ACT. 9 CONSOLIDATION REPORT

SOCRATES 2.0
FAST SAFE GREEN

SOCRATES[2.0] is co-funded by the European Commission

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1. INTRODUCTION

SOCRATES$^{2.0}$ has built the foundations to introduce and deploy the next step in traffic management. We call this concept 'interactive traffic management', meaning a close cooperation and collaboration between different public and private partners in the traffic management ecosystem. As part of this concept, traffic management information is exchanged and translated into intelligent decisions and behaviour, with the overall goal of enhancing the quality, safety and efficiency of traffic for road users. The concept is expected to lead to more business opportunities for the private partners and more cost-effective traffic management for the public authorities.

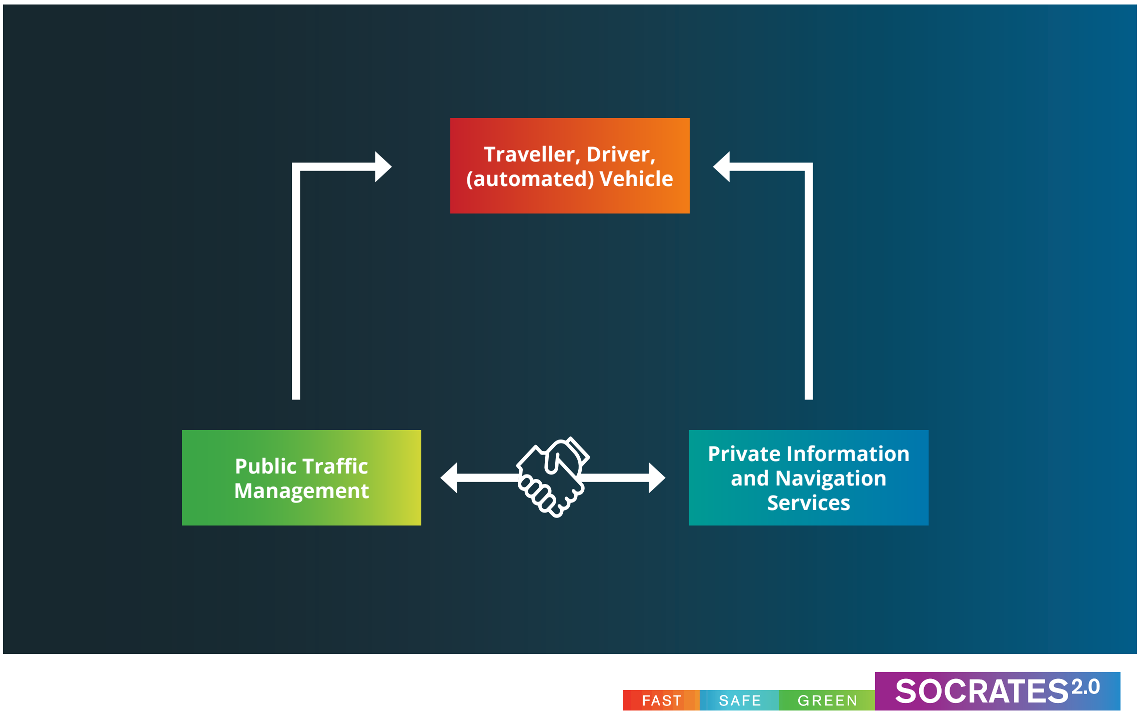

Figure 1. Concept of interactive traffic management

In more concrete terms, SOCRATES$^{2.0}$ developed a cooperation framework and demonstrated pilot deployments of new measures and services for the interactive traffic management concept.

This report consolidates the outcomes of the entire project, draws conclusions and provides recommendations and guidelines for deploying the concept of interactive traffic management on a wider scale.

Furthermore, the report proposes follow-up activities to evolve and roll out the interactive traffic management concept after conclusion of the project, eventually leading to a European-wide deployment.

This way, the Consolidation Report deals with two perspectives: first, looking back at SOCRATES$^{2.0}$ experiences, and then looking forward to a Post- SOCRATES$^{2.0}$ era, to allow potential follow-up activities take on the experience and guidance made in our project.

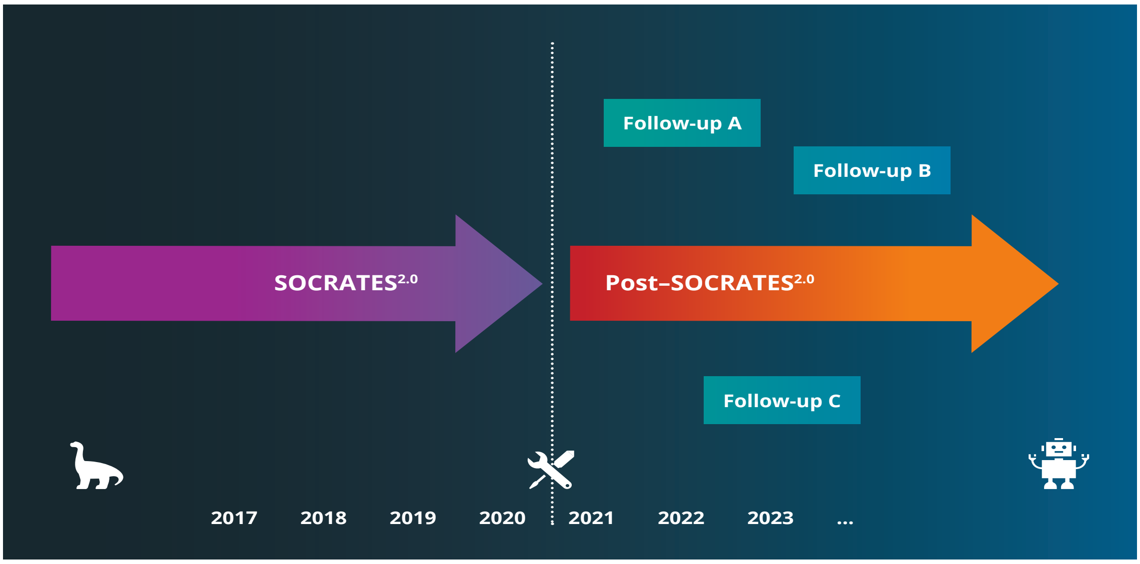

Figure 2. Two perspectives of the Consolidation Report

The report is intended for stakeholders, such as public administrations, service providers and car manufacturers, and relevant European initiatives involving emerging intelligent transportation systems and advanced traffic management schemes. The conclusions in this report can support these actors in making decisions about the deployment of new traffic management measures and services, as initiated in SOCRATES$^{2.0}$.

This report is part of the final dissemination activities of the SOCRATES$^{2.0}$ project:

- The Consolidation Report (the current report) represents a consortium perspective on basic components and overarching issues of the SOCRATES$^{2.0}$ project, as well as its underlying concept of interactive traffic management.
- The Evaluation Report[1] is an evidence-based perspective on the outcomes of the Socrates$^{2.0}$ project.
- The digital magazine[2] presents a bird's view of the SOCRATES$^{2.0}$ story.

The current Consolidation Report is organised as follows:

- Section 2 presents basic elaborations on aspects that facilitate the concept of interactive traffic management. This includes mainly the cooperation framework, common formats for digital data exchange, and means for communicating with road users.
- Section 3 gives recommendations for concrete implementations of the concept, based on learnings from the project deployments.
- Section 4 compiles lessons learned about selected enablers and bottlenecks, with the goal to enable the concept on a wider scale, again based on project experiences.
- Section 5 identifies arrangements required for further deploying the concept after conclusion of the project, put together as a follow-up plan.

Whereas this report is considered a central document about all aspects of SOCRATES$^{2.0}$, some further, specific resources provide more insights on selected aspects. These other resources are cited throughout the report, and can be downloaded from the SOCRATES$^{2.0}$ website.

[1] See the SOCRATES$^{2.0}$ Final Evaluation report
[2] See the SOCRATES$^{2.0}$ digital magazine

2. SETTING THE STAGE FOR INTERACTIVE TRAFFIC MANAGEMENT

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2.1 Vision and conceptualisation

The SOCRATES$^{2.0}$ interactive traffic management concept aims to enable a new approach to network-based traffic management. It presents new means and methods to steer transport networks. The approach integrates control mechanisms in the responsibilities of both road authorities and service providers that increase the efficiency and consistency of components of individual traffic management systems. The approach is based on the TM$^{2.0}$ initiative[3] and is shown in the next figure.

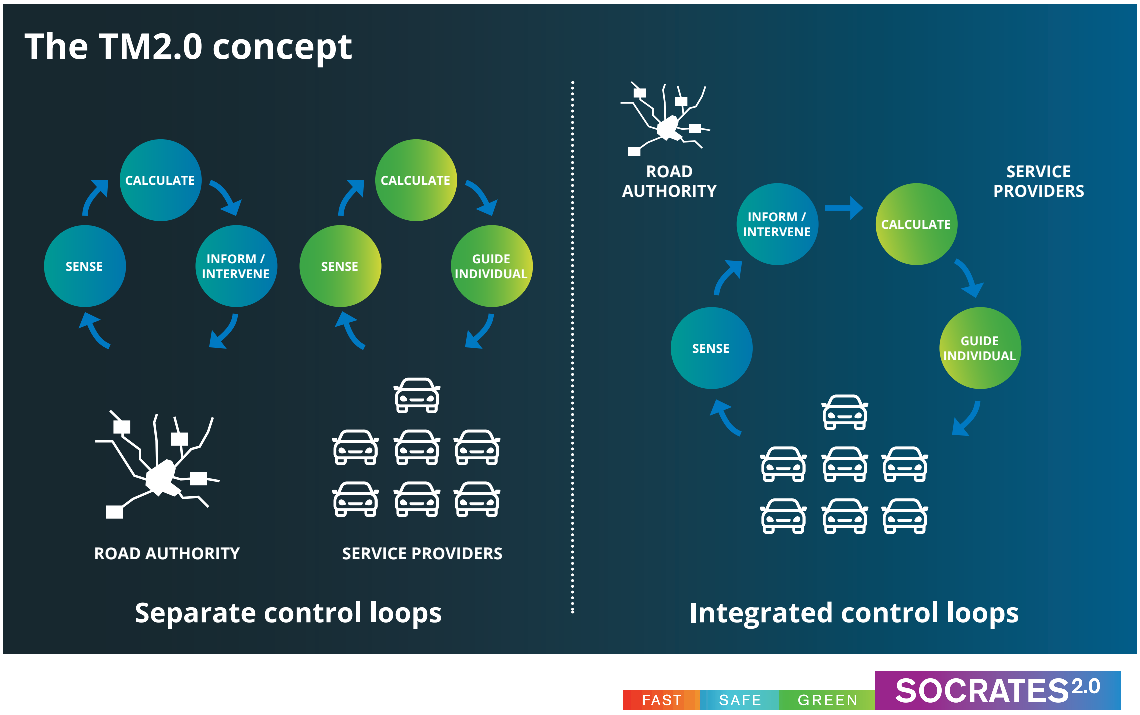


Figure 3. TM2.0 concept

Before concretising and deploying the above concept, the project partners elaborated a shared, higher-level vision for the long-term development in traffic management. This vision considers technological advancements affecting the transportation system, such as new communication channels and enhanced connectivity, as well as the individual needs of stakeholders involved in the transportation system, namely road users, public actors and private actors in traffic management.

The vision looks at four perspectives: technology, community, customer and cooperation, for which slogans, main ideas and principles were defined (see the next figure). This shared vision identified the individual and joint motivations, interests and expectations. And assembling the shared vision together helped build trust and a common language between the partners. This was the basis for exploring the possibilities of cooperation.

[3] ERTICO Traffic Management 2.0, See: https://tm20.org/

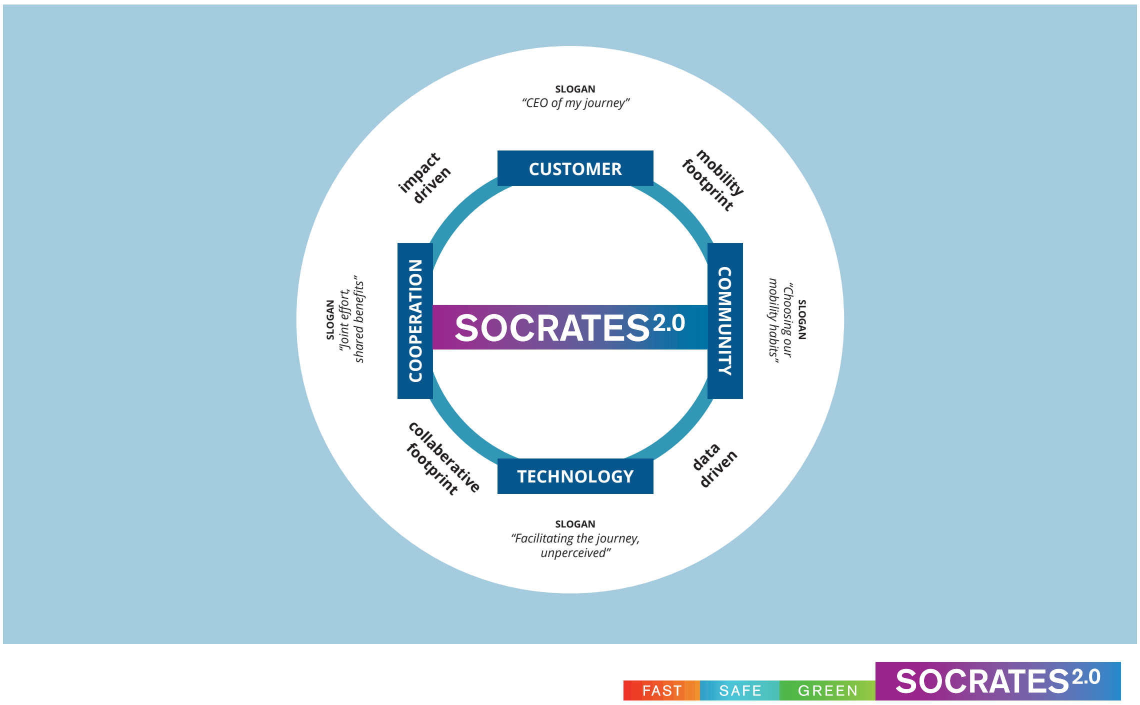


Figure 4. The four elements of SOCRATES2.0 and their slogans

The four elements of the vision are explained as follows:

CUSTOMER
Making the customer an active part of interactive traffic management: let them provide and consider feedback. But also let them provide specific information, guidelines and motivation on common traffic strategies for their own journey. The customer should be convinced of the benefit of the offered service. However, customers will not actively be involved in the development itself; this will be achieved via the service providers.

COMMUNITY
People as a group can have a certain impact on society or a city with their travel behaviour. By supporting communities during their journeys, the alliance can influence that impact.

TECHNOLOGY
Technology serves as a means to support the individual user, society, communities and the alliance. The project aims to combine technologies in a smart, user-centred way (balanced route optimisation, gamification, predictions).

COOPERATION
Make the cooperation fit impact-driven business models. A key aspect is to define collaboration KPIs: how to measure who contributed what to the common goals.

This vision forms the basis for the entire project elaboration, and is detailed in a separate report[4].

[4] See the report "Shared vison, framework and bottlenecks in the SOCRATES2.0 project"

This strategic perspective was translated into a more tactical perspective, proposing specific solutions, which were later trialled in real-world SOCRATES$^{2.0}$ pilots. These solutions mostly involve harmonised elements that enable the interactive traffic management concept to be deployed on a European-wide scale (after validation and further roll-out). These harmonised elements include functional, organisational and technical aspects, and are detailed in the next sections.

2.2 Cooperation framework

A basic building block for the concept of interactive traffic management, as elaborated and demonstrated in SOCRATES$^{2.0}$, is a cooperation framework. This represents a functional and organisational architecture, allowing a smooth and efficient cooperation between the participating stakeholders, namely road users, traffic management centres, the automotive industry and data- and service providers.

All SOCRATES$^{2.0}$ partners believe that by cooperating, new business opportunities can be developed for private partners, more cost-effective traffic management can be achieved for public authorities and most importantly better services can be provided for road users and communities. The SOCRATES$^{2.0}$ partners call this a win-win-win for all stakeholders. The goal of SOCRATES$^{2.0}$ is, to test if this added value can be achieved by a closer cooperation and find out how this can lead to sustainable business cases for all stakeholders.

To make such win-win-win happen, a cooperation framework is introduced in the centre of the SOCRATES$^{2.0}$ concept, as indicated by the next figure.

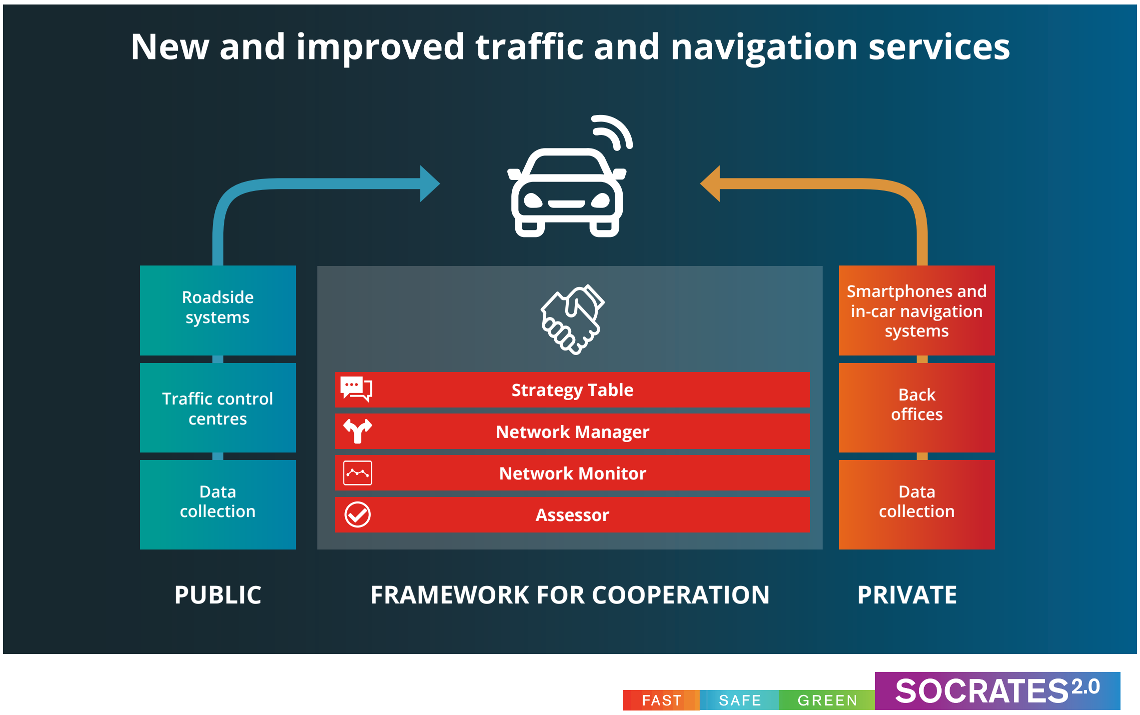


Figure 5. SOCRATES2.0 cooperation framework

The SOCRATES$^{2.0}$ cooperation framework has elaborated three cooperation models. These models describe the type and intensity of cooperative tasks among the participating partners. Next, we will take a closer look at these cooperation models, describe the differences and elaborate on the benefits and challenges for each model.

Furthermore, we take a look at the 'roles' needed to conduct cooperation in traffic management. For each cooperation model, a pre-selection of roles should be considered. Besides traditional roles like data- and service providers, four new roles were introduced by SOCRATES$^{2.0}$. These new roles relate to intermediary roles, and are an integral part of the SOCRATES$^{2.0}$ cooperation framework, as indicated by the figure above.

Cooperation models: Exchanged Data, Shared View and Coordinated Approach

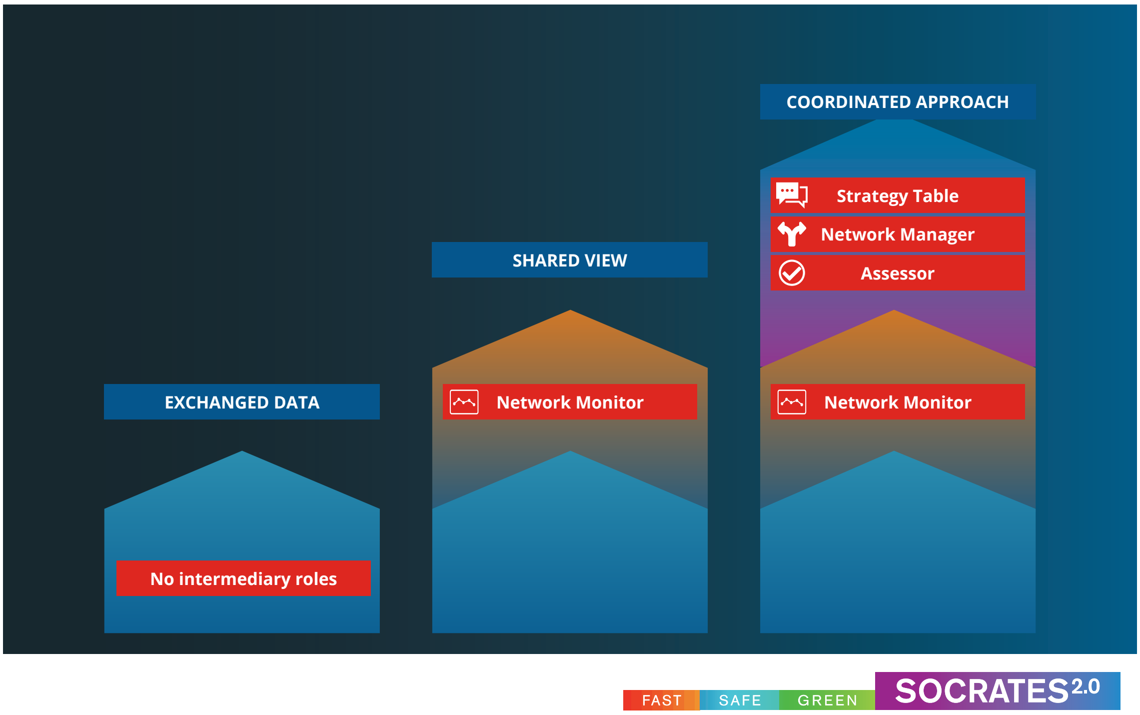


Figure 6. SOCRATES2.0 cooperation models and intermediaries

The SOCRATES$^{2.0}$ partners created a cooperation framework that defines three ways of working together – called cooperation models – and identifies four new roles – the intermediary roles – that are necessary to make the cooperation work. The figure above indicates the three cooperation models (as vertical arrows), and the corresponding intermediary roles (as red boxes). The main distinction between the cooperation models is the level of communality. The communality determines how close partners work together. In other words, partners can choose to just 'wave', 'shake hands' or 'hug' each other.

The first cooperation model is comprised of agreements for sharing public and private traffic data, based on agreed data exchange formats (Exchanged Data). The second model brings the cooperation partners a step closer to each other. The partners create a Shared View for the road network (e.g. common situational picture). The Shared View is based on Exchanged Data. Partners use the Shared View independently from each other. The most elaborate level of cooperation arises when, based on Exchanged Data and a Shared View, partners develop and implement coordinated actions and services towards the travellers (Coordinated Approach).

Depending on the envisaged service or use case, the level of cooperation can vary. For a danger warning service, the Exchanged Data cooperation could be suitable. Optimising traffic flow over an entire network on the other hand may require a Coordinated Approach. So, the selection of the use case mainly determines the type of cooperation model. On the other hand, the complexity of creating and running a cooperation is mainly determined by the use case.

This table gives an overview of some of the characteristics of the three cooperation models. It is noted that these cooperation models can apply to any of the layers of traffic management: operational, tactical, and strategic, according to common definitions[5].

Table 1. Characteristics of the three SOCRATES2.0 cooperation models

	Exchanged Data	**Shared View**	**Coordinated Approach**
Level of communality	'wave'	'handshake'	'hug'
Main activity	Sharing data	Creating (and using) a common situational picture	Coordinating actions
What is common?	Exchange format	Situational picture	Approach strategy
Data	Standardisation of format	Enrichment of data content	Meaningful and impactful
Typical Scalable	European	National	Regional
SOCRATES$^{2.0}$ Use cases	Speed and lane information	Roadworks and environmental zones	Optimising network flow

[5] Spoelstra, J., van Waes, F., Mann, M., Kontantinopoulou, L., Dr. Tzanidaki, J., 2017. Exchanging Traffic Management Plans data between Traffic Management Centres and Service Providers in Traffic Management 2.0. 12th ITS European Congress, June 2017, Paper no. TP0809.

Exchanged Data cooperation model

This model of cooperation is about exchanging data on a voluntary base using an agreed standard protocol. There are multiple European standards and variations for the same purposes. Agreeing on one standard and using it in an aligned way is the challenge.

This is the entry model. It is a building block for the two higher cooperation models. But it is also suitable for services aiming at spreading information without the need for further enrichment of the data or coordinated actions. This is applicable for speed and lane information as was developed in the SOCRATES$^{2.0}$ Antwerp pilot site. The main focus is sharing information in order to obtain a maximum information coverage for the end users. Each party continues to use its own services to communicate with the end user.

1. Exchange data

The benefits of this model are:

- improved information coverage for public and private parties (back-end).
- improved service quality for end users (front-end).

The challenges of this model are:

- Agreeing on which standard to use for multiple partners. For some applications, multiple standards are available.
- Agreeing on how to use that standard and to keep the scope for the use case manageable (less is more).
- Partners participating in this cooperation model need to make certain efforts to make their data available and accessible.

Exchanged Data is a basic model for cooperative traffic management. It promises relatively low technical hurdles to start with cooperation. It can already add value to the system, especially for the end users, as it improves the availability of relevant data. In many cases it requires low investments, as most of the required infrastructure and interfaces will be already available and only minor adjustments will be required (adaptation to harmonised standard). The aspect of identifying the appropriate business model remains a challenge, as even in a data-driven society few models are available for data sharing in a money-driven economy.

Shared View cooperation model

This model of cooperation is based on the cooperation model Exchanged Data, but introduces the concept of a common situational picture. This means all involved parties, public and private, operate on the same consolidated information.

This cooperation model is suitable for use cases in which sharing data to enable a ‘common situational picture’ will add value to the system. This is applicable for environmental zones and roadworks information as was developed in the various SOCRATES$^{2.0}$ pilot sites.

In this case, several parties have similar, sometimes complementing or overlapping information, but instead of just exchanging the content the value is in cleaning, completing, merging, aggregating and distributing the content and thus allowing all parties to operate on the identical ground truth. This approach will eliminate the risk of contradicting/unaligned information provision to the end user which may happen in the Exchanged Data cooperation model. Still each party continues to use its own services to communicate with the end user.

The Shared View cooperation model requires an additional, intermediary role to achieve the common situational picture, the so-called Network Monitor. In a nutshell the Network Monitor collects data from the various sources, executes quality checks, merges the content and delivers the consolidated content through a standardised interface. More details can be found in the section on roles below.

The benefits of this model are:

- improved information coverage for public and private parties (back-end).
- improved service quality for end users (front-end).
- trusted entity (intermediary) operating the Network Monitors enables data sharing even between competing parties.
- same foundation for taking actions for all parties.
- alignment of information provided to the end users.

The challenges of this model are:

- identification of the appropriate standard for (enriched) information exchange.
- harmonised (read and write) usage of the identified standard.
- scaling of standardisation aspects from regional to national and European level.
- agreeing to appropriate business model for sharing data.
- agreeing to terms and conditions allowing not only the sharing of data, but also the modification and merging.
- identifying commonly accepted trusted parties.
- establishing trust between parties involved.

The Shared View cooperation model is an improved model for cooperative traffic management with limited technical hurdles for interacting with each other. The main benefit for the overall system and the end users is, that all actions are based on the same operational picture and no contradicting information should be provided to the travellers ('just informing').

The investments to make this cooperation model happen are expected to be higher than for the Exchanged Data cooperation model as the initial costs for implementing the Network Monitor and continuous costs for operating the Network Monitor will need to be covered. Related to that, but also considering the enablers for data sharing, identification of the appropriate business model is key.

Coordinated Approach cooperation model

This model of cooperation is far more ambitious than the previous two cooperation models. It is not only about achieving a common ground truth, but agreeing on coordinated actions amongst all parties involved, public and private, to achieve a set of previously agreed common goals.

This model is suitable for use cases in which a set of commonly identified and agreed goals can only be achieved by coordinated actions of all parties.

This model is suitable in cases where achieving common goals in traffic management require coordinated actions of the partners involved. This can be the case especially in routing services, where the sum of all individual optimal routes does not (necessarily) result in the collective optimum. In order to achieve that collective optimum as a common goal, a Coordinated Approach is needed. Partners first need to agree upon this common goal (e.g. an optimal distribution of traffic over the network). Subsequently they need to obtain a common picture of the actual traffic state and the desired action to be taken. As some of these actions might be suboptimal on an individual base (e.g. leading to a longer individual route) a form of compensation might be needed in order to seduce the end user to comply with this action.

Service providers still have the flexibility to identify the right and acceptable recommendations to their users while not only considering but also contributing to the common. This ambitious cooperation model was chosen for the Optimising Network Traffic Flow use case and was implemented in the SOCRATES$^{2.0}$ pilot sites in Amsterdam, Antwerp and Copenhagen. In the Coordinated Approach cooperation model, end users and travellers become an important role as well, as the more actively they participate, the more likely they are to follow advice and change their behaviour, thus resulting in a better impact. An appropriate incentive and reward model may stimulate the contribution of end users.

The Coordinated Approach cooperation model requires several additional intermediary roles to operate a system of coordinated actions. One of the roles is the Network Monitor, already introduced and needed for the Shared View.

The other required roles are:

- the Strategy Table – aligns public and private goals, translates commonly agreed goals into measurable KPIs and determines available services.
- the Network Manager – determines the problem state based on the actual and desired situation, determines a solution based on available services, sends so-called service requests (coordinated actions) to public (road authorities) and private (navigation) service providers.
- the Assessor – assesses the contribution of all service providers (public and private) to the commonly achieved KPIs.

More details can be found in the section on roles below.

The benefits of the Coordinated Approach are:

- improved information coverage for public and private parties (back-end).
- improved service quality for end users (front-end).
- enables the identification of common goals, set of agreed services (or high-level actions) per partner and KPI framework as common framework for operational success.
- trusted partner enables data sharing even between competing parties.
- trusted partner enables operation of coordinated actions.
- trusted partner allows neutral assessment of performance indicators per partner as basis for impact-driven business model.
- the coordinated actions enable "true" interactive and cooperative traffic management to improve network efficiency.

The challenges of this model are:

- identification of the appropriate standard for information exchange.
- harmonised (read and write) usage of the identified standard.
- scaling of standardisation aspects from regional to national and European level.
- agreeing to appropriate business model for trusted roles.
- agreeing to terms and conditions allowing not only the sharing of data, but also the modification and merging.
- identifying commonly accepted trusted partners for intermediary roles.
- establishing trust between parties involved.
- appropriate governance and business model.
- appropriate tendering process.
- establishing mechanisms to motivate road users to behave according to common goals, even when they experience suboptimal situations, such as longer routes.

The Coordinated Approach cooperation model is a blueprint for interactive and cooperative traffic management with organisational and technical challenges. The main benefit for the overall system and the end users is that commonly agreed and coordinated actions are the success factor for an improved network management while considering the benefits to individual travellers at the same time.

The upfront investments to make Coordinated Approach cooperation model happen are higher as for the former two cooperation models, as there are additional costs for implementing and operating the new intermediary roles. Operating new (impact-driven) business models can be an additional short-term cost factor as well. However, in the long run, additional societal benefits are expected.

Roles

The main building blocks for the cooperation models are the 'roles'. A role is defined as a set of tasks (or functions) that need to be carried out together with a responsibility to create added value for the cooperation as a whole. A role could be performed by one or more partners, as long as the responsibilities within the role are clear. For example, partner A is responsible for the content and partner B is responsible for the technology within one role. The number of tasks assigned to a role makes the role more or less complicated to perform. Also, one partner can perform multiple roles. This makes the SOCRATES$^{2.0}$ Framework flexible and adaptable for regional situations.

To enable a public-private cooperation for interactive traffic management (e.g. the TM$^{2.0}$ concept) four new intermediary roles were introduced: Network Monitor, Network Manager, Strategy Table and the Assessor role. They work closely together with the more traditional roles like data provider, service provider and traffic management centre (TMC).

We define an 'intermediary' as a dedicated role between the traditional public and private sector that enables central and crucial functions of the interactive traffic management concept. The intermediary role is performed by a trusted public or private organisation; or a combination. We realise that in many modern TMCs, some such roles are already embedded, for example a Network Manager may be part of the TMC's unit to manage traffic by its own means via CCTV and VMS. However, we prefer to isolate such tasks as explicit roles, because we think an explicit role definition makes it easier to implement advanced and innovative tasks of such roles, for example by giving those tasks to a dedicated, maybe more agile partner, instead of trying to integrate them into legacy systems of say a TMC.

The main interactions between the roles are visualised in the slide below.

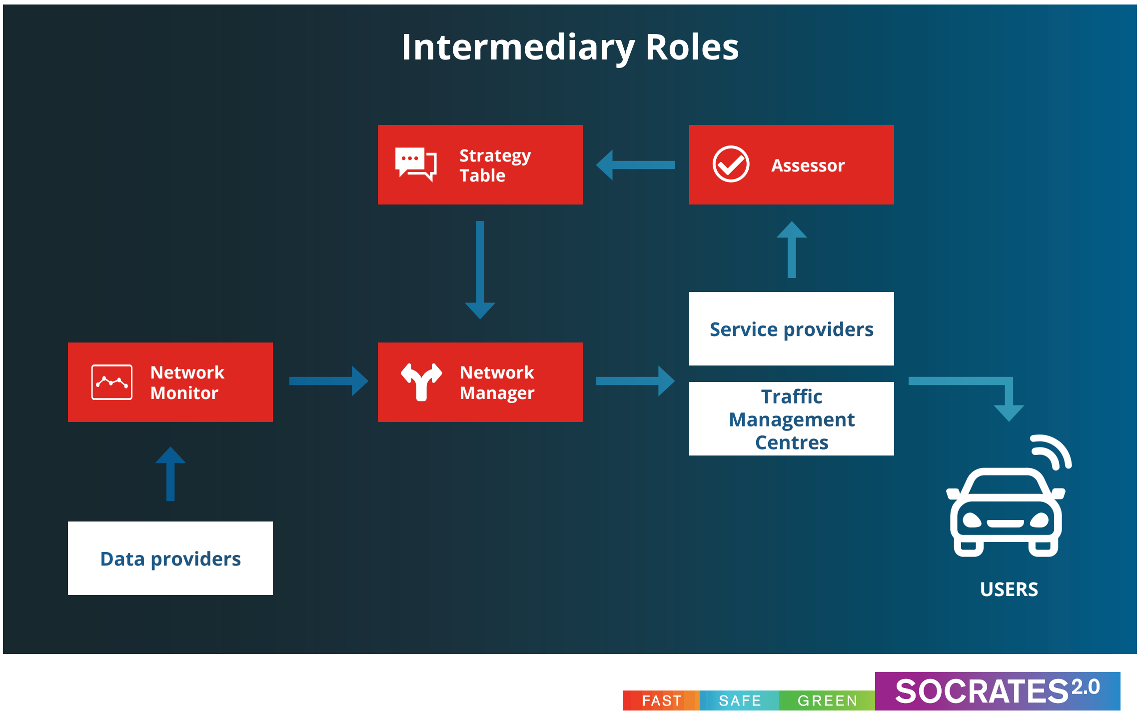


Figure 7. Interactions between the intermediary roles

In logic order the roles are:

Data provider

One or more data providers are responsible for the delivery of data. Both public and private partners can be data providers. We recommend exploiting any existing and emerging data sources for the goals of interactive traffic management, such as static road maps, roadside detectors, crowd- and fleet-based traffic data, and, in the future, data from cooperative systems (C-ITS)

Task 1: Data collection

Data provided by public partners typically include induction loop or other road sensor data that provide information on traffic conditions (volumes, speeds, vehicle categorisation). Public sources also include data on road works, incidents, dynamic speed limits and dynamic lane openings/closures. Information on air quality, the status of environmental zones and the status of traffic management measures can be shared as well. Private data providers typically share GPS based floating car data (speeds and travel times) and crowd sourced data on incidents, roadworks, lane openings/closures, etc., as reported by their travellers.

Task 2: Alignment and Data distribution

Public and private data providers send their data in real-time to the Network Monitor. They make agreements with the Network Monitor on how to transmit these data. APIs are set up and corresponding specifications are provided to the Network Monitor explaining the used protocols, the temporal and spatial referencing systems, etc. Data providers and the Network Monitor make agreements on data transmission specifics including latency, data quality standards and data protection regulations.

Network Monitor (new intermediary role)

When partners decide to cooperate by exchanging their data and based on that create a shared view, the Network Monitor needs to be implemented. The Network Monitor is especially useful if multiple data providers are available and a high quality common view is needed. To this end, the Network Monitor collects data from road authorities and private data providers and determines the shared view for a predefined use case related to network and indicators. In this process the Network Monitor can perform data handling services such as quality assessment, data completion and fusion of different public–private sources according to use case and business requirements. The Network Monitor distributes the network common state to other intermediary roles and other agreed parties. Partners then can base their own services on a higher-quality shared view.

Task 1: Data collection

The Network Monitor collects the data from one or more data providers. Depending on the use case, several input data sources are used. Traffic information sources consist of regular induction loop data (volume, speed), floating car data (travel times), incidents, road closures and road works. Other data sources have also been used and developed in SOCRATES$^{2.0}$. In Copenhagen, data sources about the number of cyclists and air quality were used, and in Amsterdam information about the status of environmental zones was collected and a data feed was developed with traffic management measures activated by the TMCs.

Task 2: Data processing

In this task the Network Monitor performs data handling services such as quality assessment, data completion and fusion of different public–private sources. In most SOCRATES$^{2.0}$ use cases, it is first determined for which roads or for which road network the service will be performed. The challenge for the Network Monitor is to ensure that the information from the different sources is linked to the correct road segments. During the use cases where new networks were needed, it turned out that a lot of time was spent on determining the network and the map matching of the data. If done correctly, a common current (and if possible predicted) state is determined. Possible extra tasks are mapping, standardising, data fusion, completion and prediction. The Network Monitor distributes or shares the 'state of the network'.

Task 3: Data distribution

After collecting and processing the data, the data is published publicly or sent specifically to the Network Manager. This depends on the chosen cooperation model. This data output stream is neutral and factual.

Agreements about the data exchange are important here: for example the format to be used, the frequency of delivery (e.g. on a minute basis) and the method of delivery (push by Network Monitor or pull by customer). The connections and data points are set up on the basis of these agreements. For the data format, there was a separate agreement between the SOCRATES$^{2.0}$ parties that laid down which data formats were used for which purpose (TMex). The DATEX II format was frequently used here.

Network Manager (new intermediary role)

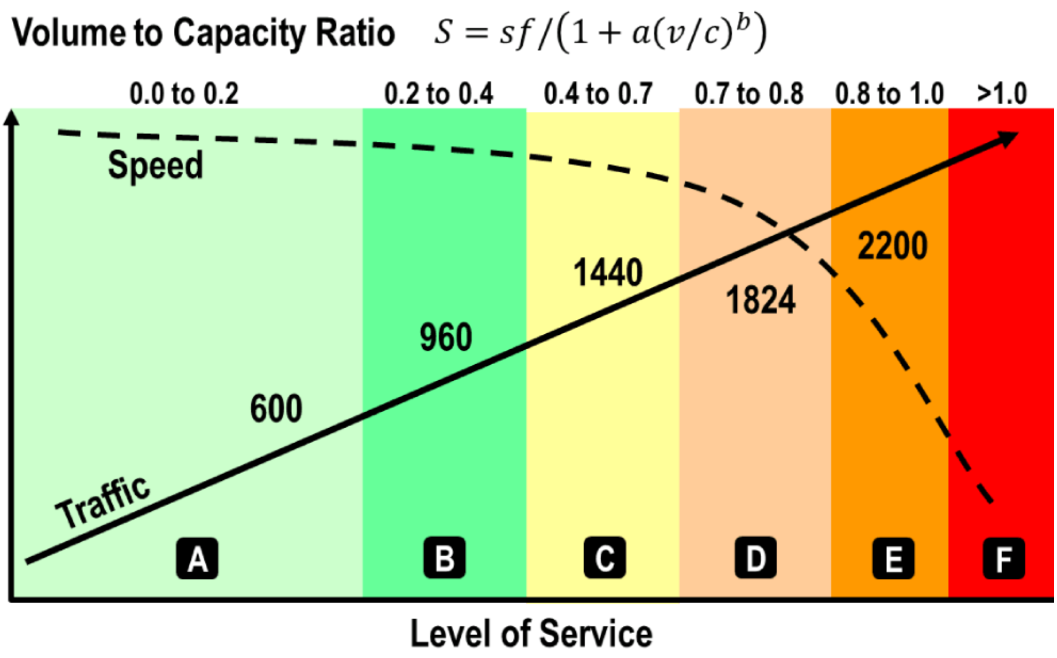
The Network Manager is an important role needed for the Coordinated Approach cooperation model. The Network Manager has the strategic goals and KPIs from the Strategy Table as input. These strategic goals are translated to tactical KPIs and used to determine the network problem state.

Task 1: Determination of problem state

The Network Monitor provides the Network Manager with traffic data (e.g. volumes, speed and active services) possibly supplemented by other data like emissions. Using predicted traffic state data is useful to have, but not crucial. These traffic states are then compared to the KPIs derived from the Strategy Table. Now the Network Manager can determine the problem state for each link of the entire network; for example, a level of service (LOS) according to the Highway Capacity Manual (HCM2016). The LOS could be 'A' to 'F', with 'A' being low density traffic and free flow speeds and 'F' being high density, low speed traffic or forced flow. A problem on a link occurs if the current state and predicted state fall below a certain level, causing a trigger reaction.

Task 2: Selecting services to alleviate the problem

The Network Manager has a set of services which are realised by the TMCs and service providers. These services are stored in a 'toolbox'. Each type of service has its own data attributes (unique name, ID, trigger level, effect area, location, etc.). Triggered by a KPI like decreasing LOS, a service is selected (or nominated) to be activated with the goal to reach a better LOS. The Network Manager takes into account the effect (e.g. change in volume) of the selected service(s). In addition, already activated services are taken into consideration since services can have contrary effects. A service can also support other services. This means that services can be used on links where there is no immediate traffic problem. The services act like intelligent agents searching for opportunities to improve the situation.



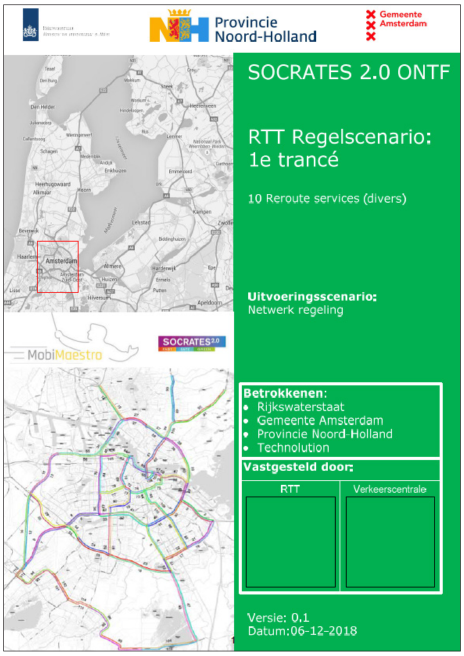
All these choices and conflicts are taken into account when the Network Manager selects services. This can be done through a conflict resolution matrix where priority is given to certain types of services. This can result in solutions where, for example, three supporting services are activated to alleviate the traffic problem on one link. The Network Manager does not differentiate between services of TMCs and private service providers when deciding which service to activate but looks at the impact a service can generate.

Task 3: Service requesting
The process of requesting another partner to conduct a particular service is called a ‘Service Request’ (SR). SRs to TMCs are sent in an agreed exchange format (e.g. DVM Exchange: this is a Dutch standard for requesting services between TMCs). SRs to service providers can be sent in a DATEX II format; a European standard for traffic related data exchange. In SOCRATES$^{2.0}$ most SRs were ‘advisory’ messages. It is important to allow some operational freedom, unless services concern legally-binding regulations, such as speed limits. Public services are ‘increase outflow’ (e.g. adapting traffic light green times), ‘reduce inflow’ (e.g. ramp metering) and ‘reroute’ (e.g. VMS). Private services are typically but not exclusively done through the routing algorithm of a navigation system. These services have the benefit of targeting individual road users. In Socrates2.0, private services are mainly based on the ‘avoid’-SR and ‘reroute’ SRs. An avoid SR means that services should be activated to avoid a specific network link, while a reroute SR means that services should be activated to rerouted traffic following a specific route (made up of several network links). Once a service is requested by the Network Manager, the TMC is requested to deploy their service. The private service providers are simultaneously requested to reroute their users based on the same principles as the public service providers and in this way support the goals of the public service provider.

Task 4: Short cycle evaluation
A short cycle evaluation can be accomplished by setting a team consisting of all participants that meet regularly to discuss issues regarding development and operational use. They use analytic tools to analyse algorithms, traffic data and the quality of the requested services. This leads to gradual improvement of the Network Manager.

Traffic Management Centre (TMC)
A TMC is the operational organisation of the road authority for traffic management. In general responsibilities are managing incidents, objects, roadworks and/or congestion. However, managing traffic on a big scale network is rather new. TMCs use viable message signs, traffic light controllers, cameras, etc. to manage traffic. In the SOCRATES$^{2.0}$ Amsterdam pilot, TMCs received SRs for the purpose of network optimisation.

Task 1: Preparation and quality validation



Prior to the operational phase, traffic engineers need to translate the (pre-agreed tactical) SRs to concrete measures that can be activated in the TMC. For example, a reroute SR is translated to text messages for VMS or other roadside equipment parameters. Before and during the operational phase, traffic engineers check the quality of the incoming SRs. Questions are: does the SR add value to the operational process and does it (still) improve the service to the costumer (road user)?

Task 2: Operator assessment and activation

During the operational phase, the operators receive SRs. They can either acknowledge, decline or snooze a request. When acknowledged, accompanying existing services (a selection of one or more traffic management measures) are activated (e.g. the display of a message on a dynamic panel, adjustment of green times of traffic lights, and the activation of ramp metering). An operator assessment can be fully or partially automated if the quality is good enough.

Task 3: Logging

For evaluation purposes all actions and special circumstances are logged by systems and operators. This information is then collected and analysed by the TMC engineers and frequently forwarded to the Assessor for further analyses of impact and value.

Service provider

The service provider receives the SRs in its backend system and will assess these SRs to determine whether or not to distribute these to its individual service users. The service provider may try to encourage desired behaviour by its users and may evaluate this. The service provider provides input to the Assessor.

Task 1: Receive SR

A service provider receives an incoming SR that is sent out by the Network Manager. The SR has a predefined structure following a protocol standard (e.g. DATEX II or DVM-X). Depending on the use case, the frequency of incoming SRs may vary from a few SRs per second to a few per hour (or even per day or per week or per month).

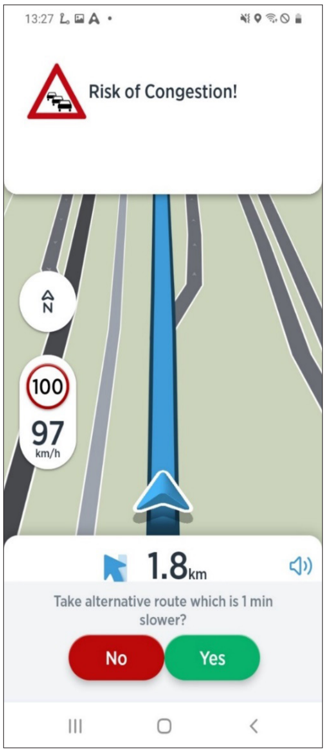
Task 2: Assess SR

An incoming SR will be (temporarily) stored in the backend system of a service provider. The service provider will assess the SR to determine what to do with it. This assessment may differ per use case and also per service provider and is in function of the agreed-upon cooperation model. Some assessment criteria may be:

- Compare SR with the previous/current/upcoming advice of the service provider's own system
- Take into account the number of (almost) identical SRs that have been received
- Take into account the number of (almost identical) advice messages that the service provider has sent out to its users
- Assess foreseen impact of SR and balance cost and benefit of involved incentive and reward

Not all service providers will use all of these assessment criteria.
The outcome of the assessment will determine whether or not to use the SR.

Task 3: Distribute to user



An SR that has been assessed and determined to be used will be distributed to the users of the service provider's service. The service provider will transform the SR to match its own communication service channel. This communication channel could be for example:

- Routing advice in a navigation system
- A pop-up message in a navigation system
- A message and a hyperlink to a navigation application in a text message

Above formats are examples; more formats and combinations are possible.

Task 4: Encourage and evaluate user behaviour
If the aim (of road authorities, service providers and/or other initiators) is to have a fast, safe and green impact on traffic, then they need to establish a marked effect on or at least influence the behaviour of individual traffic participants.

The service provider has the possibility to encourage desired behaviour and also to evaluate the actual behaviour.

The service provider can encourage behaviour by means of:
- Awareness campaigns
- Indirect incentives
- Direct/financial incentives

The service provider can evaluate user behaviour by means of:
- Feedback from users
- System data

Task 5: Provide input to the Assessor
Service providers provide input to the Assessor. This input can consist of system data and/or elaborated evaluation data. The input is provided following a predefined format and frequency.

Assessor (new intermediary role)

The Assessor supports the Coordinated Approach cooperation model by providing the Strategy Table (and the Network Manager) with insights on the service performance based on data and information individually collected by all partners involved in the delivery of the service. The Assessor translates them into the predefined goals and KPIs. The partners seated at the Strategy Table use the validated insights from the Assessor for data-driven strategic decisions on how to improve the jointly developed services.

Task 1: Collection of data and information
The Assessor collects a vast amount of data from all the roles involved in the delivery of the smart routing service. It "reads" the Network Monitor data feed on the current and predicted state. It also collects the periodical log on activated measures from Network Manager and the SRs sent out to each of the service providers and TMCs. And it collects the self-assessment report from TMCs and service providers based on the pre-agreed Waterfall report where several data indicators provide information on the reception, usage and implementation of the SRs information in each of their end-user services, including:

- aggregated volumes of users (travellers) which received (route) advice from an SR;
- how many (likely) changed their routes accordingly or not;
- reasoning for (non)acceptance of SR or not providing 'requested' advice to users;
- context information (e.g. TMC logging) from their perspective on the network conditions during an SR.

Task 2: Validation of collected data and information
The collected reports contain data and information on the technical and functional performance of each of the systems and services. The Assessor reviews the data with plausibility checks which are also used for operational reports to the Network Manager and validation dialogues with service providers. For example: indications on the uptime of each of the services, completeness of data or information, volumes of data exchange or even questionable data values or SRs.

Task 3: Translation to KPI framework and reporting
The Assessor translates the validated insights to the predefined KPI framework established by all the partners sitting at the Strategy Table. This information is used to regularly establish the impact of each partner in achieving the goals of the total ecosystem.
The results are used to assess if adjustments of the KPIs and/or toolbox are necessary and in how far the cooperation of the participating partners is successful.

The Assessor plays an expert independent role when evaluating both technological and commercial aspects of the cooperation. It supports the management of the SLA agreements and ensures that the cooperation principles are honoured. Because of its independent unbiased role, the Assessor can act as a trusted third party to collect and interpret information that is preferably not shared with the whole consortium. Only the agreed-upon information is shared with all stakeholders.

Strategy Table (new intermediary role)

The Strategy Table develops the joint strategy of all participating parties. The collaborative model of the Coordinated Approach revolves around jointly managing strategic KPIs.

Task 1: Alignment of goals

The Strategy Table is responsible for strategic alignment of public and private goals into commonly agreed goals. These goals are implemented by the Network Manager to determine the problem state and possible measures. To this end, KPIs are established for the entire network under control and translated into KPIs like LOS of the network sections at hand and stored. To achieve these strategic KPIs, the intermediary role of the Network Manager translates them into tactical KPIs and a set of services. These services are collected in the toolbox. A short cyclic consultation monitors the extent to which the tactical KPIs are achieved with the services. If needed, adjustments can be made in the toolbox. An overview of the different KPI types, including examples, is shown in the next table.

Table 2. KPI framework

	Strategy Table	Network Manager	Service providers and TMCs
KPI type	Strategic KPI	Tactical KPI	Operational KPI
Example	Less pollution in the region	Avoid traffic on link X	Number of rerouted users on link X

Task 2: Monitor and adjust

Based on data from the Assessor (from the Waterfall reports), the Strategy Table examines whether the strategic KPIs are being achieved, or whether adjustments are needed. If adjustments are needed, this is further shaped by the Network Manager. This creates a feedback loop – based on data from the Assessor – between the Strategy Table and Network Manager.

The Strategy Table also monitors whether the predefined win-win-win is met. If needed, adjustments can be discussed at the Strategy Table.

An overview of the new four intermediary roles is shown in the next table.

Table 3. Intermediary overview

	Network Monitor	**Strategy Table**	**Network Manager**	**Assessor**
Tasks and responsibilities	Merge and complete data Define view of current and predicted traffic state	Find and define common goals and KPIs Make adjustments	Develop toolbox (services) Optimise algorithms Automatic activating service requests	Monitor, assess and feedback of performance Determine added value of cooperation (per role/partner)
Relationships	Public and private data providers Network Manager	Participants are road authorities and automotive industry/service providers Assessor	Both automotive industry/service providers and TMCs Network Monitor and Strategy Table	Both automotive industry/service providers and TMCs Strategy Table
Conditions	Reliability view Willingness of parties to share data	Dialogue Possibilities to measure performance	Quality and explainability service requests Willingness of parties to follow up on service requests	Independency and auditable Trust between parties
Dependencies	Little or none; support role	Quite a lot within the region	Guided by Strategy Table	Little or none; neutral role

2.3 A common digital language for exchanging TM information

Background and approach

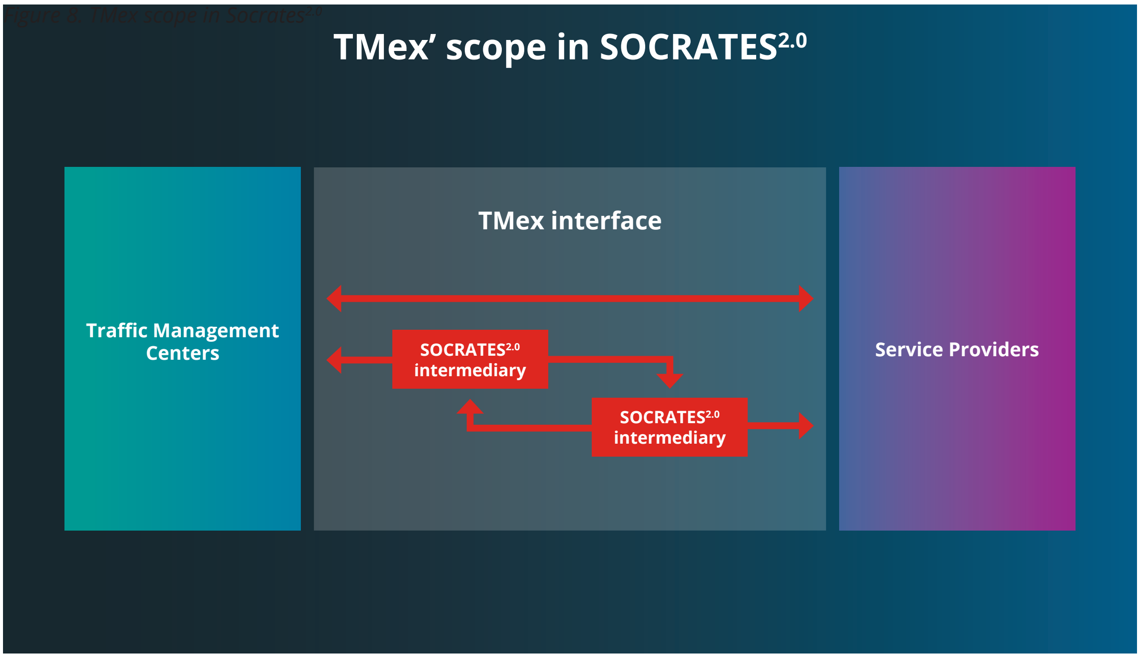
Within the SOCRATES$^{2.0}$ project, a conceptual architecture for the exchange of traffic management data between the participating partners was established under the working title TMex.

The overarching goal was to harmonise data exchange by establishing common data description mechanisms and interfaces for all partners to use. The harmonised data exchange was applied across the SOCRATES$^{2.0}$ pilot sites, and is also envisioned for a future Europe-wide roll-out of similar deployments of interactive traffic management.

During the project runtime, a harmonised data exchange was approached via a conceptual phase, looking at partner requirements and pilot site specifics. Based on those, a technical development was initiated of concrete data formats.

A major focus point of this activity was the interaction between traffic centres and service providers, called the TMex interface.

The figure below shows the overall architecture, with the TMex interface positioning in the context of SOCRATES$^{2.0}$ pilot sites. On the left, the TMCs are shown. Traditionally, they provide their data streams in a wide variety of protocols from the domain of road authorities (e.g. DATEX II, IVERA4 and RSMP). On the right, the service providers are shown. Usually, they deal with data formats that are rather industry-based (e.g., TPEG). The TMex interface concept connects the two to define a common way of exchanging data that is based on existing formats as much as possible. In the SOCRATES2.0 deployments, such connections may be supported by one or many intermediary roles, as introduced in Section 2.2. Here, TMex is also applied for any data exchange mechanism between TMCs, service providers and the intermediaries.



FAST SAFE GREEN SOCRATES2.0

Figure 8. TMex scope in Socrates2.0

The data exchanged in this context relates to sharing information and requesting services. The requesting services is route-related data that simultaneously supports optimal individual routes and serves the collective KPIs in terms of flow, environment, etc. The sharing information supports a common operational picture so all stakeholders can observe the traffic situation and take measures to optimise the situation.

An important baseline for the data format harmonisation was found in DATEX II, a well-established electronic language used in Europe for the exchange of traffic information and traffic data[6].

First, we took a number of data models from DATEX II for requesting services and sharing information and further enhanced and expanded them to meet the SOCRATES2.0 use case requirements. After that, we 'cut out' the relevant data elements and compiled a lean profile without any unused data elements.

Based on close interaction between the SOCRATES2.0 deployment partners and DATEX II experts, a DATEX II-based messaging concept was developed for the specific use cases and pilot sites. This resulted in updated DATEX II profile specifications for the three following topics:

- TMPlan for smart routing and avoidance
- Regulated zones for environmental zones
- Roadworks

[6] De Vries, Bard, 2021. Why DATEX II is a strategic choice, Presentation at: 6th DATEX II Forum, November 2020, https://datex2.eu/sites/default/files/2020-12/2020.11.25%20UF%20Webinar%20-%20D2%20as%20a%20strategic%20choice.pdf

The DATEX II-related elaborations, and experiences with them during the pilot deployments, could also be of relevance to actors outside the project. In particular the profile specifications could be reused and further enhanced in follow-up activities. The next section further details these profile specifications. The section after that summarises pilot-site-based experiences and recommended follow-up actions.

Further functional details on the usage of the profile specifications are presented in the pilot site reports[7].

Harmonised DATEX II profiles

DATEX II profile: Traffic Management Plan for network optimisation

This profile aims to communicate service requests (avoid/reroute) between the Network Manager and service providers in the SOCRATES$^{2.0}$ Optimising Network Traffic Flow and Smart Destination use cases.

Corresponding message elements include a location reference to effected links and alternative routes, the reason for the service request and the start-time and expected end-time. In the other direction, service request responses are communicated, containing accept or decline information.

This profile development is based on a combination of:

- TMPlan extension of the DATEX II group
- The strategic routes profile from the German MDM extension
- OpenLR additions from DATEX II 3.0

The result of this elaboration is provided online, allowing for it to be used outside SOCRATES$^{2.0.}$ It includes a schema file (XSD), example files (XML), a model file (EAP) and some accompanying textual guidance:

https://www.datex2.eu/implementations/extension_directory/extentions-smart-routing-and-avoidance

DATEX II profile: Environmental Zones

This profile was newly developed within the SOCRATES$^{2.0}$ project. It serves to communicate the location and characteristics of environmental zones, allowing drivers to react before they enter an environmental zone.

The profile is considered a major achievement. It addresses the current digitalisation needs to efficiently deploy local access regulations, and assists with environmental zone regulations currently being imposed in many cities across Europe.

[7] See reports "The SOCRATES$^{2.0}$ pilot in city of Amsterdam", "The SOCRATES$^{2.0}$ pilot in city of Copenhagen", "The SOCRATES$^{2.0}$ pilot in city of Munich", "The SOCRATES$^{2.0}$ pilot in city of Antwerp"

The Environmental Zone profile development is based on a combination of other profiles for the domains of traffic regulations and the UVARbox project (see Section 5.6).
The result of this elaboration is provided online, allowing for it to be used outside SOCRATES$^{2.0}$. It includes a schema file (XSD), example files (XML), a model file (EAP) and some accompanying textual guidance:

https://www.datex2.eu/implementations/extension_directory/socrates-20-regulated-access-zone-publications

DATEX II profile: Road Works

This profile aims to communicate planned and actual roadworks from a road authority to an intermediary in the Road Works use cases.

The main goal of building this DATEX II profile was to allow the intermediary to harmonise the data feeds from various (Dutch, German and Flemish) road authorities. All data feed from the partners was aligned with a harmonised, agreed-upon dataset. Information was added if one of the partner's data feed had specific useful information.

Within the Road Works use case, a number of information objects were defined that had to be included in data communication with the stakeholders of the use case. The fields included the following:

- probability_of occurrences
- probability_rate
- number_of_occurrences

In order to make this work, the Road Works container, as defined within DATEX II, had to be extended. A practical approach was foreseen within the project, in which the existing DATEX II object would be extended with the above fields (inserting). This method work sufficiently when the roadworks event was already available in the DATEX II feed from the road authority. If the roadworks event was new (not yet known to the road authority), a new event needed to be inserted. A smaller or more compact container is suggested for this purpose, as service providers are unable to provide all the same fields that are available within a DATEX II message.

Within SOCRATES$^{2.0}$, a conceptual data model was developed for the proposed Road Works container, however no final DATEXII profile was defined. This work will be concluded in a future elaboration by the European DATEX II working group.

Pilot-site experiences and outlook

Interviews with SOCRATES2.0 deployment partners provided insight into the viability and efficiency of the elaborated DATEX II profiles. The partners spoke about whether the profiles sufficiently met the need of the pilot site and use case, and whether they encountered any problems when using them.

Altogether, the DATEX II-based messaging concept in the SOCRATES$^{2.0}$ pilot environments has proven itself. There were clear benefits to using a harmonised data format for the interactive traffic management concept. Most importantly it improved the efficiency and allowed transferability between the individual deployments and communication partners involved.

The choice of DATEX II, a well-established European approach, is considered beneficial and proved to be a good baseline for a uniform approach, with promising perspectives in terms of interoperability and sustainability.

We also identified a certain level of flexibility in how messages are composed within DATEX II. Sometimes, messages could be formatted in different ways to achieve the same goal. This meant that when drafting a message, both the sender and recipient had to be consulted. Since the DATEX II messages are not entirely self-explanatory, we recommend they be accompanied by an explanation to avoid misinterpretation.

Furthermore, some open issues were identified regarding the efficiency of DATEX II-based communication. A crucial point regarding service request messages is the ability of service providers to incorporate the alternative route from such a message in their navigation algorithms. Another crucial point relates to road works information, which originates from varying data sources. Data harmonisation of such information depends on uniform source data formats, which so far has revealed many inconsistencies. So further harmonisation and usage guidance would be beneficial here.

These outstanding issues are further discussed in the Follow-Up Plan in Section 5.2

2.4 Communication to road users via information and navigation services

One of the innovations in SOCRATES$^{2.0}$ is the involvement of state-of-the-art road user services, such as information and navigation services embedded in smart phone apps or as connectivity features of OEMs. According to the cooperation framework (see Section 2.2), service providers play a crucial role in the SOCRATES$^{2.0}$ architectures by, among others, distributing service requests coming from TMCs to individual service users.

The reason to engage service providers in our concept corresponds to one of the overall project’s goals: to advance with traditional traffic management schemes. Considering the increasing penetration of private-party services, the increasing connectivity of road users and cars via cellular networks, and the increasing complexity of traffic management concepts, we feel that traditional channels, such as traffic radio and VMS, are not sufficient anymore, and need to be complemented by new channels provided by service providers. This increases the outreach and efficiency of public-body traffic management schemes, but also improves the service quality of private services. With the road users experiencing more qualitative services, we again address the win-win-win of SOCRATES$^{2.0}$.

In any of the SOCRATES$^{2.0}$ pilot deployments, private-party information and navigation services were an integral part to showcase the new opportunities arising from this concept. In this context, some existing services were upgraded with new features, or new services were installed.

Next, we want to highlight some of the innovations developed by the service providers participating in SOCRATES$^{2.0}$, indicating how these innovations look like in practice and how they can contribute to the interactive traffic management concept.

Furthermore, we discuss how service providers see their role in interactive traffic management deployments, and what the future directions might look like.

Innovative service solutions in SOCRATES$^{2.0}$ deployments

The following example shows how existing end-user services were upgraded to allow innovative traffic management schemes, as part of the SOCRATES$^{2.0}$ deployments.
In the Antwerp Smart Tunnel service[8], we deployed a proactive routing of travelers over two alternative tunnels crossing the Scheldt river. To do so, the following functionalities were implemented: a reroute advice, based on the current network state, and an awarding mechanism, via a tunnel toll reduction.

These functionalities were implemented within the Flitsmeister navigation app by Be-Mobile and the BMW in-car app, see the next figures.

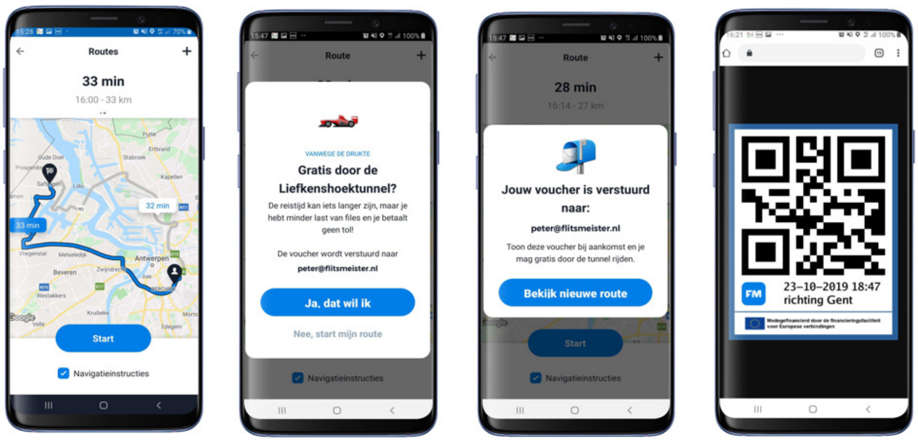


Figure 8. TMex scope in Socrates$^{2.0}$

Figure 10. BMW Smart Tunnel Drive Service

[8] See report "The SOCRATES$^{2.0}$ pilot in city of Antwerp"

Both services inform about the applicability of an alternative route, depending on the traffic state and expected travel times. They further instruct the driver on how to use the toll reduction via a voucher, to be shown at the tunnel entrance. Whereas the first feature is well-known from conventional routing apps, the toll reduction is a best example of how additional features with a traffic management focus can be seamlessly integrated in such apps. Here, a well-elaborated interaction between the service's engines, the driver and the tunnel operators (who check the vouchers) was established.

It is evident that a such use case is barely feasible with conventional channels (e.g. via VMS). Also, an approach without integration (e.g. with a separate app for the voucher) would likely not be very convenient for the driver.

In the next example, we showcase how parking guidance is embedded for drivers who are on the way to a bigger venue (stadium, arena, etc.). In this case, the benefit is not only for the TMC, by proactive management of incoming traffic, but also for service providers, as their navigation services are expanded for the 'last mile' (i.e. for the path to the final parking destination). Such a last-mile service is rarely implemented in today's navigation apps, at least not for big-venue locations with multiple and dynamically-filling parking lots.

The BrandMKRS Smart Destination service in Munich[9] aims to provide routing advice to event visitors. This is realised by targeting and approaching users on social media (via Facebook, WhatsApp, Google Maps, and text messages). Users can register and, in return, are provided with relevant information (see the next figure). On the day of the event, the user receives a route with the best access and parking destinations. This information is aligned with the user's original route, and the current traffic and parking situation.

Here, we trialled social media as an emerging communication channel, so far rarely exploited by traffic managers. A similar parking information service was delivered by BMW, again via an in-car app.

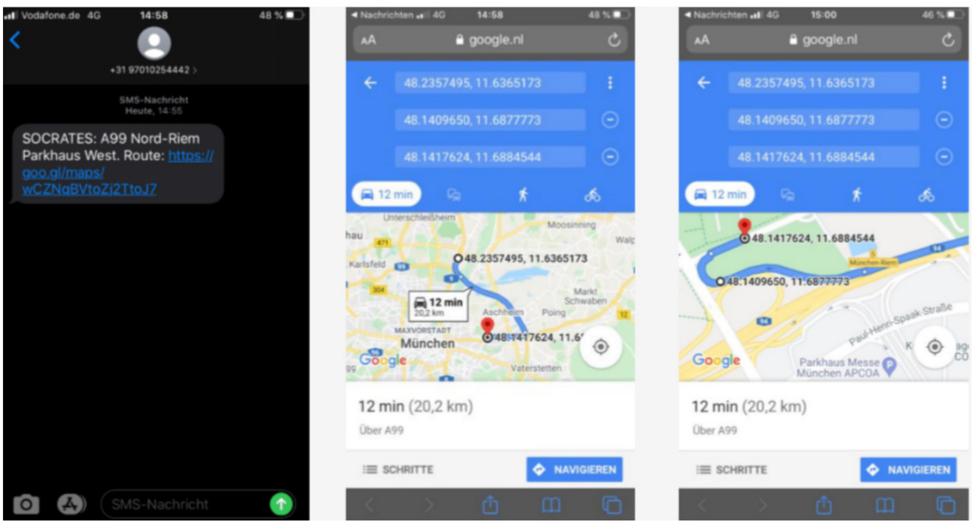


Figure 11. BrandMKRS Smart Destination service

[9] See report "The SOCRATES$^{2.0}$ pilot in city of Munich"

Another expansion to existing navigation services was showcased in the Speed and Lane Information use case in Antwerp. Here, the Flitsmeister navigation app by Be-Mobile was upgraded to mirror lane-control information (i.e. lanes open or closed, speed limits) from the lane-control system of the TMC (see the next figure).

Here, we complemented the strategic traffic management (route advice with voluntary compliance) with tactical traffic regulations (lane control with obligatory compliance) within one end-user service. The expectation is to increase the awareness and acceptance of such traffic regulations. As a side note, this raises the (long-term) question whether conventional lane-control systems, which operate via expensive VMS, could be replaced at some point.

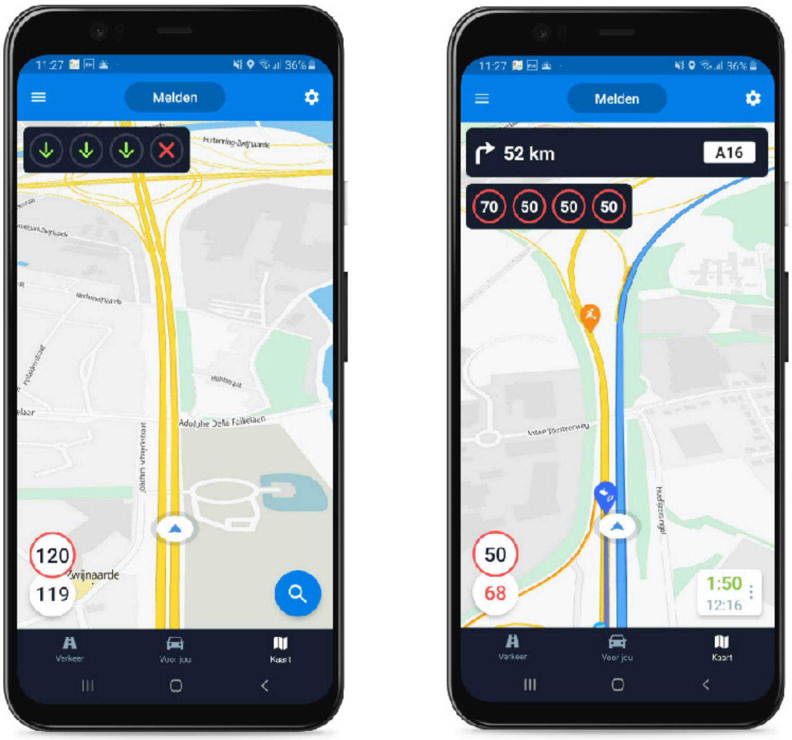


Figure 12. Speed and Lane Information by Be-Mobile

Lastly, we look at how access regulations, as an emerging traffic management scheme in many European cities, can be embedded in conventional navigation services. Here we deployed information about static and (partially) dynamic environmental zones in Amsterdam and Copenhagen[10].

Be-Mobile and TomTom demonstrated corresponding functionalities in the TruckMeister app and the AmiGo app (see the next figures). It seems evident to use navigation apps to disseminate such information, as such information is otherwise hard to communicate to drivers, especially for foreign visitors who are not familiar with local rules.

[10] See the reports “The SOCRATES$^{2.0}$ pilot in city of Amsterdam”, “The SOCRATES$^{2.0}$ pilot in city of Copenhagen”

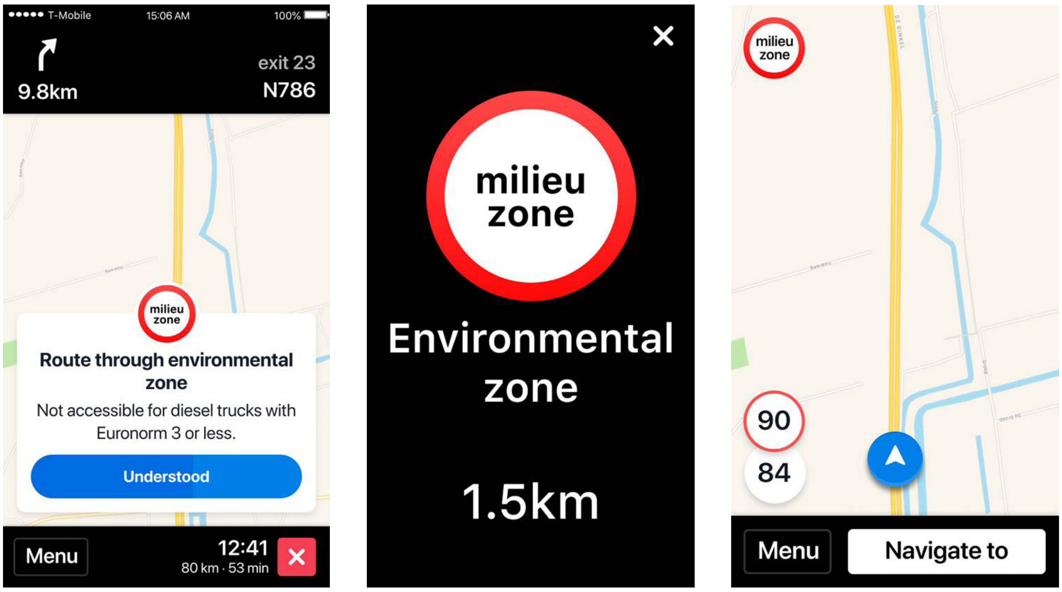


Figure 13. Environmental zones service by Be-Mobile

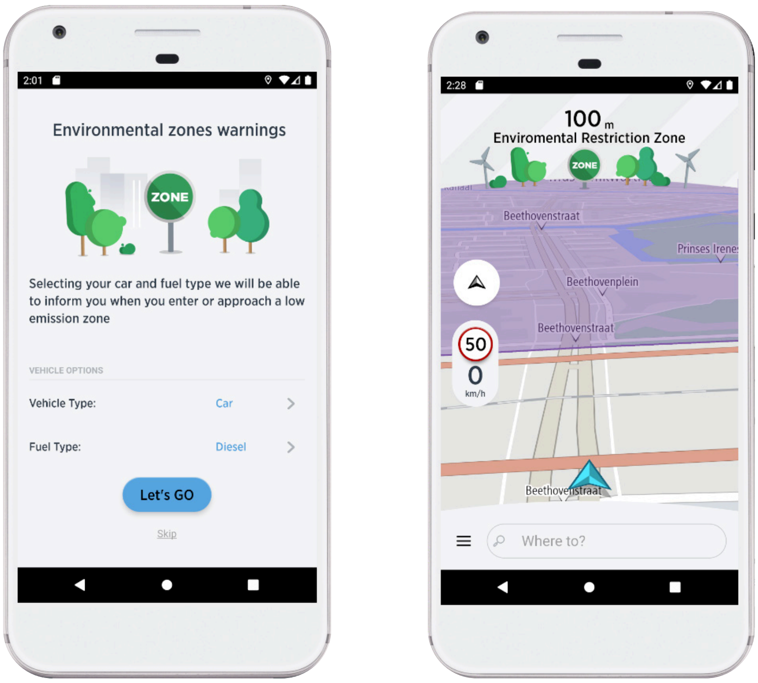


Figure 14. Environmental zones service by Be-Mobile by TomTom

Based on these examples, we learned the following:

- From an end-user perspective, the services are focused on clear and direct information about the traffic situation and travel options. There are no hints about the underlying, sometimes complex processes of communication and negotiations between service providers, TMCs and intermediaries. This simplifies the user interaction, and works towards understandability and acceptance of the traffic management advice.

- In most end-user services, there is a freedom to follow and comply with a traffic management scheme. This is done by, e.g. actively accepting or denying a reroute advice. Further, some services offer a feedback function, verifying the acceptance and behaviour of a user. With the user being in full charge of his or her decisions, and allowing communication back to the service provider, this corresponds to our vision of the 'customer as the CEO of the journey' (see Section 2.1).
- Multiple service providers can operate in parallel in the same use case, even with different communication channels (smart phone app, in-car app, social media). This is important as we expect that there is no one-size-fits-all end-user solution, but that we need to utilise all existing and upcoming channels and technologies. As service providers are usually at the forefront of such advances, this is a clear argument to have (multiple) service providers as integral parts of use cases.

Service provider's role in interactive traffic management

The service providers who participated in SOCRATES$^{2.0}$ reflected on their contributions to the project as well to the entire concept, and laid down their understanding of their role in future deployments.

One of the main arguments for their involvement is that service providers know well how to communicate with their customers via their channels, as this is part of their business model. Thus, reliability and benefits to users are one of their main strengths. Further, service providers feel that their individual and direct services can enable individualised traffic management (which has been more collective so far) and increase credibility when transmitting traffic management information.

This means they can individually address road user characteristics and demands. This was evident in the Smart Destination use case, where selected parking destinations were displayed depending on the user's route, or the Optimising Network Traffic Flow use cases, where a reason was communicated why a specified route should be avoided. Clearly, such features are impossible through the conventional communication channels of road authorities.

However, service providers also stated that they rely on the competence and knowledge of road authorities or TMCs, as they know more about things like the overall current and predicted traffic state. In conclusion, the combined strengths of services providers and TMCs provide the best benefit for the road user.

One interesting discussion item was on the final implementation of traffic management measures, as defined by the TMCs, within the private-party services. It is considered problematic if TMC-based information directs user behaviour too explicitly (e.g. 'follow route A'). Such a request cannot be integrated in the existing concerted systems of the service providers, especially not in their routing machines. Service providers need to interpret such requests to address the right target groups in the right local context.

Instead, an SR should be composed as an indication of areas to avoid, with a detailed description of the underlying cause, the intended impact and the following traffic management operations. This information could be processed more expediently from the service provider's systems, resulting in a user-beneficial service. Altogether, TMC-based SRs should address the problem and the cause very specifically, but not the solution itself. This problem orientation instead of solution orientation when communicating between TMCs and service providers is an important aspect. It counteracts the statements of some ITS stakeholders that navigation apps should purely be used a 'fulfilment assistant' for TMCs. In the perspective of service providers, they still prefer to independently design and control their own technical assets (i.e. their systems), algorithms and user interfaces.

However, mutual benefits for both TMCs and service providers arise when TMC-based information is formatted in a way that can be easily integrated into service provider's systems. A positive example is the avoid route mechanism within the SRs, as demonstrated in SOCRATES$^{2.0}$, which can be much better reused by the service providers than the similar reroute mechanism.

There seem to be even more promising perspectives for mutual benefits when deploying impact-driven and rewarding approaches, such as pioneered in the SOCRATES$^{2.0}$ Antwerp tunnel use case. In a context like this, service providers can be put in the middle of the value chain of traffic management, possibly with new (monetary) value creation opportunities.

Altogether, service providers are ready to engage in future deployments of interactive traffic management by contributing their strengths and assets and cooperating at eye level with other partners of the concept.

3. INITIATING SOLUTIONS OF INTERACTIVE TRAFFIC MANAGEMENT

This chapter is all about recommendations and lessons learned within SOCRATES$^{2.0}$ when preparing interactive traffic management solutions. We elaborate on the governance before detailing the solution to be implemented. We also provide insights into the design phase by presenting the structured approach. We guide the reader through the process based on the work executed in the SOCRATES$^{2.0}$ design activity and examples from the pilot site activities.

The following figure defines the stepwise approach elaborated, which can be interpreted as a roadmap for the deployment of interactive traffic management solutions. This approach builds on a roadmap already initiated in SOCRATES$^{2.0}$ Activity 3[11] (see the figure below), but adds experiences gained during the deployments, especially business perspectives of such deployments.

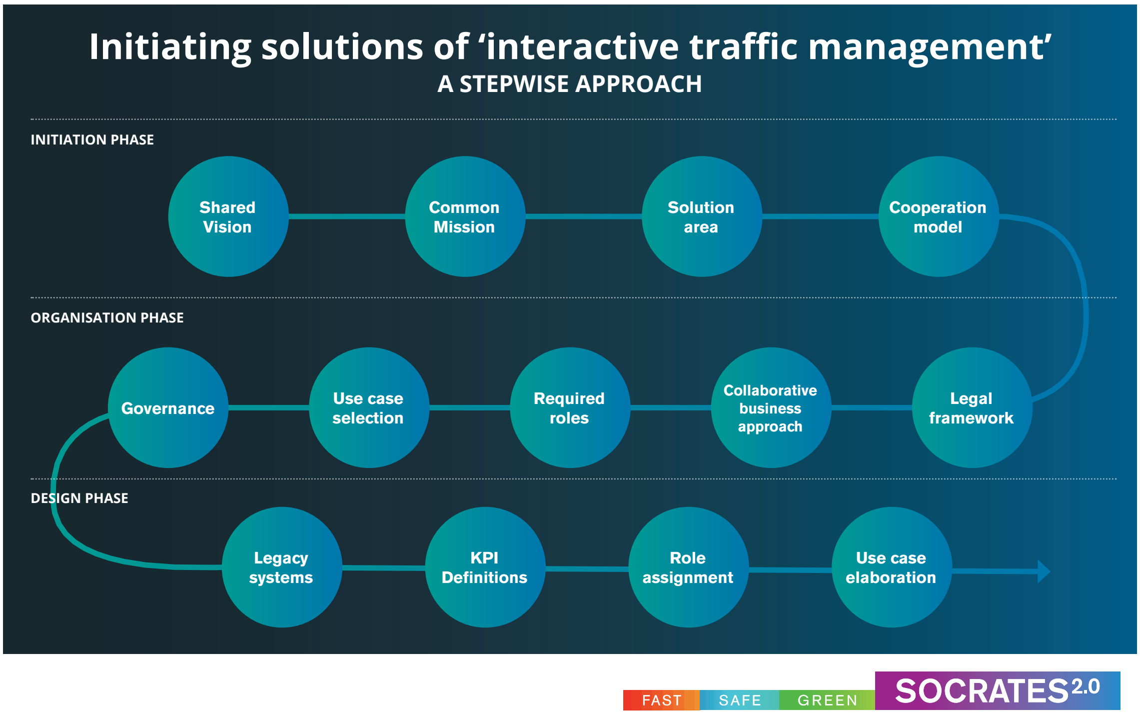


Figure 15. Roadmap for deployment of interactive traffic management

In a nutshell

- It starts with an initiation phase with the following iterative steps:

    1. Co-creation of a shared vision
    2. Identification of the common mission
    3. Investigation of the solution area and a high-level description of the improvement
    4. Pre-selection of a cooperation model

[11] See the report "Setting the stage for the deployment of interactive traffic management"

- It continues with what we call the organisation phase; this phase consists of iterative steps:

  1. Setup of an appropriate governance
  2. Selection of use cases considering local context and providing a detailed description of the use case mission
  3. Identification and selection of required roles and capabilities of (potential) partners
  4. Elaboration on the win-win-win and collaborative business approach
  5. Legal framework for cooperation

- In the design phase, the use case is further elaborated in iterative steps:

  1. Identification of existing legacy systems, services, data sources, interfaces, appropriate standards, and an inventory of required and available expertise
  2. Definition and agreement on KPIs
  3. Final assignment of the required roles, tasks and responsibilities
  4. Elaboration of the use case and system architecture (e.g. functional information flow diagram, sequence diagrams, high-level technical architecture and data exchange formats)

The next phases are at the operational level: development, testing, implementation and evaluation[12]. In this chapter we do not elaborate on those. We elaborate on the first three phases using the example of the Optimising Network Traffic Flow (ONTF) use case.

3.1 Initiation phase

The initiation phase is the starting point for organising the public–private cooperation to initiate interactive traffic management. This Chapter 3 primary covers the Coordinated Approach model (see Section 2.2). This model is based on our SOCRATES$^{2.0}$ experiences from real-life tested use cases at four pilot sites. The first phase enables cooperation between partners who are not yet familiar with each other. It is advisable that one party, often the public road authority, formally initiates the cooperation and provides some form of steering. However, any of the partners can take the initiative and propose a cooperation.

This phase may need several iterations to reflect new insights and allow new stakeholders to get on board. As this phase lays the cornerstone for all following activities, a thorough elaboration is recommended. Changes can still be applied in later stages, but will require more efforts.

[12] See the SOCRATES$^{2.0}$ Final Evaluation report and the reports "The SOCRATES$^{2.0}$ pilot in city of Amsterdam", "The SOCRATES$^{2.0}$ pilot in city of Copenhagen", "The SOCRATES$^{2.0}$ pilot in city of Munich", "The SOCRATES$^{2.0}$ pilot in city of Antwerp"

Step 1: Co-creating a shared vision
The shared vision builds on the principle of creating benefits and value for all stakeholders in traffic management: road users, public authorities and service providers. This is the win-win-win in our concept. Based on the established individual and common goals addressing the problem and needs, a set of high-level benefits is identified for each partner. The quantification and valuation of these benefits are the elements that define the 'win' for each of the stakeholders.

The sessions that facilitate this initiation phase not only provide a good use case, knowledge exchange and relationship building between the public and private parties, but also contribute widely to developing the necessary understanding of each other's cooperation needs, constraints and opportunities. All these aspects contribute to the development of a shared vision for cooperation between all the partners. Ultimately also a solid level of trust is established between all parties, supporting the right setting for aligning individual goals and services into common goals.

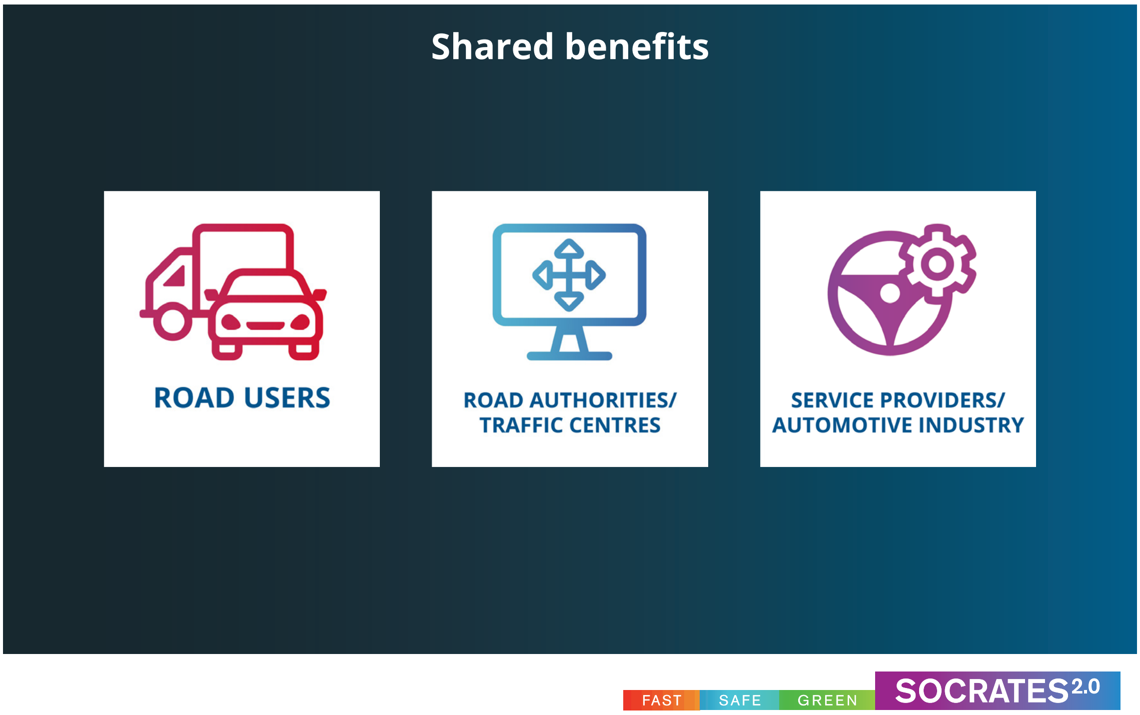


Figure 16. Shared benefits

Step 2: Identify the common business mission
At the start of a new cooperation the public and private organisations involved share their initial insights and knowledge of the initiated mission (e.g. congestion or accessibility within a specific area, region or country). They also briefly introduce their proposals and available assets and resources that can contribute to the mission. Public partners describe current and future challenges and define the agreed goals and strategy. That also includes the available traffic management systems and services used to tackle the problems. Private partners present their expectations, goals, solutions and opportunities (roadmaps) for their current and planned services. These include both data and end-user services for

information and navigation. The decision to proceed with a cooperation should be based on a positive joint assessment that the sum (or combination) of the presented proposals, assets and resources is valuable and contributes to the mission and general solution.

Step 3: Investigate the solution area and scope

Potential partners operate on different geographical levels (regional, national, European and worldwide) and must determine the outer boundaries of the intended solution. So the questions include: What road types and road users are considered? Is public transport and P+R included?

Also, more detailed information on the solution area can be provided such as the provision of route recommendations using roadside infrastructure and navigation services. Based on the information from the solution area, the required capabilities can be derived. In this case, that involves displaying advice via roadside infrastructure or routing advice via connected (navigation) services. When pre-selecting suitable cooperation models, the information gathered for solution area plays an important role as it already identifies potential stakeholders. The type of stakeholders identified influences the selection of suitable cooperation models, as the preferred cooperation model will influence the selection of required stakeholders

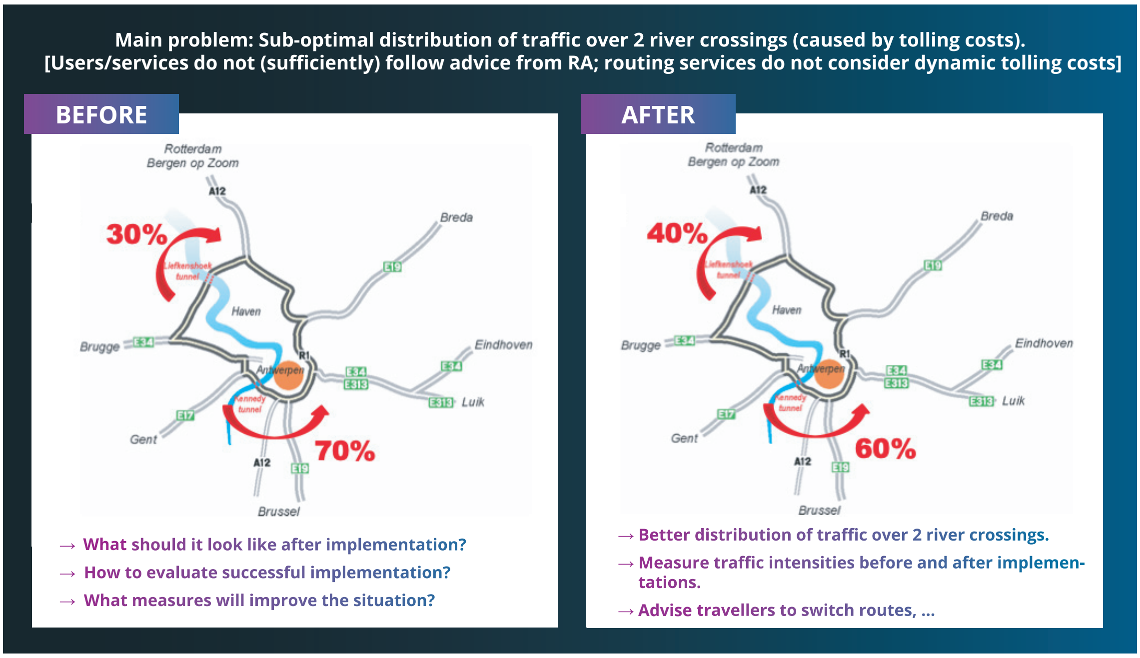


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Figure 17. Pilot site Antwerp, use case ONTF - business problem and solution area.

The use case description finally outlines the agreed solution area from the user perspective and is related to the common problem that the cooperation aims to solve. At the start of the new cooperation, multiple high-level use cases for the problem can be created and evaluated in terms of viability, usefulness, feasibility and scalability. Gradually working on the use cases is the core for progress in terms of design, organisation, development, operations and improvement. The complexity of the use case depends on the ambitions and resources the partners bring together. In the next phase (**3.2** organisation phase) partners dive into the details of the selected use case(s).

Step 4: Pre-selection of cooperation model
The cooperation model details are selected based on the initial shared vision (step 1), a first glance at the common business mission (step 2) and possible solutions (step 3). The SOCRATES$^{2.0}$ cooperation framework provides the tools for this. Partners show and explain their interest in taking up one or more roles. Missing stakeholders (e.g. adjacent road authorities who may have an interest) are identified and invited to join the cooperation. In this phase the cooperation is still volatile, since the participating partners are not yet definite and the roles not yet assigned. Potential conflict of interests can rise to the surface but do not need to be solved in this phase. They could however lead to partners leaving the cooperation, or prevent trust building.

3.2 Organisation phase

In the organisation phase we look at the following iterative steps:

1. Setup of an appropriate governance.
2. Further elaboration of the use case(s) to solve the collective problem, considering local context and providing a detailed description including use case goals, boundary conditions and main stakeholders.
3. Identification and selection of required roles and capabilities of (potential) partners.
4. Elaboration of the win-win-win and collaborative business approach.
5. Legal framework for cooperation.

Step 1: Governance
The selection of the cooperation model has an impact on the governance, which needs to be set up to build the organisation structure of the cooperation. Interactive traffic management for simple solutions (e.g. data exchange) require a pragmatic governance. For the more complex use cases (e.g. coordinated actions), a more elaborated governance is needed. Aspects that the governance should address are:

- Progress on collective results
- Maintaining a trusted environment
- Representation of partners
- External stakeholder management
- Management of the cooperation

In cooperation there should always be a healthy balance between individual partners and collective interests. With collective interest, we mean the expected results of all partners combined. The management of the cooperation should first focus on the collective results without jeopardising the individual interests. In order to build and maintain the trusted environment of the cooperation, parties should agree on a set of principles and rules of engagement: the choice and nomination of each party's representatives, the chair and support of the cooperation, the communication and meetings, and the do's and don'ts to build and maintain trust. These principles and rules are important not only for the initial or current partners but also for the introduction of new partners and the departure of partners occur.

Step 2: Use case selection
In step 2, a working group is established to elaborate on the high-level description of a specific challenge in a use case. The following format can be used, containing a summary, background, objective, expected benefits and variations.

Then a decision is made on which use case variant is preferred. Aspects to consider here include the following:

1. Match with the shared vision.
2. Relevance for end users.
3. Added value for collective mission and problem.
4. Most appealing for each partner.

As an example, in SOCRATES$^{2.0}$ we started with 20 use case variations, then brought that back to 14 and finally we choose the top 5 for deployment.

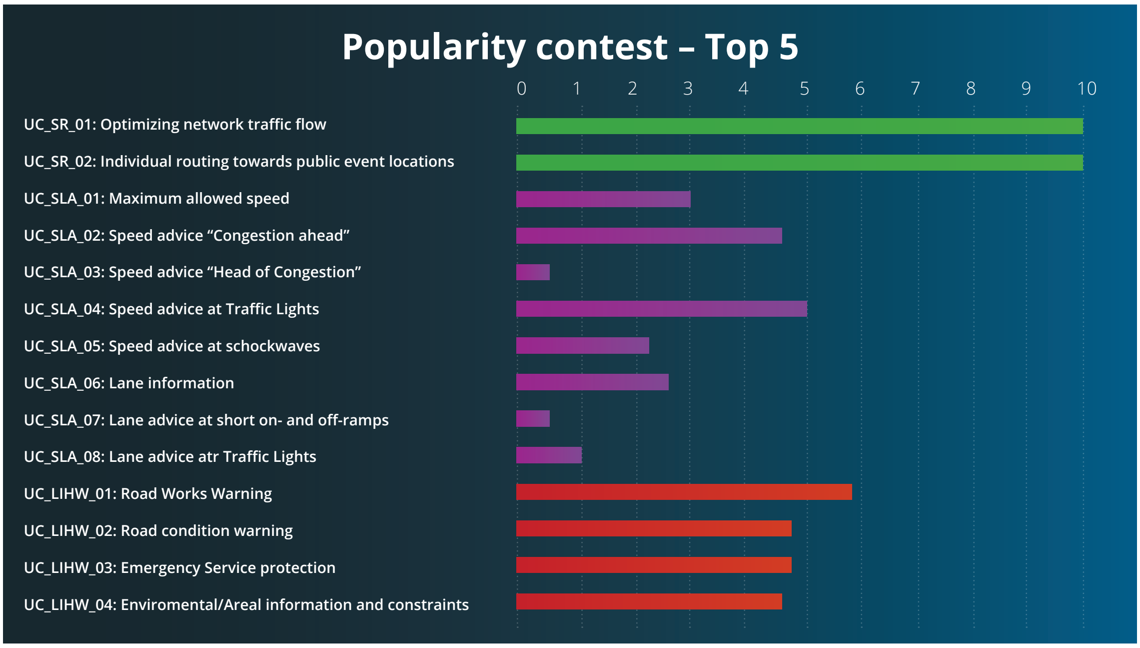


Figure 18. example of use case selection

A mission was stated for each intended use case deployment. A use case mission is a general statement of how you aim to achieve the vision. In this phase, multiple variations of the use case are possible. However, the use case mission remains the same and should provide guidance for the underlying details.

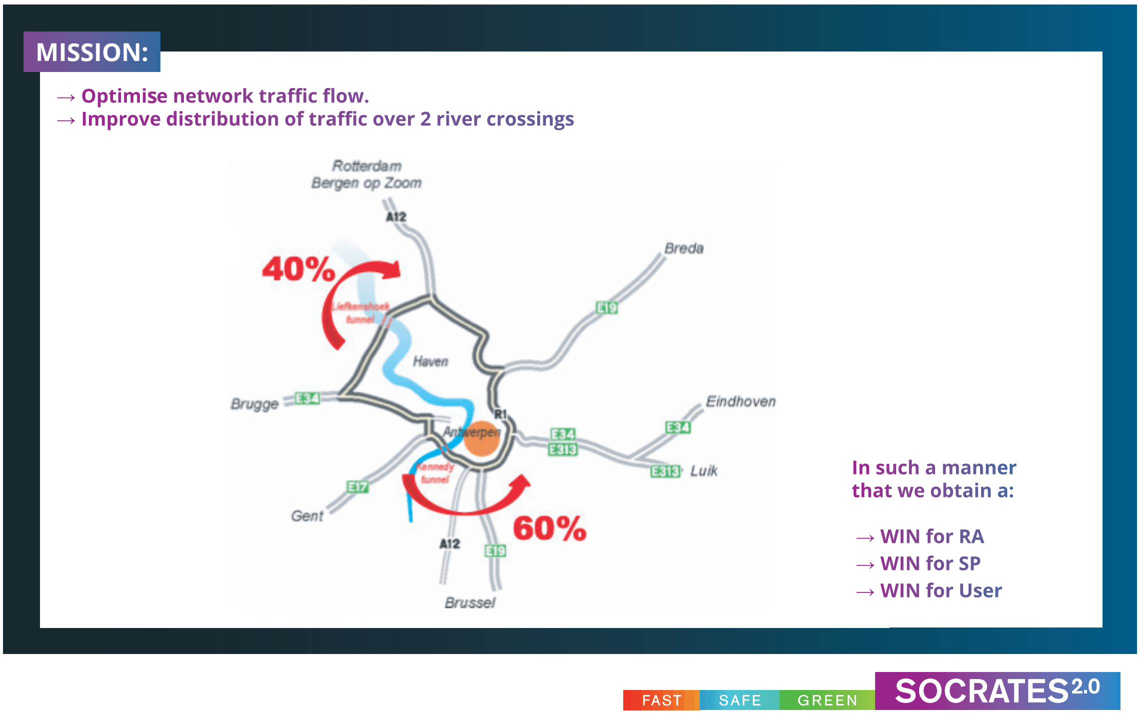


Figure 19. example of solution mission

Step 3: Identification of required roles

This step is about building the cooperation in terms of roles following the SOCRATES$^{2.0}$ cooperation framework. In this phase partners are not yet assigned roles. The focus here is to detail the required roles and attached tasks to those roles.

Table 4. Example of role/task detailing

Role	Tasks
Data Provider	Provide required data to Network Monitor / clarify quality
Strategy Table	Create win-win-win / align public and private goals / define KPIs / set up toolbox / monitor (& redefine) strategic goals and KPIs
Network Monitor	Collect aggregated data from public and private data providers / fuse data / predict state of the network / assess data quality / respect data agreements
Network Manager	Configure KPIs / create problem state / identify an effective scenario to solve the problem / send service requests / evaluate and improve scenario
Assessor	Validate partner impact / report on impact and KPIs / virtual rewarding / data archiving
Service provider	Receive and assess service requests / activate routes / measure own impact and inform Assessor
Traffic management centre	Receive and assess service requests / activate routes / measure own impact and inform Assessor

Step 4: Aligning and elaborating the business approach
Based on lessons learned and experiences from four pilot sites, multiple business ideas emerged for the different SOCRATES$^{2.0}$ cooperation models (see Section 2.2).

We structured the business growth process along the following three stages of maturity:

- Piloting stage (e.g. what we did in the SOCRATES$^{2.0}$ project)
- Effort-driven business model stage
- Impact-driven business model stage

In the first piloting stage, trust needs to be built between partners before cooperation can be effective. Learning and building trust for a sustainable cooperation are the main objectives in this stage. No immediate impact on public and private long-term goals can be expected. Short-term goals for this stage are building a common understanding on required content, suitable cooperation model(s), experience and assets each party can bring to the table. The first iteration of this stage can be challenging and time consuming. But after establishing a first concept of the technical chain, later improvements or iterations go faster.

The intended procedure is to start with the piloting stage, then move to the effort-driven business model, and after that the impact-driven business model. Stages can be skipped depending on the complexity of the use case and number of partners. Note that the impact-driven business model is only viable for the Coordinated Approach, where a change in end-user behaviour is needed to create impact. When partners do not have a mutual gain for sharing data/information with the end users, an effort-driven business model can be considered.

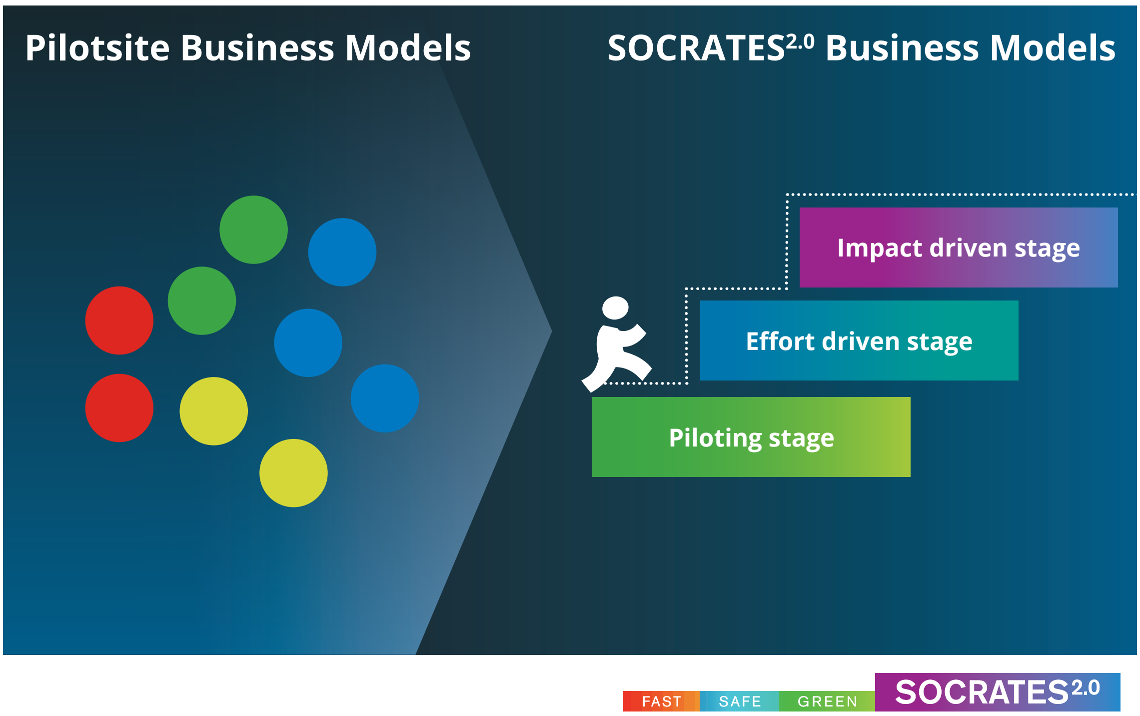


Figure 20. Stages for creating business models

Depending on the stage of maturity, the details on the collective business model are worked out by the partners. See chapters 4.4 and 5.3 for more details regarding business models.

Step 5: Legal framework for cooperation
Working together at a piloting stage is a financial challenge and risk for most partners. There is no clear business model or guarantee that individual goals will be met. So to cover the initiation costs, a governmental subsidy or compensation is advised. The distribution of the subsidy should be related to the resource contributions of partners.

In relation to the cooperation framework, a legal and financial framework is needed to progress on the collective business development. Legal-financial aspects that need to be explored are the following:

- Procurement of services and paying for delivered impact
- Flexible procurement due to the pace and changes of new technology
- Dealing with how to reward road users in relation with the tax system
- Management of intellectual property rights
- Agreement on data ownership
- Considering GDPR requirements

A more detailed outline of this step still needs to be discovered and experienced in future research and deployment projects. In SOCRATES$^{2.0}$, only first experiences in real-life environments were captured, discussed and reflected on in Section 4.1. We determine that current legal and financial frameworks still provide several constraints that need to be solved first to create an equal public-private cooperation.

3.3 Design phase

In the design phase, the use case is further elaborated in iterative steps:
1. Identification of available legacy systems, services, data sources, interfaces, appropriate standards and an inventory of required and available expertise.
2. Definition and agreement on KPIs.
3. Final assignment of the required roles, tasks and responsibilities.
4. Elaboration of the use case and system architecture (e.g. functional information flow diagram, sequence diagrams, high-level technical architecture and data exchange formats).

Step 1: Identify legacy systems

Interactive traffic management is rarely built from scratch. In most cases, local, regional and national traffic information systems, procedures and standards already exist to a certain extent. There are multiple aspects to consider here:

- TMC central systems (e.g. decision support)
- Roadside equipment (e.g. actuators)
- Private end-user services
- Existing user base
- Data types, data collection and data coverage and quality (sensors)
- Exchange formats and standards
- Specific expertise

An elaborate investigation should be conducted of existing systems, services and procedures (e.g. on decision support) in TMCs and on the roadside (e.g. VMS, ramp metering, traffic controllers). Also, service providers need to clarify what services (e.g. in-car, navigation apps, social media) can be made available and how this can be done. It is also important to know how many active users can be reached or recruited for new services. What data sources, sensors and monitor systems are in place and whether that data is suitable and available for the intended use case. Identify existing interfaces and standards for data exchange. Create an overview, detail pros and cons, and decide for each interface which standard data exchange profile is most appropriate. Note that multiple standards may be available for each interface, but avoid developing new ones. Last but not least check the required and available technical standardisation expertise; DATEX II in particular. The main role for DATEX II experts is to guide partners to existing formats and to support the usage of those formats, not to create new variants.

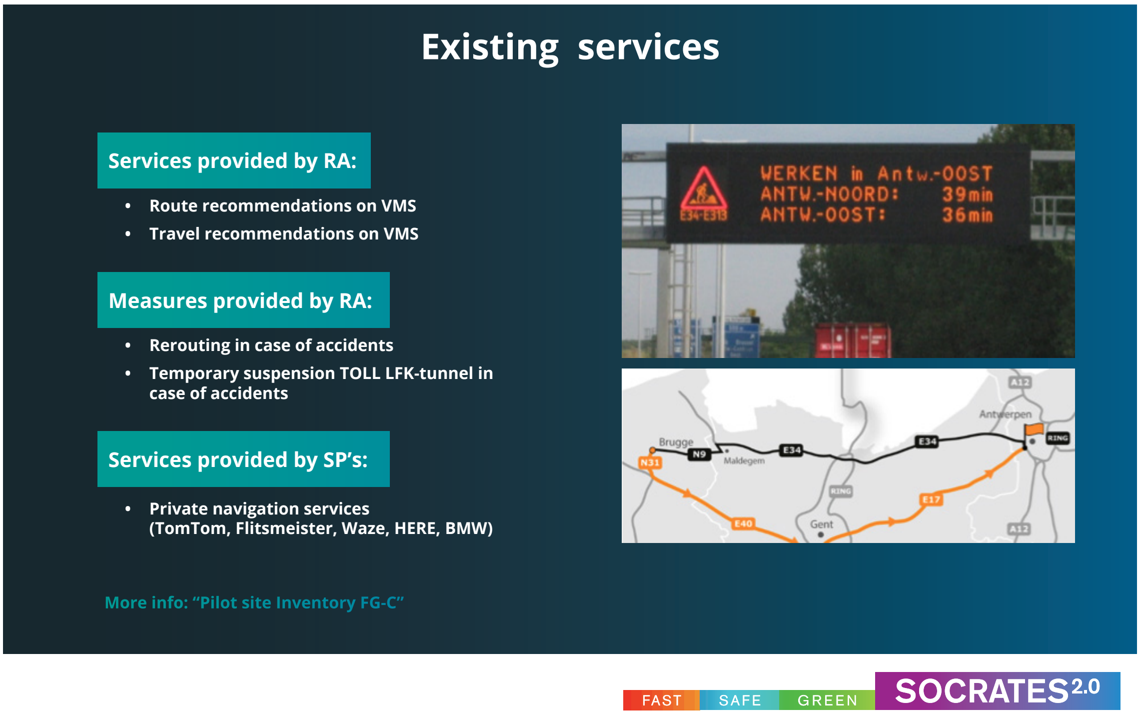


Figure 21. Identified existing services

Step 2: Definition of KPIs

Translate the identified and agreed common goals into an initial set of KPIs to measure the impact and functioning of the jointly developed service(s) at a strategic level. This is done to manage and monitor the performance and success of the cooperation.

These strategic goals then need to be translated into operational KPIs and are used to determine the network problem state. The definition of suitable KPIs is also crucial for identifying relevant data for evaluating the impact of services that will be needed for impact-driven business models.

Step 3: Assignment of roles and tasks

Part of the use case progress is the distribution of roles among partners. Some intermediary roles can be integrated and/or conducted by the same partner. This involves considering who can perform the needed role best. This also depends on legacy, ambition and the position of different partners. A basic structure of roles and responsibilities is designed for the specific goals of the use case. The roles are: intermediaries, data providers and service providers and the TMCs. More or fewer functions (or tasks) can be added to each role to develop a tailored cooperation framework. The added value of each role should be made measurable.

Table 5. Example of public-private role distribution

Role	Leading Partner	Supporting Partner
Strategy Table	MAPtm	NDW
Network Monitor	NDW	
Network Manager	RWS	Technolution
Assessor	MAPtm	
Service provider	BMW, Be-Mobile TomTom, BrandMKRS	
Data provider	HERE, BMW, Be-Mobile, NDW, TomTom	
Traffic management centre	RWS AMS PNH	

Step 4: Detailing the use case

Looking at the example of the ONTF use case in Antwerp, we will elaborate on detailing the use case.

This use case aims for a better distribution of traffic on the ring road around the city, especially when the southern part of the Kennedytunnel (B) becomes congested and there is still capacity on the northern part passing the Liefkenshoektunnel (A), which is a toll tunnel.

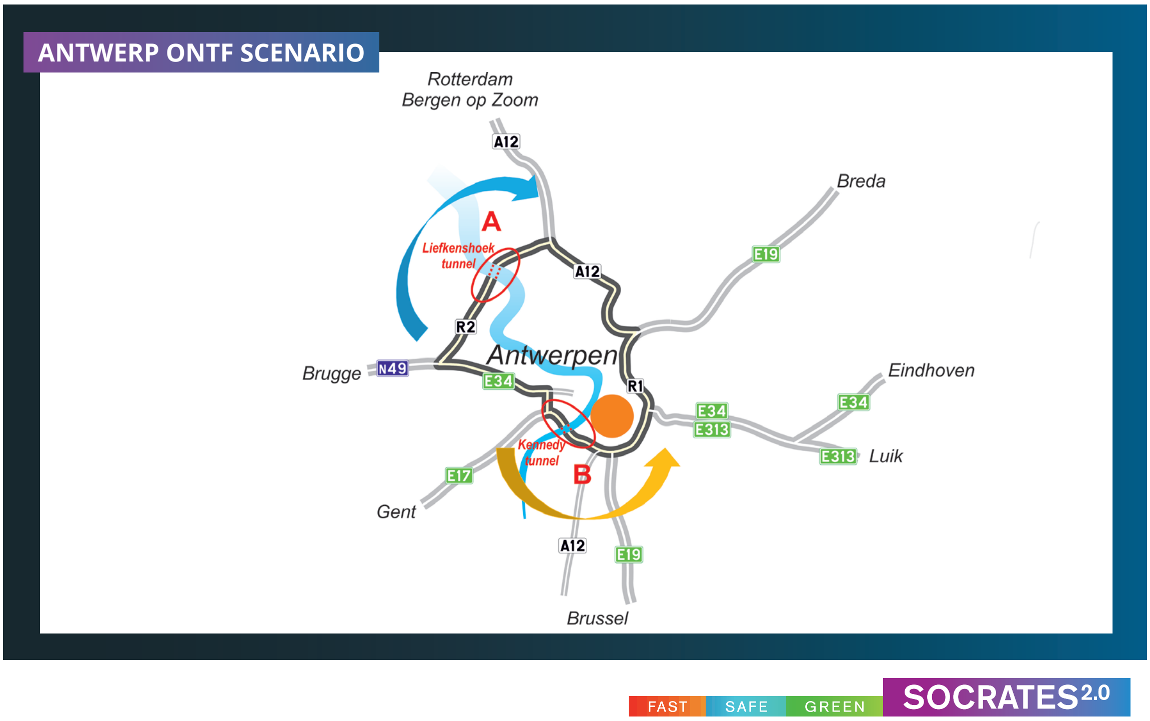
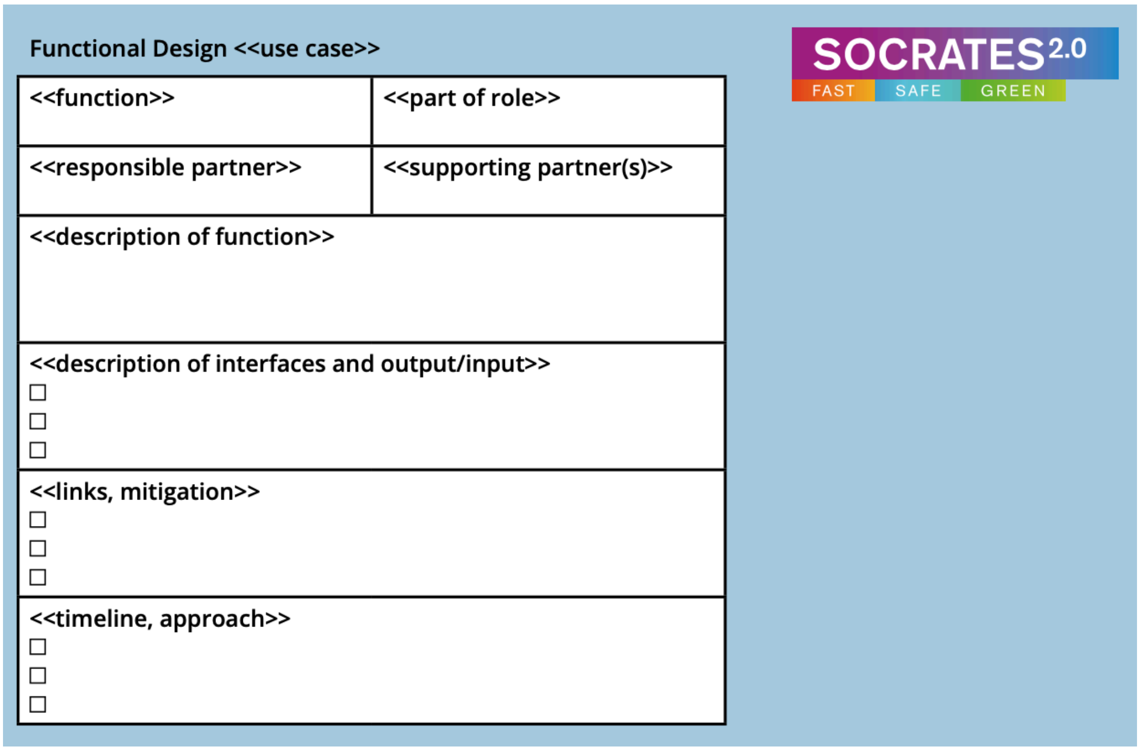


Figure 22. Antwerp ONTF Scenario

When detailing the use case, we recommend starting with a detailed look at the different levels:

- Strategic level – describing the policy goals e.g. (1st) increasing network efficiency; (2nd) reducing emissions and improving traffic safety**.**
- Tactical level – describing the target level, e.g. Distribution of traffic flows over the two river crossings → optimal distribution.
- Operational level – detailing on the actual measures to be taken e.g. RA: Impose (dynamic) toll, and SP: Advise users to take certain routes, ...
- Situational level – elaborating on the status or situational picture e.g. Actual traffic conditions, actual distribution of traffic flows, origin-destination patterns**.**

It is also helpful to use an appropriate template to describe the use case(s).



<<function>>	<<part of role>>
<<responsible partner>>	<<supporting partner(s)>>
<<description of function>>	
<<description of interfaces and output/input>> ☐ ☐ ☐	
<<links, mitigation>> ☐ ☐ ☐	
<<timeline, approach>> ☐ ☐ ☐	

Figure 23. Use case function template

In a second step, a system overview can be sketched including the levels mentioned above, naming the contributing parties, adding existing and required new roles and services and the relationship between them.

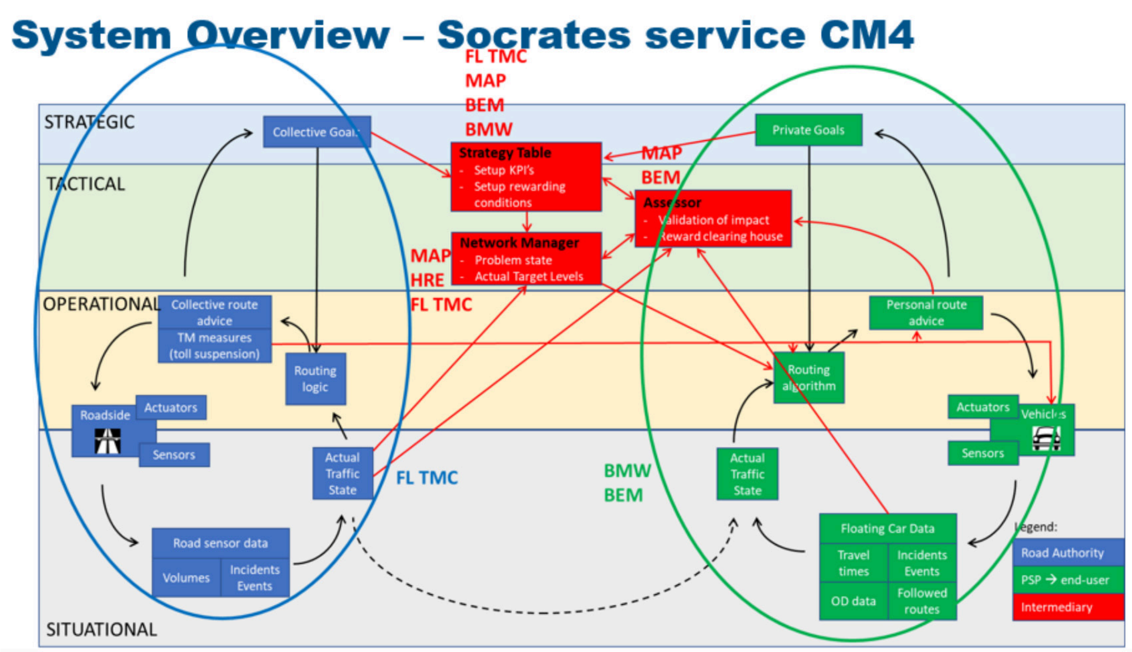


Figure 24. System overview Antwerp ONTF

In a third step, it is advisable to accurately record and agree on:

pre-conditions – activities that must take place or conditions that must be true before the use case can be started.

- post-conditions – state of the system when concluding the use case.

Pre-conditions – CM4

Pre conditions: activities that must take place or conditions that must be true before the use case can be started:

- Tasks, roles, responsibilities need to be elaborated, identified & agreed.
- Sufficient amount of test users available.
- Agreed toll- and rewarding system (also external stakeholders).
- Agreed monitoring system.
- Definition of location and trigger condition that activates the measure (detour recommendation for travellers passing Kennedy Tunnel plus toll reduction) → e.g. splitting percentage in use of Kennedytunnel vs Liefkenshoektunnel is expected to reach a certain threshold level
- Definition of protocol to be used and minimum profile requirements to be met for detour recommendation and toll reduction message.
- Definition of location and trigger condition that deactivates the measure (no more detour recommendation and toll reduction) → e.g. splitting percentage in use of Kennedytunnel vs Liefkenshoektunnel is expected to reach a certain threshold level.
- Identify legal constraints which may jeopardize data exchange between partners → to be defined by all parties collecting and exchanging data.
- Define characteristics of Beta/Test Users which shall be addressed to test the service → to be defined by all parties (e.g. commuters travelling from A to C via Kennedy Tunnel).
- Pre-condition for SP's and users: Traveller intended to use Kennedytunnel, prior to getting incentive.

Figure 25. Pre-conditions ONTF Antwerp

Post-conditions – CM4

Post conditions: state of the system at the conclusion of the use case execution. This description includes minimal guarantees (what must happen even if the actor's goal is not achieved?):

- Rewarding conditions should be taken into account by the PSP's routing algorithm.
- Benefits
  - For road authority: better traffic distribution
  - For service provider: additional information to improve routing and end user service, additional revenue from road authority
  - For traveller: reduced travel costs, improved information

This description includes success guarantees (what happens when the actor's goal is achieved?):

- Road users have changed their routes.
- Improved distribution of traffic over 2 river crossings when toll is lowered/suspended for certain users.
- Valid business model is identified.

Figure 26. Post-conditions ONTF Antwerp

The last step is to sequence diagrams, which can help visualise the flow of information and chain of interaction between actors and services.

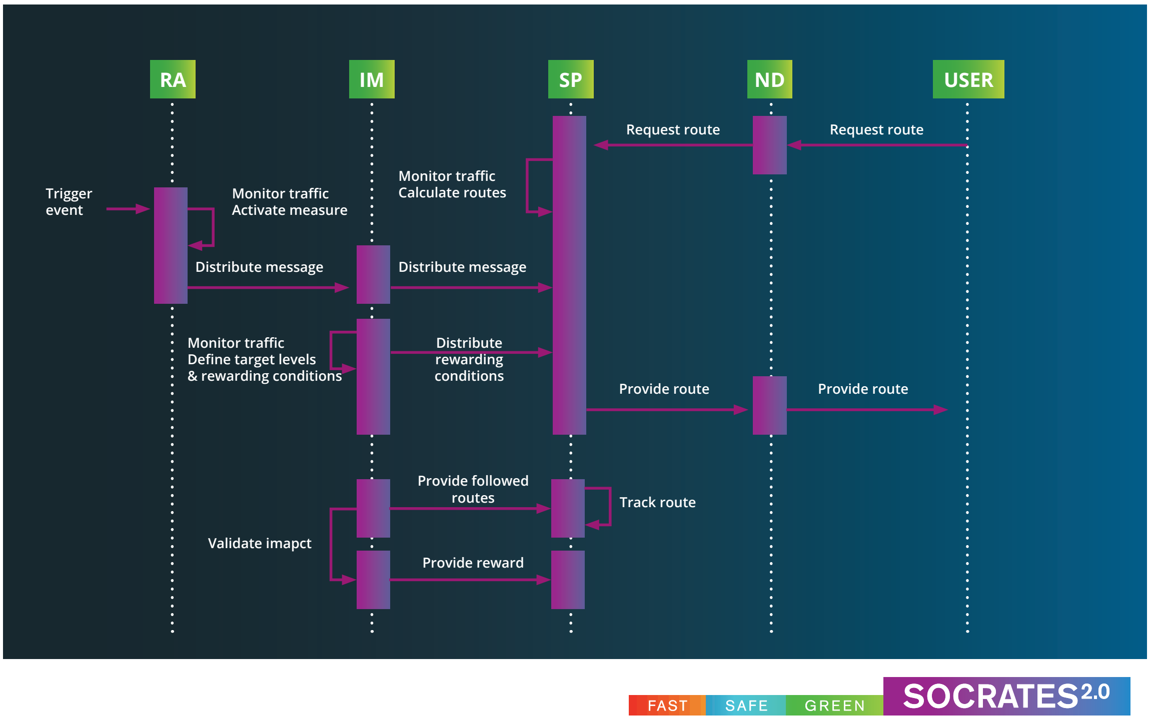


Figure 27. Sequence diagram ONTF Antwerp

The sequence diagram and the system overview help to identify interfaces that need to be further elaborated in the discussion among the actors considering required data/signal, data formats and standards, security mechanisms, etc.

Following the stepwise approach, as described in this section, the SOCRATES$^{2.0}$ partners were able to reach a common understanding of the business problem, align solution areas and KPIs and prepare the implementation phase in a way that reduced unforeseen obstacles and hurdles and guaranteed a smooth preparation of the solutions and pilots.

4. ENABLERS AND BOTTLE-NECKS FOR INTERACTIVE TRAFFIC MANAGEMENT

SOCRATES 2.0
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SOCRATES2.0 paves the way for the next generation of traffic management. On the path ahead lay several concepts and opportunities, or generally speaking, enablers, which can facilitate or accelerate the concept of interactive traffic management. But there are also challenges, impediments and bottlenecks, which can delay or even hinder some of the envisioned goals.

The enablers and bottlenecks can affect any traffic management solution during the preparation or deployment phase, either at pilot sites or in a European roll-out. Also, they will likely differ depending on the type of use case or local conditions.

In the SOCRATES2.0 Activity 2 report[13], potential bottlenecks were analysed before the pilots took place and clustered into the following categories:

- Data bottlenecks
- Technical bottlenecks
- Organisational bottlenecks
- Business-related bottlenecks
- Legal bottlenecks
- Conceptual bottlenecks

The initial bottleneck analyses can now be revisited based on the experiences and evaluation outcomes of the planning, deployment and operation of the concept at our four pilot sites. The project also provided a number of explicit enablers, such as the cooperation framework and the TMex concept (see Section 2).

The next chapters highlight the lessons learned about selected enablers and bottlenecks. These lessons are also placed in the context of the broader idea in interactive traffic management and public–private cooperation. In this context, higher-level actions are determined for use outside this project, for instance in legislation or standardisation, and recommendations are given on how to handle the enablers and bottlenecks in future interactive traffic management activities.

[13] Koller-Matschke, I. et al., 2018. Proposed Cooperation Framework & Bottlenecks, Deliverable of the SOCRATES2.0 project. https://socrates2.org/download_file/force/112/184

4.1 Data enablers & bottlenecks

Accessibility of data

In interactive traffic management, availability and exchange of data is one of the cornerstones for successful implementation. Relevant, respectively required data is often in the domain of various stakeholders. Specifying and agreeing on suitable terms & conditions for data exchange and usage while on the same time guaranteeing privacy and last but not least identifying sustainable and attractive business are key for successfully opening up the access to data sources and thus enabling “interactive traffic management”.

In SOCRATES$^{2.0}$ the partners operated in a special, pre-commercial environment which removed the obstacles for data exchange. In other words, data exchange mechanisms between affected partners were planned and deployed within the pilot environments. Any arrangements for data provision were made via pilot specifications, especially via the intermediary concept. Due to this project-specific framework in place, the mutual trust between the involved parties and the introduction of the concept of a trusted intermediary, data could easily made available and shared amongst the involved stakeholders.

Due to these specific circumstances it was neither required to elaborate appropriate business models nor to setup specific terms & conditions for the data exchange. Still, in the Munich pilot site, the German National Access Point could be used as technical enabler for data exchange, including related and existing terms & conditions. Further, in the Amsterdam pilot site, the intermediary role Network Monitor was implemented and used as technical enabler for exchange of data.

It has to be realised that such a high level of data accessibility, as demonstrated in the SOCRATES$^{2.0}$ pilots, cannot be taken for granted, especially when there is a situation with no funded project. The pure provision of digital data, such as Traffic management measures, can be mandated by law, as already done by EC Delegated Regulations[14], However, such regulations will most-likely not cover all data, as required in complex Traffic management schemes, as demonstrated in SOCRATES$^{2.0}$. Thus, data accessibility, sufficient to allow interactive traffic management, cannot be guaranteed this way. It can neither be guaranteed, that such data is reused and integrated by all relevant partners of interactive traffic management.

In contrast, we have shown in SOCRATES2.0 that data accessibility, sufficient to allow interactive traffic management, relies on mutual agreements and agreed interactions between affected partners. This has been concretised in SOCRATES$^{2.0}$ via cooperation models, and should be further elaborated as business models (see Section 5.3.).

[14] There is an obligation to provide some traffic management-related information by road authorities, using the DATEXII standard and a National Access Point, however only for certain parts of the road network. See: European Commission (2014). Commission Delegated Regulation (EU) 2015/962 of 18 December 2014 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services.

Those aspects still need to be addressed for future “interactive traffic management” solutions.

Availability of data

The implementation of some innovative aspects of interactive traffic management will not be attainable without relevant data being available.

First, availability refers to data and information that makes digitalised Traffic management possible, i.e. any data about the traffic state (e.g., traffic volumes and speeds), triggering conditions (e.g., events, air quality) and corresponding Traffic management measures. Such data and information usually lies in different hands and in different formats. Within SOCRATES$^{2.0}$, this was not a big issue, as the majority of data, as required for the SOCRATES$^{2.0}$ use cases, was already available or made available by project partners, e.g. by digitalising new management schemes.

However, as stated above for data accessibility, this cannot be taken for granted in any circumstance. With the aim of a large-scale roll-out of interactive traffic management, data and information about any transport infrastructure elements, and from any corresponding authorities needs to be available. This is also true for the availability of data (e.g. speed and volume) for the lower road classes and rural areas. Looking at medium- and small-size municipalities in Europe, traffic management related information is sometimes not digitalised sufficiently, or even not existent. In this context, a stronger support and investment into the technological advancement of the transport network and related authorities, e.g. via sensors and TMCs, is an ongoing field of action. Several follow-up projects tackle this issue[15].

Availability of data is also relevant for impact-driven approaches in which the contribution of the involved stakeholders (public, private and end users) to the successful operation shall be not only measured but also incentivised. This relates to data and information about efficiency and reaction of road users, regarding Traffic management measures. Such data is a very innovative aspect in SOCRATES$^{2.0}$, and requires special attention.

To measure the performance of the single services contributing to an interactive traffic management solution, information is required such as:

- the number of end users reached with a specific service, or
- the number of recommendations accepted by end users, allowing insights into follow-up behaviour.

[15] For example, the new SATURN project in Germany aims to digitalize Traffic management measures in smaller municipalities, and provide such information to service providers in a harmonized way via the National Access Point. See:https://www.bmvi.de/SharedDocs/DE/Artikel/DG/mfund-projekte/saturn.html

Based on such information, it will be possible to measure:

- the effectiveness of the system,
- the contribution of stakeholders and
- the behavioural changes / willingness to adopt of individuals, thus constituting a feedback loop.

Within SOCRATES$^{2.0}$ this kind of insights was barely available, e.g. via limited data evidence by the Evaluation activity, as this touches the very sensitive interaction (GDPR) between service providers and their end users.
However, new impact-driven business models / incentive schemes may require the gathering and exchange of this information. The partners of SOCRATES$^{2.0}$ see this topic as relevant for future activities, e.g. looking at frameworks and mechanisms to make end-user-based and service-provider-based data available in a wider scale.

Quality of data

When acquiring data from external parties, it is not always clear if the data meet the requirements of the data consumer. Quality of data is rarely systematically assessed and transparently documented. The reliability and safe operation of services contributing to an "interactive traffic management" solution may be negatively impacted by poor or varying data quality. This may lead to erroneous information within the information chain, but also to false recommendation to the end user which may have a negative impact on the user acceptance and consequently on follow-up rates and finally on poor system performance.

SOCRATES$^{2.0}$ neither elaborated new solutions for data quality nor excessively used existing data quality frameworks. There are some frameworks to describe quality criteria and minimum quality levels[16], however, they need to be specified and validated in local and project-specific environments. Nevertheless, the project partners learned that having commonly accepted metrics to describe data quality will not only reduce required efforts when working with similar or overlapping, and sometimes duplicate data coming from various sources, but also help to make the value of data from various sources comparable. This may be an important aspect when introducing impact-driven business models.

SOCRATES$^{2.0}$ recommends to further work on agreed and uniform data quality assessment procedures going beyond the existing approaches and being more suitable for "interactive traffic management" solutions. Such procedures and agreements should be commonly established with all related parties. A concrete proposal is given in the follow-up plan (see Section 5.4).

Data security

A security infrastructure, assuring integrity and privacy of vehicle data, has been proposed by C-ITS stakeholders, but is not in place yet. Within the SOCRATES$^{2.0}$ project state-of-the-art procedures has been used. No further effort was put into the topic.

[16] For example, there is a EU-funded activity about ITS Data Quality, which publishes agreed and uniform Quality Frameworks for specific ITS domains. https://www.its-platform.eu/highlights/update-eu-eip-quality-package-srti-and-rtti

Data standards

To enable smooth exchange of data the use of commonly accepted standards is a prerequisite. Within the SOCRATES$^{2.0}$ project DATEX II, DVM Exchange as well as OpenLR were used as foundation and even extended, to meet the requirements of the implemented use cases.

The project partners worked on the extension of the standards to exchange Traffic management Plans and Environmental Zone information, in close cooperation with the responsible bodies for standardisation.

Major observations and challenges faced were the following:

- Using a harmonised data standard, as s baseline for data exchange in Traffic management, is considered a prerequisite for interoperability and scalability across users and deployments. In certain cases, a DATEXII profile could be transferred from one SOCRATES$^{2.0}$ pilot site to another. This saves deployment efforts and increases the acceptance by (potential) data re-users.
- However, a standard which is not commonly used is hard to work with. In this context, usage guidance and harmonisation is on ongoing issue, by clearly defining the syntax and semantics of the modelled information. For a further roll-out of interactive traffic management, fostering such harmonisation across Europe is key to tackle the issue.
- OpenLR as standard for location referencing is an issue for many parties as they lack in expertise in using it. Still OpenLR as a map-independent standard does not solve all interoperability issues, as the usage of different maps may lead to misinterpretation when exchange data.
- While DATEX II is meant to be the standard for exchanging traffic related data between backends, there is only a limited number of experts available. We learned that DATEX II is not self-explanatory, when using it, and even more complicated to handle, when developing an own, DATEXII-based data model. This is hindering not only smooth implementation by the different stakeholders, but also put obstacles in the discussion between the parties.

Recommendations for future projects with regards to standards are the following: identify required standards, if possible, before the beginning of the project and make sure, that required expertise and knowledge is available either at the parties involved, or can be made available through external parties. In case there is no mature standard available, e.g. for an innovative use case, think about how to efficiently advance with an existing standard, or even propose a new one. In this case, be in touch with data standardisation bodies and data harmonisation activities in Europe, to make sure your approach is sustainable and compatible with ongoing developments outside your project. It is also strongly recommended, that the DATEX II community takes responsibility for harmonised usage of the standards. The existing dialects prevent smooth scalability of data exchange.

4.2 Technical enablers & bottlenecks

Compatibility with TMC legacy systems

Existing TMCs, especially the older ones, have gaps when it comes to communication, interfaces in correlation with external actors. Integration of new data/information and processing of the latter is also a challenge mainly due to old software architectures in place. In the worst case this may impact the Europe-wide roll-out of interactive traffic management solutions or lead to redundant systems where “old” and “new” solutions run in parallel.

In pilot projects the aspects mentioned above do not play such a big role as they will be usually worked out within the project frame.

In SOCRATES$^{2.0}$, the public and private parties were partly able to overcome the obstacles mentioned above. Within the pilot sites Amsterdam and Antwerp, the use cases implemented required an interaction between public TMC and private services. This connection was actually realised by the help of intermediary roles.

A major observation was that using existing standards help overcoming connectivity issues, as it is in the interest of today’s TMCs to interact in a standardised way with 3rd parties.

Recommendation for future projects: creating an overview on existing interfaces to the legacy systems at the very beginning, a detailed list of required interfaces together with an elaborated view on future processing chains and required capabilities for each identified interface will lead to a smooth implementation and roll-out of new services and solutions enhancing the existing traffic management capabilities. Involving the people working at the TMC from the early beginning is also beneficial, as they can provide insights into their operational tasks and workflows which shall be considered when implementing a new solution.

Market penetration of connected vehicles

Today the penetration rate of connected cars, services interacting with traffic management and TMCs with interfaces to connected services is still very limited. This leads to hardly measurable impact of interactive traffic management solutions and is thus a barrier for promoting the introduction of such solutions.

Also, product life cycle management from connected vehicle services need to be considered as it needs a significant run-in period before new services can be integrated into a commercial offering. In SOCRATES$^{2.0}$, we saw how this can impact the development of a solution and ultimately lead to the decision, that a solution cannot be implemented at all.

Within SOCRATES$^{2.0}$ pilot site Amsterdam and Antwerp were able to recruit a large amount of pilot users using mobile as well as in-dash connected services. Nevertheless, this number was still too small to measure impact.

Recommendation for future projects: for large-scale pilots start as early as possible with promoting the upcoming services and check on the one side for suitable stakeholders on a regional level but also with global players with interest in interactive traffic management. Implementing a professional campaign may support the recruitment of a sufficient number of pilot users required for evaluating impact of interactive traffic management solutions.

Cellular communication networks

Connectivity is a prerequisite for connected services. All services require full availability and network coverage. Within SOCRATES$^{2.0}$ no stakeholder from the telecommunication industry was involved. But within the scope of the project all use cases could be successfully implemented and tested using the existing infrastructure.

SOCRATES$^{2.0}$ did not further investigate the topic, but recommends considering the communication infrastructure aspects from the early planning stage on as it may become an issue especially in non-urban environments.

Advanced traffic management algorithms

In some cases, existing TMCs are still isolated systems, including proprietary sensor data and actuators, and (automated) algorithms triggering traffic management measures. New solutions of interactive traffic management will require, respectively use, new sensors and data sources as well as integrating new actuators. To consider these aspects the existing algorithms have to be at least re-designed and re-validated. Even an enhancement of the traffic theory behind the aforementioned algorithms may be required.

Within SOCRATES$^{2.0}$ pilot site Amsterdam several algorithms with focus on traffic prediction, load balance and free flow were implemented and tested to facilitate a proactive management of traffic measures. But those algorithms were not based on new sensors or data sources.

In all pilot sites connected services from private service providers were used to complement the set of existing actuators to influence traffic and travel behaviour. It was demonstrated, that technically the new actuators can be integrated into interactive traffic management solutions. However, due to limited number of pilot users, a quantitative impact of those new actuators could not be measured.

For future activities, the SOCRATES$^{2.0}$ partners recommend to have a closer and probably more research-focused look into the added value from traffic theory and algorithms. Also, the integration and impact of new actuators as part of interactive traffic management solutions can be further.

4.3 Organisational enablers & bottlenecks

Consensus on cooperation models

One of the challenges is to identify and define a viable cooperation model that does not only fit to the solution(s) anticipated, but also needs to be accepted among the participating partners for each deployment of interactive traffic management.

The SOCRATES$^{2.0}$ partners agreed, that a cooperation model should add value for each participating party. In SOCRATES$^{2.0}$ we call this the win-win-win concept. Within the project we learned, that the win-win-win is not easy to find. Altogether, the SOCRATES$^{2.0}$ partners see a risk in sustainable deployment, as long as a proper business model is missing (see Section 4.4), indicating clear impacts for each partner.

Within the SOCRATES$^{2.0}$ project several cooperation models were elaborated, discussed and successfully implanted in the pilot sites. Three categories of cooperation models were identified. They mainly differ in the level of commonality. The parties working together agree to:

- The first model is on exchanging data on a voluntary basis using an agreed standard protocol. This model is suitable for services aiming at spreading information without the need for further enrichment of the data or coordinated actions with main focus on maximum information coverage for the end users.
- In the second model the participating parties operate on a common situational picture. This approach will eliminate the risk of contradicting / unaligned information provision to the end user which may still happen in the first model. Still each party continues to independently optimise and operate its own end-user services.
- Finally, the most ambitious model is the third one. It not only requires a common situational picture but does also aims for coordinated actions of the public and private parties involved to actually come close to a global optimum without completely ignoring individual needs.

All three models were applied to different use cases at the four pilot sites. Feedback and recommendation from the pilot sites is to start identifying the most suitable models as soon as possible when planning / tendering a new project as some of the models will not only require additional roles but also additional parties fulfilling the additional roles.

When identifying and selecting the appropriate cooperation model, it is also recommended to keep the added value for each party involved in mind. As already mentioned at the beginning of this section, in SOCRATES$^{2.0}$ we call this the win-win-win for public and private stakeholders as well as the end user.

There are no obvious solutions for such win-win-win. Incentives and rewards are assumed to be part of the solution. The enabler is, that we experienced that road users are willing to comply with traffic management related advice, when the right conditions apply and that service providers are willing to provide reach and impact to the road authorities. On the other hand, a bottleneck is that the latter are not automatically willing to pay for such services as the gained impact is unclear and required funding is difficult to get. Due to the local setup of the Antwerp pilot site, SOCRATES$^{2.0}$ was not only able to showcase value of an incentive-based solution, but also how an appropriate business model can look like. But a win-win-win is not per se a monetary value, but can also be an increased user base, improved service offering (better data coverage) smarter route or destination recommendations

Further, the precondition to realise the win-win-win is the digitisation and accessibility of required data and information, and supporting mechanisms such as National Access Points (see Section 6.3).

4.4 Business enablers & bottlenecks

Return of Invest

For public and private parties, investments in technical infrastructure, additional data sources or services extensions need an economic justification. Not only for private parties the identification of sustainable business models is crucial for the implementation of interactive traffic management solutions.

Therefore, SOCRATES$^{2.0}$ put strong emphasis on identifying the win-win-win for all involved parties (public, private and not to forget the end user) already in the pilot-preparation phase. It was agreed by all parties, that without a convincing win-win-win situation the willingness to invest, respectively adopt will be rather low or not sustainable.

Several approaches were discussed:

The most promising approach for the more complex cooperation models seems to be an impact-driven approach. In this model, all involved parties are remunerated based on their contribution to achieve commonly agreed targets. Due to the complexity of this approach. as well as the so far missing skills to elaborate at least a basic model, SOCRATES$^{2.0}$ did not come up with an impact-driven business model.

Still, SOCRATES$^{2.0}$ was able to develop a new model based on a publicly funded incentive scheme. This model was successfully applied at the Antwerp pilot site for the Optimising Network Traffic Flow use case. The very specific local conditions of the Liefkenshoek Tunnel made such a model possible.

Exchanging data, as a third approach for a business model, was also implemented within SOCRATES$^{2.0}$. Nevertheless, it needs to be stated, that this was possible due to the specific contractual situation of the project.

Last but not least, the sharing a common view presents a specific approach, where all parties have access to the same information and can distribute this information to their customers. The result is a uniform state of knowledge at the end-user level. The Environmental Zone use case, as implemented in the Amsterdam pilot site, demonstrated the added value of information provided by the road authorities, incorporated into the applications of the private service providers and thus maximising the reach to the road users.

The SOCRATES$^{2.0}$ partners have identified the missing of appropriate business models as a main obstacle for the for the successful introduction of interactive traffic management solutions. To overcome this gap further work is needed. The challenges identified and to be addressed on follow-up activities:

- What is the value of data, how can the value be measured and how can data sharing models look like?
- To which level (in terms of time and volume) is public funding needed to enable first implementations of interactive traffic management?
- How can impact-driven business models, to improve road safety, efficiency and sustainability, look like? What are appropriate KPIs and how can they be measured? What is the value a service can deliver and how can that be quantified?
- Is a trusted entity required to enable interactive traffic management solutions and respective cooperation models, and how do they fit into the business model?

4.5 Legal enablers & bottlenecks

Privacy concerns

Within the SOCRATES$^{2.0}$ activities, we did not focus on data protection and privacy topics which was in retrospective a missing aspect for subsequent project activities.

When it comes to data privacy the SOCRATES$^{2.0}$ partners learned quickly, that GDPR measures prohibit service providers in measuring the service usage and impact as tracking of people and their behaviour is a very sensitive topic and needs the consent of the end user, which shall not only include the rights to collect the data, but also to gain insights and share aggregated conclusions.

Within the SOCRATES$^{2.0}$ deployment, neither the means to collect such required data, nor the appropriate consents could be implemented during the duration of the project, as this requires good and exhaustive legal preparation.

It is recommended to further elaborate on the topic in the future and have required consent in place, before starting projects in which information on individual user behaviour is required. This will not only increase the user acceptance, but also limit the risks for project execution.

The SOCRATES$^{2.0}$ partners agree that finding a suitable approach for the topic will be a prerequisite for the further elaboration of impact-driven business models. The expectation of road authorities is, that they get transparent information for what impact they actually spend their money.

Liability

Faulty or inaccurate data or information as well as malfunctioning systems can have severe impact on service execution in interactive traffic management which may lead to legal and liability implications for the actors involved; in the worst case resulting in complicated legal trials and possible high costs. This is especially important for use cases providing legally-binding information.

Within the Speed and Lane Advice use case in the Antwerp pilot site, information displayed at gantries along the road was delivered to the drivers using a mobile app. In such case, users of this app should be aware that the speed and lane advice displayed at the gantries do overrule the information presented in the application.

Further, we were faced with liability in context of the technical chain. However, acceptable latency and down times of the system did not lead to any issues here. Therefore, we recommended focussing on the quality of the data and impact on the services.

Besides that, SOCRATES$^{2.0}$ did not further elaborate on the topic. However, the liability aspect needs further elaboration and is expected to be a complex topic, as it is involving multiple public and private stakeholders and may include several communication channels with different responsibilities.

Data ownership:

Ownership of data may become a difficult topic in the eco-system of interactive traffic management. Questions like who owns the data (and is liable for the data) may become blurry if several parties accept to let a 3rd party aggregate their data to create a common view. A legal framework may be required to avoid misunderstandings and take care of the liability and rights to further share the content.

Within SOCRATES$^{2.0}$ the roadworks use case was implemented in pilot sites Amsterdam, Antwerp and Munich and in all implementations several parties agreed to aggregate and share the data. This was possible because of the specific project setup, but still required in some cases additional legal agreements. It is an open question if under different frame conditions the topic of aggregation and sharing would have been solved as smoothly.

It is strongly recommended to further elaborate on that topic and find solutions suitable for interactive traffic management as otherwise it may jeopardise the successful implementation.

4.6 Conceptual enablers & bottlenecks

Major conceptual aspects arise from the project approach in SOCRATES$^{2.0}$, in particular the elaborated building blocks and approaches to the various pilot demonstrations.

Common building blocks and approaches

First, many alignments and agreements about the building blocks and approaches were made ahead. Harmonised building blocks were elaborated as a shared vision, cooperation models, TMex, evaluation techniques etc., see Section 2. Further, some harmonised approaches for the pilots deployments were defined, to help to find consistency and a common understanding across all pilot deployments. To support this, general templates (e.g. functional design templates) and a common wording to describe certain aspects (e.g. for the intermediary roles) were used. This harmonisation approach indeed resulted in increased efficiency, so not every pilot had to define its approach from scratch. This also supports scalability and transferability, being overarching goals of SOCRATES$^{2.0}$, as building blocks and the individual approaches were aligned, and can be most-likely be reused in future deployments.

In general, common approaches to ITS projects are handled via ITS architecture activities in Europe. Such activities work towards integration and harmonisation of individual ITS. Basic building steps of such activities are guidelines and agreements for the creation process of individual ITS architectures[17]. One core philosophy of these activities is to provide “ITS reference architectures”, which include general design descriptions, examples and patterns for a specific ITS domain. These “ITS reference architectures” can then be transferred to concrete architectures of real ITS-services.

In SOCRATES$^{2.0}$, we followed a similar approach. The analogy is that each (pilot) deployment of interactive traffic management is an individual ITS, which eventually also needs to be integrated and harmonised. An architecture creation process is then the approach for a specific deployment. By defining common building blocks and approaches, we already provided some common ground, which should be exploited and maybe advanced in future deployments. An idea is to provide an “ITS reference architectures” specifically for the interactive traffic management concept, based on our SOCRATES$^{2.0}$ work. This would add further aspects on governance, organisation and technical levels for individual deployments, and eventually foster some validation and acceptability for European stakeholders, when interested in the SOCRATES$^{2.0}$ concept. Such idea may be intensified by a future, EU-funded project[18].

[17] For example, the current FRAME NEXT project aims to provide “methodologies and tools that make a modern ITS architecture attractive and appealing for its users”. See: https://frame-next.eu/objectives/

[18] In Germany, there was already an attempt to provide an “ITS Reference Architecture” for the data exchange between urban road authorities and navigation providers. However, this work is tailored to the German situation and conventional traditional traffic schemes, whereas SOCRATES$^{2.0}$ goes beyond this. See: https://fops.de/aktuelles/2020/city2navigation/

As a last note, even if a harmonised design approach is recommended across all pilots, it is still crucial to consider and respect local conditions as well as individual perspectives of partners. In SOCRATES$^{2.0}$, this has been achieved by an initial pilot site inventory and reflected as a precondition for each pilot design. The respect for local conditions must be equally allowed by any "ITS reference architectures".

Need for project flexibility and proactive project management

While many details about the SOCRATES$^{2.0}$ approach were defined at the beginning, many changes had to be made during the project, to account for changing circumstances and newly arrived needs. About changing circumstances, most-relevant was the Corona pandemic, which led to a re-visiting of the demonstrations goals, e.g. in terms of evaluation users and traffic loads across the pilot networks. Further, some partner roles changed throughout the project, resulting in new assignment between goals and partners. About the newly arrived needs, some additional agreements had to be taken on a cross-pilot level, which were not completely resolved before the pilot deployments. Such additional "pilot overarching activities" related to alignment and concretisation of topics such as data architectures, cooperation models, and beta-users.

The lessons-learned in SOCRATES2.0 is that a proactive project management with supervisory powers plays a crucial role to handle any unforeseeable circumstances. Similar management skills should be carefully laid down in the project preparation for any deployment, maybe allowing agile processes in the project development phases, or be considered by contractual regulations by the funding bodies.

5. FOLLOW-UP PLAN

SOCRATES 2.0
FAST SAFE GREEN

5.1 Follow-up focus areas

As summarised in the previous sections, SOCRATES$^{2.0}$ provides basic frameworks for and demonstrated first experiences with our interactive traffic management concept. It is evident that a further European deployment depends on further actions involving a wider stakeholder community. Throughout the project, liaison with other European initiatives and external communication and dissemination of the results were very important in creating a maximum of support for our interactive traffic management concept.

One of those activities is to address topics that require further attention after the project. In particular, we need to formulate any outstanding issues and actions, to make the concept sustainable and fully accepted. Target groups are other relevant stakeholders, such as road operators, service providers, car industries, international organisations, legislator and regulatory bodies, and others. The topics that require further attention are summarised in the follow-up plan, as presented next.

A first step is to identify relevant follow-up focus areas. This starts with a reflection on the three cooperation models, as detailed in Section 2.2, as well as on the maturity of the SOCRATES$^{2.0}$ concept, as elaborated by the Evaluation activity[19].

When elaborating and implementing these cooperation models in real-world environments, the aspects in the table below were identified as being crucial for follow-up activities. It is evident that the more advanced cooperation models have more follow-up areas. The follow-up focus areas outlined in the table are elaborated in the subsequent subsections.

[19] See the SOCRATES$^{2.0}$ Final Evaluation report

Table 6. Follow-up focus areas

	Crucial for cooperation model:		
Follow-up focus area	**Exchanged Data**	**Shared View**	**Coordinated Approach**
Data standards: enhancement, harmonisation, knowledge building. (see Section 5.2)	●	●	●
Alignment on map-independent location-referencing methods. (see Section 5.2)	●	●	●
Further exploration of the cooperation framework. (see Section 5.3)	●	●	●
Advancement of regulatory and legal frameworks for interactive traffic management. (see Section 5.5)	●	●	●
Catalysation of future deployments of interactive traffic management. (see Section 5.6)	●	●	●
Alignment on and definition of data quality. (see Section 5.4)	●	●	●
Alignment on and definition of service quality. (see Section 5.4)		●	●
Identification of an operational model for intermediary roles. (see Section 5.3)		●	●
Elaboration of a suitable governance model. (see Section 5.3)			●
Elaboration of an appropriate and manageable (impact-driven) business models. (see Section 5.3)			●
Elaboration of a suitable tendering process. (see Section 5.3)			●

5.2 Data standards: Enhancement, harmonisation, knowledge building.

As stated throughout the report, a common digital language is a crucial building block for communicating traffic management information between the various partners and enabling the interactive traffic management concept. This was concretised as harmonised data formats and interfaces, under the responsibility of the cross-pilot TMex activity (see Section 2.3).

The TMex progress results were positioned within the European DATEXII group through the continuous participation of DATEX II experts in the SOCRATES$^{2.0}$ project. This interaction resulted in two aspects:

- A number of concrete DATEXII profiles for the SOCRATES$^{2.0}$ pilots were established in the frameworks of DATEX II. This was done by reusing and, where necessary, adding information items to the DATEX II data model.
- The elaborated DATEX II profiles, including lessons learned about their usage, found their way into future DATEX II activities. This means the development of the overall data model will consider our elaborations.

Overall, the interaction with the European DATEXII group was highly beneficial as they enabled data interoperability aspects to be considered from the start. In contrast, a stand-alone data format may have been easier to implement in our pilots, but would not have been as attractive to parties outside the project. However, we concluded that the DATEX II harmonisation work within the SOCRATES$^{2.0}$ project should only be a small part of the puzzle within the wider scope and stakeholder landscape of a data harmonisation group.

In particular, the elaborated DATEX II profiles are not yet mature enough to be deployed on a European scale, and further validations and enhancements are needed. In particular, we expect that new or enhanced specifications need to be defined, for example, for network optimisation or rerouting use cases. With added maturity, DATEX II-based communication is expected to be even more efficient in the domain of interactive traffic management.

While DATEX II is widely promoted in the EU, it is applied differently from country to country and even from party to party (public and private) and sometimes even within parties.
The lack of a heterogeneous usage was also identified as a bottleneck during our pilot deployments. Alignment is therefore needed of how to apply DATEX II profiles, for example, by means of supporting documents with a clear semantic description of model elements.

Furthermore, DATEX II messages often contain geo references expressed through various location-referencing methods. Experiences gained during the SOCRATES$^{2.0}$ deployments show how important it is to align methods across the many data use cases and communication partners. This would help avoid inconsistencies when interpreting georeferenced data and avoid post-processing of that data. OpenLR, as a map-independent approach, is promising in this context, but not commonly used. ALERT-C, as a pre-coded method for location referencing, is used more often, but does not cover all roads, especially in urban settings. As for DATEX II in general, harmonisation is needed of location-referencing methods and support to users.

The major follow-up action needed here is for the DATEX II group to take on data-related harmonisation and support issues and any other activities with data standard aspects. The goal is to advance with the DATEX II specifications for specific interactive traffic management use cases, and to validate those DATEX II specifications under future deployments. A specific recommendation here is to consider the heterogeneous field of data partners, each with their different roles and expectations when using a data specification. Fostering further dialogue with partners would provide a solution.

A situation where our DATEX II harmonisation efforts could be directly transferred to a follow-up activity is the Environmental Zone use case. For this, contacts have been established with the European UVARbox project (see Section 5.6). Results and lessons learned were shared about the SOCRATES$^{2.0}$ Environmental Zones pilot in Amsterdam. This is a best practice in terms of a follow-up action already in place.

Another open issue concerning data standards is knowledge sharing and building. There are only a few DATEX II experts who can help with harmonisation, specifically when specifying local deployments of interactive traffic management. This clearly shows that individual knowledge sharing and consulting is needed on the correct usage of the DATEX II framework for specific deployments. This would allow for highly efficient use of the DATEX II information model, and for parties to take advantage of the ongoing standardisation process of the European DATEX II group.

An upcoming European project in this context is NAPCORE, which, among others, will focus on the education of more experts in the field, addressing the mentioned lack of DATEX II expertise in Europe (see Section 5.6).

5.3 Further exploration of the cooperation framework

Towards a sustainable business model for the Coordinated Approach

Based on lessons learned and experiences gained from four pilot sites, multiple business ideas emerged for the SOCRATES$^{2.0}$ Coordinated Approach cooperation model (see Section 2.2). The most innovative and promising examples refer to an “effort-driven business model” and “impact-driven business model”, where the main goal is to create a common value proposition. These two ideas for business models are explained below as a guideline to foster business aspects for the Coordinated Approach cooperation model.

According to Section 3.2, we structured the business growth process along the following three stages of maturity:

- Piloting stage (e.g. what we did in the SOCRATES$^{2.0}$ project)
- Effort-driven business model stage
- Impact-driven business model stage

In the piloting stage trust needs to be built between partners before a cooperation can be effective. Learning and building trust for a sustainable cooperation are the main objectives in this stage. Otherwise, no immediate impact on public and private long-term goals can be expected. A short-term goal for this stage is to have a common understanding on required content, suitable cooperation model(s), experience and assets each party can bring to the table. The first iteration of this stage can be challenging and time consuming. But after the establishment of a first concept of the technical chain, later improvements or iterations will go faster. The intended procedure is to start with the piloting stage, then go to the effort-driven business model stage, and after that the impact-driven business model stage. However, depending on the complexity of the use case and number of partners, some stages can be skipped.

Effort-driven business model stage

The effort-driven business model stage empowers an already initiated or established cooperation (e.g. piloting stage). The goal would be a more effective cooperation, where some goals are met. It is advised to start with 100% public goals for the optimisation, to get a clear view of the benefits for the optimisation. Then the piloting stage can be revisited and improved based on lessons learned.

Continue the cooperation

Anyone can initiate the continuation of the cooperation; however, the road authority should orchestrate the cooperation. For the first iteration, a government is needed that is committed for a longer period. For private firms, the cooperation should be open and transparent. The cooperation must be open for newcomers, and existing partners should be free to leave the cooperation. In order to reach sustainable cooperation, a legal framework is needed for government spending and procurement and a level playing field for private companies.

Some real-life impact

Small impacts can be expected on public goals. There will be some impact on private goals, at least to cover the cost. On top of that, private service providers can explore additional business opportunities and can improve services for clients. New business opportunities are available for private trusted intermediaries.

Emerging business model

In the second stage, no big investments are needed from the government. Most upfront investments were part of the previous piloting stage. However financial reservations should be made to compensate service providers for their efforts in reaching public goals with private services. The main business case for private service providers is an effort-based reward for service requests. They receive compensation for showing messages to their users, regardless of the generated impact. There is no obligation for service providers to follow or accept the service requests. However, for a significant number of cases it would be in the service providers’ interest to accept the service requests.

Rewarding concept

A smart rewarding concept was developed in the SOCRATES$^{2.0}$ Amsterdam pilot with different tiers of rewarding making the cooperation flexible for new partners. In short there is an incentive (or reward) for everyone who participates. However, the fee rate differs per tier. The lowest fee (R0) is basically an encouragement to participate without legal obligations. The highest fee (R3) is related to proven impact.

Table 7. SOCRATES$^{2.0}$ smart rewarding concept

	Piloting stage	Effort-driven business model stage	Impact-driven business model stage
R0 – *participate*	√	√	√
R1 – *effort*	(√)	√	√
R2 – *impact*		(√)	√
R3 – *impact +*		(√)	√

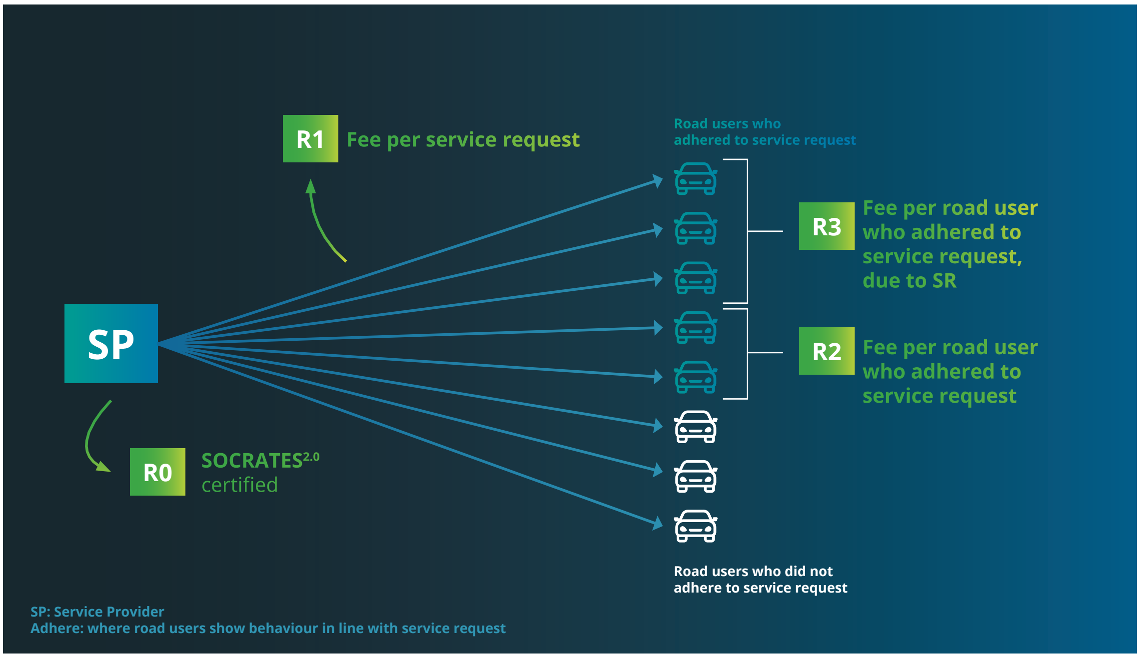

Figure 28. Rewarding concept in the SOCRATES$^{2.0}$ Amsterdam pilot

Impact-driven business model

This business model is mainly based on an exploration of expert ideas for future development. This model supports a sustainable cooperation for an effective and efficient execution of traffic management. The main goal of the cooperation is a common value proposition. All partners work closely together and maximise the added value for the whole chain.

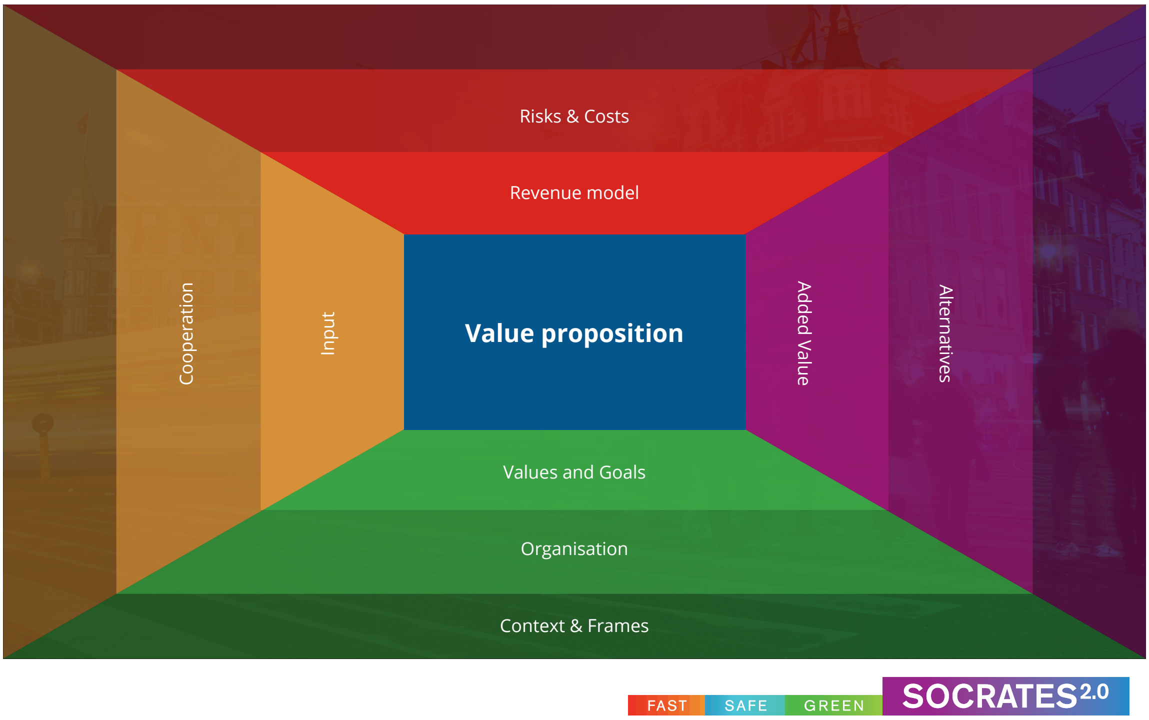

Figure 29. Aspects of value proposition for the SOCRATES^2.0 cooperation framework

Continue the cooperation part 2

Network wide traffic management is the next step in optimising the traffic flows after the optimisation of intersections and corridors. Network optimisation requires a fairly complex technical system, but also an effective organisational structure. In this section, we focus on the organisational aspects. In order to optimise the traffic flows on a wide road network, you need to organise a cooperation of partners for an extended period. You need to create a sustainable long-term framework that also provides focus for the long term and flexibility for the short term.

It is again advised to start with public goals (less congestion, less emission, safer roads) as the common goals. This makes the revenue streams clearer and as such increases the willingness of partners to participate. Especially for the service providers, it is important to leave ample room for business opportunities without jeopardising the common goals. All intermediary roles can be conducted by both separate public and private partners.

Business model found! But hard to reach?

No investments are needed from the government for this stage. The main business case for private service providers is an impact-based reward (R3) for service requests. This means, service providers are compensated if their contribution to the common goals is proven. Service providers sell impact. Compensation depends on measurable impact. This creates an incentive for service providers to maximise impact (e.g. re-routes). It aligns the objectives of service providers with those of road authorities. Service providers can nudge or incentivise their users in order to increase follow-up behaviour and impact. Service providers are often better placed to create impact in a more effective or cheaper way, since they can target specific users and use their creativity (e.g. in gamification concepts).

Besides such ideas, business-relates aspects need to be deepened in follow-up initiatives together with new stakeholders. First, we feel that proper foundations for business models should be detailed out, with a focus on a multi-party cooperation with public and private partners in the traffic management domain. Among others, this relates to new procurement, contractual and rewarding schemes. Based on that, the value of such integration needs to be further demonstrated, with new use cases and experiences, in order to gain more insight on the win-win-win and to further elaborate on the business perspective.

Results

A strong alignment of private and public services can be realised together with TMCs. As such, a large impact can be expected on public and private goals, and traffic management can become more cost-efficient and effective. There are also plenty of opportunities for private, trusted intermediaries to add value to the chain.

The role of NAPs in facilitating data cooperation

Data exchange is a basic functionality of the SOCRATES$^{2.0}$ Cooperation Framework. It is a cornerstone in all of the three elaborated cooperation models (see Section 2.2). Data exchange implies at least some effort on the part of the communication partners: data must be made available, accessible and reusable. Whereas for the SOCRATES$^{2.0}$ pilot deployments, those efforts were covered by the project resources. The question now is how to lower those efforts for non-project situations, especially situations with evolving data ecosystems and perhaps even where the communication partners are not yet known.

One well-known approach to this is the National Access Points (NAPs). NAPs are digital interfaces that make ITS data accessible for a wide range of data users. They are triggered by the European legal framework on ITS, the EU ITS Directive and the corresponding Delegated Regulations[20]. NAPs can ease data exchange by establishing a central many-to-many data interface (see below). So, NAPs are considered a crucial digital building block when establishing a uniform mobility data ecosystem in Europe for crossing borders, transport modes and responsibilities[21].

[20] See. https://ec.europa.eu/transport/themes/its/road/action_plan_en

[21] Jorna, R., et al., 2017. National Access Points: Challenges for Success. Presented at: 25th ITS World Congress. September 2018, https://eip.its-platform.eu/activities/monitoring-and-harmonisation-national-access-points

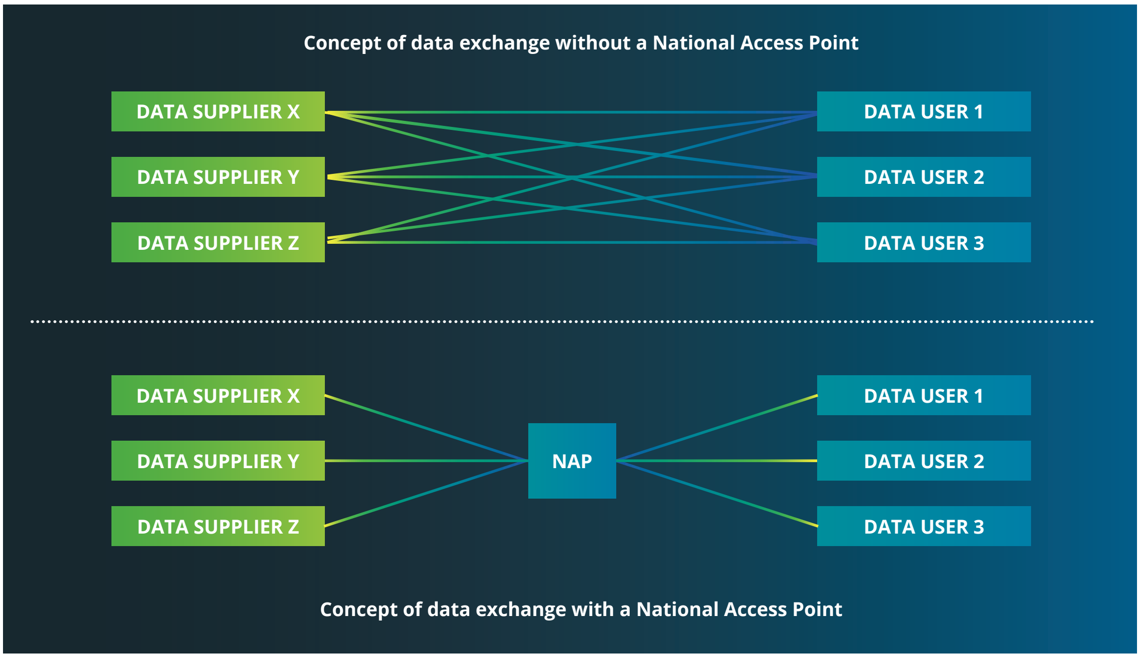

Figure 30. Concept of data exchange without a NAP (left) and with a NAP (right)

The concept above allows for a combination of data from multiple sources, creating new opportunities for end-user services, also for the domain of traffic management. Such multi-source environment is also a baseline for the establishment of NAPs[22].

Several new NAP data connections were established for the SOCRATES$^{2.0}$ deployments. One example concerns the data feed from the Bavarian Road Authority on the German NAP, which distributed service requests for the Smart Destination use case at the Munich pilot site. The data offer was not only available for the service providers involved in the project, but is now also available for any interested data users. This example shows how a NAP can facilitate the Exchanged Data cooperation model even beyond the project.

Regarding this example, the German NAP not only enables pure data exchange (the basic function mandated by the EU regulation), but also gives the data supplier some control by supporting contractual relationships with data users. This helped strengthen the trust aspect within SOCRATES$^{2.0}$. Furthermore, NAPs could also serve many other functions in future scenarios. In fact, there are discussions about features of the German NAP that could even support the other two cooperation models, for example, via data apps attached to the NAP, such as allowing data fusion and other data processing.

[22] Aifandopoulou, G., et al., 2020. National Access Points for Intelligent Transport Systems Data: From Conceptualization to Benefits Recognition and Exploitation, Computer Science - Computers and Society, October 2020, https://arxiv.org/ftp/arxiv/papers/2010/2010.12036.pdf

According to SOCRATES$^{2.0}$ understanding, a NAP can facilitate the more advanced cooperation models, when it fulfils at least one Network Monitor task (e.g. central data distribution of unique and/or trusted data, enrichment of data, data fusion or prediction). This way, a NAP can contribute to the SOCRATES$^{2.0}$ Cooperation Framework, depending on the NAP system capabilities.

Altogether, we believe NAPs should be considered a basic building block for future deployments of interactive traffic management. The main argument for this is that it can ease data exchange between communication partners, and foster scalability through many-to-many data interfaces.

However, there are still some open issues regarding the current capabilities and efficiencies of the individual NAPs.

In theory, the scope of NAPs also includes traffic management related information, including static and dynamic traffic management plans and measures. The EC Delegated Regulations stipulate that such information should be provided by corresponding data suppliers, such as road authorities, and be considered by data users, such as service providers.

Looking at the current NAP practice, however, shows an inconsistent data landscape across Europe in terms of data coverage, data standards and data quality. This is especially true for more advanced data categories, such as traffic management related information. There are only a few road authorities who provide such information in NAPs in a dynamic and harmonised manner.

In this context, further efforts are needed to enable potential data providers to provide traffic management related information via NAPs in an efficient and harmonised way. This would involve not only defining harmonised data formats (see Section 6.2), but also establishing the technical and organisational prerequisites to facilitate data provision in the first place. This includes the digitalisation of traffic management measures as such, and technical tools to make data digitally available, especially for smaller road authorities. These prerequisites need to be tackled first before NAPs can be applied on a wider scale for interactive traffic management.

As a follow-up, further enhancement is needed of the capabilities and efficiency of data provision via NAPs. Aspects such as these will be addressed by the future EU-funded NAPCORE project (see Section 5.6).

Applying the concept of cooperation models for automated driving

Whereas the approach of interactive traffic management, as initiated and demonstrated by SOCRATES$^{2.0}$, relies on today's technologies, the project approach also anticipates future technology scenarios, such as Cooperative, Connected and Automated Mobility (CCAM). In such scenarios we expects an increasing connectivity and automation. This implies an increasing integration of the elements of the transport system, so a systematic approach to cooperation between elements seems evident. The question is whether the SOCRATES$^{2.0}$ Cooperation Framework with its three cooperation models, as introduced in Section 2.2, can also be applied or integrated into the CCAM domain.

In automated driving, which is a prominent use case of CCAM, systems are designed to operate under certain conditions, often called Operational Design Domains (ODDs). These are specified by the OEMs, and decide when, along a specific route, an automated driving mode is permitted or applicable. ODDs depend heavily on the infrastructure conditions, including physical and digital prerequisites of the infrastructure. These conditions are often called Infrastructure Support for Automated Driving (ISAD). ISAD indicate which infrastructure-related conditions relevant for automated driving functions can be expected by vehicles in the currently traversed road section. These can be physical features, such as the nature of lane markings, or digital features, such as V2I services. Both ODDs and ISAD can be classified[23].

From a traffic management perspective, there may be a need to control the presence and lack of presence of specific ODDs for specific situations, called ODD management. Imagine an incident location, spotted by a TMC, which needs to be instantly communicated to an automated vehicle to deactivate the automated functions. The 'end locations' of ODDs (i.e. locations where automated driving mode is switched back to manual) may also be of interest for traffic management, as ODD endings can provoke so-called minimal risk manoeuvres, and thus prevent risky driving behaviour. Lastly, in more advanced scenarios, a remote supervision of entire fleets, such as robotaxis, maybe be an interesting aspect for traffic management.

For all these technological scenarios, different cooperation scenarios can be defined for the interaction between automated vehicles, the traversed infrastructure and network-related traffic management. Some first attempts have been made for an analogy between the three SOCRATES$^{2.0}$ cooperation models and the above CCAM scenarios[24] (see below).

[23] Aigner, W. et. al., 2019. Vehicle fleet penetrations and ODD coverage of NRA-relevant automation functions up to 2040, deliverable of project: MANTRA: Making full use of Automation for National Transport and Road Authorities – NRA Core Business, CEDR Transnational Road Research Programme, https://www.mantra-research.eu/wp-content/uploads/2020/03/MANTRA_Deliverable_D2.1_1.0.pdf

[24] Kulmala, R., 2021. Traffic, fleet and ODD management for highly automated vehicles. Presentation at: Third European Conference on Connected and Automated Driving, April 2021, https://www.connectedautomateddriving.eu/wp-content/uploads/2021/04/EUCAD2021_D3_BO2_Risto-Kulmala.pdf

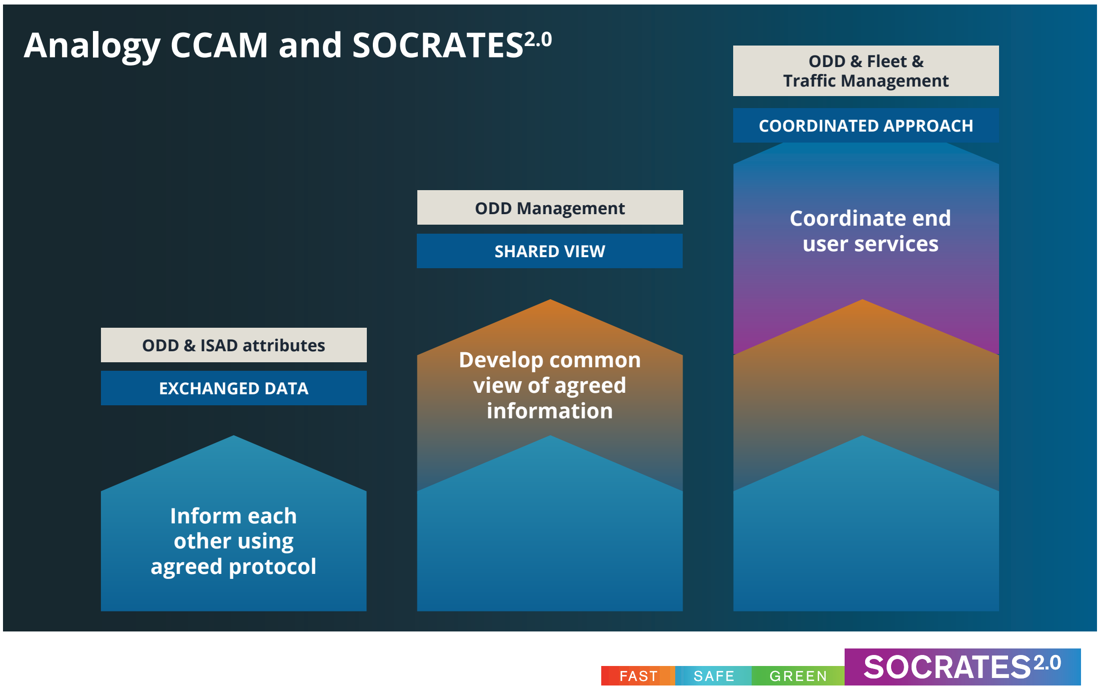

Figure 31. Analogy for SOCRATES2.0 cooperation models and scenarios in Automated Driving

This analogy builds on the concept of data exchange between road operators and vehicle fleets, by exchanging, for example ODD and/or ISAD attributes related to a specific situation, a specific network element or a specific vehicle. Such exchange may be advanced to a shared view of automated vehicle capabilities versus road conditions and infrastructure classification. The shared view is the stepping stone towards a Coordinated Approach for (autonomous) fleet and traffic management, and conserves good quality of service for both sides while reducing the risk of network degradation which is often associated with unmanaged (autonomous) vehicle fleets. In this sense, the same three-level approach of cooperation models seems applicable for technological scenarios in automated driving.

Another, similar analogy is found in a correlation between the well-known automation levels (SAE J3016[25]) with a pre-definition of so-called cooperation classes[26]. According to this approach, cooperation is crucial for automated driving, for safety and other reasons. The context of cooperation classes may differ, as they focus on machine-to-machine communication functions, not the organisational superstructure, as in the SOCRATES2.0 Cooperation Framework. However, the stepwise cooperation approach, as defined in SOCRATES2.0, can also be found here.

[25] See: https://www.sae.org/standards/content/j3016_202104
[26] Dopart, K., 2020. U.S. DOT Cooperative Driving Automation Research, Presented at: SIP-adus Workshop 2020, November 2020, https://www.sip-adus.go.jp/evt/workshop2020/file/cv/07CV_04_Dopart.pdf

Altogether, the SOCRATES$^{2.0}$ legacy on the cooperation models should be further exploited by stakeholders in the CCAM domain, as already done by SOCRATES$^{2.0}$ partners MAPtm and BASt. This exploitation should take a deeper look at applicable cooperation concepts in CCAM, by first elaborating corresponding cooperation frameworks and then specifying them in technical and organisational terms, as previously done in SOCRATES$^{2.0}$. This is currently also being explored by ongoing research projects[27].

5.4 Alignment and definition of service and data quality

Similar to the data standards (see Section 5.2), there is an evident need to align and define (minimum) levels of service and data quality. This is partly because multi-actor environments, as envisioned by SOCRATES$^{2.0}$, rely on a certain level of agreement on what data and services should look like to make a data-based cooperation efficient and sustainable.

In the context of data quality, we talk about certain characteristics of information items or data streams, as communicated between partners in the interactive traffic management concept. Quality criteria are, for example, accuracy, latency and completeness. A negative example in terms of completeness is the SOCRATES$^{2.0}$ Road Works use case, where we experienced some inconsistent data coverage from the many data providers, making data fusion challenging.

In the context of service quality, this concerns the performance of systems participating in the interactive traffic management concept. This relates to any role, as introduced in Section 2.2, including intermediaries. Considering that the entire use case depends on the proper functioning of every participating system, some agreements are needed for aspects such as the operational availability and robustness of the systems.

In the context of quality levels, this often concerns minimum (or basic) levels required for a use case. Imagine, for example, a maximum latency for specific information to be transmitted to a road user. Ignoring that level may result in a road user rejecting the information, and thus making the entire system inefficient.

Beyond the minimum levels, we also foresee some advanced levels with gradually improved qualities, based on the system's and partner's capabilities. Such an approach may enable a step-by-step deployment (starting with e.g. a minimum level and advancing from there), and also leave room for a quality-based competition between various partners in the concept (e.g. if there are multiple data providers operating in the same region).

[27] For example. Future projects under the call "Impact of CAD on Safe Smart Roads" by the CEDR Transnational Road Research Programme", https://www.cedr.eu/news-data/1501/CEDR-Research-Call-2020-is-open!

Some definitions of similar quality criteria and quality levels have been elaborated within the EU EIP project[28]. These contain some first agreements on data and service qualities for various ITS domains, based on stakeholder consultations and real-world data use cases. However, the EU EIP definitions are on more of a generic level, meaning they look at the RTTI domain as such, and do not detail quality levels for aspects such as individual data categories. Further, the EU EIP definitions look at the road operator's responsibilities, meaning they focus on data detection and provision on a NAP, and exclude subsequent data processes by private service providers. Data quality issues in the context of service providers were discussed by TISA[29], but on a strategic level, without concrete level definitions.

Within SOCRATES$^{2.0}$, we did in fact look at the quality aspects as part of the Evaluation activity. Here we found the encountered quality levels were considered sufficient or could be resolved within the pilot development. However, in other circumstances, for example without a setting of a limited project, there might be a clear need to pre-define such quality levels. This might be the case when selecting and assessing new partners in a deployment, based on a procurement procedure.

Thus, we recommend further concretising (minimum) service and data qualities for future deployments of interactive traffic management. This may be a concrete definition and quantitative determination of quality levels for different quality criteria, separated for different data categories, different services and different use cases of interactive traffic management. Such definitions must, of course, reflect the requirements of any participating partner, and should be validated in real-world environments.

A result might be a tabular determination as follows. Besides a definition of dedicated quality criteria, explicit requirements for each criterion should be laid down. Looking at the example about the Road Works use case above, such a definition might include a minimum requirement for data completeness, which needs to be ensured by each data provider before starting any deployment.

Table 8. Example for a tabular determination of quality criteria

Quality Criterion	**Definition**	**Quality Requirements**		
		*** (basic)**	**** (enhanced)**	***** (advanced)**
Data latency				
Data accuracy				
Data completeness				
Service availability				
Service robustness				
etc.				

[28] See: https://www.its-platform.eu/achievement/quality-of-european-its-services-and-their-data

5.5 Regulation & legislation

We have learned that many prerequisites for the interactive traffic management concept may be derived from stakeholder elaborations and pilot deployments, as demonstrated in SOCRATES$^{2.0}$. This is considered a bottom-up approach, which may be scaled up and streamlined in future deployments. In contrast, a top-down approach seems similarly important, to concretise necessary actions by the various partners in our concept, and to provide rules, support and perhaps incentives to accept such tasks. Next, we look at frameworks for regulation and legislation in the context of interactive traffic management.

An important key player when setting such frameworks on the European level is the European Commission (EC), in particular DG MOVE. One major motivation for DG MOVE to fund the project was to spread out the project results on a wider scale, potentially across the European TEN-T network. As such, the follow-up discussion explored potential further triggers and prerequisites to advance the concept. During the project runtime, the SOCRATES$^{2.0}$ management was in close contact with DG MOVE to exchange highlights and learnings and verify the alignment of the EC strategic considerations with our project approach.

In parallel, DG MOVE elaborated new legislatures and frameworks that relate to our concept of interactive traffic management.

One current EC regulatory measure is a planned revision of Delegated Regulation (EU) 2015/962, a specification for EU-wide real-time traffic information services (RTTI)[30]. First, the scope of this specification will be extended, by adding data categories, such as urban access regulations, and expanding the covered network elements, such as urban roads. The revision aims to facilitate transportation-related data access in urban settings, which so far has been a side topic in EC regulations. This kind of additional data should be provided at National Access Points, which according to Section 5.3 play an important role for data exchange in the SOCRATES$^{2.0}$ Cooperation Framework. Second, the revision will sharpen some of the requirements to increase the efficiency and outreach of the Exchanged Data. One example is specified quality levels that the Exchanged Data should satisfy. Further, the role of service providers will be highlighted, being transmitters of traffic management information to road users. We expect this revision can serve as an accelerator for the interactive traffic management concept if appropriate and sufficient data offers are made available by the various data providers addressed in the regulation. This kind of data availability cannot be taken for granted. As such, certain technical and organisational prerequisites, especially in urban settings, need to be tackled first, as mentioned in Section 5.3.

[30] See the EC Working Programme for the ITS Directive. https://ec.europa.eu/transport/sites/transport/files/legislation/c20188264_en.pdf

On a higher level, the EC has strategic frameworks that are also in line with our concept. First, the "Sustainable and Smart Mobility Strategy 2020"[31] elaborates on the goals and actions for the clusters of sustainable, smart and resilient mobility, each with environmental and climate impacts in mind. Especially in the cluster of smart mobility, many topics can be linked to the SOCRATES$^{2.0}$ concept. One of them is digitalisation, which aims to generate business opportunities, innovation, new services and business models. All these topics were central parts of the SOCRATES$^{2.0}$ elaboration. The other clusters were also targeted by SOCRATES$^{2.0}$, sometimes indirectly. For example, the sustainability aspect was addressed by the Copenhagen pilot, where one of the Network Manager's roles was to foster sustainable travel modes. We feel that SOCRATES$^{2.0}$ paves the way to achieve some of these strategic goals as well.

Furthermore, the "Data Strategy and the White Paper on Artificial Intelligence"[32] aims among other goals to create safer and cleaner transport systems via data-driven applications. Obviously, both data and applications play a central role in the SOCRATES$^{2.0}$ concept, and applications may be assigned to our intermediary roles or the end-user services. This EC strategy aims to boost the data economy in Europe. This is also one of the SOCRATES$^{2.0}$ goals, which we aim to achieve by elaborating new business opportunities for service providers, for example. On the other hand, we still consider the road authorities (without a primary economic focus) as crucial players in our concept, so we focused more on the aspects of cooperation. However, business aspects are also identified as an important follow-up action (see Section 5.3).

Altogether, we realise that any deployments of interactive traffic management should be backed by strategic considerations, such as the ones mentioned above. This may incentivise further actions in terms of interactive traffic management. It may for example be a reasoning for responsible public authorities when deciding on future investments in traffic management schemes.

5.6 Post-SOCRATES$^{2.0}$ deployment

Within the SOCRATES$^{2.0}$ deployments, various components were developed that are considered mature enough to be used beyond the project. This relates to basic elaborations, as introduced in Section 2, but also concrete techniques from the pilot deployments. This legacy is important for future deployments, as some components can be reused or further advanced. This re-usage may generate momentum to implement the interactive traffic management concept on a wider scale.

[31] See the Fact Sheet on the EC Mobility Strategy. https://ec.europa.eu/transport/sites/transport/files/mobility-strategy-factsheet.pdf

[32] See the Fact Sheet on the European Data Strategy. https://ec.europa.eu/commission/presscorner/api/files/attachment/862109/European_data_strategy_en.pdf.pdf

Potential future deployments may also tackle some outstanding issues, as identified in the previous subsections. This relates, among other matters, to a further validation of the (more advanced) cooperation models Shared View and Coordinated Approach. It also relates to a full realisation of 'integrated control loops', a basic philosophy of the TM2.0 concept (see section 2.1). More concretely, this implies that service providers need to fully integrate specific traffic management advice in their end-user systems, and that systematic feedback loops on the compliance of that advice are established to better measure impacts of the concept. Talking about impacts, more experiences are needed on the behavioural change of road users when applying these services. Due to limited evidence collected in SOCRATES$^{2.0}$, more empirics are needed to measure the outreach and effect of our concept on behaviour, possibly looking at different types and mobility demands of road users.

Altogether, there is a clear need to catalyse future deployments, based on the SOCRATES$^{2.0}$ concept, to validate and advance the current elaborations. In the following section, we look at concrete plans and activities of the SOCRATES$^{2.0}$ partners, and, beyond that, at selected initiatives on regional, national and European levels.

Regional and national initiatives

On a regional and regional level, it is interesting to see how the SOCRATES$^{2.0}$ concept is perceived locally, and whether there are any ambitions to use our elaborations in local deployments, or perhaps even to reframe our concepts to consider local conditions. There are many regional and regional initiatives underway aimed at advancing conventional traffic management schemes, thus touching on similar goals as in SOCRATES$^{2.0}$. These initiatives are coordinated outside the SOCRATES$^{2.0}$ project, either as a follow-up by SOCRATES$^{2.0}$ project partners, or by external parties. Some examples are given in the next table.

According to this table, there is a variety of follow-up initiatives across Europe, indicating that our concept and the first deployments are of high interest for stakeholders inside and outside the project. This means that there are ambitions to continue some of the SOCRATES$^{2.0}$ deployments, based on the ambitions of some of the project partners to sustain the developed use cases even beyond the project timeline.

There are also some external projects where our elaborations have been taken over as a template or a reference to establish similar concepts, possibly with some reframing and involving further stakeholders. One example of this is the German project City2Navigation, which is reusing some of SOCRATES$^{2.0}$ concepts such as the cooperation framework, even though the project's scope is slightly different. In City2Navigation, the focus is on a wide scale, but low-tech effort, and thus enabling as many cities as possible to establish the lowest SOCRATES$^{2.0}$ cooperation model (data exchange), rather than having a few advanced solutions.

Altogether, the many identified follow-up initiatives reveal that SOCRATES2.0 addresses an important field of actions among European ITS and traffic management stakeholders, and that these initiatives have the potential to deepen and validate our first steps for interactive traffic management.

Table 9. Examples for Regional and national initiatives

Activity/project	Partner(s)[33]	What	When	Remarks/further info
City2Navigation	BASt, TomTom, Here	Project aim: to establish a conceptual foundation for exchanging traffic management information between urban TMCs in Germany and service providers. Mutual knowledge exchange with SOCRATES$^{2.0}$ on cooperation models, intermediary roles, common data formats.	Finished in 2021	https://www.mdm-portal.de/forschungsprojekt-city2navigation/
Continuation of SOCRATES$^{2.0}$ Optimising Network Traffic Flow use case in Amsterdam	Rijkswaterstaat, MAPtm, Technolution, Be-Mobile, Nationaal Dataportaal Wegverkeer	Extend deployment due to pandemic, to enhance quality of evaluation data	until Dec 2021	Without prediction
Environmental Zone use case in the Netherlands	Rijkswaterstaat, Nationaal Dataportaal Wegverkeer, MAPtm, TomTom, Be-Mobile	Knowledge is contributed to ongoing projects to share environmental zone information (such as UVARbox and VM-IVRA)	ongoing	Relation with UVARbox project (see Section 5.6)
Continuation of SOCRATES$^{2.0}$ Speed and Lane Information use case in Antwerp	Flemish government, Be-Mobile	Deployment transferred into continuous production	ongoing	
Mobilidata	Flemish government	Some use cases piloted in SOCRATES$^{2.0}$ will be continued	until 2023	https://mobilidata.be/en/about-mobilidata
Continuation of SOCRATES$^{2.0}$ Optimising Network Traffic Flow use case in Antwerp	Flemish government, Be-Mobile	Deployment transferred into continuous production	ongoing	Cooperation model "Exchanged Data" applied
SOCRATES$^{2.0}$ Masterclasses	Rijkswaterstaat	Series of 8 digital meetings explaining specific SOCRATES$^{2.0}$ learnings	May 2021 November 2021	In Dutch Open to everybody

[33] BAST = BASt; TTM = TomTom; HER = HERE; Rijkswaterstaat = Rijkswaterstaat; MAP = MAPtm; TEC = Technolution; BEM = Be-Mobile; Flemish government = Flemish government; Nationaal Dataportaal Wegverkeer = Nationaal Dataportaal Wegverkeer

Dutch Policy Paper on Public-Private Cooperation	Rijkswaterstaat	Lessons learned serve as input for the internal discussion	Jan 2021–May 2021	Confidential
SATURN project	BASt, TomTom	Conceptualisation and deployments for dissemination of traffic management info to service providers via the NAP, including four pilots in Germany	2021-2023	https://www.bmvi.de/SharedDocs/DE/Artikel/DG/mfund-projekte/saturn.html
Plateau Planning Rijkswaterstaat/ Focus point Smart Mobility	Rijkswaterstaat	Lessons learned serve as input from testing to deployment to production	ongoing	
VM-IVRA (Traffic Management Information For Route Advice)	Rijkswaterstaat, Nationaal Dataportaal Wegverkeer	sharing information from the TMC scenarios and policy information, so service providers can inform road users even better. Using SOCRATES2.0 data formats and systems.	ongoing	
SmartWayZ regional smart mobility program / "Slim sturen" pilot initiative	Rijkswaterstaat, MAPtm. Be-Mobile, Nationaal Dataportaal Wegverkeer	Discussion how to digitalise and disseminate policy rules from road authorities to traffic information and navigation service providers.	2021	https://www.smartwayz.nl/nl/actueel/2020/11/slim-sturen-in-zuid-nederland/ https://www.smartwayz.nl/en/
Amsterdam Practical Trial	Rijkswaterstaat	The Amsterdam Practical Trial (APT) is a series of major pilot tests that use the latest innovations, both in cars and on the road. The APT tests new and improved services that integrate innovative systems on roads and in cars for road users. The objective is to improve traffic flow, make traffic safer and help make cities cleaner.	Summer 2021	https://www.praktijkproefamsterdam.nl/en
TEMPUS	BMW	Lessons learned from SOCRATES$^{2.0}$ serve as input for needed content of and ways of exchanging strategic information	2021 - 2023	
"Wakanda" initiative Belgium	Flemish government	Knowledge exchange regarding the Road Works use case	?	

Traffic, fleet and ODD management for highly automated vehicles, Helsinki	MAPtm	Application of cooperation framework	yet to start	CEDR MANTRA
RWS Tender for Safety Priority Services	Dutch Ministry of Infrastructure and Water management	Widespread dissemination of safety-related events or conditions on the following topics: 1) Traffic jam ahead warnings 2) Emergency vehicles approaching 3) Safety-related traffic information 4) Traffic law	yet to start	

Europe-wide

Follow-up activities also relate to the European level. The goal here is to foster further harmonisation activities, to make the initial interactive traffic management concept more stable and sustainable across borders and responsibilities. There are several activities on the way, fostered either by stakeholder's organisations and by the European Commission. Three prominent activities are presented next.

During the SOCRATES2.0 project, a close relationship was built with the TM2.0 ERTICO platform, e.g. by participating at a Special Interest Session about the Road Works use case, organised by TM2.0 at the Virtual ITS European congress in 2020. The session revealed several positive reactions and follow-ups about the SOCRATES$^{2.0}$ approach. Further, TM2.0 initiated a new task force on the subject of the SOCRATES$^{2.0}$ concept, including SOCRATES$^{2.0}$ partners Rijkswaterstaat, HERE, Be-Mobile, TomTom and Technolution. The objective is to disseminate the results of SOCRATES$^{2.0}$ to the platform members, and provide context to the applicability of the results for other deployment initiatives. The outcome of this task force will be reported at the ITS congress 2021 in Hamburg.

A new, EU-funded project NAPCORE will start in the near future. It will be dedicated to the enhancement and progress of NAPs[34]. As discussed in Section 5.3, NAPs are an important building block for data cooperation between various partners in the transportation system. However, even if many NAPs are already in operation across Europe, some issues and bottlenecks have been identified in terms of efficiency and the impact of individual NAPs. In particular, significant variations and heterogeneities in the status-quo of NAPs have been revealed in terms of aspects such as portal usability, applied data formats and the data coverage[35].

[34] An official inauguration and a web site for NAPCORE are planned for summer 2021.
[35] Hendriks, L., Jorna, R., Barr, J., Lubrich, P., Niculescu, M., Hjärp, L.O., Ilina, L., Gomes, R., Conceição, L., de Quirós, M. B., Rey, L. (2021). EU EIP - Annual NAP Report 2020, https://www.its-platform.eu/filedepot_download/1971/6703

To address these issues, NAP operators have teamed up as a stakeholder group, with the aim to support each other, exchange experiences and elaborate harmonised approaches when developing and operating NAPs. This group also proposed a concrete project NAPCORE, addressing a recent EC call for proposals with a focus on NAP federation[36]. This project will tackle harmonisation topics identified within this follow-up plan related to matters such as data standards (see Section 5.2) and data quality (see Section 5.3). Also, support actions will be initiated with the goal to enable and intensify data exchange in the domain of (urban) traffic management. We expect that such actions may accelerate future deployments of interactive traffic management.

The time line of NAPCORE is set from mid-2021 until mid-2024. Former SOCRATES$^{2.0}$ partners Rijkswaterstaat, BAST and the Flemish road agency AWV will participate in this project.

Another ongoing EU-funded project is UVARbox, with the goal of digitising data about urban vehicle access regulations (UVAR) across Europe[37]. One of the expected results is a pilot setting with five pilot member states: the Netherlands, Belgium, Germany, Austria and Italy, and a focus on low emission zones. Digital information about individual UVAR will be formatted via DATEX II, thus building on the DATEX II profile, as elaborated for the SOCRATES$^{2.0}$ Environmental Zone use case (see Section 2.3).

The timeline of UVARbox is from 2020 until 2022. Former SOCRATES$^{2.0}$ partners MAPtm is participating in this project.

Altogether, such European activities contribute to a wider acceptance and maturity of the interactive traffic management concept. As stated throughout the report, important cornerstones of the interactive traffic management concept need to be agreed upon among various stakeholders and across geographical boundaries. Consequently, any European activities are appreciated which continue with the exploration of the interactive traffic management concept, either as a whole, or looking at some elements of it.

For the future, we recommend identifying further funding and deployment opportunities with a European focus. An option might be to adapt and enhance the SOCRATES$^{2.0}$ use cases in other European cities and regions, or to elaborate new use cases with interoperability features, for example with cross-border traffic management schemes. This way, the foundations from SOCRATES$^{2.0}$ could be further integrated across Europe.

36 Programme Support Action under the CEF Transport related to MOVE/B4/2020-123 - the implementation of a Coordination mechanism to federate the National Access Points established under the ITS Directive (2010/40/EU)

37 See: https://uvarbox.eu/about/

ANNEX

SOCRATES 2.0
FAST SAFE GREEN

ANNEX I: Glossary

Assessor:	A SOCRATES$^{2.0}$ intermediary role, in charge for providing insights on the service performance of partners involved in the delivery of the service (see Section 2.2)
Business model:	A further elaboration of the cooperation framework with the goal to create a common value proposition (see Section 5.3)
Cooperation framework:	A basic building block for the concept of interactive traffic management (see Section 2.2)
Cooperation model:	A model describing the type and intensity of cooperative tasks among the participating partners (see Section 2.2)
Data provider:	A public or private partner responsible for the delivery of data (see Section 2.2)
DATEX II:	An electronic language used in Europe for the exchange of traffic information and traffic data (see Section 2.3)
DVM Exchange:	Dutch data exchange format between TMCs in order to request services (see Section 2.2)
Environmental Zone (EZ):	A use case in the SOCRATES$^{2.0}$ deployments (see Annex II and the pilot site reports)
Interactive traffic management:	The basic SOCRATES$^{2.0}$ concept integrating road authorities and service providers (see Section 2.1)
Intermediary:	A dedicated role between the traditional public and private sector, enables central functions of the interactive traffic management concept (see Section 2.2)
Network Manager:	A SOCRATES$^{2.0}$ intermediary role, in charge for determination of the problem state, service selection and service requests (see Section 2.2)
Network Monitor:	A SOCRATES$^{2.0}$ intermediary role, in charge for data collection and determination of the shared view (see Section 2.2)

Optimised Network Traffic Flow (ONTF):	A use case in the SOCRATES2.0 deployments (see Annex II and the pilot site reports)
Service request:	The process of requesting another partner to conduct a particular service via an agreed exchange format (see Section 2.2)
Smart Destination (SD):	A use case in the SOCRATES2.0 deployments (see Annex II and the pilot site reports)
SP Service Provider (SP):	A public or private partner in charge for receiving, assessing and distributing service requests to individual service users (see Section 2.2)
Strategy Table:	A SOCRATES2.0 intermediary role, in charge of developing the joint strategy of all participating parties (see Section 2.2)
TMex:	A conceptual architecture for the exchange of traffic management data between the SOCRATES2.0 partners (see Section 2.3)
Traffic Management Centre (TMC):	An operational organisation of the road authority for traffic management

ANNEX II: SOCRATES$^{2.0}$ project history and set-up

To develop and demonstrate the above-mentioned concept, six road authorities from four countries, five international traffic information and service providers, one car manufacturer and two companies for Intelligent Transport Systems (ITS) agreed to cooperate in a common project called SOCRATES$^{2.0}$

In July 2017, the European Commission decided to support and co-fund the project under Grant Agreement No INEA/CEF/TRAN/M2016/1366032 under the Connecting Europe Facility (CEF) programme.

In 2017 and 2018, the project partners developed new services for traffic management and traffic information. In 2019 and 2020, they deployed and tested these new services. The testing was done with a test fleet of more than 10.000 road users in the regions of Amsterdam, Antwerp, Copenhagen and Munich. In 2021, evaluation and consolidation activities looked back at the project outcomes, and defined follow-up activities.

The project is divided into nine activities. Besides a management activity (Act. 1), there were eight activities to develop, demonstrate and reflect the SOCRATES$^{2.0}$ concept, following a "v approach", see figure below. They start at a strategical level (Act. 2), proceed via a tactical level (Act. 3) to an operational level (Act. 4-7) , and from there back again to tactical (Act. 8) and strategical levels (Act. 9).

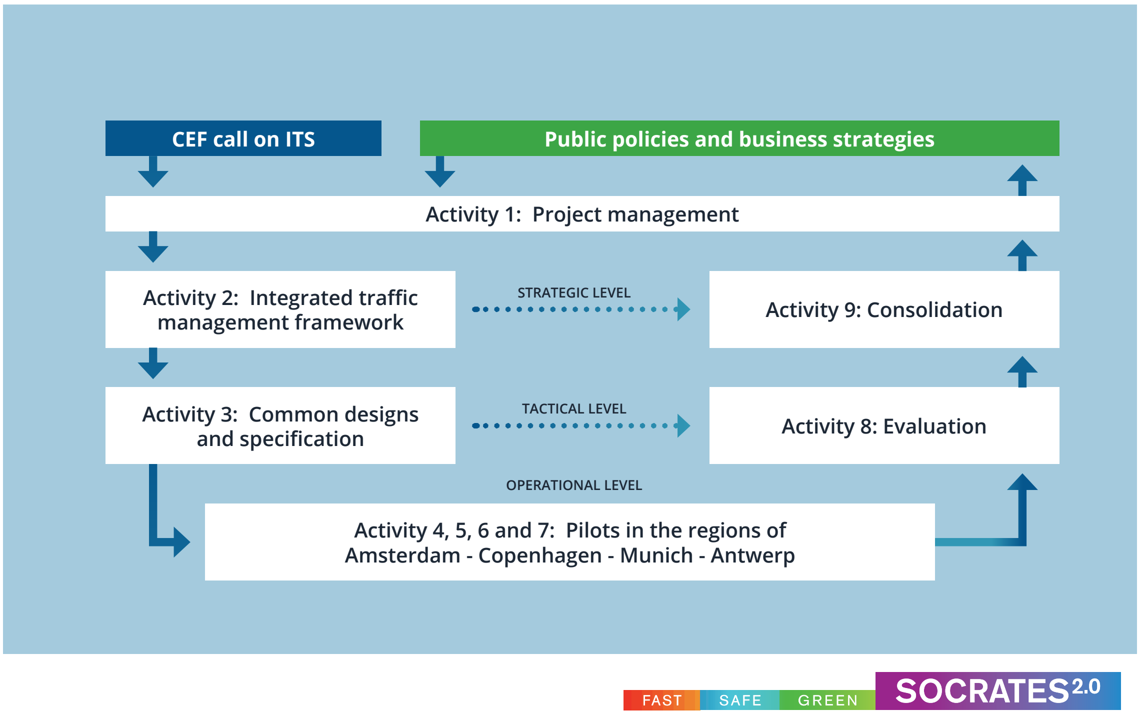

Figure A1. SOCRATES$^{2.0}$ project set-up

In Activity 2, all partners were involved in setting up the SOCRATES$^{2.0}$ vision as the basis for the further work in the other activities, making sure to create a mutual understanding of the objectives, context and terminology and establish a successful collaboration between partners based on trust and common goals. This vision is explained in Section 2.1. To fulfil such vison, various steps were undertaken to concretise the project approach. Since the road user is a central element in the vision, potential use cases were illustrated. These include a list of steps defining the interactions between actors and systems to achieve the goals. Then, it was assessed how the stakeholders can cooperate to be able to take these steps. And finally, the concept of the cooperation models and corresponding intermediaries is explored, to enable the elaborated use cases. The cooperation model and intermediary concept is explained is Section 2.3.

Activity 3 prepared the pilot deployments of the interactive traffic management concept, by predefining and agreeing on certain cornerstones and building blocks, thus working towards consistency across each pilot setting. Major work was done by concretising the uses cases to be deployed by each participating city, as well as cooperation models (as initiated in Activity 2) and the corresponding Intermediaries. The selected uses cases included:

- Optimising Network Traffic Flow (ONTF)
- Smart Destination (SD)
- Speed and Lane Information (SLI)
- Road Works (RW)
- Environmental Zones (EZ)

Eventually, a matrix was built combining the selected use cases, pilot cities and cooperation models as follows. It is evident that there was a good spread of use cases and cooperation models, promoting a “big picture” in terms of learnings and outcomes.

Table A1. SOCRATES$^{2.0}$ matrix with selected use cases, pilot cities and cooperation models

	Pilot Site Amsterdam	Pilot Site Copenhagen	Pilot Site Munich	Pilot Site Antwerp
Optimising Network Traffic Flow	**Coordinated Approach**	**Coordinated Approach**		**Coordinated Approach**
Smart Destination	**Coordinated Approach**	**Coordinated Approach**	**Shared View**	
Lane Information				**Exchange data**
Road Works	**Shared View**		**Shared View**	**Shared View**
Environmental Zone	**Shared View**	**Coordinated Approach**		

Further definitions and agreements were made about data exchange mechanisms, called the TMex approach. Here, data availabilities and requirements per pilot site, use case and partner were inventoried and concretised. For certain data exchange aspects, uniform solutions were elaborated, namely harmonized DATEXII profiles, with the recommendation to be used across the different pilot sites. This approach is contributing to the envisioned scalability and transferability of the SOCRATES$^{2.0}$ concept.

Activities 4, 5, 6, 7 were about demonstrating the concept by operating the cooperation framework in four different European Cities using five different use cases. A main goal was to test and showcase the viability, scalability, applicability and cost-effectiveness of the elaborated concepts. The approach in each pilot city was organised into four stages:

- Stage 1: Specifications & Interface descriptions
- Stage 2: Development, Implementation & Testing, approval of recruitment plans and evaluation data collection plans
- Stage 3: Execution & Operation
- Stage 4: Restoring & Settlement

The pilot deployments had the following characteristics:

- Activity 4, Pilot Amsterdam, operations between December 2019 and December 2020
- Activity 5, Pilot Copenhagen, operations between April 2020 and December 2020
- Activity 6, Pilot Munich, operations between since December 2019 and December 2020
- Activity 7, Pilot Antwerp, operations between October 2019 and December 2020

In Activity 8, Evaluation, different resources were exploited, in order to find conclusions for predefined evaluation questions. To do so, relevant data about the four pilot sites were collected and stored. Other resources were logbooks, questionnaires and interviews.

The data-driven evaluation approach represents another innovation in the SOCRATES$^{2.0}$ approach: a database and a data dashboard were developed and deployed, making it possible to monitor and assess the collection of the evaluation data throughout the deployment period. To feed this evaluation database, several data exchange connections were set up with the deployment partners in the different pilot cities. Thus, a sophisticated data ecosystem to simultaneously monitor various pilot settings was established, allowing high efficiency and comparability for the generation of evaluation results.

Overall, the evaluation took place on 4 levels, as shown the following figure:

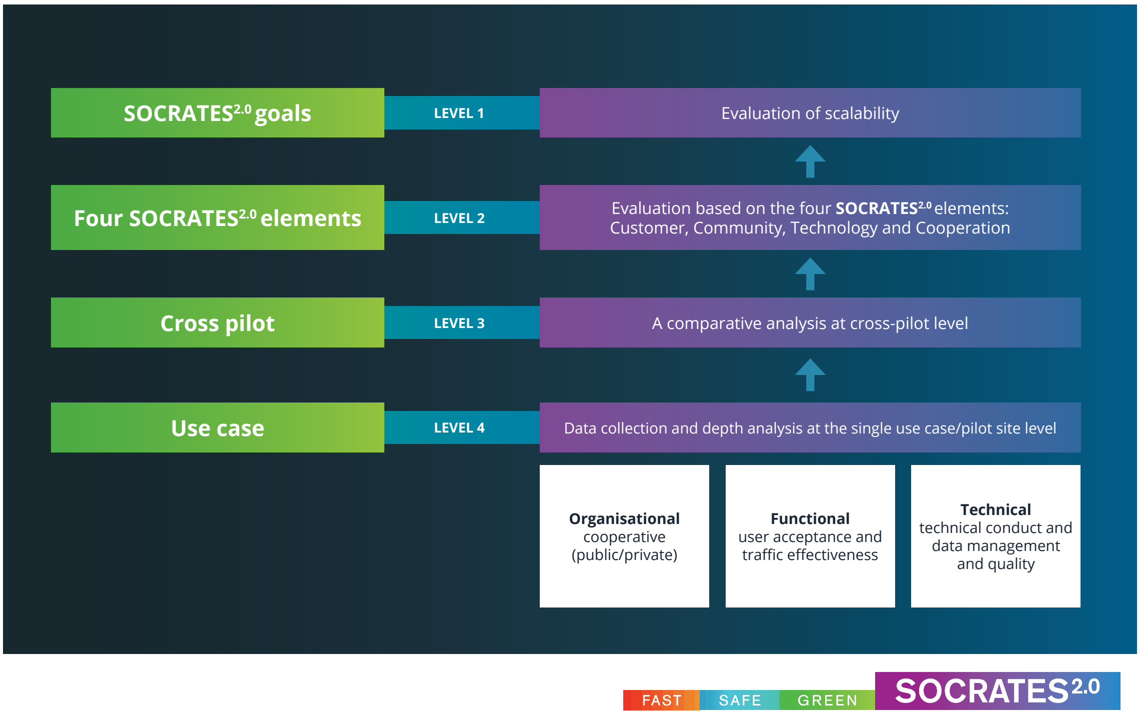

Figure A2. SOCRATES$^{2.0}$ evaluation set-up

As pilot-specific evaluations on level 4, the evaluation perspective was on:

- Technical performance: focusing on quality, reliability etc. of the developed systems and services
- Functional performance: focusing on the impact the services, e.g. by considering the number of the amount of reached users
- Organisational performance: focusing on the way the partners cooperate, related to the developed cooperation framework

The outcomes of the evaluation activities are reported in D8: SOCRATES2.0 Evaluation.

Activity 9, which main result is this Consolidation Report, wraps up the entire project, in terms of the validation of the SOCRATES$^{2.0}$ concept, and compiling future actions as a follow-up plan.

ANNEX III: Pilot site elaborations and inventory

As the pilot sites evolved mostly independently, we made some efforts to identify all pilot site-related results in a comprehensive manner. To do so, a "Content List" was created for each pilot site, being an inventory of all elaborations divided into six main types: Software applications, Algorithms, Standards, Documents, Software Interfaces and Data Feeds.

The goal of such "Content List" is (a) to have an overview on pilot site-related contents/ elaborations and (b) to determine dissemination activities regarding relevant contents. Such dissemination was eventually a major input for this Consolidation Report. For a generic impression, only the Content List for Amsterdam consists of more than 50 items.

Comparing all Content Lists, there seem be repeating, basic components for the six mentioned types throughout many pilot sites. These are summarised in the next figure, which may be considered a "construction kit" for a typical set-up of a pilot deployment.

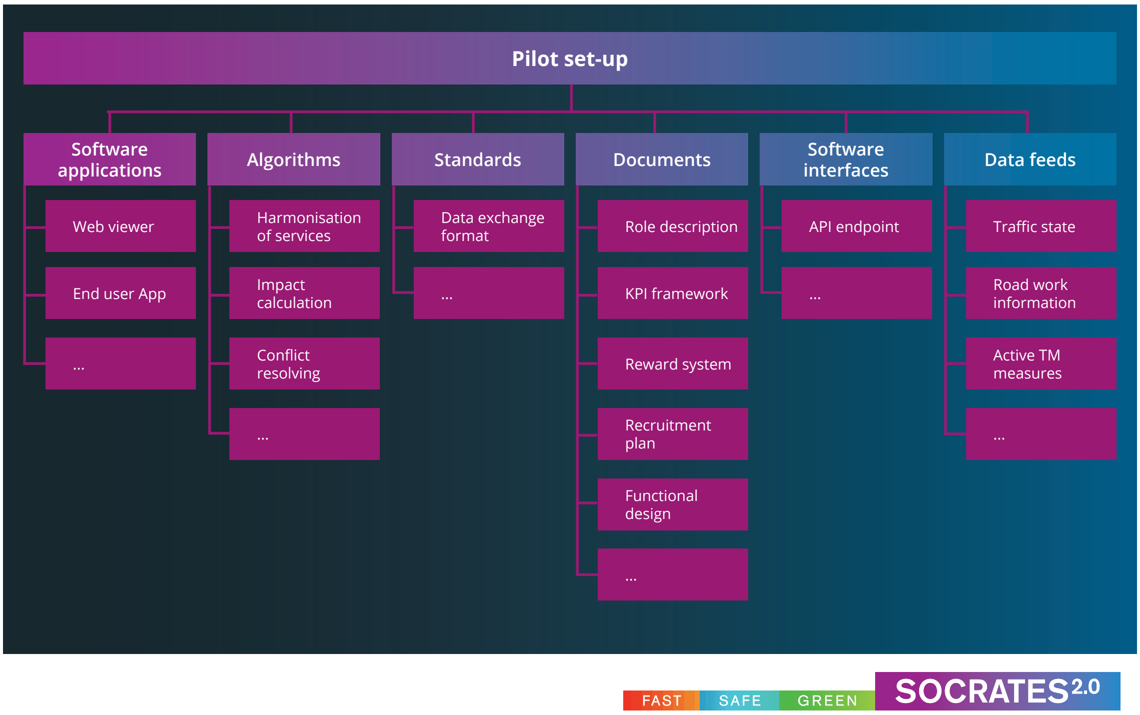

Figure A3. Basic components of a pilot deployment

It can be concluded that that a typical pilot deployment involves some basic components, which are necessary to establish the interactive traffic management concept as such. Whenever applied across multiple pilot sites and/or use cases, such basic elaborations should be harmonised, where possible. This was done in SOCRATES$^{2.0}$ via, e.g. a common data exchange format, see Section 2. Other elaborations, on the other hand, are specific from pilot to pilot, due do different set-ups and use cases.

The individual "Content Tables" for the four pilot sites are presented on the next pages.

Table A2. SOCRATES$^{2.0}$ content table for the Amsterdam pilot site

SOCRATES$^{2.0}$ Content	Type of content	Owner (SOCRATES$^{2.0}$ partners)	Reference for further information
ONTF Description of the role Strategy Table Amsterdam	document	all	Fact Sheet about Strategy Table, Pilot Site Report Amsterdam
ONTF Strategy Table KPI framework	document	all	Fact Sheet about Strategy Table, Pilot Site Report Amsterdam
ONTF Description of the role Network Monitor Amsterdam	document	all	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
ONTF Description of the role Network Manager Amsterdam	document	all	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF Description of the role Assessor Amsterdam	document	all	Fact Sheet about Assessor, Pilot Site Report Amsterdam
ONTF Tilted table specification	document	Nationaal Dataportaal Wegverkeer	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
Protocol for a Reward system	document	Be-Mobile/MAPtm	Fact Sheet about Rewarding System, Pilot Site Report Amsterdam
End User Service Be-Mobile	software application	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Amsterdam
End User Service BMW	software application	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Amsterdam
End User Service TomTom	software application	TomTom	Pilot Site Report Amsterdam
End User Service BrandMKRS	software application	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Amsterdam
Development of new or additional functionality and HMI's of Be-Mobile	software	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Amsterdam
Development of new or additional functionality and HMI's of BMW	software	BMW	Fact Sheet End-user Services BMW, Pilot Site Report Amsterdam
Development of new or additional functionality and HMI's of TomTom	software	TomTom	Pilot Site Report Amsterdam
Development of new or additional functionality and HMI's of BrandMKRS	software	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Amsterdam

ONTF DVM Exchange Active Traffic Measures from Road Authorities to Tilted table data exchange (MobiMaestro RA's - Nationaal Dataportaal Wegverkeer)	data feed	Nationaal Dataportaal Wegverkeer + RA's	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF Tilted table data exchange from Network Monitor to Network Manager	data feed	Nationaal Dataportaal Wegverkeer	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
ONTF Data feed predicted state data delivery TomTom	data feed	TomTom	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
ONTF Data feed predicted state data delivery Be-Mobile	data feed	Be-Mobile	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
ONTF Predicted traffic state data delivery Nationaal Dataportaal Wegverkeer/PTV	data feed	Nationaal Dataportaal Wegverkeer / PTV	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
ONTF MobiMaestro web viewer	software application	Technolution	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF MobiMaestro application	software application	Technolution/ Rijkswaterstaat	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF Toolbox -set of services	document	Technolution/ Rijkswaterstaat	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF Predicted problem state definition Network Manager	document	Technolution/ Rijkswaterstaat	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF Harmonisation of services, impact calculation and conflict resolving (Technolution / Rijkswaterstaat)	algorithm	Technolution/ Rijkswaterstaat	Fact Sheet about Network Manager, Pilot Site Report Amsterdam
ONTF AVOID Service Request (part of TMEx)	data feed	Technolution/ Rijkswaterstaat	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
ONTF AVOID Route Service Request (part of TMEx)	data feed	Technolution/ Rijkswaterstaat	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
ONTF REROUTE Service Request (part of TMEx)	data feed	Technolution/ Rijkswaterstaat	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
SD and ONTF REROUTE Service Request (part of TMEx)	data feed	Rijkswaterstaat	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
Recruitment plan Be-Mobile	document	Be-Mobile	Pilot Site Report Amsterdam

Recruitment plan BrandMKRS	document	BMK	Pilot Site Report Amsterdam
Recruitment plan BMW	document	BMW	Pilot Site Report Amsterdam
Recruitment plan TomTom	document	TomTom	Pilot Site Report Amsterdam
SD Data exchange format (DATEX II): road closures	data feed	Nationaal Dataportaal Wegverkeer	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
SD DVM Exchange parking guidance to DATEX II service request (MobiMaestro Amsterdam- Technolution)	data feed	Technolution + Amsterdam	Pilot Site Report Amsterdam
EZ Data exchange format / DATEX II - RAZ	data feed	Nationaal Dataportaal Wegverkeer	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
ONTF “Intekentool VM-IVRA”: tool for TMC’s and RA’s to register traffic management measures	application	Nationaal Dataportaal Wegverkeer	Fact Sheet about Network Monitor, Pilot Site Report Amsterdam
EZ API endpoint: environmental zone (EZ)	software interface	Nationaal Dataportaal Wegverkeer	Pilot Site Report Amsterdam
SD API endpoint: road closures	software interface	Nationaal Dataportaal Wegverkeer	Pilot Site Report Amsterdam
SD API endpoint: service requests parking and reroute	software interface	Technolution	Pilot Site Report Amsterdam
Recruitment Dashboard	document	all	Pilot Site Report Amsterdam
EZ: DVM Exchange dynamic EZ from Amsterdam to DATEX II - RAZ dynamic and static message EZ	data feed	Nationaal Dataportaal Wegverkeer + Amsterdam	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
Functional design of service per use case Be-Mobile	document	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Amsterdam
Functional design of service per use case BrandMKRS	document	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Amsterdam
Functional design of service per use case BMW	document	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Amsterdam
Functional design of service per use case TomTom	document	TomTom	Pilot Site Report Amsterdam

ONTF: map matching from Data Provider network segments to Nationaal Dataportaal Wegverkeer segments	algorithm	Nationaal Dataportaal Wegverkeer	Pilot Site Report Amsterdam
ONTF: Waterfall method for reporting impact	document	MAPtm	Fact Sheet about Assessor, Pilot Site Report Amsterdam
ONTF: Waterfall method for reporting impact	software application	MAPtm	Fact Sheet about Assessor, Pilot Site Report Amsterdam
RW: Improved Road Works information feed	data feed	MAPtm	Pilot Site Report Amsterdam
Road Works: Socrates service Data feed specifications: JSon / XML message	document	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
SD DVM Exchange Road Closures Amsterdam to DATEX II Road Closures Nationaal Dataportaal Wegverkeer (MobiMaestro Amsterdam - Nationaal Dataportaal Wegverkeer)	data feed	Nationaal Dataportaal Wegverkeer + Amsterdam	Fact Sheet about DATEX II, Pilot Site Report Amsterdam
Template Network Manager and Toolbox (Excel sheet)	document	Rijkswaterstaat	Fact Sheet about Network Manager, Pilot Site Report Amsterdam

Table A3. SOCRATES$^{2.0}$ content table for the Antwerp pilot site

SOCRATES$^{2.0}$ Content	Type of content	Owner (SOCRATES$^{2.0}$ partners)	Reference for further information
ONTF/ CM4 Description of the role Network Manager Antwerp	document	all	Fact Sheet about Network Manager, Pilot Site Report Antwerp
End User Service Be-Mobile	software application	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Antwerp
End User Service BMW	software application	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Antwerp
Development of new or additional functionality and HMI's of Be-Mobile	software	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Antwerp
Development of new or additional functionality and HMI's of BMW	software	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Antwerp
ONTF / CM4 current traffic state data delivery AWV	data feed	AWV	Fact Sheet about Network Monitor, Pilot Site Report Antwerp
ONTF / CM4 Network Manager web viewer	software application	MAPtm	Fact Sheet about Network Manager, Pilot Site Report Antwerp
ONTF / CM4 Current state / Problem state algorithm	software application	MAPtm	Fact Sheet about Network Manager, Pilot Site Report Antwerp
ONTF / CM4 Problem state definition Network Manager (thresholds)	document	AWV / MAPtm	Fact Sheet about Network Manager, Pilot Site Report Antwerp
ONTF / CM1 / CM4 API end point	data feed	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
CM1 and CM4 API	data feed	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
Functional design of service per use case Be-Mobile	document	Be-Mobile	Fact Sheet about End-user Services Be-Mobile, Pilot Site Report Antwerp
Functional design of service per use case BrandMKRS	document	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Antwerp
Functional design of service per use case BMW	document	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Antwerp
ONTF / CM1 Measures	data feed	AWV	Fact Sheet about Network Manager, Pilot Site Report Antwerp

ONTF/ CM4 Waterfall method for reporting impact	document	MAPtm	Fact Sheet about Assessor, Pilot Site Report Antwerp
RW: Improved Road Works information feed	data feed	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
RW: Socrates service Data feed specifications: JSon / XML message	document	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
RW: Network Monitor ingestion and fusion system	software	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
RW: digestion of Road Works by SP's (public and private)	software	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Antwerp
SLA current lane control signing data delivery AWV	data feed	AWV	Fact Sheet about Network Monitor, Pilot Site Report Antwerp
ONTF/ CM4 voucher system description	document	all	Fact Sheet about Voucher System Antwerp, Pilot Site Report Antwerp
ONTF/ CM4 voucher system contract nv Tunnel Liefkenshoek	document	all	Fact Sheet about Voucher System Antwerp, Pilot Site Report Antwerp
ONTF/ CM4 voucher system toll collector instructions	document	Liefkenshoek	Fact Sheet about Voucher System Antwerp, Pilot Site Report Antwerp
ONTF/ CM4 description of system setup leading to win-win-win	document	all	Fact Sheet about Voucher System Antwerp, Pilot Site Report Antwerp

Table A4. SOCRATES$^{2.0}$ content table for the Munich pilot site

SOCRATES$^{2.0}$ Content	**Type of content**	**Owner (SOCRATES$^{2.0}$ partners)**	**Reference for further information**
Route Strategies Munich Fair + Allianz arena (VMS contents + georeference via OpenLR)	document	Bavarian Motorway Administration	Pilot Site Report Munich
Route IDs Munich Fair, including route description and reason (Lookup-table)	document	Bavarian Motorway Administration	Pilot Site Report Munich
DATEX II representation of route recommendations to Munich Fair (“StrategicRouting.xsd”)	data feed	Bavarian Motorway Administration	Fact Sheet about DATEX II, Pilot Site Report Munich
DATEXII publication “Strategisches Routing WWW” on the MDM	data feed	Bavarian Motorway Administration	Fact Sheet about DATEX II, Pilot Site Report Munich
BMW internal back-end, including geofenced service dissemination to end users	software application	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Munich
BMW end-user service (“Managed City Drive”)	software application	BMW	Fact Sheet about End-user Services BMW, Pilot Site Report Munich
RW: Improved Road Works information feed	data feed	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Munich
RW: Socrates service Data feed specifications: JSon / XML message	document	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Munich
RW: Network Monitor ingestion and fusion system	software	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Munich
RW: digestion of Road Works by SP’s (public and private)	software	MAPtm	Fact Sheet about DATEX II, Pilot Site Report Munich

Table A5. SOCRATES$^{2.0}$ content table for the Copenhagen pilot site

SOCRATES$^{2.0}$ Content	Type of content	Owner (SOCRATES$^{2.0}$ partners)	Reference for further information
EZ Data exchange format / DATEX II (area instead of stretch of road)	data feed	TNL	Fact Sheet about DATEX II, Pilot Site Report Copenhagen
End User Service TomTom	software application	TomTom	Pilot Site Report Copenhagen
End User Service BrandMKRS	software application	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Copenhagen
Development of new or additional functionality and HMI's of TomTom (considering environmental zone & cyclist information)	software	TomTom	Pilot Site Report Copenhagen
Development of new or additional functionality and HMI's of BrandMKRS (messages which are time-based dependent of event)	software	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Copenhagen
Recruitment plan BrandMKRS	document	BMK	Pilot Site Report Copenhagen
Recruitment plan TomTom	document	TomTom	Pilot Site Report Copenhagen
Recruitment Dashboard	document	all	Pilot Site Report Copenhagen
Functional design of service per use case BrandMKRS	document	BMK	Fact Sheet about End-user Services BrandMKRS, Pilot Site Report Copenhagen
Functional design of service per use case TomTom	document	TomTom	Pilot Site Report Copenhagen
ONTF Description of the role Network Monitor Copenhagen	document	all	Fact Sheet about Network Monitor, Pilot Site Report Copenhagen
Gathering data from air quality sensors for Network Monitor	software	Technolution	Fact Sheet about Network Monitor, Pilot Site Report Copenhagen
Gathering data from cycling sensors for Network Monitor	software	Technolution	Fact Sheet about Network Monitor, Pilot Site Report Copenhagen
ONTF Description of the role Network Manager Copenhagen, multimodal approach	document	all	Fact Sheet about Network Manager, Pilot Site Report Copenhagen

ONTF Data feed current state data delivery TomTom	data feed	TomTom	Pilot Site Report Copenhagen
SD MobiMaestro application	software application	Technolution	Fact Sheet about Network Manager, Pilot Site Report Copenhagen
ONTF Toolbox -set of services	document	Technolution	Fact Sheet about Strategy Table, Pilot Site Report Copenhagen
ONTF Harmonisation of services, impact calculation and conflict resolving, incl. cyclists data to send an avoid	algorithm	Technolution	Fact Sheet about Network Manager, Pilot Site Report Copenhagen
ONTF AVOID Service Request (part of TMEx)	data feed	Technolution/ Rijkswaterstaat	Fact Sheet about DATEX II, Pilot Site Report Copenhagen
Log of Network Manager and Toolbox (Excel sheet)	document	Technolution	Fact Sheet about Network Manager, Pilot Site Report Copenhagen

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