), provides a level playing field for all MPs. I note that real customer aware routing still needs customizing the network (or at least the routing algorithms).

Costs

The exercise of gathering the information about all network segments and connecting them is a big challenge. Integrating/connecting them is a huge effort and it is very hard to automate this process; a lot of decisions are hard to make in a general way, to solidify these decisions in rules. Modalities behave differently but cross each other (like pedestrians crossing streets). To make a real usable, routable multimodal network is very costly. On the other hand, it would be a major asset to provide to all the MPs (and TOs).

B. Changes in networks and areas

Changes to the network or area (for a period of time) can have a big impact on the traffic. Taking this into account will enhance routing. For instance, if a roadwork is being implemented, busses cannot use that specific lane anymore, or at least the capacity of that road/lane is reduced. But also, the opening hours of off street parking areas do have an impact.

Subtypes

Road works

The road works in the Netherlands can be obtained from the NDW. The data is open and communicated in Datex-II. It is not public downloadable, please contact NDW.

> https://ndw.nu

Bridges

Bridge openings are available at the NDW, http://opendata.ndw.nu/. The coverage is good, but openings are only reported during the opening itself, not in advance. Officially there should be a report of opening and closing, but these lack often.

> http://opendata.ndw.nu/

Train crossings

The train crossing closures are not available.

Opening hours of parking lots

In the 'nationaal parkeer register' there are a lot of parking facilities that report their opening hours. This data is not available for a lot of bike/shared car stations/facilities.

> https://npropendata.rdw.nl/parkingdata/v2/

Events

The events that are administered by most cities in the Netherlands are also available at the NAP, in the same feed as the road works.

> https://ndw.nu

Time dimensions

These changes are in the future or sometimes in the present. Like road works are often planned, bridge openings are sometimes planned and sometimes just reported.

Historical data of these types are required to facilitate predictions: how long the bridge is open, how long it will take until the railroad crossing will be closed, etc. This information is a "could have": it will make routing more accurate, especially when routing for short distances (bike/pedestrian). Actually, the historical data is needed to predict the future data. Providing predictions for the nearby future could be a good extension on the playing field, making historical data obsolete for the purpose of constructing predictions.

Supply/demand of TOMP

The network or area changes are currently merely used by the TOMP parties. It is likely that MPs will incorporate this data to provide better routing.

The roadwork authorities are the main producers of this data, thereby also accountable for the quality. For a MaaS ecosystem this data isn't needed, but 'low hanging fruit', since it is already partly available data.

Challenges

Impact determination: This data type is very diverse, and every data subtype should be treated differently. It is also sometimes hard to decide what the impact will be of changes.

Availability: there are quite a few different subtypes, diverse in source, but also in format and technique.

Added value

Some data sub types are already available in the current NAP, creating some kind of level playing field. MPs (and data analysts) can obtain this data and use it. It enhances routing.

Costs

Most data sub types (roadworks, bridge openings, events) are already available in the NAP. The ownership and quality is from the origins where the NAP obtains it from (road authorities, water authorities). The current costs are already covered, but the quality should be monitored and if possible improved. In the Netherlands this is done in the 'Krachtenbundeling' programme.

Closing times of railway crossings are not (yet) available.

Other changes, like opening times of e.g. bike parkings should be accessible using the discovery service. The costs and ownership are in this case in the hands of the TOs.

C. Network and area usage

This data type gives us information about non-static dimensions of the network. Counts, travel times and speeds are reported using this data type. But also, alerts are a part of this data type.

Subtypes

Floating car data

Realtime floating car data can be acquired from a lot of sources (even resellers or the NAP), but none of them is free of charge. BeMobile, HERE, Inrix, TomTom and Google all deliver the average speed at segments in the Netherlands, but the quality can be argued about. If sample vehicles lack, most of the sources fall back to profiles or older data is used (unclear latency). This makes it sometimes untrustworthy and unusable to create accurate predictions.

This data is for good route planning, since it is one of the few sources you can rely on for regional and urban roads.

https://here.com
https://be-mobile.com
https://tomtom.com
https://ndw.nu (be-mobile)

Loop detector data

The NDW is the portal for LDD in the Netherlands, giving a very good coverage of the whole country. The quality is good, not many detectors are failing (in other countries we see completely different situations). The only disadvantage is that the data is hard to process. In general, this data is a very good source to get indications about the traffic state on the highways. Regional and city roads are hardly covered.

http://opendata.ndw.nu/

Travel times

The NDW also provides travel times on trajectories. It is dependent on how local municipalities configure the trajectories (so coverage is low and constantly changing). For case studies this is of course an optimal instrument, but it is less usable for generic usage.

http://opendata.ndw.nu/

(i)VRI data

Traffic lights are often provided with detectors, mostly even on different distances from the crossing itself. This data can be obtained directly from the hardware maintaining organisations and provide of course only information about a specific crossing/arm/lane. It is very expensive to use this information (direct connections, very local information) for route planning or creating predictions.

Traffic jams

Traffic jams are reported by several market sources, like TomTom, ANWB/NDW and Google. The latency is larger than using e.g. LDD data (where obstructions often can be derived from). For simple route planners, this data will be sufficient, but it tells only about traffic jam locations, not where it's crowded.

http://opendata.ndw.nu/
https://googleapis.com/

Parking area occupancy

This data source is not yet available in the Netherlands, but can be derived. In the data source NPR the amount of parking spaces is most of the times specified. And if the parking lot also provides the dynamic part, the occupancy can be derived.

https://nationaalparkeerregister.nl/home.html

Alerts

Alerts are partly available for the traffic on the roads (traffic jams) and about delays in trains and busses (Bison, DOVA). Alerts from other modalities are hard to get (from a central place). Facilitating in a central place where alerts are gathered (and broadcasted on a uniform way) could help the end user in travelling untroubled.

https://bison.dova.nu/
https://ndw.nu/

Accidents

Accidents are real time available in the Netherlands, using sources like Waze (Google). But it's also possible to derive them from the loop detector data and floating car data.

https://developers.google.com/waze/data-feed/feed-setup
http://opendata.ndw.nu/

Time dimensions

This data is needed in the past, the present and the future. The past is needed to create predictions for the future. And – of course – the predictions are needed for routing, since the planned trip will be in the future, not in the present. On short trips the present will be sufficient, but for longer trips predictions will probably be needed.

Supply/demand of TOMP

Again, the MP is the main consumer of this data type. Using the data from the past to predict data in the future, that can be used in the routing process (since booked trips are normally happening in the future).

The MP is also keen on getting alerts, just to validate the current journeys and advice adjustment of these trips.

The TO is a possible source of alerts; problems with their operations should be reported to cooperating MPs.

Challenges

Availability: diverse, open and paid, a lot of formats, a lot of techniques

Network matching: these data types are directly related to one network and must be projected on the network to use.

Latency: all sources have different latency, so it actually reports the status of a short while ago. These sources cannot be combined easily.

Added value

Enhancing this data type will benefit again the MP: routing and adjusting are mainly benefited. Actually, adjusting current running journeys is part of one of the steps that hasn't evolved much, this could be an opportunity to stimulate the development of this functionality.

Costs

Alerts that should impact journeys, are not available or at least at very different locations and formats.

The TOs are the only ones who can give the alerts. General alerts, but also specific alerts for booked assets (e.g. train x doesn't ride due to blocked railway tracks). The costs to make this data more accessible, exists of setting up a central location referring to the locations where someone can find the alerts and maintaining the reference list (discovery service).

Other subtypes, like FCD, LDD, travel times can also be accessed by referring from a central place (or continue the current situation).

D. Asset availability

Subtypes

Parking areas

The nationaalparkeerregister.nl provides for a lot of parking areas dynamic data (available parking lots). This is not covering the complete country (not every parking lot is automated to this level), but the larger cities and companies provide a good coverage. The latency of this data is also not high; most sources report every minute.

https://nationaalparkeerregister.nl

Charging stations

The availability of charging stations is not open source; data can probably be acquired from oplaadpunten.nl or oplaadpalen.nl.

https://oplaadpunten.nl
https://oplaadpalen.nl

Bikes

Bike availability data is sparse in the Netherlands. There are a few open data sources that can be found in the GBFS GitHub (https://github.com/NABSA/gbfs/blob/master/systems.csv), but there are also a lot of organisations who do have a GBFS feed, but don't publish it to the public.

The GBFS implementations are also not very useful; the availability part of these public feeds is often not implemented or accurate.

https://github.com/NABSA/gbfs/blob/master/systems.csv

Shared cars

There is no central place for finding shared cars (as well the location as their availability). Larger shared car organisations can be contacted to get this information. Getting the data will be at this moment require propriety connections.

PTO schedules & progress

This data can be acquired using Bison in the Netherlands (NDOV loket). The schedules are covering the Netherlands at a very high percentage (only a few PTOs don't provide them using this platform). The progress is reported by the larger companies. Availability/occupancy was only reported by a few, but as of October 2020 all PTO's do. This data still needs improvement to provide a reliable ecosystem.

Other modalities (micro)

This data is not centralized in the Netherlands, just like the shared cars.

Time dimensions

The past of the availability could be interesting to competitive organisations, the present number of available assets is needed for direct booking and the future estimated number is needed for planned trips.

Supply/demand of TOMP

This data type is created by TOs and needed by the MPs. Other TOMP parties do not use this data.

Challenges

Availability: not easy to acquire, different formats (GFBS(+), GTFS, SPDP (parking data)).

Latency: how accurate are the sources?

Added value

Again, this information is needed for planning. Otherwise the MP cannot provide information about the availability of assets.

Costs

The TOs in the ecosystem are the only ones who can provide this data. Setting up central list of TOs (in the discovery service) could work, the costs of maintaining the availability are for the TOs.

E. Personal data

Personal data stores lack at this very moment in the Netherlands. Belgium is starting to setup a national data store. The main problem of course it's very sensitive data and should be protected at a very high level.

Personal data is very diverse, not yet standardized and people tend to protect it. The suspicious altitude to provide information and lose control over it, is a burden we have to take away to facilitate real personalized MaaS travelling.

Subtypes

Personal data

Like birthdate, name(s), addresses, phone numbers and other data that can be considered as 'attributes' of a person. This does not cover data from a person in relation to other bodies, like memberships, agreements, licenses.

> https://mydata.org/
> https://github.com/privacybydesign

Cards and licenses

Persons do have agreements with other bodies, and these agreements do have their specific attributes, like a membership (which has a supplying party, membership numbers, expiry date, level, etc) or licenses (supplying party, description of license, licensed asset type, etc). These can be considered as sensitive data and should be handled like the core 'personal data' attributes.

(Travel) budgets

This subtype is very diffuse. Employers provide budgets to employees, cities provide travel budgets to handicapped people, etc. This data is not owned by the person who is given the budget (and it can't be altered by the person), but he has the right to use it. This subtype will create nasty problems: who is allowed to see this data (and who needs it) and who is allowed to alter (increment or decrement) these budgets.

Handicaps and other limitations

This subtype can be stored in a normal PDS, but is of course very sensitive. The 'Traveler Characteristics Dictionary' from the CROW is a good starting point for standardising this kind of data.

https://www.crow.nl/publicaties/woordenboek-reizigerskenmerken

Time dimensions

Since personal data is legislated by the GDPR, it must be used in a minimal way. It would be very easy to have the historical information and a prediction of this data to serve the end user best. GDPR makes it very hard to store or to interpolate this data. Only the present state can be used and acquired from the PDSs at the moment it is needed.

Supply/demand of TOMP

This data can be used by the MP for routing purposes, is required for the TOs to validate things like age, driver licenses etc. The end user has to supply this data, optionally using the PDSs.

Challenges

Outdated information: Personal data is nowadays often duplicated, for every purpose required personal data is stored, but people tend to distrust the parties who need this data to serve them in the best way they can. The challenge is of course to have only 1 place to store this data in a secure way (GDPR) and let the end user control the access to specific items. Once a MP (or TO) needs this data, it can request access to it.

GDPR: personal data should only be used when needed and end users should be aware of who is getting this data and what they are going to do with it. They also must be able to request removal of their stored data.

Ownership: the personal data is often not really personal, but related data. For instance, a driver license. It permits a person to drive in e.g. a car, but it a permit from an authority, which can retract the permit. Things like travel budgets, credit cards, memberships etc. are relational data.

Added values

The added value for the end user is simple: control of his/her personal data, at one single point. This means that changed personal data will be available to all parties the end user has allowed to access this. And of course, he can retract the access whenever he wants.

The added value for the MP is that it doesn't have to cope with GDPR legislation, as long it doesn't store this information. The same counts for the TOs.

This data could also add value to the reports of the data analysts, but legal aspects block the usage of this information at this stage.

Costs

The costs should be completely covered by parties who see a business model in hosting PDSs. The PDSs can of course be supported/set up by the government (or the government itself can support a national PDS, similar to the Belgium initiative).

To make it really work, the PDSs should standardize their interface AND content (ontology). That might also be quite costly.

F. Travel right stocks

Travel right stocks are at this moment reserved to the PT organisations in the Netherlands; they have one central organisation to handle this (Translink).

Travel rights and access information can be considered as data. It is information that is stored somewhere and can be accessed when needed (entering/exiting assets, onboard inspections).

Time dimensions

It is not really necessary to store this information for a long time, because it is only relevant for trips in the present or in the future.

Supply/demand of TOMP

TOs and MPs both need access to these travel rights. Often the TO supplies the access information related to the travel right. The MP will need access to it to let the app operate gates, locks etc., but also to show to inspectors on the train. It should not be allowed that other parties than the MP and the TO involved can access this information.

Challenges

Access rights: who is allowed to access these travel rights or access information? Who is going to store it?

Subtypes
Train or other PT tickets, access information for locks (e.g. Bluetooth), but also physical locations for storing keys, addresses and contacts to visit to get access.

Added value
Nowadays this information is provided by the TO and used by the TO to validate access and inspect. To facilitate one travel right for a complete trip, containing multiple legs, the concept of a TO based travel right should be removed and the travel right (and access data?) should be decoupled from the TO. The added value to the end user is limited, because the MP should be able to open assets/gates and the end user doesn't care if it is one thing during one trip or there are multiple, as long the app can open the assets.

Costs
This exercise will take a big investment, unless it is kept close to the current situation: the travel rights/access information nearby the TO who is supplying it.

G. Payment information
This data is needed for validation and clearing purposes. MPs can request TOs to supply the details about the trips they have made for the specific MP, the clearing houses can transmit the payments from MP to TO (or sometimes vice versa).

Time dimensions
The payment information is historically needed for e.g. tax purposes. The present data is often not yet available (because these are often created in nightly batches), but irregular or direct claims should be addressable directly (like deposits, fines). It is not required to have an overview of the predicted costs of planned trips.

Supply/demand of TOMP
The payment information has multiple aspects in the ecosystem. The MP should inform the clearing house it is willing to pay for a trip, the TO can validate this willingness and the TO can -after the trip has finished- register the real amount of money it wants from the MP. When this is done, the clearing house can calculate periodically the total amount of money to transfer from MP to TO.

Challenges
Access rights: who is allowed to view this information?

Subtypes
Fares, fines, deposits, credits, etc

Added value

Adding clearing houses, containing the willingness to pay and the clearance information, will decouple the peer-to-peer situation between MPs and TOs on a financial level. As soon a clearing house is contracted by as well a MP as a TO (and they both can have a lot of contracts with separate clearing houses), the payment can be guaranteed by the clearing house. This facilitates a (inter)national scale up tremendously, since the payment is always a controversial issue.

Costs

There are already existing clearing houses, for PT and non-PT. They should uniform their process to make it interoperable.

H. Common data

There will always be data that supports this ecosystem and seems not directly relevant, like weather data and 'meta' data like OD matrices and SEG information. Meta data about TOs (like chamber of commerce data, contact information, the membership or reduction cards, etc) are in this data type. The only thing they have in common is that it is not related directly to the layer model or to the process flow.

Time dimensions

This data could be very relevant for specific processes, like analysis or creating traffic profiles for predictions. Since the data types are very diverse, it covers the past as well (profiles are derived from history figures) or the present (current weather status). Future might be relevant for planning options (weather predictions, upcoming road works).

Supply/demand of TOMP

This data is not easy to describe, since it's really diverse. Some data is needed for trust (payment agreements, travel conditions), some is for analytical purposes. Most of the data isn't created by TOs and MPs. They are merely supportive to the environment.

Challenges

-

Subtypes

Weather data, social economic geographical data, OD matrices, payment agreements, travel conditions, payment methods

Costs

-

4. PlantUML

A. Planning & booking

```
@startuml
Title planning & booking with discovery service, \n clearing houses and transaction processors
participant user
participant mp
participant discovery
participant known_to
participant unknown_to
participant ch1
participant ch2
participant trs1
participant trs2

user->mp: I want to \n go from A to C
mp->mp: B? that's not in my region!
mp->discovery: who's in or around B?
discovery->mp: answer: unknown_to

mp->known_to: POST /plannings/ A to B
known_to->mp: leg 1, pay \n through clearing house 1
mp->unknown_to: POST /plannings/ B to C
unknown_to->mp: leg 2, pay \n through clearing house 2

mp->mp: ok. I've got contracts \n with both of them

mp->user: show options
user->mp: book this trip!

mp->ch1: POST willingnes to pay leg 1
mp->ch2: POST willingnes to pay leg 2

mp->known_to: POST /bookings/1
known_to<->ch1: check willingness
known_to<->trs1: post access info for leg 1
known_to->mp: ok, booking PENDING
```

mp<->unknown_to: POST /bookings/2
unknown_to<->ch2: check willingness
unknown_to<->trs2: post ticket for leg 2
unknown_to->mp: ok, booking PENDING

mp->known_to: POST /bookings/1/events { COMMIT }
known_to->mp: ok, booking CONFIRMED
mp->unknown_to: POST /bookings/2/events { COMMIT }
unknown_to->mp: ok, booking CONFIRMED

mp->user: ok!

@enduml

B. Trip execution

@startuml
Title trip execution \n with clearing houses & travel right stocks
participant user
participant asset
participant mp
participant known_to
participant unknown_to
participant ch1
participant ch2
participant trs1
participant trs2

user->mp: start leg 1
mp<->trs1: get access info
mp->user: provide access info
user->asset: open sesame!
asset<->known_to: validate & open
user->mp: asset open
known_to->mp: POST /legs/1/events { SET_IN_USE }

== user arrives at B ==

user->asset: lock asset

```
asset<->known_to: lock
user->mp: asset locked
known_to->mp: POST /legs/1/events { FINISH }
known_to->ch1: POST actual costs

== user access leg 2 ==
user->mp: start leg 2
mp<->trs2: get access info
mp->user: provide ticket
user->asset: open sesame!
user->mp: asset open
mp->unknown_to: POST /legs/2/events { SET_IN_USE }

== user arrives at C ==

user->asset: lock asset
user->mp: asset locked
mp->unknown_to: POST /legs/2/events { FINISH }
unknown_to->ch2: POST actual costs

@enduml
```

C. NAP Class overview

```
@startuml

title MaaS Participant - NAP point of view

class MaaSParticipant {
  +UUID id
  +Role role
  +String name <<sync>>
  +String shortName <<sync>>
  +String chambreOfCommercePlace <<sync>>
  +String chambreOfCommerceNumber <<sync>>
  +ProductType productType <<sync>>
  +TypeOfSystem systemType <<sync>>
}
```

```
class Url {
  +String uri
  +UrlType type
}

class Region {
  +String name
  +String polygon
}

class PhoneNumber {
  +String number
}

class EmailAddress {
  +String address
}

class Connection {
  +ConnectionType type
}

MaaSParticipant "2" -right-{ "n" Connection : <<sync>>

MaaSParticipant --{ "1-n" PhoneNumber : phoneNumbers <<sync>>
MaaSParticipant --{ "1-n" EmailAddress : emailAddresses <<sync>>
MaaSParticipant -up-{ "1-n" Region : regions <<sync>>
MaaSParticipant --{ "n" AssetClass : assets <<sync>>
MaaSParticipant -left-{ Url : urls

enum UrlType {
  WEBSITE
  SUPPORT_URL
  TOMP_BASE_URL
}

enum Role {
```

```
  TRANSPORT_OPERATOR
  MAAS_SERVICE_PROVIDER
  CLEARING_HOUSE
  NATIONAL_ACCESS_POINT
  CERTIFIER
  GOVERNMENT
  TRAVEL_RIGHT_STOCK
  DATA_ANALYST
}

enum ConnectionType {
  HAS_CLEARING_HOUSE
  HAS_TRAVEL_RIGHT_STOCK
  HAS_NAP
}

enum ProductType {
  RENTAL
  SHARING
  PARKING
  CHARGING
}

enum TypeOfSystem {
  FREE_FLOATING
  STATION_BASED
  VIRTUAL_STATION_BASED
}

enum AssetClass {
  AIR
  BUS
  TROLLEYBUS
  TRAM
  COACH
  RAIL
  INTERCITYRAIL
  URBANRAIL
```

```
  METRO
  WATER
  CABLEWAY
  FUNICULAR
  TAXI
  SELFDRIVE
  FOOT
  BICYCLE
  MOTORCYCLE
  CAR
  SHUTTLE
  OTHER
  PARKING
  MOPED
  STEP
}
@enduml
```

5. Usable standards

a) TOMP API (tomp-wg.org)
b) OSLO model (https://overheid.vlaanderen.be/oslo-wat-is-oslo)
c) NeTEX (http://netex-cen.eu/)
d) SIRI (http://www.transmodel-cen.eu/standards/siri/)
e) GBFS (https://github.com/NABSA/gbfs)
f) GTFS (https://gtfs.org/)
g) SPDP (https://nationaalparkeerregister.nl/fileadmin/files/Open_Parkeerdata/Standard_for_the_Publication_of_Dynamic_Parking_Data_v2_0.pdf)
h) CDS-M (https://github.com/TOMP-WG/CDS-M)

6. Literature

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