BONVOYAGE

From Bilbao to Oslo, intermodal mobility solutions, interfaces and applications for people and goods, supported by an innovative communication network

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Abstract:	This deliverable is version 2 of the Project Vision and Roadmap; it has been updated along the project's lifespan by means of Internal deliverables, and it is now a consolidated version, at the end of the project. This report is compiled starting from the Description of Work document, and taking into account results generated within the project, other relevant scientific, technological or market developments, and the long term strategies of the EU and project partners. The deliverable includes three main sections: i) what is the ideal vision of the project and related exploitation and impact; ii) how we have realized that vision; iii) a detailed breakdown of the project activities.
Keyword List:	Project Vision; Roadmap; Objectives; Scientific, Market and Social aspects; Impact, Work performed

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Abbreviations

ABBREVIATION	DEFINITION
API	Application Programming Interface
CAPEX	CAPital EXpenditure
IoT	Internet of things
ICN	Information Centric Networking
IT	Information Technology, generally referring to the systems concerning the transmission and elaboration of information
ITS	Intelligent Transport Systems
KPI	Key Performance Indicators, which are indicators that characterize a certain system and that are used to evaluate the performances of a particular activity/system
MDHT	Metadata Handling Tool
NAP	National Access Point
OGB	OpenGeoBase
OPEX	OPerating EXpenditure

Table 1: Abbreviations

BONVOYAGE Glossary

Table 2 lists and describes the terms that have been considered relevant in this deliverable.

BONVOYAGE GLOSSARY	
TERM	DEFINITION
Vision Statement	A Project Vision Statement is an idealistic view of the desired outcomes to be produced for the business after successful project completion.
Project Roadmap	The Project Roadmap is a high level overview of the project 's goals and deliverables presented on a timeline.
Federation	A federation is a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of distinct, formally disconnected networks, which have different internal structures, is obtained.
Planning/Routing service/Soloist	A service providing a set of travel solutions for going from A to B in a local context (limited area and/or transport means and/or involved operators, etc.)

Table 2: BONVOYAGE Dictionary

1 Introduction

1.1 Deliverable Rationale

Having a clear project vision is very important to the success of complex initiatives such as R&D multi-partner, multi-objective collaborations. BONVOYAGE additionally has an inter-disciplinary nature, cross-fertilizing research between the science of transport networks and the science of telecommunication networks, which poses more burdens to the scientific coordination work.

The vision and roadmap are essential to distribute a common understanding of where the project is going within the Consortium itself, first and foremost. It also serves the purpose, especially in its latest version, which is produced at the end of the project, of communicating such common understanding outside the project, publicly, and to the project 's reviewers and funding entities.

1.2 Quality review

Version Control Table			
Version N.	**Purpose/Changes**	**Author**	**Date**
0.1	Draft index of the document	Maria Bianco	03.04.2018
0.5	First consolidated TOC	Andrea Detti	12.04.2018
0.9	Draft sections 1-3	Giuseppe Tropea, CRAT, SINTEF, TRIT, CEA	20.04.2018
0.9.5	Integration of review feedback	ATOS, CNIT	26.04.2018
1.0	Final review loop	Giuseppe Tropea, Andrea Detti, Ignacio Gonzalez	27.04.2018

1.3 Executive summary

1.3.1 Deliverable description

This deliverable reports the final version of the Project Vision and Roadmap, which is delivered at the end of the project. The document starts from the original Description of Work document, and takes into account results generated within the project, other relevant scientific, technological or market developments, and the long-term strategies of the EU and project partners. Thus, it includes parts of the original proposal, updated when needed, concise description of work performed, and new/updated concepts.

In some cases this document duplicates information provided in other deliverables, but its aim is to concisely describe the project as a whole, and publicly. More details can be found in project deliverables (http://bonvoyage2020.eu/results/deliverables/), which are quoted in this document by their official abbreviation, Dx.y for final deliverables and Ix.y for internal, intermediate deliverables. All deliverables are available for reviewers and advisory board members, while only those marked as "P(ublic)" are publicly available.

As for the organisation of the document, after a brief introduction, in Section 2 we report the vision of the project, detailing major features and expected benefits, potential market, and comparison with other solutions. In Section 3, we describe how we have reached our vision, by: i) listing specific objectives; ii) describing scientific/technical, market and societal aspects of the project. Finally in Section 4, we give an account of the work performed, including both design and lab prototyping activities and related expected impact.

1.3.2 Summary of results

This document summarizes the vision of BONVOYAGE and the work performed throughout it, providing in a single document a bird's eye view of the project. This is the second version of the deliverable, due at the end of the project at month 36, providing a complete picture of our achievements.

1.3.3 Changes from v1 to v2 of this document

CHANGES	WHERE
Introductory section renamed to "BONVOYAGE project at a glance"	Section 2.1
The BONVOYAGE Federated Architecture updated	Section 2.3
Societal Vision updated	Section 2.5
H2020 ITS Cluster activities updated	Section 2.6.1

Reference Scenario updated	Section 3.2
New sections about the BONVOYAGE layered architecture	Section 3.3
New section about freight-specific issues	Section 3.5
New section about privacy concerns	Section 3.4
New section about car-pooling strategies	Section 3.6
Business plan section expressed in terms of two sustainable market deploy scenarios	Section 3.10
Updated list of prototypes	Section 4.2
Updated R&D achievements	Section 4.1
Updated standardization results	Section 4.3
Updated market impact	Section 4.4
Added section about usage of stress level data	Section 3.7

2 Vision Statement

For several years now, journey-planning websites have helped transport operators and public authorities to improve the quality, the ridership, and revenues of transportation services. Traditionally, these instruments have been conceived as closed systems, and planning services (aka routing services) are often times outsourced to a small number of specialist providers.

Quite recently a growing tendency to publish and share transportation data directly on the web has emerged. As an example, Google is trying to define a standardized format, namely GTFS, which exposes public transportation schedules and related geographic information, while EU-backed formats are mature (such as DATEX II) and extremely expressive (NeTEx).

This new trend is laying the foundation for an emerging open source model for the Intelligent Transport Systems, which brings to two fundamental innovations.

First, diverse and competing suppliers (including one-man app developers) can be able to implement their own applications with the data. Consequently, wide access to travel-centric data is supporting the intermodality of the solutions delivered by the application, because it simplifies and promotes the configuration of journeys encompassing different transportation means and domains.

Second, we witness a pervasive integration of sensors into cars, trucks, and other transportation units, which can be networked and exploited for monitoring of traffic and road conditions, predicting arrival and departure information, ensuring traffic safety, and so on. As a result, it is expected that a huge number of real-time data (coming from websites, data-centres, sensors, vehicles, goods and people on the move) will shortly be adopted in ITS applications, giving birth to innovative enhancements, which are yet to be fully comprehended.

What are the obstacles along the path towards these innovations?

Many of the centralized journey-planners currently available in the market have the limitation that the scope of route searches is geographically restricted to a region or a metropolitan area or specialized for one transport mode. Given the speed of networks and the storage capacity of today's commodity computer hardware, some centralized applications are emerging (Google Maps/Transit, rome2rio), which try to scale continent-wide or worldwide and to multimodal travels. Although theoretically possible, to organize and exchange raw transit and schedule data for an entire continent, such that each planner instance has access to all raw schedule data, is practically not feasible when:

- real time constraints are to be taken into account;
- user profiles are involved;
- different optimization schemes are to be applied, depending on localities and region-specific constraints;
- rate of transit data updates is different between different regions;
- there exist some concerns about openness of data on the part of the large, sometimes cautious Transport Operators;
- it would be hard to convince transit businesses or authorities about their need to allocate funds to ITS applications with a worldwide scale, even though the costs of computational resources are becoming cheaper.

This is why the European Union Directive 2010/40/EU draws a legal framework for developing specifications to make ITS interoperable across borders.

Furthermore, the ITS business does not immediately achieve openness of the solutions and interoperability just by adopting standardized formats for transit data or by developing new applications on top of available open source components. Beyond that, easy and efficient data dissemination is required when external players, transport operators, sensors, passengers, and other data sources, may publish and use travel data to plan journeys, and to manage them, on any scale. As an example, OAG Aviation (the world's largest network of air travel data) not only provides schedules in any format the customer requires, but offers real-time data feeds and alerts with a schedule changes notification system, adopting an incremental publish/subscribe scheme.

In addition, the highly heterogeneous data sources, including data-centres, sensors, vehicles, goods and people on the move, their distributed and mobile nature, as well as the coexistence of heterogeneous network protocols, calls for an innovative information delivery paradigm, which simplifies the development of ITS application when compared with traditional use of the current TCP/IP Internet architecture.

The vision of the BONVOYAGE project is twofold:

- for the end-users, to provide the best information to go from a place to another, before and during the travel, door to door, by using any combination of any transport means, both for people and goods, taking into account real-time conditions and user preferences;
- for the EU and ITS community, to provide an open and federated architecture able to cluster local planning services and data sources, exploiting the functionality of an innovative information-centric networking approach, open data and open interfaces.

To this end, the project has designed, developed and tested a platform that integrates travel information, planning services, non-real-time data from heterogeneous databases (on road, railway and urban transport systems); real-time data (expected arrival times, traffic, data from smartphone and wearable sensors); user profiles; user feedback. An innovative communication network that collects and distributes all data required to optimize a travel supports the platform.

2.1 The BONVOYAGE Project at a Glance

The project focuses on the design, development and test of a rich platform comprising three main system components: i) applications and interfaces, to cope with personalized, multimodal, dynamic, distributed, multiparty, open scenarios; ii) a set of travel optimizers which provide travel instructions that are tailored for each class of users and specific to particular transport conditions or a given context, and then linked together so that multimodal and multi-context solutions are produced; iii) a communication network, which provides large scale search and delivery of all relevant services and data, from static schedules to real-time information.

Figure 1 shows the main slide from the BONVOYAGE presentation at the ITS European Congress in Strasbourg, June 2017. It summarizes how the BONVOYAGE design of above system components, in our vision, is able to innovate some crucial aspects of the ITS state-of-the-art.

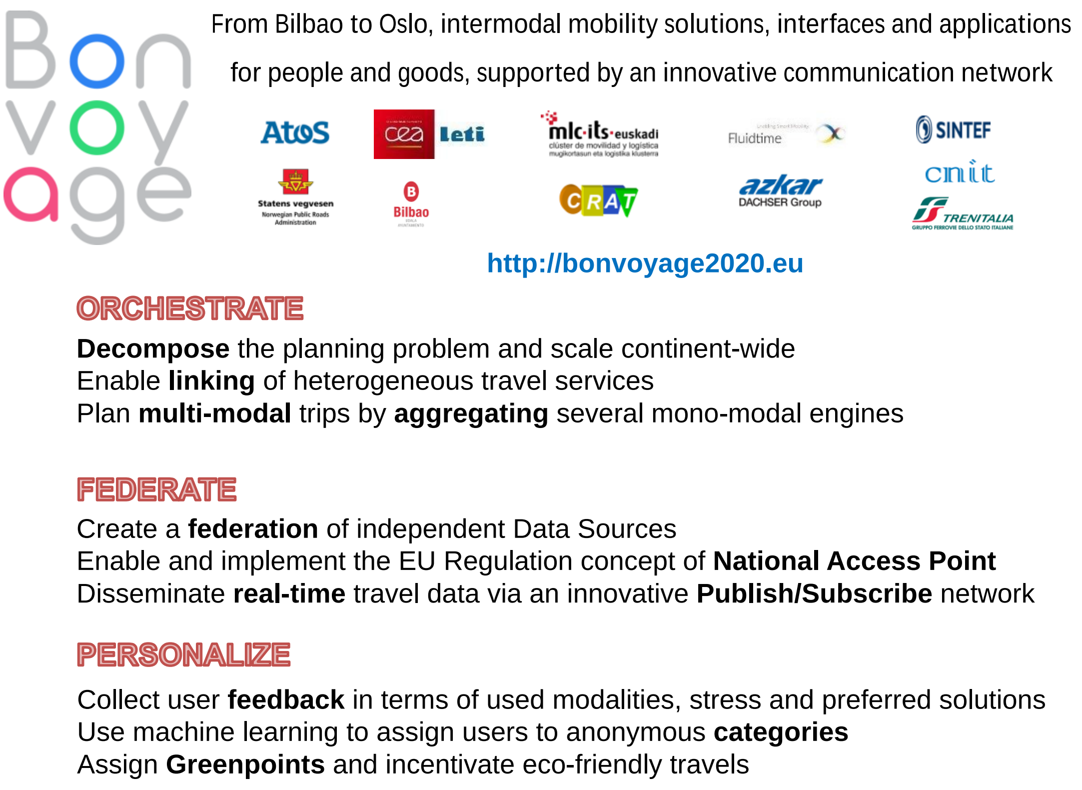


Figure 1. BONVOYAGE key concepts presented at ITS European Congress 2017, Strasbourg

The project revolves around three key concepts: Orchestrate, Federate, Personalize.

In the following we first describe in more details each of the platform's system components and their relationship with those key BONVOYAGE concepts; then we summarize the more innovative/appealing characteristics of the project; finally we conclude this "vision" chapter by matching the project's achievements with the current European regulation about travel services, discussing possible an exploitation path for our work.

2.1.1 Applications and Interfaces: Personalize

Applications and interfaces allow external heterogeneous actors to seamlessly interact with the BONVOYAGE platform. Mobile Android apps that provide real-time route information and collect relevant user feedback using participatory sensing were developed to interact with end users.

Also, several corollary web interfaces for testing various aspects of the platform have been developed.

Applications are composed of their front-ends and a supporting application server back-end.

The main BONVOYAGE application server offers personalisation services. It relies on a database of user-centric data, which is dynamically collected through the mobile clients that interact with end users. The user 's behaviour and feedback data are used to derive data-driven user profiles that are used to customize services and travel solutions. These personalization and solution-ranking services are based on state-of-the-art machine learning techniques.

The main BONVOYAGE Android mobile client provides route information to the user and collects relevant user feedback while she is traveling, feeding the personalisation and participatory sensing services of the application server. It enables users to find the best way to go from one place to another taking into account the users personal needs and preferences in terms of schedule, duration, costs, transport means, transport mode related to low user 's stress level, etc. The application follows an interactive design (see deliverable D6.2 Apps) allowing users to intuitively request required information and receiving personalized multimodal travel routes. Users ' feedback, including feedback coming through smart wearable sensors, gets collected via both unattended and attended apps running on the client.

The application server is able to track and assign Greenpoints to the users, and thus BONVOYAGE is able to incentivise eco-friendly traveling.

In summary, applications in BONVOYAGE are able to:

- Collect user feedback in terms of used modalities, stress and preferred solutions
- Use machine learning to assign users to anonymous categories
- Assign Greenpoints and incentivize eco-friendly travels

The main interface between applications and the BONVOYAGE planning services is the SPROUTE format (https://github.com/dts-ait/ariadne-json-route-format), which BONVOYAGE has adopted and extended. It is able to convey articulated travel requests and the corresponding set of responses, as well as to capture the constraints and weights along the preferred traveling dimensions of the specific user, anonymously, so that the travel planning algorithms can fully personalize the computed solutions.

In order to access and use external services and data, BONVOYAGE provides adaptation mechanisms to integrate technology dependent solutions from other providers. Symmetrically, we have also developed APIs for easy access to the publish/subscribe and discovery infrastructure of BONVOYAGE, in order to allow external players exploit our platform.

2.1.2 Multi-modal travel optimization: Orchestrate

The multimodal travel optimization is a core function of the BONVOYAGE platform. Our solution is a collaborative framework for distributed optimization services. This approach enables the necessary scalability to handle continent-wide travel networks combined with personalized travel preferences. At the same time it also enables fast response to real-time events. Hence, the resulting solutions are truly intermodal, handling combinations of any private and public modality in the same journey. The existing, alternative technology heavily relies on extensive pre-processing, which limits the possibility to exploit real-time information as well as personalized user profiles. The BONVOYAGE travel optimization goes beyond these limitations thanks to its distributed architecture and its novel algorithms, and is centred around the concept of orchestrating several different local routing services, to meet the following goals:

- Decompose the planning problem and scale continent-wide.
- Enable linking of heterogeneous local routing services.
- Plan multi-modal trips by aggregating several mono-modal or multi-modal routing engines.

A local routing service is a route resolver whose scope may be limited with respect to one or more planning domains, including: geographical area, transport modality, operator, etc. For instance a city administration may provide a multi-modal local routing service that copes with any transport means available at the city but whose geographical scope is limited to the city boundaries; a transport operator may provide a mono-modal local routing service whose solutions only take into account owned transport means.

The developed BONVOYAGE platform contains a collection of different local routing services, using different route optimization algorithms, operating at different level of aggregation and detail. Each route-planning algorithm is continuously updated with data relevant to the geographical area and the modalities that it covers.

The orchestration service is triggered by a planning request containing anonymous user data collected from the personalization services and provides intermodal routes optimized according to the request, the personalized user profile and the real-time situation. To be able to scale the service into a continent-wide route planner the orchestrator is in charge of decomposing the request, and it distributes the sub-requests to the most appropriate local routing services.

The orchestration service acts as a distributed route planner component, and exposes to the applications an SPROUTE interface for invoking its route-planning functionalities.

2.1.3 Telecommunications Network: Federate

The highly heterogeneous, distributed and mobile nature of transport data, coming from data-centres, sensors, vehicles, goods and people on the move, calls for a new networking model.

The current Internet model is based on the Internet Protocol (IP) and provides users with communication channels between hosts (e.g. a client and a server) that are identified by an IP address. Our alternative reference model is called Information Centric Networking (ICN), a paradigm emerged to overcome some intrinsic limitations of the current Internet. In ICN, the network provides users with access to information by names, instead of providing communication channels between hosts. The idea is to provide "access to named data" as the fundamental network service. This means that all information (e.g. a document, a picture) is given a name that does not include references to its location; then, user's requests for a specific information are routed toward the "closest" copy of such informatio n, which could be stored, at the same time, in a server, in a cache contained in a network node or even in another user 's device; finally the content is delivered to the requesting user by the network. With ICN, the communication network becomes aware of the name of the information that it provides and the routing decisions are made on the basis of the information name. In addition, ICN secures the information package itself, instead of securing the communication channels, thus information can be trustily delivered also by untrusted servers or nodes and remain protected also when emerges from a communication channel (e.g. a picture is protected not only while it travels into the network but also after arriving at destination).

In BONVOYAGE, we have been working on three main networking issues.

The first one is to contribute to the design of basic functionality of ICN, of which we are among the first designers, including interplay with cloud/virtualization concepts, name to location resolution, routing/forwarding table scalability.

The second issue is to develop a declination of ICN, which we call Internames. Internames evolves from ICN 's host(s)-to-name model to a name-to-name principle in which names identify both source and destination entities, and names are used to identify all entities involved in communication, not only content but also users, devices, network functions and services. With Internames, travel-centric contents and sensor-generated and user-generated data can be retrieved by using both request-response and publish-subscribe communication models. The publish-subscribe mechanism is based on an asynchronous interaction: a user issues a subscription request for a sensor-generated data (e.g., weather conditions); then, every time the sensor registers a new value (e.g., the temperature went below 0 °C and the road may be icy), the considered source of information and the network itself are in charge of delivering that data to all the subscribed applications.

The third issue is about a decentralized large-scale storage system used for building our georeferenced mobile and web applications, which we call OpenGeoBase. OpenGeoBase exploits ICN and Internames to collect and make available georeferenced transport-related data. Basically, OpenGeoBase allows anyone to publish data relevant to a specific geographic area, ranging from transport schedules to sensor-generated or user generated real-time information, but also, point of interests, etc. Publishers are not forced to upload their data in a central repository but they can keep them in local, distributed repositories, under their control. OpenGeoBase logically puts together all individual repositories and make it easy for users to search for and retrieve the data they are interested in. OpenGeoBase is: i) distributed, not requiring a centralized entity, ii) scalable, capable of growing without bounds; iii) secure, every piece of content can be secured in a customizable way and can include configurable policies as to who and when and where can access the information; iv) slice-able, several tenants and users can use it in parallel and independently; v) reliable: no single point of failure; vi) fast.

As a result, Internames and OGB are the building blocks to achieve the following goals:

- Create a federation of independent sources of geo-referenced information
- Enable and implement the 2010/40/EU Directive concept of National Access Points, where each database site is a National Access Point offering discovery services and storing metadata about data sources and local routing services
- Disseminate real-time travel data via an innovative Publish/Subscribe network

As a concluding remark, we point out that all our ICN technology and related applications are released as open-source code.

The next two sections summarize the main innovative characteristics and explain how the innovative characteristics of BONVOYAGE, together with our approach, match the current 2010/40/EU Directive about Intelligent Transport Services.

2.2 Innovative characteristics

Innovative characteristics of BONVOYAGE with respect to current solutions include:

- supporting different optimality criteria and ranking options of multimodal trips (e.g. resulting from a combination of bike+train+plane+bus+on foot), for both passengers and goods
- taking into account dynamic, real time, conditions (e.g., delay of trains, construction work on a road, bad weather, user 's stress level)
- taking into account user preferences and profiles, including dynamic information like preferred transport modes and user 's stress level related to different transport modes as

estimated from previous travels through data collected by wearable smart sensors and smartphone sensors

- facilitating the large-scale search, sharing and delivery of transport solutions and related data among transport providers, travel service operators, applications and users; this is one of the main problems nowadays: how to collect transport information not only from big airlines/train operators but also from all the millions, small scale, bus/local transport/private providers
- allowing transport providers to keep their data and services in their premises, with their formats and interfaces, rather than transfer them to a third, centralized party (e.g. Google) and/or to comply with specific format (e.g. GTFS)
- allowing travel operators or applications to get data directly from the transport providers rather than from a third party
- allowing any one to easily publish transport solutions, including private citizens (e.g. for car sharing purposes, hitching a lift)
- allowing any one to set up access restriction and privacy policies on published data and then verify the owner and the authenticity of published data
- allowing any one to easily exploit all such information (e.g. anyone can develop an application and become an online travel platform provider).

The innovative characteristics described above lead to the creation of a truly open platform supporting the interaction among a large number of actors (i.e., passengers, travel operator, localized journey-planners, sensors, and so on) across the boundaries of organizations and domains, becoming a very powerful enabler of a continent-wide smart-transportation system.

In turn, such open platform allows adopting a truly innovative model in the scenario of journey planners, which is a distinctive feature of our project: that of a federation of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of distinct, formally disconnected networks, which have different internal structures, is obtained; this is a very important characteristic and innovation of BONVOYAGE, and we devote the next section to describe it.

2.3 The BONVOYAGE Federated Architecture

A central idea of BONVOYAGE is to implement an open and federated architecture, to establish an infrastructure for continent wide travel planning, grounded on an ICN network layer.

Differently than a generically distributed or P2P system, a federation is a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of distinct, formally disconnected networks, which have different internal structures, is obtained.

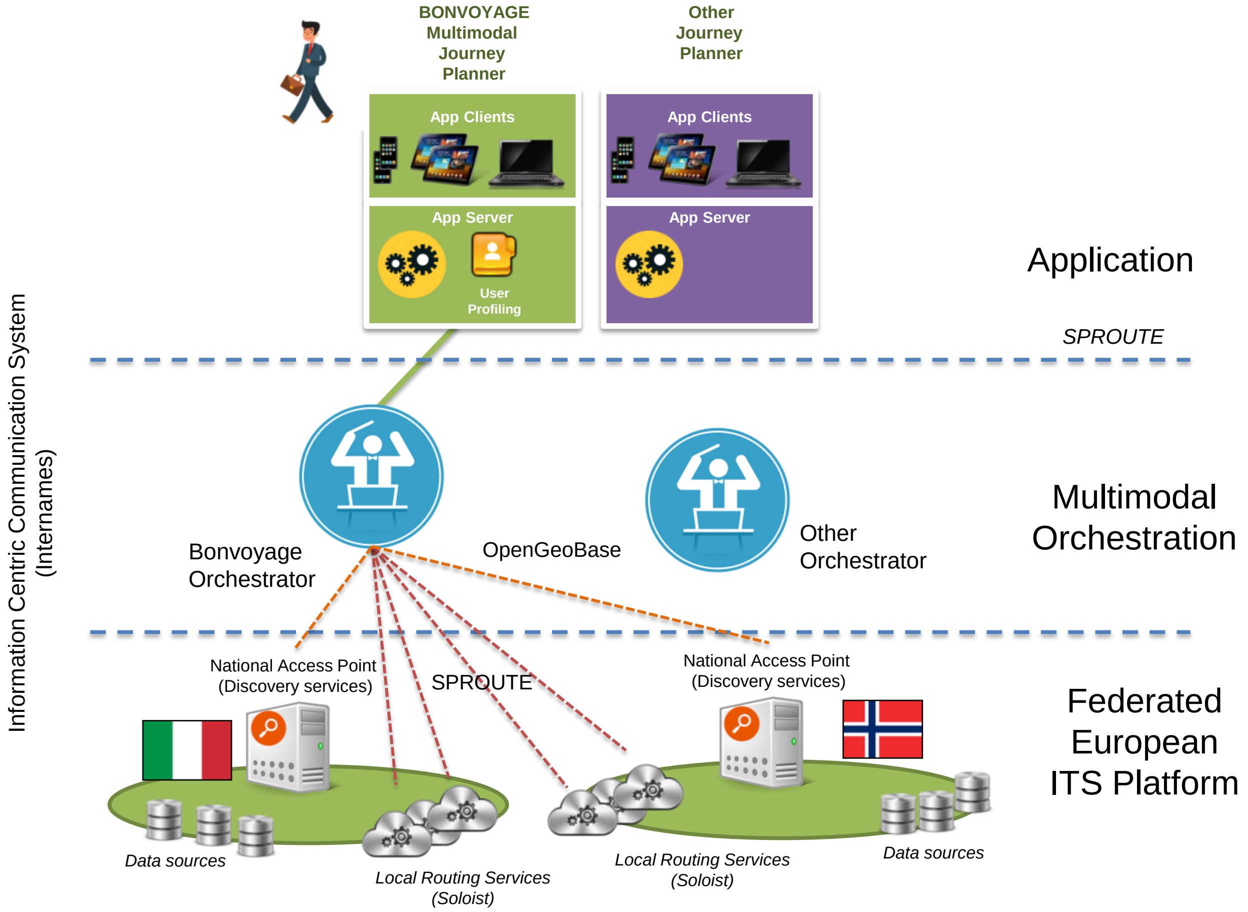


Figure 2. BONVOYAGE federated architecture

Figure 2 describes the BONVOYAGE federated architecture. We have front-end App Clients that use a back-end multimodal journey planning application, which is the Application Server. For route resolving purposes, the Application Server contacts an orchestrator (many competing for the market orchestrators are possible) which in turn accesses a federated architecture formed by: a set of Local Routing Services, Data Sources, and National Access Points. Both data and routing services refer to a given geographical area (e.g. a country) and given transport modes (e.g., car+bus, plain+train, car sharing, etc.). Routing Services and Data Sources are discovered through a Discovery Service offered by the National Access Points.

A declination of ICN, which we call Internames (see 2.1.3), supports the internal communications among National Access Points and publish-subscribe data sources. For compatibility purposes, external interfaces are based on HTTPs.

Guided by this federated approach, BONVOYAGE has designed, developed and tested its platform for optimizing multimodal transport of passengers and goods.

2.3.1 The EU Legal Framework

We are using the term National Access Point on purpose.

In 2010 the European Union started setting up Directive 2010/40/EU ("Framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport") establishing a legal framework for the coordinated deployment of ITSs among Member States, in the field of road transport and for interfacing with othe r modes of transport. Basically it is a framework for developing specifications to make ITS interoperable across borders. It envisages four primary ITS goals (aka priority areas): i) optimal use of roads, traffic and travel data; ii) continuity of traffic and freight management ITS services; iii) ITS road safety and security applications; iv) linking the vehicle with the transport infrastructure.

The European Union is acknowledging the difficulties arising from a strictly centralized solution to the problem of continent-wide future-proof ITSs, and to achieve these goals the directive recommends six priority actions. The six priority action areas set out by the Directive are:

- Priority action (a): "the provision of EU-wide multimodal travel information services ". (This priority action has been under development throughout almost all of the project 's lifespan, being finalized with Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017).
- Priority action (b): "the provision of EU-wide real-time traffic information services". (Commission Delegated Regulation (EU) 2015/962 of 18 December 2014).
- Priority action (c): "data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users". (Commission Delegated Regulation (EU) No 886/2013 of 15 May 2013).
- Priority action (d): "the harmonized provision for an interoperable EU-wide eCall". (Commission Delegated Regulation (EU) No 305/2013 of 26 November 2012).
- Priority action (e): "the provision of information services for safe and secure parking places for trucks and commercial vehicles". (Commission Delegated Regulation (EU) No 885/2013 of 15 May 2013).
- Priority action (f): "the provision of reservation services for safe and secure parking places for trucks and commercial vehicles". (This priority action has been shelved due to lack of sufficient interest in this area).

For each priority action there is an additional Delegated Act (in parentheses is the above list) that better details the action. From a technical point of view Delegated Acts specify the following:

- Each Member State shall set up a National Access Point (NAP), which shall constitute a single point of access for users for accessing ITS data (static and real-time) of different transport modes. The NAP may take various forms, such as a database, a data ware house, a register etc.

- A NAP shall provide discovery services making possible to search data or services using the content of corresponding metadata, timely provided by transport authorities operators, etc.
- Local, regional and national travel information service services providers should expose functionality and metadata of their routing services though a standard interfaces, thus making possible linking of services in order to resolve a cross-border/region door-to-door multimodal journey planning. The metadata includes the handover points, i.e. the location where the results from different routing services can be linked to produce one door-to-door journey.
- Recommended data formats for ITS data are: DATEX II for roads static and real time data; for scheduled services (metro, buses, trains, etc.) NeTEx for static data (e.g., routes, schedule, fares, etc.) and SIRI for dynamic data (e.g., real time scheduling update).

In summary, the delegated regulations on priority actions (b), (c) and (e) require the setting up of a single National Access Point (NAP) and its associated "discovery/search and browse" functionality, by each Member State. This will enable those interested in accessing the data to find it all in one place. Data owners in the public and private sector will be requested to make their data accessible via the NAP. Each National Access Point will offer a single point of access to the road and traffic data of a given territory or network, which are available for re-use by any potential user. Through the discovery services any user will be able to effectively access the data and find out what data is available (in relation to a specific topic or purpose), where it is stored (and possibly who owns it), how to use it (possible terms and conditions of re-use under specific contractual agreements).

The specifications for priority action (a) refers not only to a national access point but, in addition, to a "linking service" which will enable the service exchange between national travel routing services and the possibility to plan trips continent wide.

We believe that BONVOYAGE can play an important role in supporting this regulation and the implementation of the National Access Points, as well as giving relevant input on how to establish an infrastructure for continent wide travel planning, as shown in Figure 2. This way, the project contributes to an open and pan-European solution by establishing several collaboration mechanisms between several multimodal planners (local routing services), towards the realization of the discovery and linking services concepts established in the EU 2010/40 directive. We point out that this framework is not competitive to the current Google service or other existing ones. Conversely we believe that Google, such as any other big/small/medium local/global enterprise providing routing services, could be part of the European federated architecture just by i) wrapping their routing services with the SPROUTE interface and ii) advertising their availability at National Access Point level by inserting proper discovery metadata (GeoJSON format). Indeed, as a proof-of-concept we have successfully inserted in our prototypical platform Google Transit Services as a local routing service together with other developed routing services (for Oslo, Bilbao and Rome).

2.3.2 Innovation to the ITS community and EU

Priority actions (b), (c) and (e) require each Member State to set up a single NAP able to perform discovery, search and browse functionality. BONVOYAGE provides a federated architecture enabling the integration of data sources and routing services, matching the EU directive. Here we briefly explain how BONVOYAGE constitutes a global platform for the ITS community where orchestration of data and planners makes possible to easily setup novel multimodal journey planning applications.

BONVOYAGE implements the federated architecture in its key components (see Figure 2): a discovery service, some focused routing services and connections to existing data sources.

Through the discovery service authorized users can publish georeferenced information (metadata) related to their data or routing services to make them discoverable, and they can retrieve all information (data and routing service) available in an area through a spatial query, which is needed to plan/orchestrate an optimal multimodal trip. Information retrieval can be carried out also in deferred way, subscribing interest on events that occur in given areas, e.g. a new planner or source of information is made available or traffic conditions change. The discovery service is based on the OGB federated spatial database, which exploits Internames, our version of the Information Centric Network (ICN) layer. In our vision the National Access Points become the access points of OpenGeoBase. Each country can autonomously manage its own OpenGeoBase site (a National Access Point) while being part of a global federated system.

Each metadata inserted in and sent back by a National Access Point is signed by the data owner (ICN data-centric security), i.e. the provider of the routing service or of the data source; routing service and data source are not hosted by the National Access Point but stay on the provider's servers. This approach to data certification relieves responsibility of the National Access Point regarding data validity, which is completely in the hand of data owners. Proof is guaranteed by digital signature verification.

BONVOYAGE has actually implemented a federated system formed by three NAPs, real-time and non-real time data sources (DATEX II, GTFS, etc.), and a set of local routing services exposing a common interface. The project has implemented multimodal specialized routing services for Bilbao, Oslo, Rome; a mono-modal planner for car, which wraps the Google APIs; a mono-modal planner specialized for airplane transportation; a planner specialized for car sharing, etc …

BONVOYAGE also deals with novel forms of data sources based on wearable sensors, which measure real-time behaviour of a traveller to assess her stress level or her mode of transport (driving, walking, cycling, etc.), as well as with real-time data coming from DATEX II servers or services in the premises of BONVOYAGE partners.

Clearly the BONVOYAGE architecture can federate a variety of novel routing services and data sources including the ones developed by other European projects, thus federating algorithms for travel planning that are able to respect particular local restrictions and area-specific constraints.

2.3.3 Innovation to the end-user

Nowadays, the number of multimodal journey planning applications is still very limited, albeit their undeniable usefulness. Two issues that limit the development of such applications are: the complexity of multimodal planning algorithms and the practical difficulties of retrieving massive ITS data. The BONVOYAGE federated architecture enables developers to easily overcome these impairments, simply orchestrating routing services provided by others, so fostering the diffusion of multimodal journey planning applications.

In addition, BONVOYAGE provides its own multimodal journey planner applications, which exploits the federated architecture and takes into account specific, user-profile-based travel preferences in order to drive multiobjective optimization algorithms, which communicates with the user both before and during travel. For instance, before the travel starts a user can be notified if some segment of the planned trip must be changed due to a temporarily cancelled bus stop. Similarly, real-time events may be taken into account and notified during the trip. The application exploits a User Profiler Tool whose key difference with state-of-the-art solutions consists in the automatic learning of user preferences from the user behaviour. Moreover, crowd-sourced data coming from users is used to influence travel planning. It comes from two main sources: sensors embedded in the smartphone, wearable sensors (Empatica E4 connected watch). This information can be included in the user profile and used by the application to preferentially propose the transport modes with lower stress level, which improves user 's wellbeing during her travels.

2.4 Market Vision

The market vision for multimodal transportation, both for passengers and goods, is an increasingly Interconnected European Space where information on trips and ancillary services are provided by multiple operators and services providers. Today 's market related to trip planning is evolving on the basis of these main trends:

- High quality required by travellers in choosing transport mode, both for short and long distance. Long-distance travel is a growing market segment. Analysis of the user requirements shows that modes are chosen based on travel costs and time. In this view, moving by car is still the transport mode that presents higher resistance to change in these two factors than trains and buses[1].

- Integration of long-distance travel with the last urban mile: travellers are more keen on changing transport mode when it is possible to reach main cities by trains and there enjoy city visits and sightseeing by comfortable urban transports, taxi or car sharing, car pooling and bikes. Better connections with the last urban mile impact even more on commuting trips.
- One ticketing selling point: mobile technologies enable the possibility to plan a trip and buying tickets instantly. The possibility to plan an end-to-end trip and buying in just one click all the required tickets increases the inclination of users and on the other hand broadens the offer of services (transportation, touristic information, special events), which the travellers can enjoy along the trip.

As for the movement of freight different trends shall be taken into account:

- High efficiency required by freight operators in choosing main routes for moving goods. Currently the higher share of freight transportation mode is related to road traffic with 75.4%, while train counts 18% (the percentage share of each mode of transport in total inland transport expressed in tonne-kilometres (tkm); the remaining share is related to inland waterways[2].
- Fast Connections to ports mooring ocean shipping vessels with high capacity. Ocean shipping moves nearly 80% of international trade and the ports ' capacity to moor such big vessels, as consequence, implies a huge traffic by road, as reported above. Increasing multimodality services and complementary rail services can split such traffic on different modes such as rail motorways and mayor transport corridors[3].

BONVOYAGE has the ability to:

- overcome the heterogeneity of data and to provide them in an open platform;
- provide travel planning solutions that include local, area-specific regulations and restrictions, by means of the federated architecture;
- design tariff schemes for multi-modal long-distance trips operated by a partnership between air transport and high-speed rail, having (i) pricing rules that allow the transport operators that build the partnership to increase their profits; (ii) benefit for passengers and (iii) reduction of pollution.

This promptly makes it possible to provide travellers and freight operators with journey and route plans with the following added values:

- Higher quality of life in travelling on long distance and urban last miles, based on user needs (including users with special needs).

[1] "Intermodal Passenger Transport in Europe. Passenger Intermodality from A to Z". LINK project.
[2] Eurostat source
[3] Trans European Transport Networks (TEN-T)

- Better planning of logistics for movement of freight that ultimately improves inventory management with just-in-time delivery, which is what supply chains critically depend on.

2.5 Societal Vision

The EU transport policy aims at a form of mobility that is sustainable, energy-efficient and respectful of the environment. These goals can be achieved by using multimodal transport that combines optimally the various modes of transport, exploiting each one 's strength and minimising the weaknesses. The European Commission hence pursues a policy of multimodality by ensuring better integration of the transport modes and establishing interoperability at all levels of the transport system (see https://ec.europa.eu/transport/themes/logistics-and-multimodal-transport/digitalisation-transport-and-logistics-and-digital-transport-and_en).

More broadly, the societal challenge "Smart, Green and Integrated Transport", aims at minimising the impact of transport systems on climate and the environment, improving mobility in urban areas, but also promotes the global leadership of Europe in transport through smart control systems. Relevant to the project are also, indirectly, the challenge "Climate action, environment, resource efficiency and raw materials" and "Secure, clean and efficient energy".

The main inspiring ideas from the above challenges that have influenced the societal vision of BONVOYAGE are those of a:

- Reduction of the dominance of road transport (83% of passengers and 72% of freight are still moved on roads), and consequent reduction of CO2 emission.
- Smart city where traffic congestion is lowered by parking management, bike and car sharing promoted by municipalities, and a smart management of urban public transport.
- Personalised trip solution that improves travel experience for a growing number of elderly people, as well as for persons with special needs (kids, people with disabilities).
- Economic growth sustained by the creation of new added value services in the field of ITS.

The above objectives are captured by BONVOYAGE. The proposal of effective multi-modal solutions combined with tariff schemes promoting green behaviours (score policy) aimed to influence users mobility choices with the ultimate goal to reduce the environmental impact of the travel solutions selected by the users, pushing them to avoid the use of a personal car, thus reducing traffic congestion, and to select travel solutions comprising transports with a low level of CO2 consumption, because they can be cheaper.

The transparent monitoring of user behaviour and transport mode recognition with consequent machine learning based profiling and, if needed, the use of a wearable device (e.g. Empatica E4 watch devices) for inferring stress level, are used to provide real-time automatic feedback under the form of participatory sensing, to monitor the preferences and the wellness of the travellers and possibly change or adapt the on-going trips.

Finally, the federated approach of the architecture and the possibility for transport providers to join by just offering routing services rather than disclosing their travel data (which usually they dislike to do), should stimulate transport providers and also small/medium enterprise to join the European federated platform, thus supporting the economical growth and the creation of new and better ITS services, as a consequence of a greater number of competing actors. Indeed, nowadays, only top players with big data centres running centralized planning tools fed by big data can successfully enter the wide-area planning market. With the European federated platform envisaged by BONVOYAGE, also small and medium enterprises developing their simple orchestrators or local routing services can have a role in the European ITS market, without to high a CAPEX to enter the arena.

2.6 Relationship to Current Initiatives and Contribution

BONVOYAGE is one the 12 projects belonging to the first phase of the H2020 Intelligent Transport Systems “Mobility for Growth” EU call, which will globally span a total budget of €216.2 million, and articulates in 17 topics. The Mobility for Growth call is part of the Horizon 2020 Smart, green and integrated transport challenge. It addresses the following transport challenges:

- mode-specific (aviation, rail, road, waterborne);
- transport integration specific challenges (urban, logistics, intelligent transport systems, infrastructure);
- cross-cutting issues.

Targeting cross-fertilization among different groups and projects, especially within the above mentioned call, BONVOYAGE has established liaison with other related EU and international research projects, leveraging both the contacts already established by project partners as well as networking contacts established during EU cluster meetings and EU initiatives. BONVOYAGE is actively pursuing liaison and clustering with projects working both on ICT/ICN and on transport related issues.

In the following sections we report about the positioning of BONVOYAGE within the ITS Connected Vehicles Cluster, its relationship with other relevant EU projects, and its contribution in the scope of the work programme.

2.6.1 ITS Connected Vehicles Cluster

BONVOYAGE is cooperating with other projects funded in the framework of the 2014 call H2020 (within Mobility for Growth) named ITS Connected Vehicles Cluster, and is part of the cluster itself. These projects created a so called ITS cluster that eases inter-projects cooperation in the ITS and connected vehicles domain. The objective of this cluster is to enhance project outcomes and results by joint activities, to enhance visibility of Connected ITS related projects, augment information flows between projects and their individual partners, foster clustered dissemination activities, with the goal of addressing a larger community.
Collaboration within the cluster includes workshops, regular meetings and conference calls, cluster working groups, data sharing and cross-reporting, development of promotional material. A joint cluster workshop was held in Brussels in November 2015.

BONVOYAGE is part of the cluster together with the following other projects:

- CIMEC - a city-focused project which will explore the role cooperative ITS systems (C-ITS) can play to support city authorities, both in managing their transport networks and the delivery of other transport-linked services. http://cimec-project.eu
- CODECS – Cooperative ITS Deployment Coordination Support, also involving the support of the Network of ITS National Associations. http://www.codecs-project.eu
- ETC – The European Travellers Club: Account-Based Travelling across the European Union is an initiative of several European e-Ticketing Schemes in Public Transport Members and the Open Ticketing Institute (OTI). The project aims to ensure that all travellers in Europe can use trusted, easy and seamless Account-Based Ticketing services, integrated with journey planning and travel information. http://54138954.swh.strato-hosting.eu/
- EU Travel – Optimodal European Travel Ecosystem. EU Travel attended the ITS Observatory User Requirements Workshop held in June 2015 in Brussels. The two projects will collaborate mainly in the framework of Dissemination activities and administration of surveys. Both projects will promote each other's events and activities. http://www.eutravelproject.eu/
- HIGHTS – High precision positioning for cooperative ITS applications. The goal of the project is to achieve high precision positioning system with the accuracy of 25cm in the area of Cooperative systems. http://hights.eu/
- The ITS Observatory is a 2 year support action which aims to develop a flexible and easy to use intelligent tool able to provide accessible and understandable information on Intelligent Transport Systems as developed and deployed in Europe. http://its-observatory.eu
- MASAI – Mobility based on aggregation of services and applications integration: http://masai.teleticketing.eu/

- OPTIMUM – Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility. The project is working to unveil state-of-the-art information technology solutions to improve transit, freight transportation and traffic connectivity throughout Europe. Through tailor-made applications, OPTIMUM is strivin g to bring proactive and problem-free mobility to modern transport systems by introducing and promoting interoperability, adaptability and dynamicity. http://www.optimumproject.eu
- ROADART – Research Alternative Diversity Aspects foR Trucks. http://www.roadart.eu/
- SocialCar – Open social transport network for urban approach to carpooling. The project aims to design, develop, test and roll out a service that simplifies the car-sharing experience of citizens in urban and peri-urban areas. http://socialcar-project.eu/about-project
- TIMON – Enhanced real time services for an optimized multimodal mobility relying on cooperative networks and open data. http://www.timon-project.eu/

Especially important is the concept of obtaining complementarity in development activities and implementations, so as to avoid overlaps, and try to focus effort on synergies, within the cluster.

In line with this idea, BONVOYAGE already offered a preliminary solution of its Internames concept plus a Nation-level distributed Discovery Service software stack to other fellow projects belonging to the cluster.

Indeed, besides participating all general activities of the Cluster, BONVOYAGE is specifically active part of the Open Data Work Group of the Cluster itself. Within the WG Open Data, through regular conference calls, a joint activity between projects BONVOYAGE, EUTravel, TIMON, OPTIMUM and DORA was carried out. The Project Coordinator attended the H2020 ITS Workshop in Brussels on 11.12.2017, presenting results and contributions of BONVOYAGE both to the Cluster and the focused Open Data WG.

The presented **idea is that BONVOYAGE 's networking technology serve**s as the communication bus that all other projects of the cluster can try to utilize for their communication needs, and to interlink their data sources. BONVOYAGE proposed its solution to collect and share transport data among participant projects.

2.6.2 Related Projects

The BONVOYAGE platform relies on advanced methodologies, models and algorithms based on the previous experience of the partners in the Consortium and on the current state of the art, both in the Transport and in the ICT areas. BONVOYAGE has examined the architecture and outputs of the following projects and tools: FP7 PEACOX, FP7 OFELIA, MIT AutoEmotive, FP7 INTERSTRESS, FP7 CONVERGENCE, FP7 GREENICN, DYNAMO (a project within SINTEF 's internal program), FP7 MOBINCITY, FP7 eCOMPASS, FP7 SMARTMUSEUM, FP7 FI-WARE, FP7 MOBINET, SMILE (a project funded by the Austrian Federal Government), FP7 Co-Cities, CIP Co-Gistics, NSF

Named Data Networking (NDN), FP7 PURSUIT, NSF MobilityFirst, OpenTripPlanner (which is an open-source solution).

Out of these, taking into account the objectives of BONVOYAGE as well as the public availability of the related information, we have selected the most relevant subset of projects and tools whose architecture and functionality the Consortium believes to be particularly worth studying and analysing for the purpose of challenging BONVOYAGE to go beyond the state-of-the-art.

Such projects and tools are hereby listed:

- FP7 Co-Cities
- FP7 CONVERGENCE
- FP7 eCOMPASS
- FP7 MOBINCITY
- FP7 MOBiNET
- FP7 PEACOX
- FP7 SMARTMUSEUM
- OpenTripPlanner (open-source).

The study is reported in full detail in deliverable D2.2. Table 3 summarizes the results of the study. It is aimed at illustrating a synoptic view of BONVOYAGE and the above-mentioned projects, and clearly shows how, when we focus on a set of cutting-edge, innovative features, BONVOYAGE is able to build on top of the current state-of-the-art and innovate it. Thanks to a federated and modular architecture, all such features characterize our project. The features we refer to are the following: (1) capability to address large-scale transportation networks; (2) capability to manage multi-modal transport; the presence of (3) a user-profiling tool, (4) a multi-objective optimization tool, and (5) a tariff scheme tool; (6) personalized door-to-door multi-modal optimal trip planning of FEV in urban areas; (7) capability to manage passenger transport and (8) freight transport; (9) the presence of a feedback loop in the architecture; (10) privacy and security; (11) the presence of an information-centric network; (12) the interoperability among heterogeneous transport operators.

Conclusively, the study shows that BONVOYAGE is beyond the state of art as (i) it is the first project addressing simultaneously all of the above-mentioned problems, and (ii) it addresses them in a context of openness and federation.

Relevant Features	Co-Cities	CONVERGENCE	eCOMPASS	MOBINCITY	MOBiNET	PEACOX	SMARTMUSEUM	OTP	BONVOYAGE
Large-Scale Transportation Networks	✓	✗	✗	✗	✓	✗	✗	✗	✓
Multi-Modality	✓	✗	✓	✗	✗	✓	✗	✓	✓
User-Profiling Tool	✗	✗	✓	✗	✗	✓	✓	✗	✓
Multi-Objective Optimization Tool	✗	✗	✓ (just a route planner)	✗	✗	✓	✗	✓	✓
Tariff Scheme Tool	✗	✗	✗	✗	✓	✗	✗	✗	✓
Personalized Door-to-Door Optimal Trip Planning of FEV in Urban Areas	✗	✗	✗	✓	✗	✗	✗	✗	✓
Passenger Transport	✓	✗	✓	✓	✓	✓	✗	✓	✓
Freight Transport	✗	✗	✗	✗	✗	✗	✗	✗	✓
Feedback Loop	✓	✗	✗	✗	✗	✓	✗	✗	✓
Privacy and Security	✗	✓	✗	✗	✓	✗	✓	✗	✓
ICN	✗	✓	✗	✗	✓	✗	✗	✗	✓
Interoperability	✓	✗	✗	✗	✓	✗	✗	✗	✓

Table 3: Comparison with related projects

2.6.3 Contribution to Work Programme

According to the work programme, the project should address one or several of a list of 5 domains. The Table 4 below describes the contribution of the project to 4 of such domains, reporting first the description of each domain given in the work programme (in italic) and then the related BONVOYAGE contribution.

Table 4 is extracted from the proposal, and reports the contributions as planned. It is the one expected from the whole duration of the project. The exact details about the project 's progress beyond the state of the art, as well as the project's innovation potential, can be found in deliverables D8.4 Exploitation Plan, D3.3 Travel-Centric and Participatory Sensing Services, and D4.1 Design of the Intelligent Transport Functionality, as well as within this deliverable D1.3 Project Vision and Roadmap.

Domain 1): Interoperability and linking of the existing services, including necessary interfaces, in order to achieve the widest possible geographical and modal coverage to enable an open single European market for mobility services. The scope of the work should extend towards full-scale early take up and solutions should be tested on large scale. BONVOYAGE contribution BONVOYAGE guarantees full interoperability among existing travel services offered by mobility operators (including, but not limited to those involved in the project) by defining and developing ad hoc interfaces, namely the Multimodal Integrated Interfaces, which are realized

through a set of distributed agents transparently embedded in strategic ITC network nodes located on both the mobility operator and user side (e.g., generic nomad devices). Data exchanged among different mobility operators will be used to automatically identify multi modal, integrated and personalized travel solutions. To this end, the Internames Communication System will be conceived as an Information Centric Bus able to break the technological barriers that hinder seamless and secure network connectivity in the current host centric Internet design. Internames will ease interoperation among entities identified by names, without a static binding of end-points or users to their current location. In addition, Internames allows for travel requests and transportation plans to be temporally separated, with the seamless integration of query/response, facilitating search for suitable itineraries, and publish/subscribe functionality allowing users to post requests for travel that may be satisfied subsequently, based on demand-response planning by transportation operators.

In addition, BONVOYAGE will open a market opportunity to a sector that relies on micro and small transport carriers to offer their services to other companies and users. Within the project, this functionality will be tested for on road transport at urban and regional level, but could be extended to National and European level.

Domain 2): Developing EU-wide common minimum standards for interoperable navigation and ticketing services, thereby facilitating regional solutions compatible with generic nomad devices (smart phones etc.).

BONVOYAGE contribution

Both technological and commercial conditions will be investigated to make EU-wide common minimum standards for interoperable navigation and ticketing services possible. The starting point will be the development of two specific components in the BONVOYAGE platform.

The first is represented by Multimodal Integrated Interfaces that enable collecting basic information for interoperable navigation by means of web services accessed even by common smart phones. To this aim, Internames will provide name-based Application Programming Interfaces that accept names as identifiers of all requested content or services. By not having a static binding between the name of a communication entity and its current location, we allow entities to be mobile, enable them to be reached by any of a number of basic communication primitives, enable communication to span networks with different technologies and allow for disconnected operation.

The second component is a module dedicated to the tariff scheme, namely the Tariff Scheme Design Tool. It is in charge of identifying and making available to end users several multi-part tariff schemes based on bilateral or multilateral agreements in order to promote the joint use of a group of complementary mobility services. This tool will allow operators to propose data-driven joint offers for complementary intermodal transport services. Thus, behaviour-based discounts will promote a larger use of the socially desirable mobility services (e.g. those with lower CO_2 emissions). Moreover, real-time measured data and user profiles will be exploited to automatically compute suitable discounts which will be then promptly submitted to the travellers in order to attract them towards alternative and less congested travelling options. Therefore, traffic congestion peaks will be effectively mitigated thanks to interoperable navigation and ticketing services.

Domain 3): Exploring more effective and more efficient cooperation and decision making mechanisms between stakeholders, including coordination of the existing European, national and regional initiatives, to foster EU-wide consolidation and deployment of high-quality integrated multimodal travel information, planning and ticketing services. This could encompass setting up a cooperation platform. BONVOYAGE contribution BONVOYAGE allows for cooperation and commercial agreements among different mobility service operators with the aim of: (i) offering a more suitable and personalized service in order to improve the quality of experience of their customers; (ii) getting the actual feedback from the customers with respect to the proposed travel solution. In particular, nowadays, user feedback is easily accessible by developing suitable 'apps' for nomadic devices. However, a key missing ingredient is a platform capable of analysing such feedback with respect to specific multimodal travel solutions and to model the degree of travel quality experienced by the users, especially when grouped together among a consistent set of user profiles. These weaknesses are fully tackled in BONVOYAGE thanks to the adoption of novel technology-independent Multi-Objective Optimization tools combined with the Tariff Scheme Design tool. The former will process system/ user feedbacks and profiles to maximize the quality of experience of travellers. The latter will provide a unified management of the possible disservices of the offered intermodal transport services. BONVOYAGE will also provide a cooperative tool for transport companies to hire delivery services among them and other users. This will allow them to better optimize the loads of each journey and therefore increasing profitability. Concurrently, this load optimization will reduce company 's emissions, helping them to achieve CO_2 emissions targets, stated in 30% reduction by the EU for 2020.
Domain 4) (partially addressed): Exploring mechanisms and structures for consensus building among stakeholders to foster EU-wide consolidation and deployment of cooperative ITS. This could encompass setting up a cooperation platform. BONVOYAGE contribution One of the partners, MLC ITS Euskadi, is formed by a group of companies, governments and associations located in the Basque area (north of Spain and South of France). The mission of this Cluster is to achieve an integral competitiveness improvement in this region, through cooperation, innovation and interaction among all the agents and companies of the transport and logistics sector. Now the Cluster has 108 members grouped across five axes: 1. Operators, 2. Users or Chargers, 3. Products and Services for the sector, 4. Infrastructure owners or Managers 5. Administration and other Agents (Technology Centres, Universities, Chamber of Commerce, Authorities, Cities...). Even if the scope of the Basque Cluster is not Europe at large, such cluster will build awareness and consensus among different types of stakeholders, helping to devise best practises for cooperative ITS, to be adopted more widely. Access and management of data bases generated for the project will be based on agreements on regional terms and will remain as an asset after the project life to foster the transport sector in the region.

Table 4: Contribution to the Work programme

3 Creating the Vision

Creating a concrete instance of the vision we have depicted in the previous sections is the BONVOYAGE challenge. To this end, the project has developed and tested a federated platform optimizing multimodal transport. An innovative communication network that collects and distributes all the data required to optimize a travel supports the platform.

In the following we will focus on a high-level description of the steps the project has taken towards the goal above. Specifically, we first re-state the general objectives of the project as they are formulated in the Description-of-Work document, to keep in mind the original project's goal; then we include a set of four Reference Scenarios, which we imagined, that serve as benchmark for the capabilities of BONVOYAGE. We then describe the main components of the platform, in more technical terms, supporting our vision within the R&D state-of-the-art. Then we describe the market analysis and operations that concretely supports our vision and its placement within the current, ever changing, business landscape of the ITS.

3.1 Project objectives

As a reference, we report in the following the specific technical goals, as stated in the original proposal, that the project seeks to achieve:

1. Multi-objective optimization. Development of an advanced multi-objective optimization algorithm to provide an optimal multi-modal travel itinerary by properly trading-off several simultaneous sub-objectives, namely travel schedule, travel duration, travel cost, travel emissions, overall travel reliability, load capability, type of goods, etc. This optimization is performed by simultaneously taking into account the following inputs: (i) non-real time characteristics (e.g., coverage, routes, schedules, type of good) of the candidate transportation means (e.g., public transport such as bus, train, boat, taxi, airplane; private transport such as car, bicycle, walking, cooperative modes like car-sharing, trucks), (ii) real-time requirements (e.g., traffic congestion, temporary road barriers, lane closures, temporary speed limits, new stops as a result of customers' requests (not the same day but some days in advance), available space and weight to complete the load), (iii) user profiles and users feedback (see the "Personalization" issue below), (iv) dynamic tariff schemes (see the "Tariff scheme" issue below).
2. Personalization. Personalization of the services offered by the platform, aimed to meet, as far as possible, specific user preferences, needs and expectations in terms of travel schedule, travel duration, travel cost, transport means, travel reliability, etc. Personalization is performed, on the one hand, on the basis of an automatic mapping of

each user to the most appropriate user profile corresponding to given parameters which are used in the framework of the optimization mentioned, and, on the other hand, on the basis of the automatic interpretation of the feedback provided by each user, as well as by users belonging to the same profile. This enables operators to have 'demand-response' systems where, based on the needs of a dynamic grouping of users with common profiles, transportation facilities may be dynamically created to meet demand. A further objective lies in the identification of the user profiles in a data-driven fashion through appropriate machine l earning techniques.

3. Tariff Schemes. Design of a tool aimed at providing tariff schemes which, on the one hand, encourage the use of specific classes of mobility and delivery services (e.g., those with a lower environmental impact, type of good), and, on the other hand, create new business opportunities for the transport operators, which can offer special prices for multimodal travel allowing them to increase the exploitation of their transport resources. The goal is to integrate the tariff scheme tool in the multi-objective optimization framework, possibly allowing dynamic changes and re-negotiations during the trip. For freight delivery services, the BONVOYAGE platform can be a perfect complement to the existing pricing services with extended and more flexible features such as real-time pricing or allowing a dynamic matchmaking between users' needs and company's offers.
4. Interoperability. Natural and simple interoperation among heterogeneous transport operators. The interoperation is designed to be technology-independent, so that it can work with any transport operator, regardless of the technology the operator adopts for data acquisition/storage, the database organization or its data format. As a matter of fact, the above-mentioned functionalities deal with homogeneous metadata obtained by appropriately converting the heterogeneous data of different, individual transport operators. On the other hand, only a few trivial functionalities are technology-dependent and have to be developed "ad hoc" for each transport operator; these are the functionalities related to the interfacing with the users and conversion of the heterogeneous data of the individual transport operators; they are implemented by means of distributed agents transparently embedded in users' smart cellular devices and in suitably selected nodes of the transport operators, respectively.
5. Internames Communication System. A pivotal feature in BONVOYAGE consists of an Information-Centric Network (ICN) that fulfils the communication requirements entailed by the aforementioned objectives by providing (i) seamless connectivity across different existing network realms (that may be administered by distinct transport operators or authorities); (ii) native support of mobility and security issues; (iii) travel-centric primitives for push/pull based services; (iv) high efficiency in communication and processing operations; (v) graceful deployability and interoperability with existing and upcoming networking systems (i.e., 5G and beyond). As anticipated in the background information box above, the highly heterogeneous, distributed and mobile nature of the

data of interest, coming from data-centres, sensors, vehicles, goods and people on the move, calls for a network that is able to go beyond current paradigms. Our network, called Internames, (better described in the following) allows name-to-name communication, without a static binding of end-points or users to their current location; in Internames names are used to identify all entities involved in communication: content, users, devices, logical points, and services. For instance, a sensor providing traffic information is identified by a name; a traveller is identified by a name; a database content is identified by a name; train, buses, cars, bicycles, planes, are identified by names; a transport service and an itinerary are identified by a name. All communications among such entities happen between names; it is the task of Internames to locate where such entities are located at a given time and to map name to location in a dynamic, context-dependent way, and to map a name not only to a current location but also to a protocol/service/communication type. In addition, the Internames architecture allows for requests from users to be treated as a subscription that is maintained in the network, so that e.g. when an itinerary at an appropriate tariff becomes available, meeting the requirements of the user (e.g., schedule including data and time of travel, quality of experience etc.), the network may then notify the user. This allows for dynamic 'matchmaking' between users (people, goods) wishing to travel from a starting point to a destination and the (potentially dynamically) demand-response based scheduled transport of selected groups of transport/mobility operators. Our aim in BONVOYAGE will be to continue the design of Internames, now at the very beginning and to exploit/adapt it to our transportation system.

6. Security and privacy. User profiles are certainly very useful (one could say needed) to program and optimize travels; however they imply an obvious threat to the privacy of users, who will be reluctant to use the platform if they are not sure that their preferences and choices will not be protected and kept private. In addition, security of all transactions in the BONVOYAGE platform (including payments) is of course a key requirement. These issues, well understood and addressed in traditional networks, require a significant rethinking when challenged against the unique distinguishing characteristics of ICNs and of our envisaged transport scenario. Traditional network security protocols, such as IPsec or Transport Layer Security (TLS), focus on protecting the communication between an information consumer and a content server, and do this by deploying trustworthy infrastructures devised to enforce authentication and access control primitives on dedicated servers. In our ICN network, the requested content is not necessarily associated to a trusted server or an endpoint location, but it can be retrieved from, say, a network cache managed by a hardly trusted administrative domain or by a sensor or by a user device. This calls for data-centric, infrastructure-less security and privacy solutions, being hardly viable a secure infrastructure that involves storage servers and network caches in heterogeneous non-collaborative domains. Access requests are addressed to a

named content, and thus cannot be protected into an encrypted tunnel or TLS connection towards a server address, or through an off-the-shelf anonymization mix network such as TOR. Thus, we will investigate data-centric techniques, where security and privacy rely on information exclusively contained in the message itself, or, if extra information provided by trusted entities is needed, this should be gathered through offline, asynchronous, and non-interactive communication, rather than from an explicit online interactive handshake with trusted servers. The ability to guarantee security without any online entity is particularly important in the fragmented network scenarios tackled by BONVOYAGE, where mobility may technically preclude the ability to connect to a remote trusted party. As matter of fact, protecting information at the source, by embedding security information in the content, is more flexible and robust than delegating this function to applications, or securing only the communications channels. For instance, data gathered by a sensor or coming from a user device, encrypted at the source, can travel over unsecure channels, and can be decrypted only by the intended receiver.

3.2 Reference Scenarios

This section reports some exemplary scenarios showing most of the key innovations of BONVOYAGE, each to different degrees and under different viewing angles, so as to demonstrate that such key innovations are the building blocks of any modern ITS.

Key innovations:

- User profiling to assist the transport system at planning phase
- Real-time sensors and dynamic data assist the transport system at travel phase
- Name-based networking to assist transport operators and developers in exchanging and searching data
- Constraint-based optimization of the proposed solutions
- Distributed approach to scale continent-wide
- Design grounded on inter-modality

3.2.1 Scenario 1: Family travels from Oslo to Italy for tourism

The first scenario is about inter-modal planning in the context of public transport, and shows how BONVOYAGE:

- Scales up to continent wide trip planning.
- Is effective at selecting the optimal combination in case of groups in need of special care.
- Can provide users with real-time information on public transport status.
- Can re-plan by taking into account dynamic conditions.
- Exploits user-profile and constraints to formulate a tailored solution (tourism with several stops, plan for events in the area, reserve for strollers and heavy luggage, budget constraints and personalized tariffs).

The family travels from Oslo to Italy for tourism with kids. They want to tour Northern Italy (Milan, Firenze, Pisa) and attend a specific paint exhibition in Rome at a fixed date.

Family has booked and purchased public transport tickets as recommended by BONVOYAGE App and they gain 400 "green points" when purchasing the cross-border multi-modal travel solution. They have reserved hotels in Milan, Firenze and Rome that are very close to the train stations, so that they can walk there.

At the end of the journey, family receives promotions/discounts from the partners of BONVOYAGE on similar events/travels, based on travel solution they eventually enjoyed, the specificities of their "family" profile and the estimated CO2 consumption.

3.2.2 Scenario 2: Business trip from Grenoble to Bilbao

The second scenario is about inter-modal planning between traveling with private car, shared cars and public transport, and shows how the private transports can seamlessly blend with the public ones, when assisted by sensors and real-time data.

This scenario focuses on:

- Receiving and processing data from sensors, either deployed on the road or from users' mobile devices.
- Conveying timely alerts to users, about incidents and dynamic events, which influence the plan.
- Inter-modal optimization of resources by car-pooling, both in a multiple-sources-one-destination and in a one-source-multiple-destinations cases.

Cristelle, a researcher from Grenoble needs to attend a meeting in Bilbao. Her user profile in BONVOYAGE is a "business" profile and she is usually happy with driving her private car as much as possible. BONVOYAGE originally offers the fastest solution, and the driver is planning to reach Lyon airport by car and then fly to Bilbao.

During the trip, say when Cristelle is collecting her luggage at the airport, she is notified that another passenger, who either was on the same flight or has got to Bilbao at the same arrival time, is going to a destination that happens to be in the same urban macro-area of the conference she will attend. Cristelle accepts to pick new person up in the previously-reserved shared car. BONVOYAGE consequently makes a local trip planning update matching the needs of the two passengers.

In a sense, Scenario 1, and Scenario 2 complement each other and demonstrate that the future ITSs are asked to support a customer-friendly blend of public and private transport, for increased sustainability, ability to absorb peaks in service utilizations and optimal coverage of the territory.

3.2.3 Scenario 3: Exploiting the platform for new business opportunities

The third scenario demonstrates that BONVOYAGE is conceived as an open platform interconnecting many data sources and routing/orchestration services. Interfaces with data sources are based on an innovative networking that collects and distributes, where needed, data as soon as they are published. Interface with routing and orchestration services are supported by a single standard, SPROUTE, thus simplifying the possible recursive stacking of services (orchestrator of orchestrator, etc.) without need of changes on the application server side.

This facilitates both transport operators and developers of added-value applications (e.g. intelligent orchestrators, multimodal city planners, etc.) to join the BONVOYAGE platform, and to create new business opportunities, opposing the centralized, one-player-solves-it-all tendency.

The envisaged scenario is the following. Expedia has become the world's biggest travel agent, The Economist reports (2016). The third-largest travel agent is also an online company: Priceline. The scale of Expedia and Priceline means they can negotiate better prices, than their smaller rivals. Google Maps has quickly become one of the widest journey planning apps on the market. The smaller online travel operators find it increasingly hard to compete with the big ones.

Emerging small travel operators would like to offer advanced transport services at regional, city or private scales in order to increase their market share and visibility.

- Regional scale
  A travel agent with an extended and well-established network of partner hotels and resorts wants to propose to vacationers a set of tours made available by heterogeneous transport operators.
- City scale
  A company would like to be able to contact parking lots owners and be informed about their availability without having to (i) establish many different business relationships, (ii) deal with different data formats, and (iii) constantly polling the external servers.
- Private scale
  Often, when major sporting events or concerts take place, public transportation goes overloaded and people prefer resorting to private cars or try to organize parallel, private-owned buses and shuttles. A smart App developer would like to create software that collects info about people offering their own vehicle with free seats, for short periods, and on a very specific area or itinerary, but realizes this is a complex goal to accomplish because, unfortunately, today technologies are not able to effectively offer user-to-user vehicle-sharing services.

Despite their valuable proposals, such small entrepreneurs travel operators may incur in serious difficulties in offering their services. They, instead, would like to get rid of technical burdens that impede a fair competition, as everyone would benefit from an ecosystem of competing online travel operators. Major obstacles are the difficult inter-operability with official journey planning services (like the Municipality public bus service), absence of inter-operability with other similar services that would provide wider and multimodal coverage, and the amount of investments required to design (and set up) a centralized server holding the required information in a secured way.

With BONVOYAGE, the three above business initiatives can be fully supported.

3.2.4 Concluding remarks on Scenarios

More in general, all three Scenarios presented above are supported because BONVOYAGE is designed from grounds up as a distributed system able to:

- Exploit and nurture local specificities of the various transport systems available in the area.
- Facilitate large-scale integration, search, sharing and delivery of transport solutions and related data among transport providers, travel service operators, applications and users; this is one of the main problems nowadays: how to collect transport information not only from big airlines/train operators but also from all the millions, small scale, bus/local transport/private providers.
- Allow transport providers to keep their data and services in their premises, with their formats and interfaces, rather than transfer them to a third, centralized party (e.g. Google) and/or to comply with specific format (e.g. GTFS).
- Allow travel operators or applications to get data directly from the transport providers rather than from a third party.
- Allow anyone to easily publish transport solutions, including private citizens (e.g. for car sharing purposes, hitching a lift).
- Allow anyone to set up access restriction and privacy policies on published data and then verify the owner and the authenticity of published data.
- Allow anyone to easily exploit all such information (e.g. anyone can develop an application and become an online travel platform provider).

3.3 The BONVOYAGE Platform

The key goal of our system is to overcome one-solution-fits-all, fragmentation and non-interoperability of travel routing services at three levels, bottom-to-top: knowledge and data sharing via the Internames-based network infrastructure; cooperation and linking of the travel optimizers via the orchestrator; personalization and ranking of received solutions via machine-learning-based applications.

As a consequence, BONVOYAGE implemented an architecture based on three Layers (again, bottom-to-top): Infrastructure Layer, Orchestrator Layer, Application Layer. This layered architecture is depicted in Figure 3. Together, these layers form the BONVOYAGE platform.

For readability purposes, we just recap here the names of the various components and briefly their purpose, and we then proceed with a description of the platform more in terms of holistic behaviour and layer-wide strategy, rather than component-specific functionality. For a component-oriented description of the platform, please refer to deliverable D7.1.

Application Layer components

- The MultiModal Mobility Database (MMMDB) stores the profile information for each user, together with history information and data coming from the machine-learning algorithms.
- The Application Server runs the User Profiling machine-learning algorithms and handles communication towards the Mobile App or other application front-ends.

Orchestrator Layer components

- The Orchestrator manages the graph formed by the various the lower-layer context-specific routing services (henceforth Soloists). It links them in the proper sequence in order to obtain a well-behaved global set of solutions.

Infrastructure Layer components

- The Soloists encapsulate existing routing services, or algorithms that we have developed within the project. Soloists have a "local" scope, i.e. may be specific for a precise context or a defined geographic area.
- The Discovery service makes possible to find raw data sources and soloists. The discovery service is implemented by means of the federated spatial database, named OpenGeoBase (OGB), exploiting Internames services. Each site of the federation can be considered as a National Access Point, and receives discovery metadata (GeoJSON) about data sources and routing services from national ITS companies. For the data sources, companies generate the metadata using a specific MetaData Handling Tool (MDHT), which parses information coming from standard data sources (NeTEx, GTFS, etc.).
- For real-time information, the infrastructure layer offers a geographical PUB/SUB service, making possible to receive updates (e.g. DATEX II) limited to a zone of interest, thus strongly limiting useless traffic and processing. The interworking between standard real-time ITS sources and the PUB/SUB service is handled by a specific MDHT.

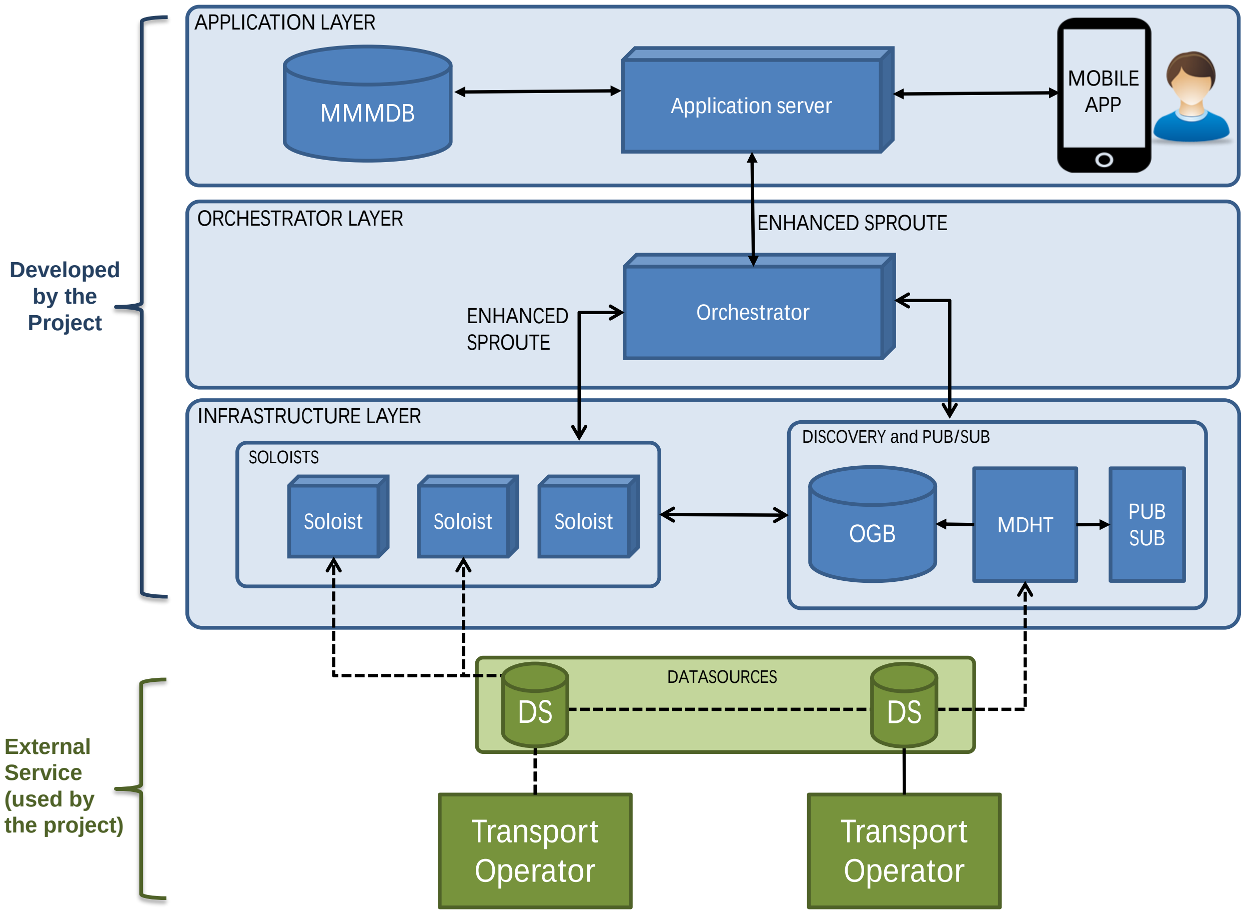


Figure 3. BONVOYAGE layered architecture

3.3.1 Federation Strategy

At the Infrastructure layer we pursue a federation strategy. Differently than a generically distributed or P2P system, a federation is a group of distinct, formally disconnected providers, which have different internal structures, agreeing upon collective standards of operation, so that inter-operation of such group is obtained.

Our solution translates into a set of distinct database sites overall acting as one big NoSQL spatial database that better supports geographical data federation, when compared to other existing NoSQL spatial databases. Database sites of different operators (or national entities) can store information related to different geographical zones. For instance, a database engine handled by an Italian national entity could store all knowledge about travel data located in Italy, and so forth. Handling of security is federated too, as each site manager independently stores security information and provides access control for its users. Spatial queries and insertions are only forwarded to those database sites that can actually handle them, e.g. a query for an Italian area is only forwarded to the Italian site (i.e. National Access Point).

Traditional NoSQL spatial databases (e.g. MongoDB) well support distributed deployments but are not suitable to easily implement federated scenarios, for the following reasons: 1) it is difficult to distribute the spatial data over different database engines following geographical rules; indeed, traditional NoSQL spatial databases usually use a hash function to distribute data, rather than geographical rules, which has the drawback of the spatial query being sent to every database of the cluster, creating unneeded load; 2) security and configuration are usually handled in a centralized way, rather than being distributed. Our solution implements a multi-tenant/multi-user data-centric security model, where both access control and authentication are data-centric, so that the data owner is inherently responsible for it, rather than the tenant or the system administrator.

Several different standardization initiatives exist (see also CEN/TC 278 on ITS), with different success rates, for ITS-specific data. But when we look at the metadata level that is crucial for federating heterogeneous resources (and is the focus of our Infrastructure layer), standards revolve around the ISO 19115 and the ISPIRE initiatives, which are for generic spatial data and services, lacking focus on metadata for transit and transport systems.

Hence, we have developed a BONVOYAGE GeoJSON for ITS simple format for encapsulating metadata about ITS data sets and services, for the purpose of discovery, at the Infrastructure layer.

GeoJSON is the widespread standard for storing into NoSQL spatial databases, and its flexibility allows us to enrich it with ITS-specific properties. We have designed a minimal set of properties that enable discovery of both travel-data sources and soloists, effective for the goal of orchestrating them, following a bottom-up approach, that is deriving the properties we needed by inspection of the existing variety of services.

For instance, in our system, the following GeoJSON for ITS structure describes a soloist for the city of Bilbao:

```
{
 "type":"Feature",
 "id":"CRAT Bilbao Soloist",
 "geometry":
 {
  "type":"Polygon",
  "coordinates":[...]
 },
 "modalities":["Walking","Biking","Driving","Public"],
 "transitions":
 [{
   "description":"Bilbao Airport - BIO",
   "modalities":["Walking","Flying" ],
```

```
  "geometry":
  {
   "type":"Point",
   "coordinates":[...]
  }
 }],
 "properties":
 {
  "url":"http://82.223.67.189/bonvoyage/Bilbao/json",
  "type":"SERVICE",
  "sub-type":"SOLOIST"
 }
}
```

For the full details of the GeoJSON for ITS format, please refer to deliverable D5.2. Also notice that the goal of our GeoJSON for ITS format is not that of being exhaustive, or to become a definitive standard. The goal is to demonstrate that a standard for metadata about travel that is based on GeoJSON is the wisest choice given an underlying implementation based on geospatial databases, which would be the norm in this case.

Overall, we think that the design and achievements of the BONVOYAGE Infrastructure layer make up for a valuable solution for implementing the EU Directive 2010/40 concept of a set of National Access Points that are each other independent, but still form a connected federation able to respond with global information valid across the whole federation.

3.3.2 Orchestration Strategy

Our solution is based on an Orchestrator linking a set of distinct Soloists that scales continent-wide without losing the area-specific constraints only those specialized local solvers can handle. As previously said many competing orchestrators can be present in the federation (Figure 2).

This concept of decomposition and federation allows shifting the focus of ITSs from interoperability at the level of data to interoperability at the level of interfaces/services. From open data, to open service. And this aspect is not so much considered (up to now) by EU regulation, which mostly recommends the use of standard open data (DATEX II, NeTEx, SIRI, etc.), but currently doesn't give recommendation about the interfaces and metadata format for discovery, routing and linking services.

We find out that defining a collaborative (linking) pattern between local routing services is a step forward to include local-optimal solutions in a multimodal and cross-border itinerary, with respect to the foreseen regulation approach, which is to attract all open ITS data in a centralized solver. Indeed,

- Many transport operators don't like to open their ITS data because they will lose the control on how customers use their transport means. As an example, a train operator might prefer to decide how its customers should go from station A to B, rather than to leave this decision to external solvers. For this reason, BONVOYAGE makes possible for a transport operator to join the federated platform by exposing its routing service through an open interface and, just in case, its ITS data, too.

- Cross-border multimodal computation has a very complex processing that requires valuable hardware (CAPEX) for collecting and elaborating big ITS data, thus limiting small stakeholders to enter the global market. For this reason, BONVOYAGE focussed on a distributed resolution schema, where a small stakeholder could have an active role with low CAPEX either as orchestrator or as (multi-modal/mono-modal) soloist.

The orchestration strategy is able to also include current routing services, e.g. wrapping the Google API for solving car routing problems, turning it into a soloist, putting it side-by-side with other specialized soloists within the federation, in a competitive or collaborative architecture. This ability to integrate many mono-modal heterogeneous algorithms into one valuable multi-modal solution for the end-user is just one key result of our linking strategy.

Generally speaking, this approach allows going beyond the three levels of aggregation (Centralised: monolithic; De-centralised: hybrid/chained; De-centralised: true distributed) described in the EU study [Study on ITS Directive, Priority Action A: The Provision of EU-wide Multimodal Travel Information Services. D5 Final Report. European Commission. Directorate-General Mobility and Transport. Under Framework Contract MOVE/C3/SER/2014-471. May 2016]. We follow the hybrid approach described in the study, but we go beyond chaining, as we allow superposition too, because our soloists are not local in terms of being limited to a geographic region but can, for instance, be limited to a single modality with continental coverage, instead, or be specialized for a peculiar context (e.g., an airport soloist able to account for the passengers' transit times due to check-in, security control, walking distances, boarding, etc. as elements of the final aggregated solution).

We have hence evolved the SPROUTE interfacing format (originally hosted at https://github.com/dts-ait/ariadne-json-route-format) for the purpose of the services' orchestration and personalization, at the Application and Orchestration layer.

We use SPROUTE at the orchestration layer, and have extended it to better include information about the personalized travel objectives (e.g., allowing a user to search for cheap and environmental travels in addition to the traditional search that minimizes travel duration or travel distance). For multi-leg trips, we allow these preferences to be specified per travel leg. We also found it necessary to be able to specify information about the travellers such as the number of travellers in a group travel. Finally, for performance reasons, we have also extended SPROUTE to allow for many-to-many trip requests.

Several more enhancements were necessary (please refer to deliverable D6.1), but one crucial point deserves to be stressed here (Figure 3): the SPROUTE format is used both between the

Application layer and the Orchestrator layer, and between the Orchestrator layer and the Infrastructure layer. In other words it travels from application to orchestrator, as well as from orchestrator to soloists. This multi-level design, which employs the same interface at different levels, greatly facilitates stacking additional levels on top of the existing ones, so that more powerful functionality or abstraction is provided, without modifying the interface. It is a well-known pattern in designing computer systems (e.g. the file-system interface is kept the same both for physical disks, as well as for RAID arrays or virtual drives), and the key to potentially link lower-level orchestrators to a higher-level orchestrator for improved scalability or more precise policing.

Again, we think that the solutions we have developed for obtaining a well-behaved linking of heterogeneous routing services are crucial for reaching the goal of "linking services" advocated by EU Directive 2010/40. Additionally, with respect to the "data focus" vs. "linking services" policy option assessed in the DG-MOVE study cited above, we think that a "data focus" policy, which would try to steer data towards a standard that is forced upon data producers, is not working in practice in the case of ITS: the study itself acknowledges that, in practice, Transmodel or Google's GTFS are vastly more successful and diffused than the CEN-level standardized NeTEx and SIRI. We thus prefer the "linking services" policy and we believe that it is better to produce metadata for facilitating data federation (at the Infrastructure layer, see above), leaving data in its original format, and favour the cooperation and orchestration (at the Orchestrator layer), which is all about defining requirements for using a standardized interface to perform distributed journey planning.

By giving priority to the linking we feel that improved quality of data and its cleaning will come as a consequence. It will be an outcome driven by the innovative ITS initiatives requiring cleaner and cleaner data to the transport operators, once successful large-scale composition of services becomes reality.

3.3.3 Personalization Strategy

The goal of the feed of information from users and sensors to the system is to make the system aware of conditions that enable personalization of its services.

User feedback (both implicit and explicit) is fundamental. It is a one directional flow that is complemented, in the opposite direction, by the reaction of BONVOYAGE, which is usually apparent to the user: after telling the application about what are her/his preferred solutions, next time the user will receive back solutions in a more and more personalized way, i.e. tailored on his/her past preferences (user-history-based parameters) and his/her inferred behavioural profile, or "user class" (user-profile-based parameters).

User-history-based parameters control the ranking of the received solutions, through an ordering algorithm that is based on user-dependent weights for different features characterizing travel solutions (is public transport preferred? Is car-sharing used? What kinds of modalities are generally selected?). These weights are strictly personal, different for each user. They stay within the application and are never communicated outside the private zone.

User-profile-based parameters control the behaviour of the orchestrator and of the soloists. They are communicated from the application to the lower layers by means of anonymous SPROUTE properties, and are expressed in terms of "user class" dependent weights for different dimensions, such as PRICE, DISTANCE, TIME, POLLUTION.

We are able to deal with user preferences in terms of multi-modal travel solutions; furthermore we have observed that sometimes user preferences, even when the user is explicitly asked about, are not coherent with what the user would then actually select. For this reason, we have conceived a machine-learning-based approach in charge of analysing user feedback in terms of selected travels, without burdening the users with articulated questionnaires, thus operating as transparently as possible.

3.3.4 System Operation

In order to illustrate the steps of typical sessions with the BONVOYAGE system, let's examine the use case of a cross-border, Europe-wide travel request. The user is interacting through an application, and wants to travel from Oslo to Bilbao.

The involved actors are: Application, Orchestrator, three federated NAPs (Italy, Spain, Norway), the Bilbao Soloist, the Oslo Soloist, a long-range Airplane Soloist, Data Sources of City Of Bilbao bus timetables, Data Source of flight schedules. We describe the three main phases of the platform's life in the above use case: (i) Soloists register to the federation and Orchestrator periodically scans for new Soloists; (ii) Data Sources register to the federation and Soloists periodically scan for new Data Sources; (iii) Application interacts with the platform to obtain travel solutions.

<u>Orchestrator Discovering Soloists</u>

(step 1) Each new Soloist that goes online registers to a known NAP (OpenGeoBase site). Figure 4 shows this in steps labelled 1, when the three soloists register by inserting GeoJSON for ITS metadata that describe them into the federation. Bilbao soloist knows how to contact the Spain NAP, Oslo soloist knows the Norway NAP and Airplane soloist happens to know Italy NAP. We see how the infrastructure layer spreads the metadata of the Airplane soloist to the Spain and Norway NAPs too (parallel steps 1a), for instance because the Airplane soloist has a boundingbox geometry spanning the whole Europe, hence overlapping the coverage area of all three NAPs.

(step 2) Orchestrator periodically asks to its known NAP what Soloists are available in its own coverage area (usually continent-wide), by querying GeoJSON for ITS metadata via spatial constraints. We see how the Italy NAP geographically forwards the spatial query to federated NAPs that satisfy the spatial constraints and fetches the resulting set of metadata describing the Soloists (parallel steps 2a), and then it answers to Orchestrator and Orchestrator updates its list of available Soloists.

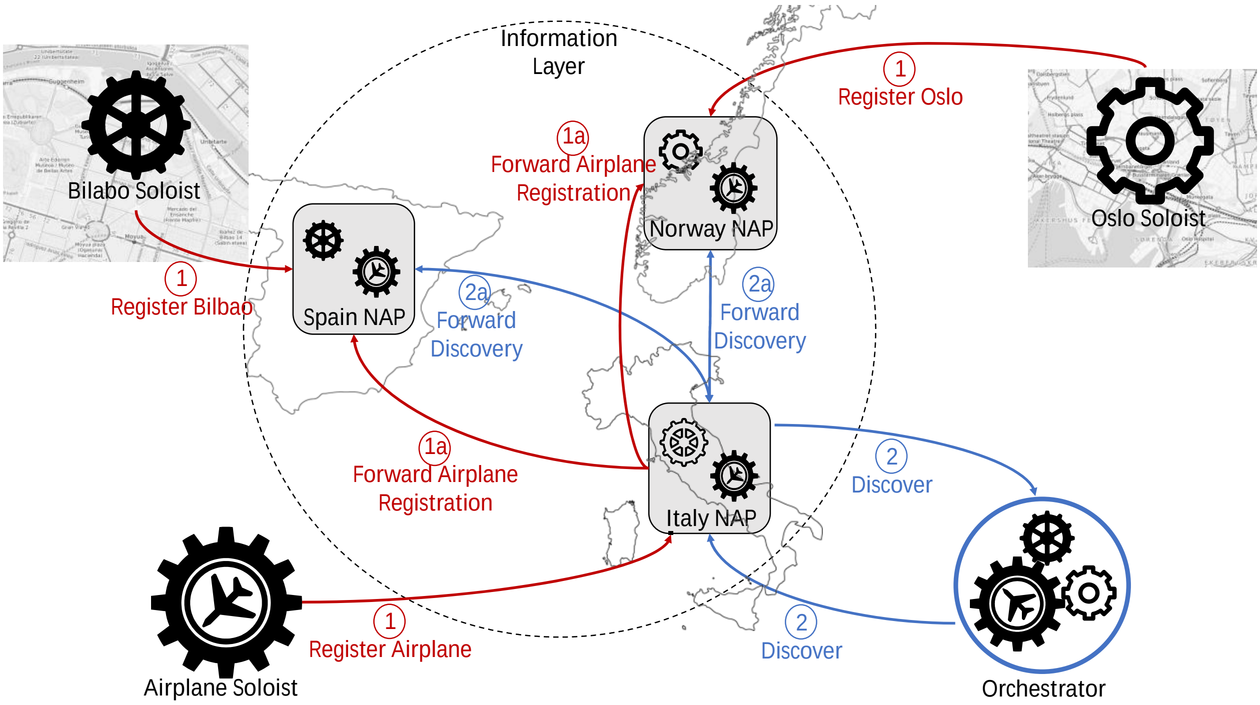


Figure 4. Orchestrator discovering soloists

<u>Soloist Discovering Data Sources</u>

(step 1) Each new Transport Operator or travel data provider that goes online registers with a known NAP, by inserting GeoJSON for ITS metadata about Data Sources.

(step 2) Each Soloist periodically asks to its known NAP what Data Sources are available in the area it covers, by querying GeoJSON for ITS metadata via spatial constraints. The known NAP geographically routes the spatial query to federated NAPs covering the area and collects the resulting set of Data Sources. The known NAP answers to Soloist and Soloist updates its list of available Data Sources.

<u>Orchestrator Responding to Application</u>

(step 1) Application requests to Orchestrator solutions to go from address A in Oslo to address B in Bilbao, in SPROUTE format.

(step 2) Orchestrator decomposes the Application's request and sends multiple (possibly parallel) requests to available Soloists impacted by the request (Airplane, Oslo and Bilbao Soloists), again in SPROUTE format

(step 3) Each Soloist solves the assigned portion (specific area and/or specific modalities) of the overall Application's request and sends it back to Orchestrator using SPROUTE.

(step 4) In case where more than one portion of the overall route is time-dependent (e.g., it relies on scheduled public services) Orchestrator may send additional requests to some of the Soloists to hence compress the overall route. For the soloists this means repeating step 3.

(step 5) Orchestrator assembles the received pieces and responds to Application with a set of solutions in SPROUTE format.

(step 6) Application applies personalization to the received solutions, by ranking them according to the User's private profile.

(step 7) User selects a preferred solution and his/her profile is updated accordingly.

In the following, we describe in more details each of the Layers, trying to summarize some key interesting design characteristics. The reader should refer to deliverable D6.1 and D4.1 for the full details of the design of the Application Layer, to deliverable D4.1, D4.2 and D5.1 for the Orchestration Layer and to D5.2 and D3.3 for the Infrastructure Layer. Finally, deliverable D7.2 provides an integrated view.

3.3.5 Application Layer

The applications provide a user-friendly way for the end users to interact with all functionalities of the BONVOYAGE platform and its technologies, for instance also managing backend duties such as annotating, collecting and training the data sets needed for participatory sensing services, or for testing the car-pooling algorithms.

Furthermore, a subset of all the important functionalities is implemented as a native Android application. The purpose of this main BONVOYAGE mobile App is the interaction with the end users. It includes the following 5 modules:

- Route information, which enables users to request routes from the BONVOYAGE platform taking into account the user's personal needs and preferences and provides all required information about the trip;
- Notification, which enables the mobile application to react on dynamic, real-time conditions that interrupt and effect the on-going trip;

- User preferences, which allow the user to define his/her preferences that are then take into account by the BONVOYAGE platform.
- Feedback, which collects unattended and attended feedback;
- End user sensing, which deducts mode of transport and further functionalities (e.g. users' stress levels).

An iterative and agile approach was not only applied to the design but also to the development and implementation of the main BONVOYAGE App. This approach ensured that the application implements the required functionality with high acceptance of the user and allows using the services of the BONVOYAGE platform in a personalised and understandable manner, encouraging users towards sustainable transport

The architecture of the mobile App and the Application Layer consists of the following elements (see Figure 5).

- Mobile Apps
  - Main BONVOYAGE App
  - User Transport Mode Recognition App and libraries
  - User Stress Level App and libraries
- Application Server (directly communicates with the Orchestrator Layer)
- Connected services
  - Feedback
  - Location
  - Greenpoints
  - Personalization
    - On Line User Profiling Module
    - Rank Tool module
  - Car Pooling and associated prototype application
  - Firebase

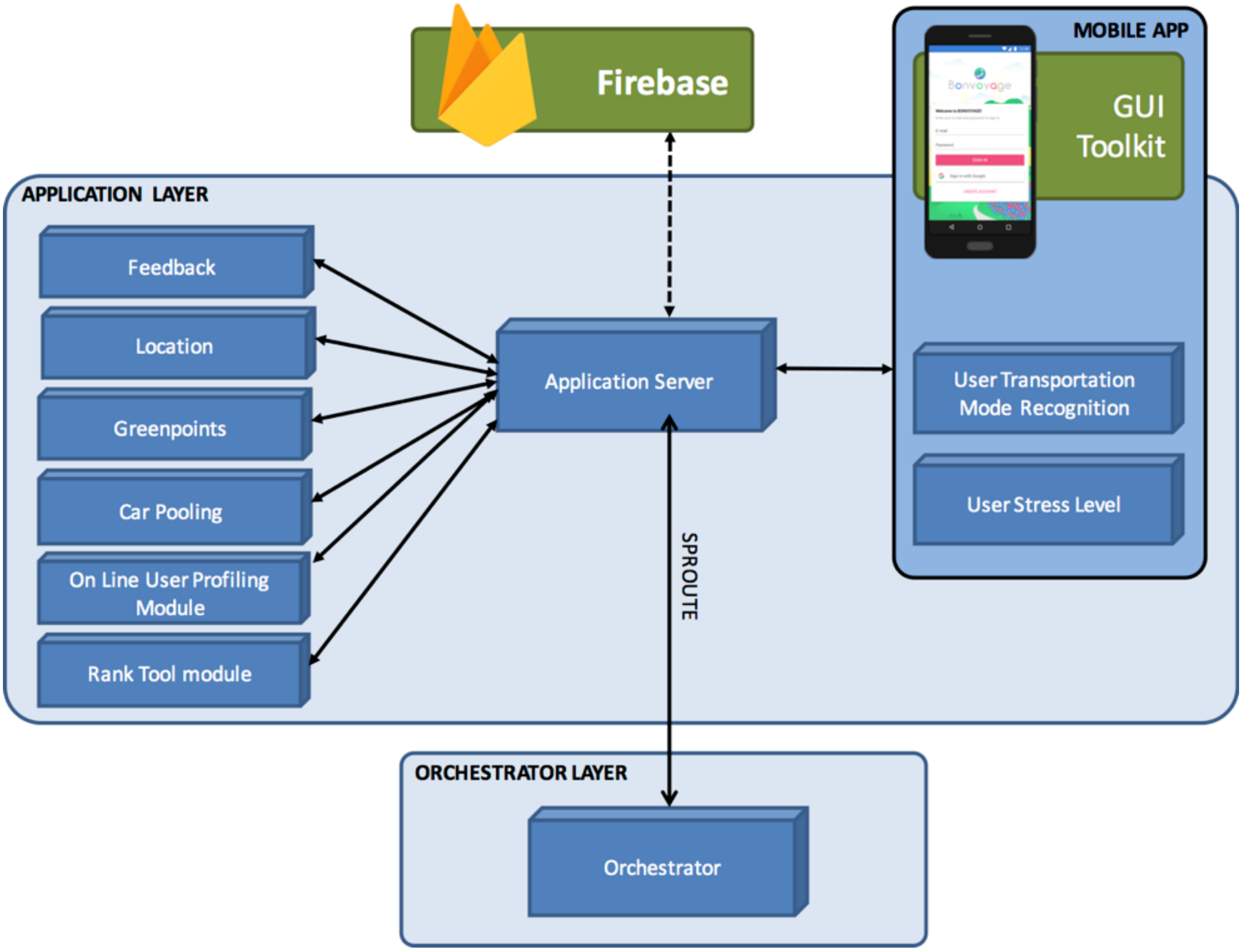


Figure 5. Detail of the Application Layer and mobile App

Note that the interfaces between these components are described in Deliverable D6.1 Technology dependent interfaces, while the details of each of the components depicted in Figure 5 is reported in deliverable D6.2 Apps.

3.3.6 Orchestration Layer

As said, in order to tackle the complex computational task involved with a real-time multimodal multi-objective route planner at continental level, BONVOYAGE develops a novel hierarchical, decomposition-based approach, the Orchestrator. It is a decomposition approach to solve the routing problem on a multimodal network N that may be viewed as a pair (N,A), where N is a multi-modal network, and A is an algorithm to find an optimal route (for a class of objective functions) between any origin/destination pair within N. To perform its task, the orchestrator relies on a set of solvers A1, …, Aq to compute an optimal route in a corresponding multi- or single-mode sub-network N1, …, Nq with the property that Depending on the specific query, the orchestrator will pick up a suitable subset of solvers, run them, collect the partial solutions and compose them into a unique one answering the original query. Please notice that what we have loosely indicated, interchangeably, as planner, planner logic, journey planner service, or route optimization algorithms, is precisely defined in the context of deliverable D4.1 with the term Soloist, which nicely matches the concept of an orchestra director orchestrating the soloists in order to perform a symphony. Briefly, a pair (Ni, Ai) is a Soloist, i.e. a match of a sub-network and a solver algorithm. This is illustrated in Figure 6.

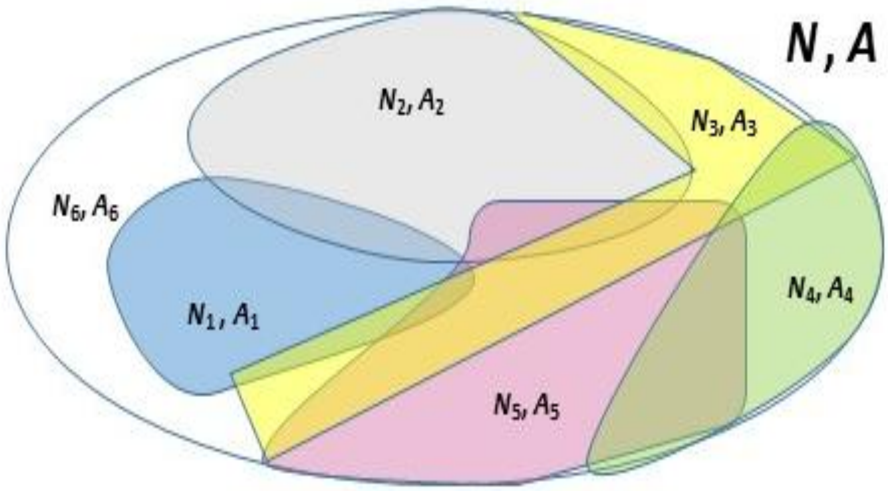


Figure 6. Soloists and Orchestrator of a multimodal network

Functionally, we know that (see D4.1 and D5.1) the Orchestrator may be viewed as an algorithm acting upon a multi-modal network, able to find an optimal route (for a class of objective functions) between any origin/destination pair within the network.

Each edge of the multi-modal network is associated with a single modality. So, for instance, if the nodes represent crossings in the roads of a city, than an edge between two crossings may be a car edge, a bike edge, a bus edge, etc. Metric data can be associated with each edge of the multi-modal network.

The initial multi-modal network may be partly unknown. The elements in the decomposition are not simple cells identified by a set of nodes, but they are (potentially multi-modal) sub-networks (the ones where Soloists operate). Connection nodes represent entry and exit points of the sub-networks. They may or may not be geographically localized. In general, connection nodes must be chosen carefully at the registration of a new Soloist into the federation.

The nodes on which the Orchestrator graph operates are the connection nodes. Within sub-networks they induce a clique in the sub-network, i.e. for every ordered pair of distinct nodes in the sub-network there is a connection edge (see Figure 7). With every connection edge we also associate a distance evaluated according to one or more pre-defined metrics. For instance, the length is the distance between the connection nodes in terms of transfer time, and may also be 0 if the two nodes correspond to the same geographical location.

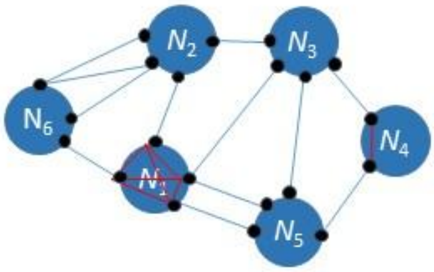


Figure 7. The Orchestrator graph. Black nodes are connection nodes

If nodes belong to different sub-networks, there is an edge only if it is possible to "transfer" from one sub-network to the other.

When handling a request for routing from origin A to destination B (see Figure 8), the Orchestrator first assigns A and B to one or more soloists, according to the coordinates and possibly other information (such as the desired modalities).

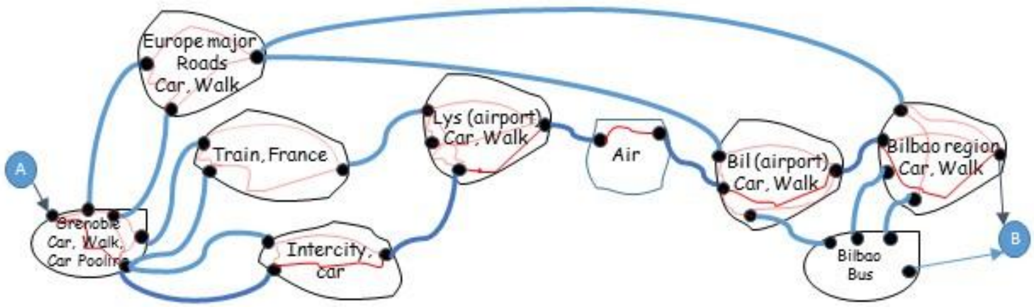


Figure 8. Orchestrator invocation

At invocation, the Orchestrator searches for a promising path from A to B in the orchestrator graph. The nodes of such path belong to a subset of sub-networks, in turn corresponding to specific Soloists. Once the proper subset of Soloists is identified, they will be invoked in a sequence represented by the oriented path from A to B.

In order to demonstrate the potentiality of the Orchestrator concept, we have implemented a number of Soloists, covering the main requirements and the many innovative features of the project.

3.3.7 Infrastructure Layer

Even if ICN is posing the foundation of the Future Internet, it is widely accepted that it is impossible to reach a worldwide network architecture completely based on ICN in upcoming years. Only few portions of the network could be really re-designed from scratch, thus integrating pure ICN communication principles (clean-state solution). Nevertheless, to push the evolution of the Internet towards the information-centric approach, ICN could be quickly deployed as an overlay network, i.e., on top of the existing IP protocol suite.

Many other pieces of the current Internet architecture will still use the conventional IP protocol. The resulting network architecture is extremely heterogeneous. Embracing this heterogeneity is fundamental to BONVOYAGE, given its federated and large-scale nature of mobile transport data, coming from data-centres, sensors, vehicles, goods and people on the move. We cope with heterogeneity aspects by, on the one hand, grouping network nodes in clusters, simply referred to as realms, where data delivering is handled by means of specific communication protocols. On the other hand, network realms will be connected to each other through dedicated border routers, thus requiring advanced internet-working solutions.

Starting from these premises, the BONVOYAGE Communication System has been conceived in order to target:

- the design of a scalable communication protocol based on the ICN principles, able to easily support the exchange of travel-centric and sensing contents across multiple domains;
- the simplified provisioning of request-response and publish-subscribe communication schemes on top of the aforementioned heterogeneous network, while ensuring a complete interoperability among different technologies and applications; Request-response and publish-subscribe communication schemes are the main mechanisms through which applications may fetch contents from the network. With the request-response scheme, data are retrieved synchronously: every time a journey planner application would fetch that content, it has to send a request towards an external source of information, which will immediately provide the corresponding answer. The publish-subscribe communication model, instead, is based on an asynchronous interaction. In that case, the journey planner application issues a subscription request for a given content of interest. Then, every time a new content is generated, the external source of information is in charge of delivering that data to all the subscribed applications.
- the development of a scalable name-space which uniquely identifies travel-centric information, sensing data, data consumers, data producers, and any operation handled at both application and network layers.

Internames, a specific instance of ICN, is purposely designed to support name-based communications across heterogeneous domains and data exchange in this multi-domain environment. Indeed, Internames evolves from the baseline ICN host-to-name principle to a name-to-name principle.

Moreover Internames can identify not only contents, but all entities involved in the communication, without requiring a statically bound to a physical location: source/destination entities and services are included. Specifically, in Internames, all elements involved in the network (including contents, services, users, and devices) are identified by names.

Additionally, dedicated logical nodes are disseminated in the network in order to offer search engines, message routing across realms, and publish-subscribe functionalities.

To support data dissemination in a way that is transparent from the underlying communication technology and that guarantees a standardized interaction among different applications, a powerful middleware layer, namely Internames Service Layer, is deployed on top of the network layer. In particular, any device involved in the communication, like data consumers, data producers, border routers, and logical nodes implements an instance of the Internames Service Layer that (i) exposes a set of standardized API for requesting, subscribing, and publishing contents to the application layer and (ii) hides all the operations executed at the network layer when triggered by aforementioned API.

A hierarchical name-space has been designed in BONVOYAGE, to identify contents, users, border routers, and Internames logical nodes, as well as any operations triggered at the network layer by the aforementioned Internames API.

Note that the entire BONVOYAGE platform jointly exploits Internames, the middleware layer and the name-space for efficiently offering request-response and publish-subscribe communication mechanisms on top of heterogeneous network architecture.

Internames offers search engines, message routing across realms, and publish-subscribe functionalities through three logical nodes: Object Resolution Service (ORS), Name Resolution Service (NRS), and Internames Rendezvous Node (IRN). They are used to execute three different high-level functionalities offered at the network layer, as follows.

Object Resolution Service offers a mapping functionality and plays the role of a search engine. In general, a data consumer that is interested to retrieve a given content could not know a priori the name that the BONVOYAGE platform uses to uniquely identify it. Therefore, it sends to the ORS node a message containing a set of meta-data. The ORS will answer with a message reporting the list of names that map the aforementioned meta-data. ORS functionality is crucial to the concept of federation and synergic to Data Discovery (see above).

Name Resolution Service handles routing operations within the heterogeneous network infrastructure. By knowing the distribution of data providers, it finds the best routing path through which forwarding the requests generated by data consumers. NRS is contacted by the data consumer or by other routers along the path every time a request should be sent towards a new network realm. This routing functionality receives as input the name of the content to be retrieved and returns as output the next hop of the path and the related network protocol to use.

Internames Rendezvous Node manages publish-subscribe functionalities. Hence, it tracks the set of contents available in the BONVOYAGE platform, processes the submission requests, and notifies subscribed data consumers every time a new content of interest is available.

Besides that, the other key building block is the Data Discovery Service, which we call OpenGeoBase, is the decentralized large-scale storage system used for building quite generic georeferenced services within the platform. OpenGeoBase exploits Internames to collect and make available georeferenced transport-related data. Basically, OpenGeoBase allows anyone to publish data relevant to a specific geographic area, ranging from transport schedules to sensor-generated or user generated real-time information, but also, point of interests, etc. Then, interested users/travel operators can search and retrieve all data available in such geographic area, which are needed to plan an optimal multimodal trip. Publishers are not forced to upload their data in a central repository but they can keep them in local, distributed repositories, under their control. OpenGeoBase logically puts together all individual repositories and make it easy for users to search for and retrieve the data they are interested in. We call slice a space in a set of Repositories and tenants the application owners (e.g. journey planners) that can rent a slice for their applications. Users of a tenant can Create, Read, Update and Delete data on tenant repositories. The database can grow without bounds by merely deploying new servers (horizontal scalability), and Internames takes care of routing the queries towards the best servers and cache the answers to popular queries to speed-up response time. By exploiting Internames's in-network multicasting and caching, massive information describing routes, prices, schedule plan, etc. can be quickly provided to millions of users, also under flash crowd conditions and severe events, such as interruption of a major road, extreme weather, disaster. By exploiting Internames security, the database can secure every piece of information in a customizable way and can include configurable policies as to whom, when and where can access the information. As a result, OpenGeoBase is: i) distributed, not requiring a centralized entity, ii) scalable, capable of growing without bounds; iii) secure, every piece of content can be secured in a customizable way and can include configurable policies as to who and when and where can access the information; iv) slice-able, several tenants and users can use it in parallel and independently; v) reliable: no single point of failure; vi) fast.

3.4 Privacy concerns

BONVOYAGE deals with two types of data: private information about users and public information about transport schedules and transit conditions.

Private information is voluntarily fed to the Application server by the user (for instance following a signed agreement about terms of use, at registration time), and the Application server uses it to judge whether it impacts on-going trips of that user. Such private information does not leave the private space of each user within the Application server, i.e. never enter the federation space. For instance, if a high preference is detected on a user travelling for a specific transport mean, BONVOYAGE will suggest alternatives to that very user, making use of her private information to rank the trip solely for her.

The trade-off of disclosing some private information with an informatics system and receiving a better service in return (e.g. more comfortable, cheaper, personalized travel solutions) is the norm of our technological society. BONVOYAGE provides all guarantees that private information stays within the platform and is never disclosed to other users or competitors. For services where limited disclosure is required, such as car-pooling, it is only disclosed after an additional explicit consent. Otherwise private information stays within the platform and under user 's control.

Public information, such as bus schedules or public authorities informing about road closures or road incidents, is opened throughout the federation instead, and it is disseminated.

Orthogonally to the private/public nature of data, both kinds may also be static vs. dynamic (i.e. real-time) and sourced through trusted official channels vs. crowd-sourced.

Examples:

- Private crowd-sourced: each user 's stress level
- Private static: each user 's home address
- Public dynamic official: a bus line temporary delay notifications originated by Bus Company
- Public static official: train schedules
- Public crowd-sourced: users informing about a road incident
- Public crowd-sourced static: Points Of Interest

Our architecture works on the following principle: private information is confined within the application server. Federated solvers don 't need it and operate by receiving an array of input data that is agnostic of the user details. All queries that are forwarded by the orchestrator to the federated solvers do not contain references to a specific user. They operate on a set of anonymous weights that cannot be traced back to a spec ific user by the solver. Only the centralized application server maintains a mapping between the user and her set of personalized weights. The local solvers make use of public data plus anonymous weights in order to compute optimal solutions that are then stitched together by the orchestrator and given the correct user context by the application server.

BONVOYAGE aims at keeping personal data as close as possible to the client (that is, within the application server). Age, gender, travel category, stress level and transport mode is the only private data transferred from the front-end to the back-end (i.e. the online user profiler running inside the application server). The request coming to the orchestrator(s) is already anonymous since the user profiler just feeds the orchestrator with a set of weights, without the need to associate them with a UserID. The link back to the corresponding UserID is not done in the orchestrator but in the application server.

The crowd-sourced public information kind (e.g. stress level, current real-time detected transport mean) contains private indications (namely the identifier of the user or smartphone that originated it), one may argue. This is the most delicate situation to deal with: such information stays private in BONVOYAGE but we speculated that it might be disseminated only if stripped from references to the originators. Additionally, the level of trust (or them being "official " or not) of that info would be difficult to ascertain. We foresee that aggregated evaluation of the crowd-sourced data is possible for the benefit of the overall community only when that information can be safely converted into publicly valuable, anonymous, averaged information. This is, though, outside of the scope of BONVOYAGE.

3.5 Freight-specific issues

Regarding freight, we haven 't of course optimized all possible scenarios; the idea of the consortium was to focus on issues that have a straightforward mapping of the architectural principles we have developed for transport of people to possible scenarios of transport of goods.

The scope of what BONVOYAGE is able to tackle in the logistic scenario is the one described in the following section, which details a reference scenario about goods delivery. It is focused on route optimization based on the time, distance, pollution and cost metrics for road trips, taking into account some general constraints related to driving regulation, exchange points, and restrictions to trucks traffic.

Soloists are provided by freight transport companies offering their transport mono/multi modal services whose discovery metadata, differently from the passengers case, change more frequently since they must include constraint that can change dynamically (e.g. volume availability, etc.) depending on the already scheduled transport services. Orchestrators are third party services that link the different soloists which respect the transport constraints.

Considerations regarding goods weight, their volume and order or strategies of loading and un-loading are out of the scope of our algorithms. They belong to the domain of travelling salesman (TSP) and vehicle routing (VRP) algorithms, and our shortest path algorithms will merely assume that this is satisfied. Hence, once cargo is to be transported from one location to another with a given vehicle, BONVOYAGE will find the most efficient way to perform the trip.

Freight Scenario Definition

In this section we show how our design is capable of coping with a detailed freight reference scenario.

The Client is a Bilbao business in need of delivering "jamon"-based goods to many shops or offices in the city of Oslo.

We have a single pick up point in Bilbao with a traditional diesel truck (A). It goes to Oslo and goods are to be delivered to several different destinations in Oslo (B1, B2).

Two competing logistics companies, one offering bike delivery service and the other offering electric vehicle delivery, cover "last mile" delivery within the boundaries of the city of Oslo, and the long haul truck stops at an exchange point at the border of the city and the goods are transferred into smaller "environmental friendly vehicles". The diagram in Figure 9 illustrates the main characteristics of our goods delivery reference scenario.

The three competing companies each have developed an own Soloists. Soloist 1 for the diesel truck company of Bilbao; Soloists 2 and 3 for the Oslo logistic companies. Each soloist is able to plan for a multipoint route that includes all the delivery points of its coverage area, starting from their respective exchange point (A, V1, V2 in Figure 9). The Soloists are capable of computing the time, pollution and cost it takes to reach each delivery point.

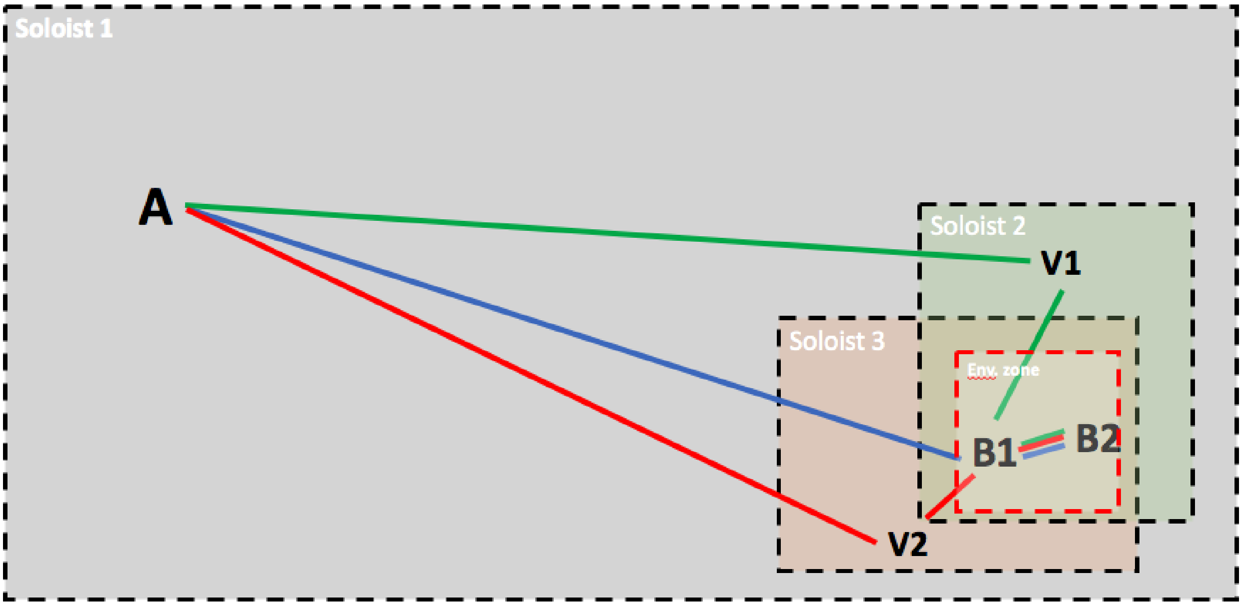


Figure 9. Diagram of the reference freight scenario

B1 and B2 are the different delivery points within Oslo. V1 is the exchange point for company 1 and V2 is the exchange point for company 2.

Three alternatives will be presented to the Client, and just two of them can be clearly categorized as "environmental friendly ones", and valid within the "Environmental zone" (smallest red square in the diagram). The three possible solutions are:

- (blue) A to B1 and then B2 using only long-haul Soloist 1 covering from Bilbao to Oslo, including the final destinations. This is not environmental friendly and will be excluded if the "Environmental zone" is enforced.
- (green) A to V1 using the long-haul Soloist 1, then exchange in V1 and from V1 to B1 and B2 using electric vehicles
- (red) A to V1 using the long-haul Soloist 1, then exchange in V2 and from V2 to B1 and B2 using bicycles

In so doing the Oslo companies are competing one against each other in the Oslo area, but they are cooperating with the big long-haul Bilbao company.

The two (three) alternatives are ranked. The first one (truck all-the-way) is maybe fastest but time is less important than the cost or pollution in our scenario. Indeed, BONVOYAGE can easily showcase the importance of multi-objective optimization taking into account three objectives: time, pollution, cost (money), in typical goods delivery scenarios.

The ranking of the solutions is further influenced by the fact that by decomposing the problem into parts, one small local Soloist, for instance the bike delivery one, can have a performance edge in terms of delivery time because of its tailored design, since in that case the operator can design it taking into account the fact say that many bicycles ride "in parallel" together.

In any case the door-to-door multipoint delivery algorithm at the orchestrator will take into account the time to stop at each delivery point and also the time at the exchange points V1 and V2.

Implementation impact on SPROUTE

- Multi point Request Response will use the "via point" concept of SPROUTE.
- "Travelling entity" will be PARCEL.
- TRUCK is not defined in the original SPROUTE modalities. We decided to add TRUCK for this reason.

Implementation impact on the Soloists

- Stop time at each exchange and destination node is known and taken into account for by the respective Soloists.
- We express restrictions in the Soloists
- One Soloist using raw data for roads from Norway/Oslo so that closed roads for trucks are not part of the "electric vans" Soloist.
- The "bike Soloist" has access to a wider variety of roads and thus can have smarter solutions.
- We tweak the Soloists so that cost calculation is done according to the vehicles and the business strategy of the company.

Implementation impact on Discovery of Soloists

- The Soloists may be flagged as "PARCEL" Soloists, accordingly.
- The metadata describing the current capabilities of each Soloist in terms of available vehicles and transport capacity are to be updated more frequently in OGB than scenarios about transport of passengers. There is the need of a much more dynamic updating of soloists ' metadata, together with much tighter communication between orchestrator and soloists about their current status.

This scenario can of course be based on public data such as the European regulation on driving conditions, and general national regulations on traffic restrictions within the boundaries of Oslo city. Publicly available information about ship or train services could easily be used to offer alternatives to the long-haul road segment, on the basis of type of service, origin, destination, schedule, transit time.

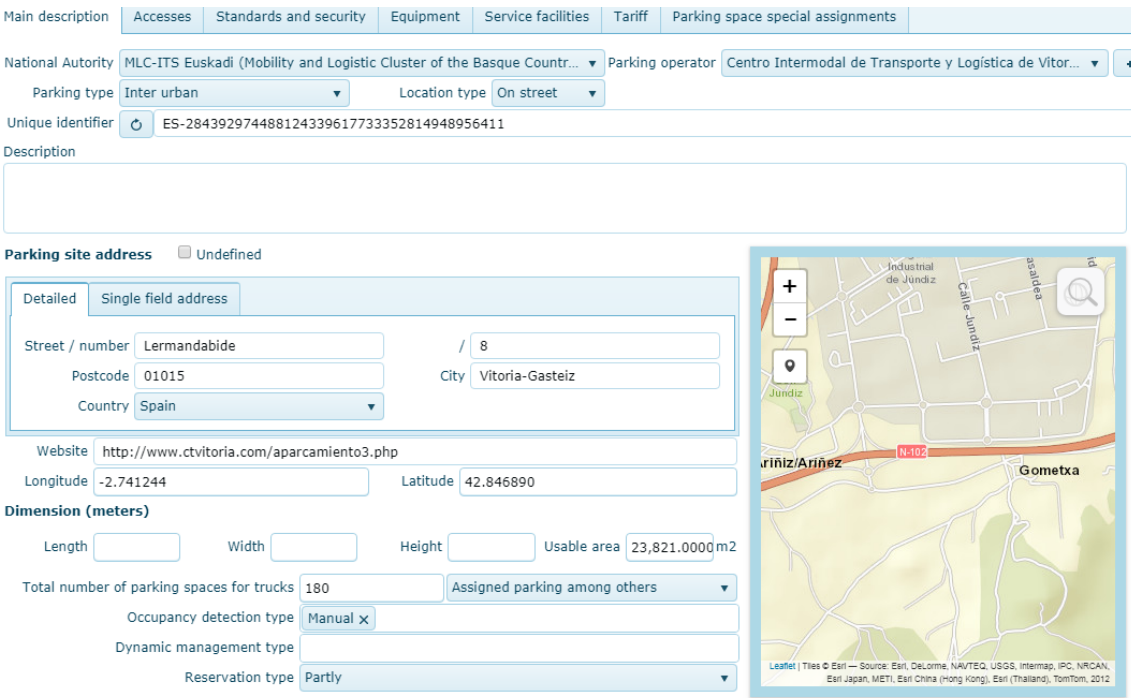
Safe Truck Parking Data in the EU Portal

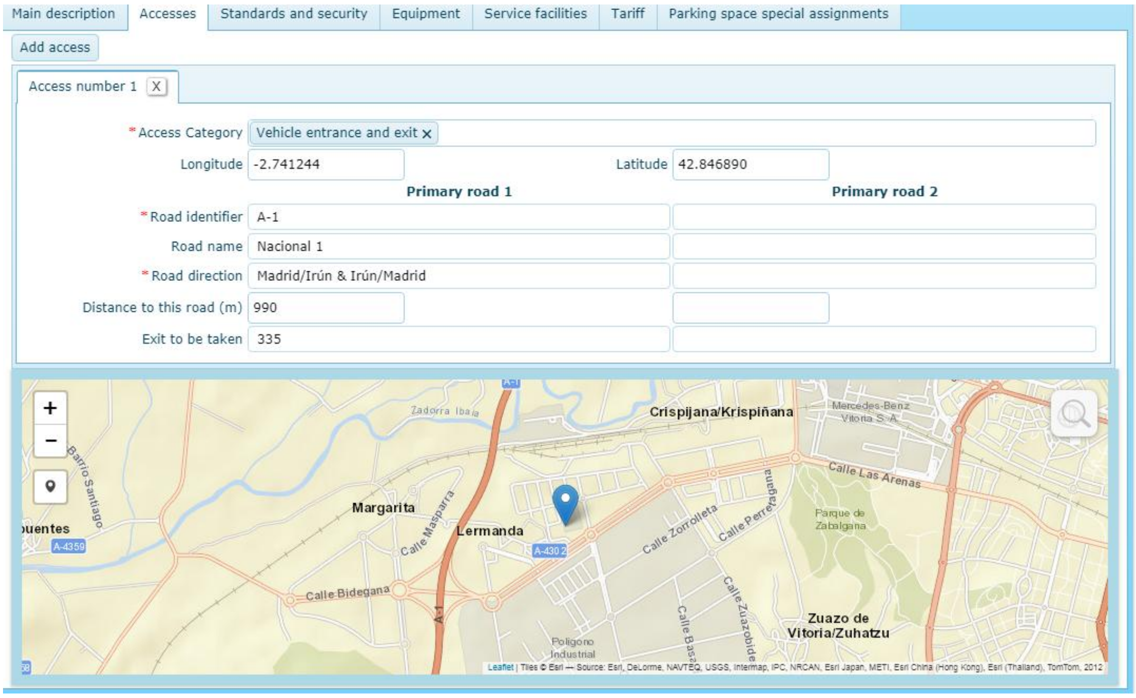
Besides the above scenario, BONVOYAGE specially focused on the EU Delegated Regulation for Priority action (e): "the provision of information services for safe and secure parking places for trucks and commercial vehicles". The project succeeded in contributing valuable information (based on skills and data available from the Azkar and MLC partners) related to parking facilities for trucks in the Basque region.

We have integrated such data as DATEX II files in the European Access Point for Truck Parking at http://data.europa.eu/euodp/en/data/dataset/etpa. It already had entries from Austria, Belgium, Czech Republic, Germany, Netherlands, in DATEX II format.

Through BONVOYAGE, the project partner MLC collected and validated missing information for known truck parking facilities in the Basque Country, producing the necessary DATEX II info, and ultimately enhancing the European Access Point with information that was missing.

The following figures are screen captures of the data insert procedures.

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Accesses
Standards and security
Equipment
Service facilities
Tariff
Parking space special assignments
Add access
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Vehicle entrance and exit x
Longitude
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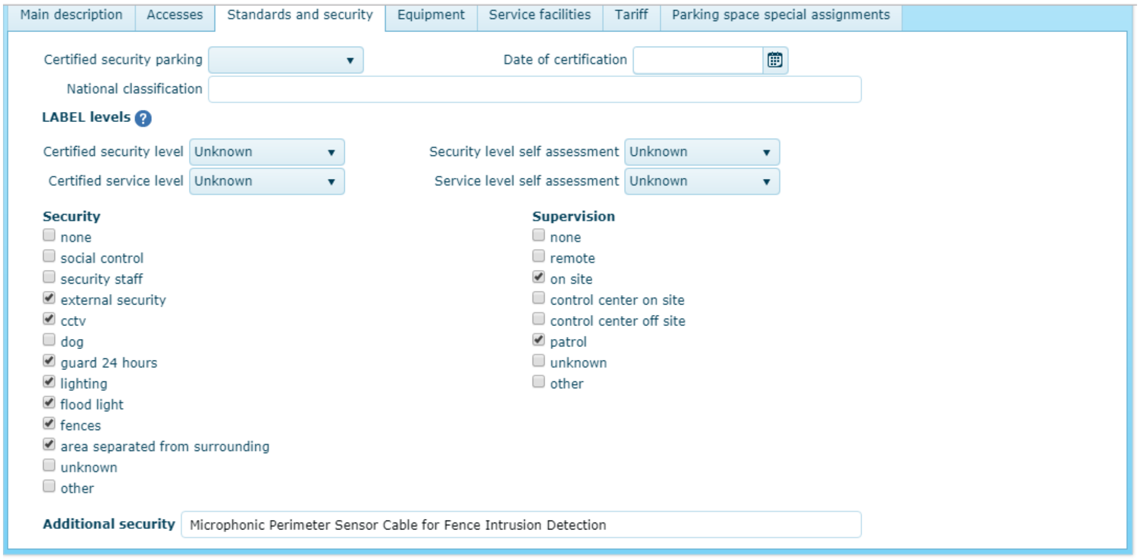
Latitude
42.846890
Primary road 1
Primary road 2
*Road identifier
A-1
Road name
Nacional 1
*Road direction
Madrid/Irún & Irún/Madrid
Distance to this road (m)
990
Exit to be taken
335
Crispijana/Krispiñana
Margarita
Lermanda
Calle Bidegana
Calle Las Arenas
Calle Zorrolleta
Zuazo de Vitoria/Zuhatzu
Parque de Zabalgana
A-4359
A-430 2
Poligono Industrial
Mercedes-Benz Vitoria S. A.
Leaflet | Tiles © Esri — Source: Esri, DeLorme, NAVTEQ, USGS, Intermap, IPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012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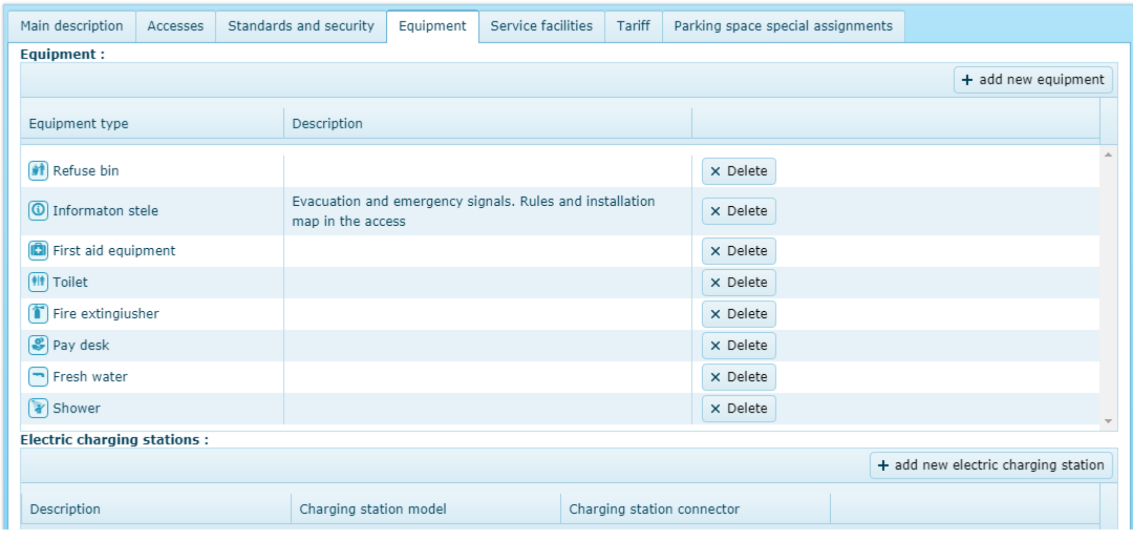
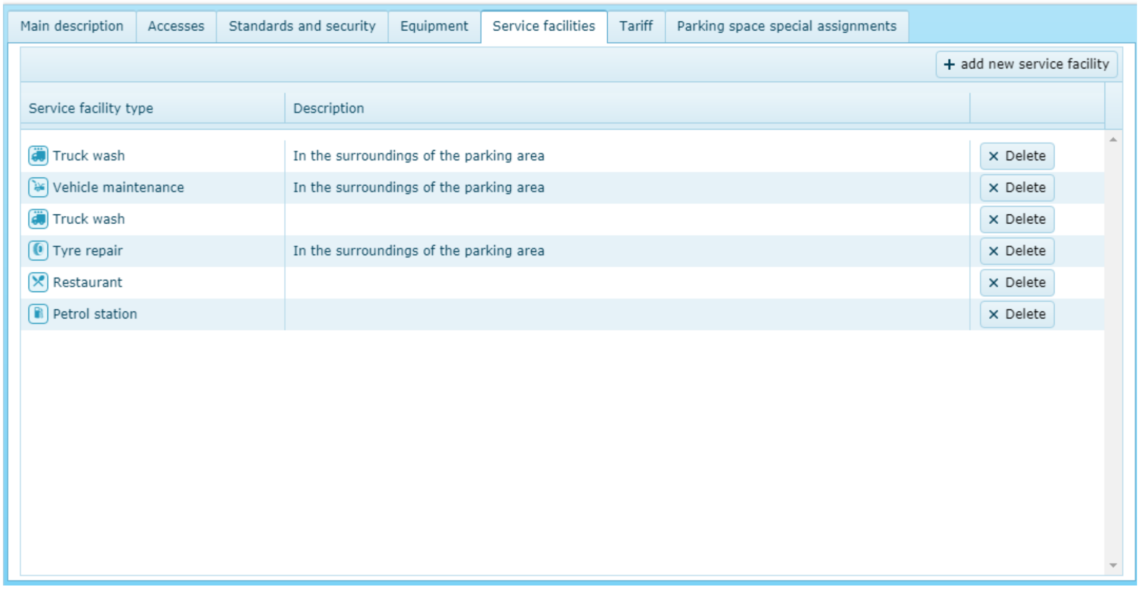
Standards and security
Equipment
Service facilities
Tariff
Parking space special assignments
Certified security parking
Date of certification
National classification
LABEL levels
Certified security level
Unknown
Security level self assessment
Unknown
Certified service level
Unknown
Service level self assessment
Unknown
Security
none
social control
security staff
external security
cctv
dog
guard 24 hours
lighting
flood light
fences
area separated from surrounding
unknown
other
Supervision
none
remote
on site
control center on site
control center off site
patrol
unknown
other
Additional security
Microphonic Perimeter Sensor Cable for Fence Intrusion Detection


Main description
Accesses
Standards and security
Equipment
Service facilities
Tariff
Parking space special assignments
Equipment :
+ add new equipment
Equipment type
Description
Refuse bin
Informaton stele
Evacuation and emergency signals. Rules and installation map in the access
First aid equipment
Toilet
Fire extingiusher
Pay desk
Fresh water
Shower
Delete
Electric charging stations :
+ add new electric charging station
Description
Charging station model
Charging station connector


Main description
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Standards and security
Equipment
Service facilities
Tariff
Parking space special assignments
+ add new service facility
Service facility type
Description
Truck wash
In the surroundings of the parking area
Vehicle maintenance
In the surroundings of the parking area
Truck wash
Tyre repair
In the surroundings of the parking area
Restaurant
Petrol station
Delete

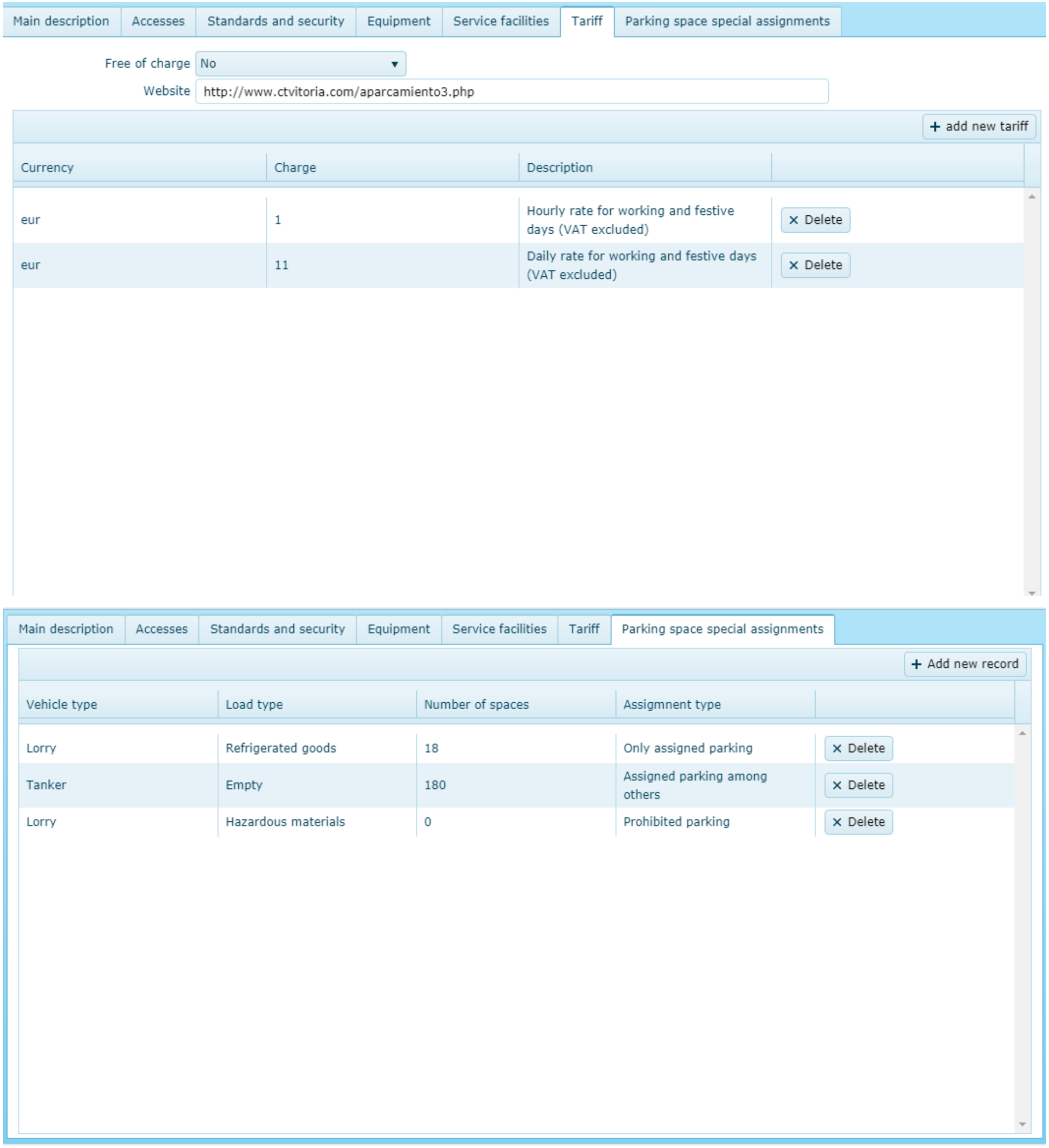

Figure 10. Screenshots of the data insert procedure in the European Access Point for Truck Parking

3.6 Car-pooling specific issues

One serious risk that each research project faces is investing effort in the development of nice, innovative functionalities that are not backed-up by any concrete user need. In BONVOYAGE the consortium has faced this question for what concerns the development of an innovative car-pooling algorithm, in which the "pick-up" function is available. Setting up a service/platform for this specific mode of transport may cost a lot of effort and there was no specific indication, at the beginning of the project, that there is a serious market potential, also because people want to know with whom they will ride meaning that some feedback about the drivers is critical for the success of the service.

So the consortium has decided to better investigate the number one player, namely BlaBlaCar. Indeed it appeared that the feedback mechanism of BlaBlaCar is working well. They have 25 million users and operate in 22 countries. The concept of "sharing economy" is backing-up this kind of initiatives. It is an area of economy where there are not many competitors to BlaBlaCar, and BONVOYAGE can lower the barrier for entering it, by providing the technical means to setup a service very easily.

Further and most important, the future of car-pooling is going to converge with autonomous-drive cars, most probably (see also Carpooling and the Economics of Self-Driving Cars. Michael Ostrovsky, Michael Schwarz, February 12, 2018). We think that the driver needs not be a human, or the car owner, ultimately. But the routing, aggregation, sharing of data and communication network technologies are fundamentally the same. Investing in the right algorithms for car-pooling is synergic to the upcoming autonomous-drive revolution.

BONVOYAGE has developed an innovative carpooling service, integrated with other transport modalities enabling it also for urban rides. At the moment, carpooling communities like Blablacar only work properly for long distance journeys. More in general, each carpooling community has its own working area, and no integration with other transport means is considered. The scope of BONVOYAGE about the carpooling service is to demonstrate that it is possible to extend the concept of urban mobility with new flexible transport modalities, computing optimal routes both for the "pick-up " driver and for the passengers accepting the ride.

The algorithm is able to establish two different "maximum detour ranges", one for pick-up driver and the other for the passengers, and calculate optimal pick-up point and pick-up times minimizing the distance for all players.

3.7 Usage of the stress level data in BONVOYAGE

BONVOYAGE is able to continuously monitor the users that wear Empatica E4 wristwatches and estimate in real-time their specific current stress level. In fact, each user suffers from stress in different situations and for different reasons and, accordingly, reacts to stress in different ways.

The Rank Tool has been designed to be able to learn and profile users based on their feedback about chosen (preferred) travel solutions. Profiling is thus based on features that typically define trips, such as the number of exchange nodes, distances within the route, variety of transport means, price. It is based on features that are clearly visible to the end-user, because they are presented to the user when the various solutions are returned.

On the other hand, the stress level is not yet an intrinsic characteristic (feature) of a trip. With the amount of data that it was possible to accumulate in BONVOYAGE, it was not possible to clearly assign a definite stress level to the {user, transport mean} couple, because the same transport mean can induce much different stress levels in conjunction with un-predictable external factors.

Nevertheless, the machine-learning approach that was developed in BONVOYAGE is high flexible, in the sense that new features can be automatically taken into account once the data set is rich enough. Throughout the life of WP4, extensive tests with real users have validated the personalization and the Rank Tool, which takes into account the above-mentioned features characterizing travel solutions. Introducing stress level among the considered features is a suitable extension of the proposed algorithm but requires additional tests by involving different groups of users that have been not considered in BONVOYAGE. We consider this to be an interesting issue to be investigated in a future exploitation phase of the project's results but we are well aware that this will require a strict cooperation between experts about the physiology of stress and experts in machine-based user profiling.

To conclude these remarks we note that, although the stress level is not currently part of the features of the ranking algorithm, it is indeed used as a valuable piece of information in the BONVOYAGE applications, which are perfectly able to inform the user about the average expected stress level that each solution will likely incurs, based on the average past recordings for the specific user.

3.8 Technical Structuring of the Project

The following Figure 11 shows BONVOYAGE's functional architecture and its relationship with Work Packages from a high-level point of view, and draws a technical perimeter for the project, which holds unchanged from the proposal document. Nonetheless, the interpretation of the functional architecture of Figure 11 has obviously progressed during the project's lifespan. We have now come to a precise understanding of the overall implementation strategy for the project, as reported in the above sections, so that we are now able to understand how the functions depicted in Figure 11 are implemented by the components depicted in the context of both the federated and the layered architecture (Figure 2 and Figure 3 above).

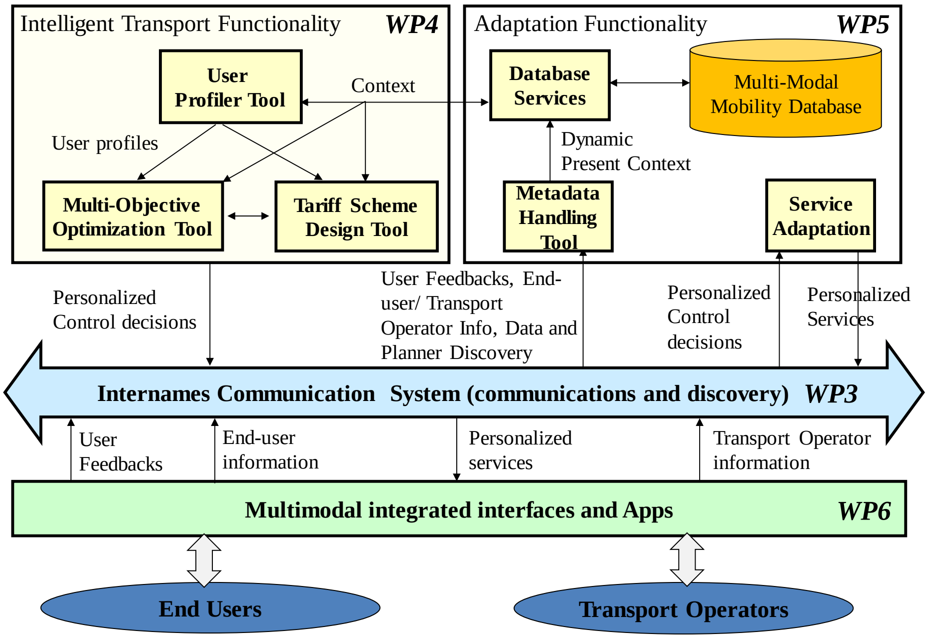

Figure 11. BONVOYAGE high–level functional architecture and relationship with Work Packages

Specifically, the BONVOYAGE architecture makes it possible to discover and exploit services offered by a distributed set of planners, which are provided by BONVOYAGE, but also by any other external project or stakeholder.

BONVOYAGE devises key proof-of-concept planners and an orchestrator, demonstrating the feasibility of the federation. They are collectively developed by WP4 and WP5.

WP4 designs individual planners ' logic and the orchestration function within the general framework of the Multi-Objective Optimization Tool (MOT), and the personalization function within the User Profiler Tool (UPT). Planners can use information related to the user coming from the UPT to better adapt the solution to the user preferences. Planners can also use tariff schemes implemented through the Tariff Scheme Design Tool to compute the cost of the possible solutions, and these tariff schemes can be function of both the user profile and the travel solution, thus fostering energy-saving (green) solutions.

WP5 takes care of collecting all the information necessary to all WP4 tools through a Metadata Handling Tool, which also takes care of publishing information, making the specific planner/soloist discoverable and retrieving information about the availability of other planners/soloists within the federation. All information is stored in a local database (Multimodal-Mobility Database, accessed through the Database Services). In addition, WP5 includes a Service Adaptation functionality that takes as input the travel plans derived by the MOT (namely, Personalized Control Decision) and sends them to the user Apps, changing them to a format properly adapted to the user device and context (Personalized Service).

WP6 takes care of designing and implementing some exemplary mobile Applications, and related interfaces, that use the federated architecture and the "official" BONVOYAGE planners/soloists, through which a user can interact with the system. Also design of SPROUTE interface is part of WP6.

WP3 develops the Internames Communication System (ICS), together with specific travel-centric data services, such as the discovery service OpenGeoBase (OGB). Most of the communication between modules exploits ICS, which offers name-based request-response and publish-subscribe services at scale. It can be simply considered as a communication middleware, which simplifies the developing since it makes possible to use names rather than IP address, provides native mobility support, handles security and privacy, efficiently distributes large set of contents exploiting internal multicasting and caching functionality. OGB is an Internames-based spatial federated database, which is used to support the discovery services of the federated architecture at large.

3.9 Market Analysis

The definition of the BONVOYAGE potential market relies upon the scoping of the overall European digital mobility services market, and upon identification of specific users groups composing this market.

European demand for transport is continuously increasing: Europeans travel around 35,000 passenger kilometres per year; a European citizen makes about 923 trips per year or 2½ trips each day. Nowadays, most of these are still made by car (64%)[4].

Nevertheless, a relevant change is taking place concerning citizens' usage and preferences of transport modes. The use of public transports has increased steadily increased in Europe since 2002 and, more importantly, Europe is becoming a primary hub for the public transport sector innovation.

In this context, it is necessary to take into account on-going and future disruptive changes driven by the digitisation in the transport sector overall. Digital technologies are causing a relevant impact on:

- the way citizens travel and make their mobility decisions;

[4] Deloitte, Transport in the Digital Age. Disruptive Trends for Smart Mobility, March 2015.

- how transport operators provide and manage their services.

In the first case, citizens are becoming more demanding about their travel experience and their expectations on transport operators ' reliability and services, due to: the increased availability and access to more travel options; the possibility to get real time information on transport and traffic status as well as to compare a multitude of travel solutions with a full set of information (e.g. price, travel duration), empowering them to make more informed mobility choices.

To provide a concrete example, at urban level, citizens expect public services to be easily accessible and highly reliable to be preferred to the private car. Also, in case of disruption, users expect to find quick wins solutions to timely complete their travel itineraries, with no major difficulties. Consequently, users are acquiring an increasing influence on the services offered and business models adopted by transport operators.

In the second case, transport operators shall increase their ability to dynamically and rapidly adapt their services to meet new travellers demands. Thus, the main challenge for transport operators is not to modify travellers' behaviour but to timely follow, accommodate and even anticipate it. They shall provide a wide range of choices targeted and differentiated to the several types of travellers, ranging from urban or inter-urban commuters to business travellers and ageing people. In this regards, the integration among different transport modes (including train, bus, subway and "new" form of transports like car sharing and bike sharing) is a key element to ease mobility at local, national and cross-border level, ensuring seamless and smooth transition from one mode to the next. For this purpose, the interconnection and integration of technologies and data is necessary and serves as a building block for the creation of an intelligent transport system, bringing together private and public transport operators and institutional stakeholders, able to ensure real response to travellers demand, external events and "assist" travellers in case of disruption.

Furthermore, payments digitisation is paving the way to the possibility for transport operators to define new, profitable models. For instance, digital payment can support new ways to charge travellers, combining their journey origin-destination request and other factors such as time of the day, class of travel, discounts, previous travel patterns and other traveller specific data.

Based on the picture described above, it can be concluded that BONVOYAGE potential market is composed of two main groups of users:

- citizens travelling at local, national and cross-border level as primary users;
- transport operators needing to satisfy citizens new demand as secondary users.

As a matter of fact, BONVOYAGE platform will be able to provide users an innovative and comprehensive mobility service and an enriched travel experience, giving them the possibility to:

- find the best door-to-door travel solution for their journey itinerary;

- receive personalised travel solutions, based on their profile, preferences and past mobility behaviours;
- receive real time information on transport modes and traffic status;
- get assistance in case of disruption.

Thus, BONVOYAGE platform will be able to meet "digital travellers" new needs and expectations for mobility services, also accommodating different users profiles, characteristics and needs.

Concerning transport operators, BONVOYAGE platform will provide them:

- a concrete mean to leverage on the potential and the opportunities offered by digital technologies in the transport sector;
- an additional and relevant cannel to convey their transport services to a wider range of users, with positive impact on their business and revenues;
- offer their customers an enriched and exhaustive travel experience, thus increasing their attractiveness and customers loyalty;
- integrate their services with other transport modes in multi-modal travel itineraries.

Therefore, BONVOYAGE platform will be able to support transport operators in keep pace with the digital transformation in the transport sector as well as to support their business objectives, providing them the possibility to reach an increased number of customers and/or providing new revenue streams.

3.9.1 Market Study

A market study was carried out in order to identify the current state of art and the different functionalities and features of the existing widely used mobility and travel platforms and Apps at national and European level. The study investigated different platforms and Apps:

- 3 Travel Platforms, including a commercial one developed by BONVOYAGE project partner Trenitalia (NUGO);
- 11 Local Public Transport solutions across EU Member States and third countries.
- 15 Journey Planners/Travel Apps

In this section a description of the market study objectives, methodology and main findings is reported, with the aim to describe the journey planners' and travel apps' so called "AS – IS Scenario" (i.e. the present situation, as it currently is) and identify the main differences between them and BONVOYAGE platform, highlighting innovation coming from BONVOYAGE and the added value brought to the market (which we call the "TO – BE Scenario").

By going through deliverable D8.3 the reader can retrieve full details of the market study. Synthetic observations about the market are here reported, though, because they are integral to the BONVOYAGE vision and its consolidation among partners.

The main goal of the market study is:

- The identification and description of the main strengths and weaknesses of the existing journey planners and travel apps, in order to identify the missing features and functionalities;
- The identification of the most appropriate positioning of the BONVOYAGE platform in the market.

The benchmark study was developed on a conspicuous number of multi-modal journey planners and travel platforms in order to identify the best solutions currently available on the market.

The platforms and Apps that were analysed are reported in the following Table 5.

N.	Product	Category	Country	Link
1.	Trenitalia Commercial Platform (PICO)	Travel (purchase) platform	Italy	http://www.trenitalia.com/tcom-en
2.	Bpass Lignes d 'Azur App (France)	Local Public Transport solution	France	http://www.lignesdazur.com/index.asp
3.	Lyon Optimod initiative (France)	Local Public Transport solution	France	http://www.optimodlyon.com/en/accueil/actions
4.	T écély Card & City Card (Lyon, France)	Local Public Transport solution	France	https://theworklife.com/experience/how-to-buy-a-carte-tecely-in-lyon/ https://www.lyoncitycard.com/?lang=2
5.	Stockholm Access-kortet (Sweden)	Local Public Transport solution	Sweden	http://sl.se/sv/info/biljetter/sl-access/kopa-biljett/
6.	Dutch OV-chipkaart (The Netherlands)	Local Public Transport solution	Netherlands	https://www.ov-chipkaart.nl/home-1.htm
7.	London Oyster Card (United Kingdom)	Local Public Transport solution	United Kingdom	https://tfl.gov.uk/travel-information/visiting-london/visitor-oyster-card
8.	Masabi solution (United Kingdom)	Local Public Transport solution	United Kingdom	http://www.masabi.com/about/
9.	Rio Card (Brazil)	Local Public Transport solution	Brazil	https://www.cartaoriocard.com.br/rcc/institucional
10.	Beijing Yikatong Card (China)	Local Public Transport solution	China	http://www.beijingholiday.com/beijing-travel-tips/beijing-yikatong.html
11.	Singapore EZ-linked card (Singapore)	Local Public Transport solution	Singapore	http://www.ezlink.com.sg/
12.	Trenitalia App	Journey planner	Italy	http://www.trenitalia.com/tcom-

N.	Product	Category	Country	Link
				en/Purchase/Mobile-Ticketing
13.	Smile / Beam Beta (developed by Fluidtime)	Journey planner	Austria	https://www.fluidtime.com/en/about-us/references/beambeta http://www.wienermodellregion.at/das-projekt/massnahmen/beam-beta-smile-wienmobil-karte/
14.	Waze	Journey planner	Israel	https://www.waze.com/en/
15.	Moovit	Journey planner	65 Countries, 1000 Cities across Europe, Asia, Africa, Americas and Oceania	http://moovitapp.com/en-gb/
16.	Superhub	Journey planner	Italy, Finland, Spain	https://ec.europa.eu/digital-single-market/en/content/superhub-tailor-made-mobility
17.	Google maps	Journey planner	Worldwide	https://www.google.com/intl/en/maps/about/
18.	MyCicero	Journey planner	Italy	http://www.mycicero.it/
19.	Carsh	Travel App	Italy	http://www.carsh.it/
20.	Musement	Travel App	Worldwide	https://www.musement.com/us/
21.	Moovel	Journey planner	North American cities	https://www.moovel.com/en/DE
22.	Mozie	Travel platform	Worldwide	https://dribbble.com/shots/2778926-Mozie-your-travel-assistant
23.	Wanderio	Journey planner	Italy (being expanded across Europe)	https://www.wanderio.com/?utm_source=google&utm_medium=cpc&utm_content=generico&utm_campaign=brand
24.	Sailsquare	Travel platform	Worldwide (mainly Italian market)	https://it.sailsquare.com/
25.	Jolly Ticket	Travel platform	Italy	https://www.jollyticket.com/

N.	Product	Category	Country	Link
26.	Waynaut	Journey planner	Europe	http://websites.milonic.com/waynaut.com/
27.	Captaintrain	Journey planner	Europe	https://www.trainline.eu/?_ga=1.36586211.2106100525.1473680418&lang=en
28.	Cheapair	Journey planner and travel App	Worldwide	https://www.cheapair.com/
29.	Rome2Rio	Journey planner and travel App	Worldwide	https://www.rome2rio.com/it/

Table 5: Applications analysed by the market study

Based on the outcomes of the benchmark study we have a vision on how to enhance BONVOYAGE "attractiveness" with respect to its main competitors.

AS – IS Scenario Analysis

The main results of the AS – IS Scenario analysis highlight that currently available journey planners and travel apps (e.g. Rome2Rio, Moovit, Captain train, etc.) are well-advanced in the multi-modal, door-to-door journey planning, however they do not offer user-centred travel solutions, and do not always take into account the travel solutions environmental footprint.

In more details, existing journey planners and travel apps present high performing functionalities relating to:

- Single mode and Multi-modal travel solutions, at local, national and cross-border level, able to provide a door-to-door travel itinerary, with particular reference to local transports;
- Provision of detailed information on different transport modes included in the multi-modal travel solution (e.g. public transport line or number, travel duration, number of stops and connections, etc.);
- Provision of mobility real time information (e.g. traffic status, possible disruptions).

Nevertheless, currently available journey planners and travel apps show relevant weaknesses with respect to user profiling and single booking, payment and ticketing functionalities.

They show no significant progress in the definition and implementation of user profiling functionalities. During the creation and the update of the user account/profile, they only request and store user "basic" profile information (e.g. name, residence address, age, preferred transport modes etc.). Relevant information for the single user profiling, such as user specific personal preferences (e.g. cheap travel solutions, need to save time, preferred travel class, limited mobility and other spec ial needs) are not taken into account to define specific categories of users. Therefore, they are not able to provide customized travel solutions for single users.

Existing multi-modal journey planners and travel apps do not allow the users to perform a single booking, payment and ticketing request for all transport modes included in the multi-modal travel itinerary, using the same system/page through which they search and select travel solutions. Actually, at the moment of the booking, payment and ticketing request the users are re-directed to different online portals of transport and travel operators involved in the multi-modal travel solutions, resulting in a complicated and time consuming process.

Contrary, platforms and apps managed by transport operators are able to provide several additional functionalities to the user, including the booking, payment and ticketing as well as the possibility to reserve or buy ancillary services. However they only deal with a single transport mode, lacking the multi-modality aspect.

Furthermore, other features and functionalities are not yet (or not properly) provided by most of journey planners and travel apps at stake. They include:

- Additional information related to the trip, such as planned measures on public transportation (e.g. strikes), additional information and services related to the point of arrival, such as weather, restaurants, hotels, culture and entertainment events, car sharing and car rental, especially for long haul trips;
- Travel solution carbon footprint;
- Possibility to activate a reminder with a related notification before the time of departure (using a connection with calendar, etc.);
- Assignment of "green" scores for each trip, with related awards and discounts;
- Sharing of trip information in real time through social networks and/or service provider 's chat.

Analysis of the TO – BE Scenario

In the context described above, BONVOYAGE aims to bring to the journey planners and travel apps market the missing and innovative features and functionalities identified for the multi-modal, door-to-door journey planning and automatic re-planning, user profiling for the customisation of travel solutions and the special attention to the travel solutions environmental impact and users propensity to choose eco-friendly travel solutions. In this way, BONVOYAGE platform will be able to mark a significant progress by providing users: an enriched and comprehensive travel and mobility experience, personalised on the basis of users preferences and needs; a proper "travel assistance" able to monitor and support users during the journey (e.g. through automatic notification and re-planning in case of disruption).

The following Table 6 shows how the BONVOYAGE multimodal door-to-door journey planning platform provides new features and services able to meet market requirements.

Feature/Service	BONVOYAGE Platform Added value

Feature/Service	BONVOYAGE Platform Added value
Journey planning	Travel Planning In addition to the capability of BONVOYAGE platform to allow the user to search for a travel solution using basic filters (e.g. price, class category), the platform will be able to allow the user to select other information in order to personalize the travel solution. For example, through the BONVOYAGE platform the user will be able to choose: preferred path (e.g. shorter) and transport modes (e.g. bus or train), special needs, point of interest (e.g. stations) etc. The user will have also the possibility to insert other information about travel scope or day time and to check travel schedule before and during the journey. Travel solution visualization BONVOYAGE platform will be able to show to the users general information about the travel solution (e.g. stops, departure and arrival time; prices). However, the innovative feature of the BONVOYAGE platform will be the displaying of the multi-modal travel solutions taking into account the preferences expressed by the user (during the user registration and on the basis of his/her behaviour). Travel solution will be also prioritised and ranked based on their correspondence to the user profile (this latter is determined by declared user category, declared preferences, actual user mobility behaviour detected by BONVOYAGE platform on the basis of actual trips made by the user).
Real-time information	BONVOYAGE platform will offer the possibility to detect real time information/input from sensors/devices according to their time and space validity. It will give also the user the possibility to share real-time information on public transports traffic/status with other users and to set an alert which provides new real-time mobility information.
Feedback, Vertical Support and Re-planning functionality	BONVOYAGE platform provides the possibility: to send notifications on possible problems the App (e.g. problems with maps, places missing; feedback if misplaced); to send feedback on how to improve the App. BONVOYAGE platform offers the possibility to receive assistance during journey to deliver an opinion and satisfaction degree on development of the trip concerning the overall travel solution and/or each single mono-modal step (e.g. during the travel, when a change of vehicle happen; on-line support). BONVOYAGE platform offers also the possibility to: receive assistance by activating the function of rescheduling with the possibility of providing a negative feedback if applicable; to send requests for help to re-plan trip in case of unforeseen circumstances; to receive support to re-plan of the travel itinerary, through the intervention of a virtual assistance. The aim of these functionalities is to improve the customer experience.
Ancillary Services	BONVOYAGE platform, such as some currently available journey planner and travel

Feature/Service	BONVOYAGE Platform Added value
visualisation and purchase	apps, will be able to calculate and give the user information on location and distance of several additional services (e.g. car services, public services; restaurants, cultures, hotels, shopping etc). However, the innovative aspect will be the possibility for the user to purchase, through the same platform, these additional services. Furthermore, BONVOYAGE platform will be able to send users push notification targeted to the user containing suggestions and/or proposals about these services. Finally, other ancillary services of the BONVOYAGE platform will be the possibility for the user to buy tickets for parking, highway, access for restricted area/zone and municipal services.
User Profiling	As previously mentioned, one of the main innovative aspect of the BONVOYAGE platform is that it will provide a "profiling function", on the basis of the preferences expressed by the users during the creation of the personal profile and on the basis of the behaviour of users over time. This functionality will allow the BONVOYAGE platform to return customized travel solutions.
Score Policy	BONVOYAGE platform will be able to assign score to the users on the basis of their behaviour, considering the selection and purchase of travel solutions more or less carbon footprint, through the definition of several user categories.
Other Features & Functionalities	Innovative feature of the BONVOYAGE platform will be also the possibility for the user to gather (and to check) points/scores based on: travel solutions purchased; quantity and type of information mobility shared with other users; achievement of objectives. Score assigned will enable the users to receive awards. Finally, other innovative functionalities of the BONVOYAGE platform will be the possibility to: share information on planned measures on rail, bus, metro, strikes, weather and places (e.g. restaurants); link status/emoticons to the profile; share status on social networks; use the chat to exchange message with other BONVOYAGE users; receive customized notifications about mobility information or suggestions; synchronise to and from calendar.

Table 6: Added value of BONVOYAGE

Compared to the journey planners and travel apps currently available, BONVOYAGE platform provides several innovative functionalities, as depicted in the Table 7 below.

Journey Planners & Travel platforms	*Integrated travel itinerary*			*Journey Planning*			*Ticket purchase*			*Ancillary services*		*Score Policy*	
	Single mode	*Multi-modal*	*Door-to-door*	*"Basic" journey planning*	*Real time info*	*Real time Re-planning*	*Single operator ticket*	*Multi-operators ticket*	*Integrated ticket*	*Services information*	*Services purchase*	*Green score policy*	*Other kinds of score policy*
Rome2Rio			●	●				●		●			
Waze	●				●					●			●
Superhub		●			●							●	●
Moovit			●		●								●
Google Maps			●		●					●			
Captain Train	●			●			●						●
Cheapair	●			●			●						
Smile/BeamBeta		●			●			●			●		
My Cicero		●		●				●			●		
Trenitalia App		●			●			●					●
BONVOYAGE			●			●					●	●	●

Table 7: Comparative innovations of BONVOYAGE

It is important to highlight that ticket purchase related functionalities do not directly fall into the project scope nor are being developed by technical work packages, due to the choice to focus the project research and development activities onto challenging issues (other than the simple integration of payment web-services), for example, on the more advanced concept of tariff scheme design, where a higher effort is needed to advance and bring them to the market.

3.10 Operation Strategy

The goal of this section is to explain the operation strategy that will underpin the steady life of the BONVOYAGE platform as well as its core components. This section is extracted from deliverable D8.4 "Exploitation Plan v2", and is hereby reported because we consider it valuable for the overall vision of the project, also beyond its life span, that is in the "steady state phase", as it is referred to in the following.

In the steady phase, most of the effort will deal with maintenance activities aimed at allowing the BONVOYAGE platform to run and provide its services once launched on the market. Operation strategy will include system maintenance, customers ' relations, business development and technology improvement activities.

The operation strategy is elaborated through the data synthesis activity based on the results of product development plan, focusing in particular on product development contributions and the Revenue model hypothesis detailed as «Expected Revenues».

The assessment of the Operative Expenses (Opex) of each BONVOYAGE Layer, after the product market launch (from TRL 9 onward), is needed in order to understand the effective day-by-day operative costs. Considering every "product layer" (i.e. focus on App, Orchestrator and Infrastructure Layer), the estimation of the effort and other costs will concern the following operation activities:

- System maintenance
- Business development and technology improvements
- Customers ' relation.

3.10.1 Operation strategy Scenarios Definition for Scalability Testing

The operation strategy, as basic element for the Financial Plan definition and starting input for the operation costs estimation, is strictly related to the technological scalability of the BONVOYAGE solution.

In order to assess BONVOYAGE scalability, two qualitative scenarios of BONVOYAGE go-to-market have been considered, which will then be associated with different day-by-day BONVOYAGE operative activities and related costs.

Indeed, as stressed within other sections of this deliverable, the project vision is to define the whole BONVOYAGE architecture as a scalable solution, considering a "municipal scale", thus aggregating small services at the municipal level, and as a "national scale".

Therefore, it is important to consider scalability not only in terms of potential market coverage but also with the evaluation of technical/architectural scalability level in different scenarios.

This activity is relevant in order to forecast the real ability of the BONVOYAGE solution to maintain high performances also for a relevant number of potential customers. This evaluation is important also in order to assess the potential spread of BONVOYAGE solution in different European national contexts.

To this end, a specific assessment has been realized considering the definition of relevant scenarios, as it allows to elaborate operation costs evaluation based on two different hypothesis of market expected impact and related technological scalability of BONVOYAGE solution, namely:

- BONVOYAGE in a Smart City framework, in which transport services are offered in terms of MaaS[5],
- BONVOYAGE in a Small Nation Framework (Up to 10 million inhabitants).

Consequently, the following two scenarios have been supposed.

SCENARIO 1 – BONVOYAGE in a Smart City framework

The scenario evaluates the operative management of BONVOYAGE, after the market launch, in a Smart City framework that, in a flexible way, takes into consideration a potential geographical market ranged up to 1 Million of potential inhabitants.

In detail, it has been assumed that the Smart city of Bilbao has invested in the innovative mobility MaaS approach because of:

- high affordability of transport modalities,
- Multi-modality relevance for potential solutions of trip planning for the urban passengers.

For each inhabitant, it is possible to plan the daily trip using BONVOYAGE App connected to the NAP for transport Data, considering at least the multimodal transport service in Bilbao.

In fact, BONVOYAGE could be easily considered as a strategic tool completely integrated in the MaaS transport offering of a "Smart City" because of its focus on the most important transport

[5] "Mobility as a Service (MaaS) is the integration of various forms of transport services into a single mobility service accessible on demand. To meet a customer 's request, a MaaS operator facilitates a diverse menu of transport options, be they public transport, ride-, car- or bike-sharing, taxi or car rental/lease, or a combination thereof. For the user, MaaS can offer added value through use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. For its users, MaaS should be the best value proposition, by helping them meet their mobility needs and solve the inconvenient parts of individual journeys as well as the entire system of mobility services.

A successful MaaS service also brings new business models and ways to organise and operate the various transport options, with advantages for transport operators including access to improved user and demand information and new opportunities to serve unmet demand. The aim of MaaS is to provide an alternative to the use of the private car that may be as convenient, more sustainable, help to reduce congestion and constraints in transport capacity, and can be even cheaper."

https://maas-alliance.eu/homepage/what-is-maas/

needs of the "End users": service customization, Eco-sustainable transport modality, inter modality and multimodality of transport offering.

Each individual will be in a condition to use BONVOYAGE taking into consideration the specific custom bundle transport services that have been opted in the innovative MaaS Transport service offering of Bilbao. In particular each inhabitant, considering his/her transport needs, will be in condition to select one of the following MasS custom bundle offering:

- BUNDLE 1

The first BONVOYAGE "End user" type:

- Lives about 10 kilometers far from his work- place in the city center of Bilbao
- faces up every day car traffic congestion and bottlenecks

He/she will opt for the transport Bundle offering 1 **with a 45 € monthly subscription fee,** being in condition to use limitless urban train and tram service. In this way he/she will plan his daily workplace trip using the BONVOYAGE application in order to find the best door- to- door trip planning solution focused on the pre-selected transport service preferences previously opted through the App interface.

- BUNDLE 2

The second BONVOYAGE "End user" type:

- lives about 30 kilometers far from the workplace in the industrial area of Bilbao
- faces up every day the traffic congestion due to the daily trip to reach the workplace in the city center

Therefore he/she opts for Bundle 2: with a 100 € monthly subscription fee he/she will be in condition to use limitless services related to Train, metro and bus. In this way he/she will plan the workplace daily-trip using the BONVOYAGE App in order to find the best door-to-door trip planning solution focused on the pre-selected transport service preferences previously opted through the App interface.

- BUNDLE 3

The third BONVOYAGE "End user" type:

- lives in Bilbao city center
- works not so far from home, thus is in condition to reach the workplace also by walking.

Nevertheless he/she is interested in Bundle 3 Bus + Taxi: considering a 90 € monthly subscription fee she could use limitless bus and taxi urban transport services. In this way, he/she will plan his/her workplace trip using the BONVOYAGE application in order to find the best door-to-door trip planning solution. BONVOYAGE Door-to-Door journey planning service will take into consideration the pre-selected transport service preferences opted through the App interface by each single "End User".

SCENARIO 2 – BONVOYAGE for the national framework

The scenario evaluates the operative management of BONVOYAGE, after the market launch, for the geographical market target of a small country, whose population can range up to 10 Million citizens.

In details, assuming a car route planning on Norway, in this scenario BONVOYAGE Layers have been useful to structure the National Access Point for transport information detailed in EU Regulation C(2017) 3574. This NAP is structured considering one single access point, one single soloist and 1 single instance of database. The "End user" is able to freely access to the linking services offered at National level through the research portal of the National Access Point.

In this way, in the Norwegian transport services framework, the "End user" freely enters the linking services through the research portal of the NAP web-site. In particular he/she is interested in visualizing the real-time traffic data from city center to his/her workplace. Consequently he/she will login the Nap Application aiming at quickly getting in touch with the NAP research portal.

The research activity begins asking to the orchestrator the needed data set. It will address the request showing the information about "Real time Dataset" Clusters. Starting from this point, it is possible to handle the metadata needed to get the request of the Data in the Norwegian transport Geo Data Base

In this way, the "End user" request will be addressed through the orchestration activity in relation with the National Infrastructure for Traffic Transport Data.

In both those frameworks, it is clear the relevance of the BONVOYAGE solution, in fact the passengers are interested in receiving a customized door-to-door trip planning service as BONVOYAGE because of its capacity to show to the "End user", in real time, different potential trips, from A to B, considering his/her specific needs in terms of transport modalities.

From the main aspects that have been considered in the scenario description it is possible to detail a comparison between the most relevant characteristics of the operation strategy scenarios aiming at defining relevant consideration for the future operative costs estimation.

	Operation Strategy Scenario 1	Operation Strategy Scenario 2
Geographical Framework	1 «Smart city» (Up to 1 millions inhabitants)	1 small country (10 millions inhabitants)
BV function in The transport services framework	BV is considered as a running innovative Door to Door Journey Planner available for the «End User» in the Bilbao framework	BV outcomes have been used for the development of the Norwegian Acces point: in detail it ha been considered 1 single access point as Orchestrator, 1 Soloist and 1 Single OGB for the nation
Business model	Mobility as as Service (Maas) in the specific Urban contest	BV Layers exploitation in the geographical national contest

Figure 12. Operation Strategy Scenarios Comparison

From this evaluation, it is possible to make considerations about the technological scalability of the BONVOYAGE solution, this is a relevant aspect for the operation strategy definition. In particular the Scalability testing is needed in order to assess the real ability of the BONVOYAGE solution to maintain high functioning performance in different geographical market size. This is an important evaluation in order to test the potential results of the solution in the go to market in different European contexts.

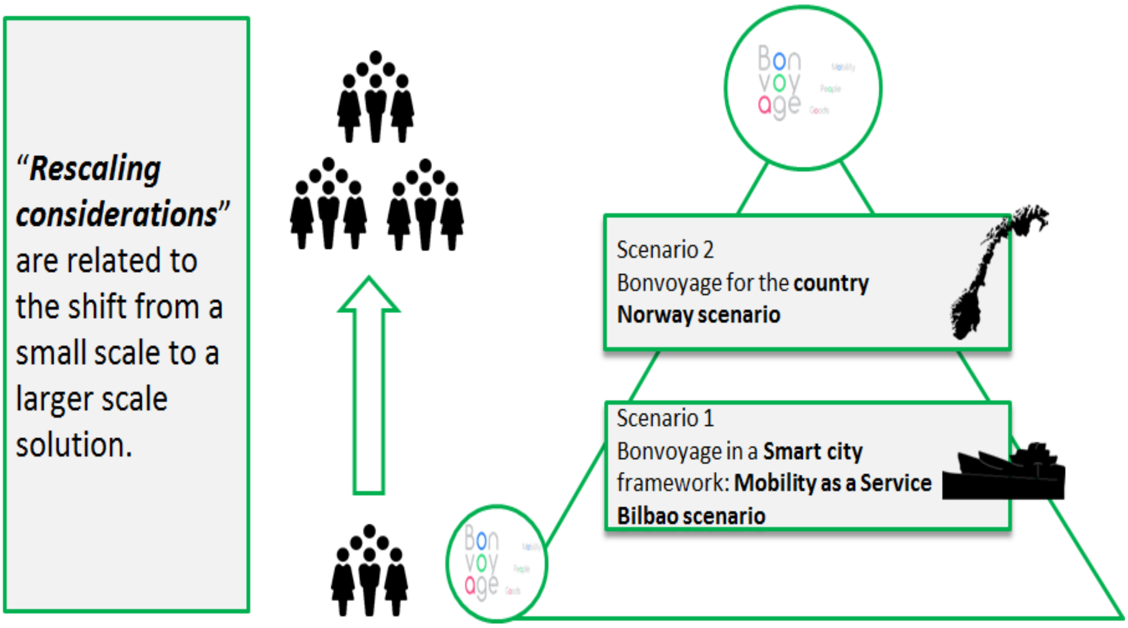

Figure 13. BONVOYAGE Scalability model

3.10.2 *Operation KPI 's Elaboration*

Preliminary set of KPI 's (annually-based) has been detailed per each BONVOYAGE layer considering the scenario of Bilbao and Norway. The KPI 's tab have been subjected to partner validation with the aim to realize a high level of harmonization for the elaboration of the operation costs that are based on the Hardware needed for each Layer.

It is needed to take into consideration that the same KPI 's have been detailed both for "Smart city" and "Nation Scenarios" considering APP, ORCHESTRATOR and INFRASTRUCTURE LAYER.

This elaboration approach it has been useful to underline the technological framework differences between the two scenarios of BONVOYAGE development and consequent marketability.

In detail, in the tables below, it has been highlighted KPI 's description and quantitative estimation considering the difference between Operation KPIs that are useful to qualitatively frame the scenario in terms of technological scalability of BONVOYAGE solution (in white) and Operation KPI's needed to elaborate a quantitative estimation of Operative expense (expressed in green)

Considering each BONVOYAGE Layer KPI 's elaboration is deepened as follows:

APP LAYER (App Server):

- Annual Download: it represents the annual number of App downloads that have been forecasted in the Exploitation Plan as inputs for the elaboration of the Expected Revenues

- Annual Active users: this is the number of users that interact with the platform at least with one action per year. It is obtained as Annual Download*retention rate (estimated at 40%).
- Response delay: response time for the single query at the App Layer, it has been considered as a Latency KPI
- App instances per second: annual active user multiplied by Response Delay

ORCHESTRATOR LAYER (SINTEF Orchestrator Integrated with CRAT soloist for the "Smart city Scenario" and "SINTEF soloist" for the Nation Scenario):

- Annual queries (K): number of monthly trip planning requests addressed by the Orchestrator
- Annual Orchestrator query per user: number of annual trip planning requests addressed by the orchestrator /number of annual active queries
- Query type: query definition embedded in D5.2 "Development and test of adaptation functionality"
- Overall Population
- Active Population: population between the age of 18 and 60
- Market Penetration rate: BONVOYAGE Orchestrator market penetration rate on the active population)
- Max Orchestrator queries per second: maximum queries that BONVOYAGE Orchestrator should be able to handle per second in the daily peak time
- Response Delay: response time for the single query at Orchestrator Layer
- Active session per second: account devices number for which BONVOYAGE has been logged in one second

INFRASTRUCTURE LAYER (OGB for BILBAO in the "Smart city Scenario", OGB for NORWAY in the "Nation Scenario"):

- Request range: maximum spatial domain in which request response is guaranteed from the OGB
- Active Population: population between the age of 18 and 60

- Market penetration rate: BONVOYAGE Infrastructure market penetration rate on the active population
- Max Requests per second: maximum requests managed in one second for the OGB in scenario
- Response Delay: response time for the single request at Infrastructure Layer
- Active Sessions per second: account devices number for which BONVOYAGE has been logged in one second

Annual Scenario Smart City (up to 1 million)
"BV for a Smart City - Bilbao has been considered as Scenario Framework"

BV Layer	KPI Name	KPI Definition	Y1	Y2	Y3	Y4	Y5	Unit of measure	Hardware quantification	Operative costs quantification
App Layer (App Server)	Annual Download	Annual Number of App Downloads	4,20	9,00	13,80	18,60	23,40	Thousands downloads	App Layer (App Server) •Hardware needed for the realization of a perfect load balancing of the App server	App Layer (App Server) •Annual operative costs on Amazon for App server
	Annual Active users in relation	This is the number of users that interacte with the platform at least with one action per year. It is obtained as Annual Download*retention rate (estimated at 40%).	1,68	3,60	5,52	7,44	9,36	Thousands Active users		
	Response delay	Response time for the single query at the App Layer	600,00	600,00	600,00	600,00	600,00	Milliseconds(ms)		
Orchestrator Layer (SINTEF Orchestrator + CRAT soloist)	Annual queries(K)	Number of monthly trip planning requests addressed by the Orchestrator	0,21	0,42	0,73	1,04	1,49	Millions Queries	Orchestrator Layer (SINTEF Orchestrator + CRAT soloist) •Hardware needed for the realization of a perfect load balancing in the interaction between Orchestrator and planners	Orchestrator Layer (SINTEF Orchestrator + CRAT soloist) •Annual operative costs on Amazon for Orchestrator+planners
	Annual Orchestrator query per user	Number of annual trip planning requests adressed by the orchestrator /number of annual active queries	12,50	11,67	13,22	13,98	15,92	Orchestrator queries per user		
	Query type	Query definition embedded in D 5.2 "Development and test of Adaptation functionality"								
	Max Orchestrator queries per second	Max queries that Bv Orchestrator should be able to handle per second in the daily peak time	300,00	320,00	340,00	360,00	380,00	Orchestrator queries per second		
	Response Delay	Response time for the single query at Orchestrator Layer	3,00	3,00	3,00	3,00	3,00	Seconds		
Infrastructure Layer (OGB for BILBAO only)	Request range	Max Spatial domain in which request response is guaranteed from the OGB	5,00	5,00	5,00	5,00	5,00	Kilometres	Infrastructure Layer (OGB for Bilbao only) •Hardware needed for the perfect load balancing of the OGB Platform	Infrastructure Layer (OGB for Bilbao only) •Annual operative cost on Amazon for OGB platform
	Max Requests per minute	Max requests managed in one minute for each orchestrator or soloist of the scenario	1,00	1,00	1,00	1,00	1,00	Requests per minute		
	Response Delay	Response time for the single request at Infrastructure Layer	100,00	100,00	100,00	100,00	100,00	Milliseconds(ms)		

Figure 14. ***Operation KPI 's for a Smart city***-Bilbao case (up to 1 Million inhabitants)

Annual Scenario Nation (Up to 10 millions)
"BV for Nation- Norway has been considered as Scenario Framework"

BV Layer	KPI Name	KPI Definition	Y1	Y2	Y3	Y4	Y5	Unit of measure	Hardware quantification	Operative costs quantification
	KPI		Year of reference						Outcomes description	
App Layer (App Server)	Annual Download	Annual Number of App Downloads	42,00	90,00	138,00	186,00	234,00	Thousands downloads	App Layer (App Server) •Hardware needed for the realization of a perfect load balancing of the App server	App Layer (App Server) •Annual operative costs on Amazon for App server
	Annual Active users in relation	This is the number of users that interacte with the platform at least with one action per year. It is obtained as Annual Download*retention rate (estimated at 40%).	16,80	36,00	55,20	74,40	93,60	Thousands Active users		
	Response delay	Response time for the single query at the App Layer	600,00	600,00	600,00	600,00	600,00	Milliseconds(ms)		
Orchestrator Layer (SINTEF Orchestrator + SINTEF soloist)	Annual queries(K)	Number of monthly trip planning requests addressed by the Orchestrator	2,05	4,19	7,31	10,40	14,87	Millions Queries	Orchestrator Layer (SINTEF Orchestrator + SINTEF soloist) •Hardware needed for the realization of a perfect load balancing in the interaction between Orchestrator and planners	Orchestrator Layer (SINTEF Orchestrator + SINTEF soloist) •Annual operative costs on Amazon for Orchestrator+planners
	Annual Orchestrator query per user	Number of annual trip planning requests adressed by the orchestrator /number of annual active queries	122,02	116,39	132,43	139,78	158,87	Orchestrator queries per user		
	Query type	Query definition embedded in D 5.2 "Development and test of Adaptation functionality"								
	Max Orchestrator queries per second	Max queries that Bv Orchestrator should be able to handle per second in the daily peak time	300,00	320,00	340,00	360,00	380,00	Orchestrator queries per second		
	Response Delay	Response time for the single query at Orchestrator Layer	3,00	3,00	3,00	3,00	3,00	Seconds		
Infrastructure Layer (OGB for Norway only)	Request range	Max Spatial domain in which request response is guaranteed from the OGB	100,00	100,00	100,00	100,00	100,00	Kilometres	Infrastructure Layer (OGB for Norway only) •Hardware needed for the perfect load balancing of the OGB Platform	Infrastructure Layer (OGB for Norway only) •Annual operative cost on Amazon for OGB platform
	Max Requests per minute	Max requests managed in one minute for each orchestrator or soloist of the scenario	1,00	1,00	1,00	1,00	1,00	Requests per minute		
	Response Delay	Response time for the single request at Infrastructure Layer	200,00	200,00	200,00	200,00	200,00	Milliseconds(ms)		

Figure 15. ***Operation KPI 's for a Nation***-Norway case (up to 10 Million inhabitants)

3.11 Roadmap

The following list, and Figure 16, describe the project 's roadmap, reporting step-by-step the main results obtained and official project milestones.

1. June 2015 – Management structures and technical infrastructure needed to run the project fully operational
2. October 2015 – Initial definition of use cases and reference architecture
3. January 2016 – Design of advanced functionalities of the Internames Communication System and preliminary design and implementation of travel-centric services
4. January 2016 – First draft of BONVOYAGE's architecture
5. January 2016 – First live demo of ICN-IOT middleware showing Internames functionalities
6. February 2016 – First design of OpenGeoBase, a decentralized large-scale storage system used for building our georeferenced mobile and web applications
7. April 2016 – Consensus on the Federated Architecture

8. June 2016 – Orchestration and Data Sources fitting in the concept of federation
9. September 2016 – Prototypes of the main platform components
10. November 2017 – Midterm review in Bruxelles
11. March 2017 – First prototype of multimodal Soloists
12. June 2017 – Real-time data sources integrated in the federation
13. September 2017 – Layered architecture workflow stabilized
14. November 2017 – Integration plan and Integration Points verified
15. January 2018 – Integrated tests
16. April 2018 – Rome technical meeting for final verification

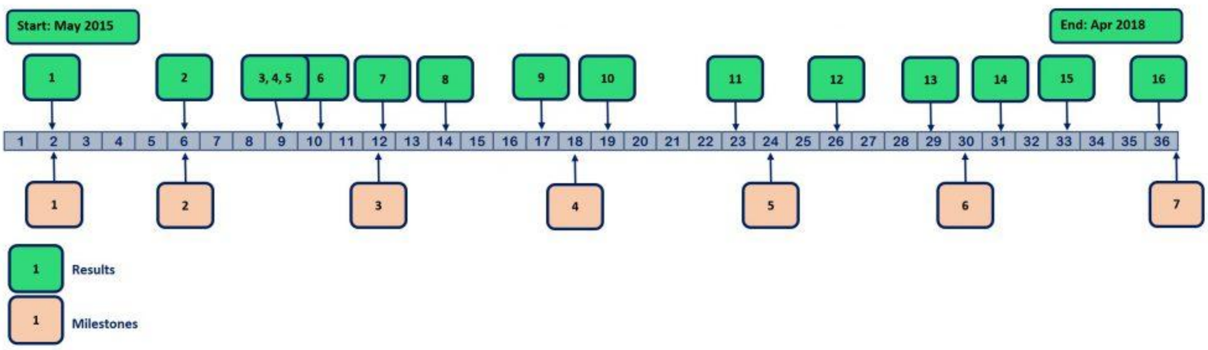

Figure 16. Roadmap at the end of the project

3.11.1 Key development milestones & timings

The official project milestones, along with their estimated date, are reported in the following Table 8, which is extracted from the original proposal.

Milestone number	Milestone name (and short description)	Estimated date	Date	Deliverables for for verification
1	Project fully operational. Management structures and procedures, including standard formats and forms for project documentation ready. Composition of boards fully defined. Technological infrastructure to support cooperative work fully operational (web server, document server, version control system for sources files, mailing lists, management & report tools, etc.). Planning of Communications, Dissemination and Standardisation activities.	Month 2	01/07/2015	D1.1

2	Mid-year milestone 1. Technical WPs producing first results, including selection and abstractions of use cases and function abstractions, draft system architecture.	Month 6	01/11/2015	D2.1, D8.5, (I2.1, I2.2)
3	End of cycle 1. System architecture and interfaces. Preliminary solutions for the Communication system, Transport functionality and Adaptation functionality.	Month 12	01/05/2016	D2.2 (I1.2, I3.1, I3.2, I4.1, I5.1, I8.1, I8.3)
4	Mid-year milestone 2: First project review; first edition of the Project vision and roadmap. Report on dissemination and open source contributions and standardization. First report on exploitation plans. Definition of communication networking functionality; Design of the Intelligent Transport Functionality; Preliminary definition of Technology/Operator dependent interfaces.	Month 18	01/11/2016	D1.2, D3.1, D4.1, D8.1, D8.3 (I6.1)
5	End of cycle 2. Definition of Publish/Subscribe and security functionality; preliminary definition of Travel-centric and participatory sensing services. Design of the adaptation functionality. Definition of Technology dependent interfaces. Preliminary Modelling and performance analysis.	Month 24	01/05/2017	D5.1,D3.2,D6.1 (I1.3, I6.2,I3.3,I6.3,I8.2,I8.4)
6	Mid-year milestone 3 and End of cycle 3. Final definition of Travel-centric and participatory sensing services. Development and validation of the Intelligent Transport Functionality. Development and test of the adaptation functionality. Definition of Apps. Integration plan completed. Platform integration and first prototype available.	Month 30	01/11/2017	D3.3, D4.2, D5.2, D6.2, D7.2
7	End of phase 3 and of the project. Second project review; second review report. Second edition of the Project vision and roadmap; second report on dissemination and open source contributions and standardization. Dissemination reaching wider audience. Second report on exploitation plans. Final Modelling and performance analysis. Final release of platform and use case code; third report on dissemination and open source contributions and standardization.	Month 36	01/05/2018	D1.3,D6.3,D7.3,D8.2, D8.4,D8.6

Table 8***: Project 's milestones***

3.11.2 Dependencies and risks

In Table 9 we report the risk originally envisaged in the proposal and we add a column reporting related issues, if any.

Description of risk and related probability and impact	WP	Proposed risk-mitigation measures	Risk state of play
Inadequate coordination Probability: Low Impact: High	WP1	CNIT has extensive experience in the coordination of EU projects. The management structures and procedures outlined in this proposal ensure that project management can closely supervise the delivery of the expected results (internal intermediate results as well as official deliverables). Meetings of the MB will identify potential problems and react early, e.g., by reducing the functionality of a prototype or by organizational changes. The Consortium inherits some management procedures and working relationships among some of the Consortium members, tested during previous EU project and have been shown to work very effectively and which have been very favourably judged by reviewers during technical reviews. The "management risk" attached to the work is therefore minimal.	Risk did not materialize
Conflicts among the partners Probability: Low Impact: Medium	WP1	The work plan has been designed so that tasks and responsibilities are clearly assigned so that conflicts are unlikely to arise. In previous projects, the BONVOYAGE management team has already successfully handled conflicts between partners. The strategy applied mixes strong leadership by the coordinator with consensual discussion and decision-making within the GB. Should unresolvable conflicts arise, their outcome will be handled as detailed in the partner dropout and "delays" risk.	Risk did not materialize
Drop-out by a partner Probability: Low Impact: Medium	All	Partners in the project are major public institutions or large companies and a rather "large" SME, which are very unlikely to fail. Drop out is highly unlikely also for academic partners, who participate with senior researchers who have been with their institutions for a long time. The risk may be marginally higher for large companies, where parent companies or central management may decide to discontinue commitments for reasons not under our control. To limit the impact of such withdrawals, all WPs include at least a second partner with sufficient expertise to take the lead of the activity. In addition, it is true that partners ' planned work complement each other without significant overlaps,	Risk did not materialize

		but we allowed for a limited redundancy and sharing of tasks, which mitigates this risk. Given that no partner has more than 14% of the total manpower, drop out of partners with no leading roles will be easily handled by either redistributing the work between other partners, recruiting a new partner, or revising the DoW to deal with the withdrawal.	
Delays in the design and development of key project 's elements Probability: Medium Impact: Medium	All	Academic partners of BONVOYAGE have extensive experience not only in research work but also in the deployment of demonstrators and test-bed, as proven by a very successful track record. The consortium includes companies certainly capable of delivering the technological components and software foreseen in the work plan. The Work Plan contains intermediate steps and partial results. The task schedule is such that there is sufficient overlap between the various phases of the project (design; platform development; application development; deployment) so that moderate delays can be accommodated and recovered without much trouble. Also, results from the various stages of the project are not monolithic entities so partial unavailability of some elements will not entirely block the next stage of the activity. As an example, system development can start with partial results from WP3-6, and same goes for the integration activity in WP7 as preliminary implementations of the components in WP3-6 are available. The development of use cases will be done in parallel.	Risk did not materialize
Feature in the use-case is not supported by the platform. Probability: Medium Impact: Low	WP5	There is a risk that the use-cases identified have features that are unsupported by the system. Given the partner contributions in other WPs throughout the project, the use-cases should be a natural progression of work and are not expected to differ greatly from those determined at the time of writing the proposal. Some refinements for the abstraction and models are expected, as feedback from WP7 and as such new use-cases or revisions to the use-cases. WPs in general are planned to be slightly longer than strictly required to take into account the possible feedback and change of requirements.	This risk did not materialize concretely, but several discussions about coverage of use-cases by the implementation have already been started. When integration activities enter a more advanced stage it will be possible to better assess this risk and correctly manage it.
Technology is superseded by competing solutions	All	Partners have connections with other leaders in the industry and academia so will be aware of other projects that are on-going and where there may be	Risk did not materialize

and/or patents are filed by competitors Probability: Very low. Impact High		overlaps. The partners are also involved in standardisation groups so will see motions by other groups in similar areas. If competing solutions are created, then collaborative efforts will be sought in the first instance, and then failing this, efforts will be made into revising the scope and target areas of BONVOYAGE.	
Standards bodies not accepting BONVOYAGE 's work Probability: Medium Impact: Medium	WP6	Several partners have extensive experience in standardization work and are already involved on topics related to the project 's ones. In addition, standardization bodies operate on long timescales, often exceeding the lifetime of this project, thus contribution to a standardization body also means providing useful input to the process without necessarily having a standard formally accepted.	Risk did not materialize
Lack of exploitation of project results Probability: Low Impact: High	All	Commercial and institutional partners of BONVOYAGE intend to exploit and push BONVOYAGE solutions. The project 's dissemination and communication activities will allow the project to reach a very large base of possible customers, and to test and advertise BONVOYAGE in real markets, a further assurance of real exploitation.	Risk did not materialize

Table 9: Envisaged risks

4 Work performed

4.1 Achievements: R&D

In this section, we report the work performed as regards R&D activities.

By reviewing the progression in time of the results achieved by the project, as reported in the above roadmap in section 3.11, it is possible to read through the story of BONVOYAGE's research and development activities during the project 's lifespan, as follows.

1. The challenge of a continent-wide platform that fosters an ecosystem of novel Intelligent Transport Systems and guarantees openness and a level of performance able to sustain millions of real-time data sources, plus user profiling and live re-planning of multimodal itineraries, can be tackled by centralized or distributed approaches.
2. Research in the area Future Internet is leading to novel implementations of scalable network cloud infrastructures for efficient dissemination and discovery of information sources.
3. The European community advocates an approach based on interlinking and interoperability across borders of ITSs.

BONVOYAGE responded to the challenge by:

- Designing a rich functional architecture.
- Inserting the rich functional architecture that was designed during the first months of its activity into the context of a federation.
- Technically enabling the concept of federation by the Internames network layer and the Orchestrator
- Fitting the federated architecture in the context of the latest EU directive on ITSs
- Developing the orchestration component
- Connecting Data Sources
- Designing a set of clear APIs
- Testing the integration among the distributed components of the federation

By federation, in contrast to a generic distributed or P2P system, we mean a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of distinct, formally disconnected networks, which have different internal structures, is obtained.

The rest of this Section is organised as follows. First, we briefly summarise our achievements, and then we detail the work done in each Work Package (WP).

4.1.1 In a Nutshell

The work performed by BONVOYAGE during the project's life has covered several aspects, including:

1) definition of use cases, system requirements, reference scenarios and functional architecture, performed in WP2;
2) design and development of the Internames Communication System, with publish/subscribe and travel-centric services, performed in WP3;
3) methodological and algorithmic development of the core Intelligent Transport Functionalities: (i) User Profiler Tool for personalizing multi/inter modal services, (ii) Multi-Objective Optimization Tool for optimizing and controlling multimodal services, and (iii) Tariff Scheme Design Tool for travel centric multimodal services, in WP4;
4) handling of the heterogeneous data, relevant to end users and to Transport Operators, and translation of them into homogeneous metadata, performed in WP5;
5) seamlessly interacting with the heterogeneous external actors of the BONVOYAGE platform, and working on the sensing and actuation functionalities of the BONVOYAGE platform. Developing an Android mobile App, in WP6;
6) System Integration and Validation (WP7). Work of WP7 has been anticipated to month 15, because of the potential advantage of gaining earlier practical insights into how the various outputs from the other WPs can be successfully integrated and to show a practical demonstration of project achievements at the first project review.
7) Communication, dissemination, standardisation and exploitation activities, in WP8.

We report in the following a more detailed description of the work performed in each WP.

4.1.2 WP2: System Requirements and System Design

The first concrete objective of this work package has been to gather and specify the BONVOYAGE system requirements combining user 's needs (administration, public transport, fleet operators) and transport operators perspectives (economic consideration, available service) as well as economic and technological perspectives (mobile apps, sensors, embedded systems, wireless devices).

Creating short stories has helped in the identification of the main capabilities to be offered by the platform. They have evolved into meaningful, business oriented use cases and a set of four reference scenarios.

Main stakeholders have been identified and grouped and BONVOYAGE terminology defined, covering key terms. Also a questionnaire (internally called BONVOYAGE services/capabilities template) was created with the purpose of collecting information on existing services and solutions available in the cities participating in the validation scenarios.

A set of functionalities has been defined addressing the identified requirements and these functionalities have been grouped into functional modules. As result of this process, the preliminary BONVOYAGE reference architecture described in the proposal has evolved into a much more detailed functional architecture.

A revision of relevant standards for the BONVOYAGE platform has been carried out and existing ICT solutions and services available in the targeted BONVOYAGE cities have been analysed to better understand the validation context for the system.

In order to select the most innovative functionalities that demonstrate the project findings, a web based software tool has been developed. This tool has supported the verification of the relationships between requirements, use cases, functionalities and modules. The architecture analysis tool allows associating a weight to each requirement and functionality, in order to rank uses cases based on their impact on requirements and functionalities.

Input and output data objects have been defined and assigned to each functionality, and a first set of software components have been identified and described, ensuring that our top-down design methodology is complemented with a careful bottom-up evaluation of the software prototypes we currently have (either developed for research purposes throughout the first year or pre-existing).

4.1.3 WP3: Internames Communication System

Internames acts as a bus to provide secure communication among all components, devices and nodes of BONVOYAGE.

Inputs from WP2 (with particular attention to the definition of the perimeter of entities involved in the platform) have been carefully taken into account for conceiving a hierarchical naming schema able to uniquely identify, in a trustworthy way, travel-centric information, actors, and service operations. Additional inputs have come from the most recent developments in the context of the General Transit Feed Specification and DATEX II standardization activities, and have been taken into account when formulating the travel-centric and participatory services that this work package provides.

Internames Service Layer

The work package has begun by accomplishing the design of core Publish/Subscribe and Request/Response primitives within Internames. The resulting communication framework is able to support a name-based data exchange between data producer (for Instance, Trenitalia) and data consumer (for instance, a travel operator) in a heterogeneous network made up of different realms (i.e., IP, NDN, and PURSUIT). Moreover, the Name Resolution Server (NRS), which is a logical entity of Internames involved in routing-by-names operations in a heterogeneous network, has been significantly extended for handling announcement and push notification services in an efficient and scalable manner. The extended NRS integrates a number of interoperating blocks, which are: NRS Service layer, Routing Capability Engine, NRS Retarget Engine, NRS Forward Manager, Local Data Base Manager, and Publish/Subscribe Engine. Together, they constitute an Internames Service Layer able to support dissemination of travel centric data, as well as the design and the development of sophisticated travel-centric services.

Publish/Subscribe, security and Travel-centric services

Tasks 3.2 and 3.3 are correlated by a very high degree of synergy. Their combined aim is to offer to the overall platform a set of Travel-Centric Services which, based on pub/sub, are able to optimize data distribution in the context of travel planning applications.

A Java library was developed, which offers well-specified APIs for Publish/Subscribe operations and is thus easy to integrate with other software components of the overall architecture. On top of this Publish/Subscribe front-end, a specialized set of Publishers has been developed, tailored to different data-sources being considered in BONVOYAGE, as candidate data-sources for the demonstrator. Namely, travel-centric data coming from the Norway NPRA servers and data coming from the City of Bilbao (in collaboration with WP5) are being monitored and updates are published as soon as changes are detected, and routed to all interested Subscribers by means of the Publish/Subscribe front-end (see a more illustrative description of the laboratory prototype derived from this activity, in section 4.2.9).

The activities above have been carried-on by continuously interacting with ATOS and the Metadata Handling Tool technologies, and take into account the design of software components and data structures coming from WP4.

Additionally, the OpenGeoBase spatial database has been devised, which is based on the Internames Service Layer (exploiting all the advantages of ICN) and is used to support generic ITS applications that want to discover public travel data repositories (e.g. GTFS files) available in a given geographic region. OGB is the cornerstone of the federated BONVOYAGE architecture, because it performs indexing of the resources available to the federation and allows discovering them. OpenGeoBase offers cutting-edge security functionality and a flexible API. The user interface is based on GeoJSON format and its security framework is based on an Authentication Center (AUC), which stores security keys and certificates that are necessary for the application of data-centric security features. Performance benchmarks have been carried out versus MongoDB. A first release of OGB has been made available to the project and published on the BONVOYAGE web site. A brief operative illustration is given later, in section 4.2.8.

WP3 also worked on the issue of video streaming transmissions in presence of network caches, such as the Internames ones. Video streaming services can be useful e.g. for ITS-related applications exploiting cameras distributed in the environment, whose location can be discovered by using OpenGeoBase.

4.1.4 WP4: Intelligent Transport Functionality

WP4 deals with the design and (methodological and algorithmic) development of the core of the BONVOYAGE platform, namely the Intelligent Transport Functionalities: (i) User Profiler Tool for personalizing multi/inter modal services, (ii) Multi-Objective Optimization Tool for optimizing and controlling multimodal services, and (iii) Tariff Scheme Design Tool for travel centric multimodal services. The main objective is to provide personalized control decisions tailored to the requesting users (e.g. optimal multi-modal travel, possible multi-modal tariff schemes, itineraries and tariffs for the delivery of goods). Personalized control decisions should be optimal with respect to user profile and should aim at promoting the use of socially desirable bundles of transport services.

Besides outer strong connections between WP4 and other technological WPs in the BONVOYAGE project, there are very strong inner connections among the three main tools designed and developed in WP4.

User Profiler Tool

CRAT proposed an User Profiler Tool whose key difference with respect to previous control and/or learning based approaches consists in jointly taking into account the user request submitted to the Multi-Objective Optimization Tool and the actual choice carried out by the user as he/she returns one or more travel solutions. In this framework, we consider the travel solution chosen by the end-user as a "user feedback" and use this choice in order to identify the actual user behavioural profiling and eventually producing the so-called Personalized Optimality Criteria, which drive the Multi-objective optimization tool in providing personalized travel solutions. The UPT is based on:

- definition of a User Data Model (UDM) for development of data mining and machine learning models and algorithms
- design of a Datalogger for statistical-inference-based monitoring of the Level of user Stress (LS) and of the User Transportation Mode (UTM). Please see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.3.

CRAT and CEA carried out a fruitful cooperation on designing advanced machine-learning-based models for personalizing multimodal transport services. The work performed brought to an advanced methodological framework for personalization of the services offered by a generic Intelligent Transportation System. The User Profiler Tool is conceived to extend traditional ITS functionalities by automatically learning implicit user preferences from the user behaviour, even in the case the user preferences are in contrast with the ones explicitly declared by the user. CRAT proposed a data driven, user centric, control based framework for the personalization of the services. The proposed framework is sufficiently general to control a generic Intelligent Transportation System.

In order to define the main data features appearing in the proposed framework, CRAT contributed to the BONVOYAGE Questionnaire by proposing specific questions about travel habits and travellers' preferences and needs.

Partners designed the User Profiler Tool as well as all software components and provided a preliminary implementation of the most important software modules. Thanks to an intensive activity of real data collection about user preferences and habits in terms of door-to-door, long distance travels, test and validation activities concerning each software component have been successfully conducted. (see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.2).

Multi-Objective Optimization Tool

The technical discussion that defined the boundaries of the trip control functionalities and the integration strategy with the trip planning tools was mainly between CRAT and SINTEF. The main contribution is the definition of the orchestrator concept by SINTEF, and a decomposition strategy consisting of a global extra-urban trip planning and a local intra-urban trip planning.

CRAT proposed a urban soloist (see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.4) for local travel solutions that has the strength of being fully in line with the methodological framework for personalization of services offered by the UPT. The personalization of the mobility solutions and the integration of different transport modalities increase the complexity of the mathematical programming-based trip-planning problem with respect to other commercial solutions. The main contribution is the definition of the local, intra-urban multi-passenger trip-planning problem by considering, besides traditional collective transportation means like metro, bus and tram, novel transportation services like carpooling operated by private people; the solution has been designed to meet both user needs, in terms of travel request, and user preferences.

The activities supporting the orchestration of the local soloists with and the global trip planning, as well as their integration in the federated architecture, are still on going.

Tariff Scheme Design Tool

The research started by an highlight of possible evolutions to strengthen the Tariff Scheme Tool innovation capabilities, comprising of an analysis of factors pushing the user towards socially desirable mobility solutions and the definition of a Tariff Scheme Tool proposal, with identification of advantages and disadvantages. TRIT and CRAT undertook a continuous dialogue for the precise definition of objectives and work methodologies, focusing both on research and on business needs to be addressed.

CRAT performed a study on the quality of service at multimodal hubs aiming at identifying the dimensions of quality of travel (i.e. the parameters characterizing the quality of travel) for passengers at multimodal hubs, in the case of long distance trip chains.

The definition of the algorithm for dynamically determining pricing rules when two transport operators (one airline and a high-speed rail (HSR) operator) plan to establish a partnership is already consolidated, though still on going. Two main scenarios have been considered:

- the airline and the HSR are pure competitors (benchmark scenario)
- the airline and HSR form a partnership to operate a multimodal market (integrated scenario).

Please see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.11.

Membership Management

Trenitalia performed core work regarding the concept of membership management. It is composed of:

- A "green" Score Policy.
- A Loyalty Programme.

They both aim to reward users that use BONVOYAGE to plan and purchase travel solutions, but with different ultimate goals: the "green" Score Policy intends to "push" passengers towards eco-friendly mobility choices and fosters the selection of means of transports with low environmental impact, while the Loyalty Programme is intended to reward users showing a high level of "fidelity" to BONVOYAGE. Please see a more illustrative description of the laboratory prototype derived from the green Score Policy activity in section 4.2.10.

All of the activities performed are detailed in Deliverable D4.1 - Design of the Intelligent Transport Functionality and their corresponding performance evaluation can be found in deliverable D4.2.

4.1.5 WP5: Adaptation Functionality

The goal of this work package is threefold:

- to handle the heterogeneous data, relevant to end users and to Transport Operators, and to translate them into homogeneous metadata (Metadata Handling Tool);
- to design and develop the Multi-Modal Mobility Database (which stores the Dynamic Present Context, the User Profiles, and supports WP4) and the Database Services;
- to design and develop the functionalities necessary to adapt the technology-independent Personalized Control decisions provided by the Intelligent Transport Functionality (developed in WP4) to the specific Transport Operators (Service Adaptation).

Task T5.1 Database design and development and T5.2 Metadata Handling Tool of WP5 started in month 9 of the project. During the project, WP5 has produced deliverable D5.1 Design of the adaptation functionality. Task T5.3 Service Adaptation started in month 13 of the project. The final design and its implementation was strongly dependent on the overall architecture and in particular linked to the design of all WP4 components that make up the Intelligent Transport Functionality. Hence results of Task T5.2 and T5.3 have been reported in deliverable D5.2 Development and test of the adaptation functionality.

Important results of WP5 are related to the scrutiny of GTFS, DATEX II and WFS data formats and the corresponding data available at the NPRA (Norway) and City of Bilbao servers. This has led to the integration of these data source into the BONVOYAGE data federation and the OpenGeoBase discovery service, as remarked above.

Overall, R&D results of this WP have become stronger in the second half of the project.

4.1.6 WP6: Multimodal Integrated Interfaces and Apps

The main goal of this work package is to design and develop all the mechanisms needed to seamlessly interact with the heterogeneous external actors of the BONVOYAGE platform. In line with this, WP6 is also in charge of the sensing and actuation functionalities of the platform. More specifically, the WP comprises the following main objectives:

- Design and development of the technology dependent interfaces towards the external actors (transport operators' systems, data sources, end user applications).
- Design and development of an application for the Mobile Participatory Sensing Services.
- Design and development of an application for Mobile Information Services.

WP6 started at M9, in a continuous interaction with the architectural and requirements perspective work done in WP2. The system components that have been developed in WP6 were identified and its functionality specified from an architectural perspective. The dependencies and communication with other work packages were discussed with a focus on WP5.

Technology/Operator dependent interfaces

WP6 has defined a concept for integration and customisation of services in cooperation with WP5, and the most important result is the focus on the development of an advanced format for route information exchange. The format is compatible to the open source SPROUTE format, but has developed a set of key extensions, because this activity is synergic to the concept of orchestration and is going to become the main enabler of the federation of soloists. It defines the semantics and syntax of the communication channel between soloists and the orchestrator.

App

Within task 6.2, WP6 has been discussing and specifying architectural design and interfaces issues of the mobile application. Furthermore, requirements of the mobile app were specified and wireframes were created, prior to effectively developing the Android code.

Modelling and performance analysis in realistic scenarios.

This task was dedicated to test and analyse the developed components in the BONVOYAGE scenarios to further improve them. It has included the following activities:

- Definition of realistic scenarios (number of users, representative test area, etc.).
- Testing for bottlenecks (e.g. battery lifetime, bandwidth, data plans, cpu load, data storage etc.).
- Revising/ fine-tuning developed solutions.

Work performed for this specific task was reported in deliverable D6.3.

4.1.7 WP7: System Integration and Validation

The main goal of this work package was to carry out the system integration, the system tests, the deployment and the validation of the developed BONVOYAGE platform.

More specifically, the WP comprises the following objectives:

- Definition of an accurate integration plan.
- Integration of the various tools, components and applications developed in WP3, WP4, WP5 and WP6.
- Tests of the correct inter-module interoperability and final system tests.
- Definition of the deployment guidelines for the final validation.
- Validation of the integrated system with real end-users and transportation operators and evaluation/assessment of the results of the validation campaign.

The System Integration and Validation work package was initially planned to start in M23 of the project. During the Fourth General Assembly, the BONVOYAGE Consortium decided to prepare and present an integrated demo for the Review Meeting planned in November 2016. This decision implied an earlier beginning of the work planned in WP7 – System Integration, initially planned to start at Month 23 (March 2017).

The reason, which lead the Consortium to this decision, was related to the potential advantage of gaining earlier practical insights into how the various outputs from the other WPs can be successfully integrated and to show a practical demonstration of project achievements at the first project review. Furthermore, the Consortium believes that early integration will generate useful feedback, to be used in improving the design activity. Also integration activity has stimulated partners to work better and together, as when a component is needed for integration, the responsible partners are more committed to provide it. On the other side, the project produced enough "material" to be integrated already in the first half of the project's life: for instance, SINTEF's and CRAT's optimization algorithms and related software; CNIT's ICN network and related software, real data coming from several partners; all this was readily made available to Fluidtime that had the opportunity to develop applications on top.

The Coordinator formally exposed justification about the Gantt changes to the Project Officer, who approved the early start of the WP7 at the date of the related official communication by the coordinator (21st July 2017).

Consequently, the new starting dates of each Task have changed to:

- Task7.1: New Starting date M15 Instead of M23
- Task7.2: New Starting date M18 instead of M25
- Task7.3: Staring date M30 – No change

Thus, this work package has started on the 21st of July; the outcomes of the activities and tasks of WP7 proved crucial to the project 's successful prototyping and developing activities of the other WPs. The work has proceeded along the following lines:

- Discussion and assessment on the integration strategies.
- Identification of technical components to be integrated
- Development of steps of the integration plan.
- Assigning integration points to respective partners.
- Updating the deployment architecture accordingly.
- Detailing the deployment plan.
- Continuously feeding back information to the technical WPs.

4.1.8 WP8: Communication, Dissemination, Standardization and Exploitation

This Work Package aimed at disseminating the project results among interested end-user communities (transportation operators, municipalities, manufacturers, etc.) and general public as well. Moreover, this WP investigates exploitation strategies for the project results and includes interfacing activities with relevant standardisation groups and more in general communication activities.

More specifically, the WP pursued the following objectives:

- Setup of the communication instruments (e.g., logo, website, promotional literature; this WP will care for the content to be communicated, the related technical tools are dealt with in WP1), in order to prepare and execute clear and effective communication and dissemination activities for the whole duration of the BONVOYAGE project.
- Development of the communication, dissemination and the exploitation plans.
- Publication of results to prestigious national and international journals and conferences, in the areas of transportation systems, optimization, telecommunications, economics.
- Development of the standardisation plan and contribution to relevant standardisation work.

In the context of communication activities, WP8 created and populated the project web site (http://bonvoyage2020.eu/), as well as the social networking channels specified by the plan

(LinkedIn Group and Twitter Account). The work package created the general presentation about the project, and produced a 1-page and 2-page factsheet, project flyer and poster.

The web site was constantly updated with the support from the different partners. Activities from the project are also reported on social networks (e.g. LinkedIn and Twitter) where stakeholders are engaged in exchange on the project outcomes. The dissemination plan template has been approved and was regularly filled in by the partners. It allowed the monitoring of activities from the whole consortium related to information given on the project at different audiences. It also created synergies among the several BONVOYAGE dissemination activities from each partner. BONVOYAGE partners have been involved in several events at EU level. The planning of dissemination activities involved routinly common activities of partners.

Several dissemination activities have been performed. Results of this work package are reported in full details in deliverable D8.2.

4.2 Achievements: Laboratory Prototypes

During the first half of the project, several laboratory prototypes have been developed and used by the partners to test and research the key components of the architecture. Integration activities have been anticipated to month 15 (see above, WP7 activities), so that the integration of the prototypes towards the final testbeds has gained momentum.

The project successfully went through its mid-term review at month 19 (November 2016).

During the second half of the project the effort was focused towards an integrated prototype, but also some new isolated demonstrators were developed.

The final review is planned for June 6th 2018, hence some of the laboratory prototypes described in the following sections are going to be re-purposed for demonstration at the final review event.

4.2.1 Android App @FLU

This prototype is managed by Fluidtime, in Vienna.

Objective: main application to interact with BONVOYAGE.

Brief Description: the App supports registration, user profiles, routing requests, greenpoints and feedback.

Figure 17 and Figure 18 show typical sessions and usage of the mobile App.

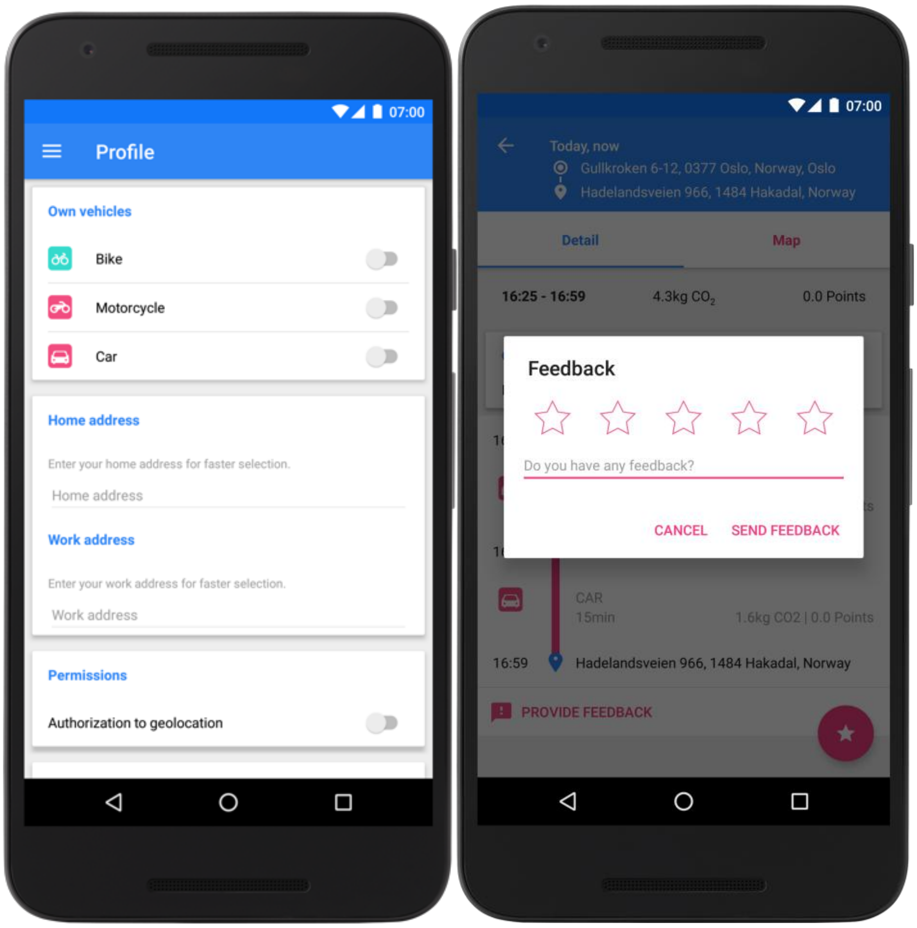

Figure 17. BONVOYAGE App – Profile and feedback screen

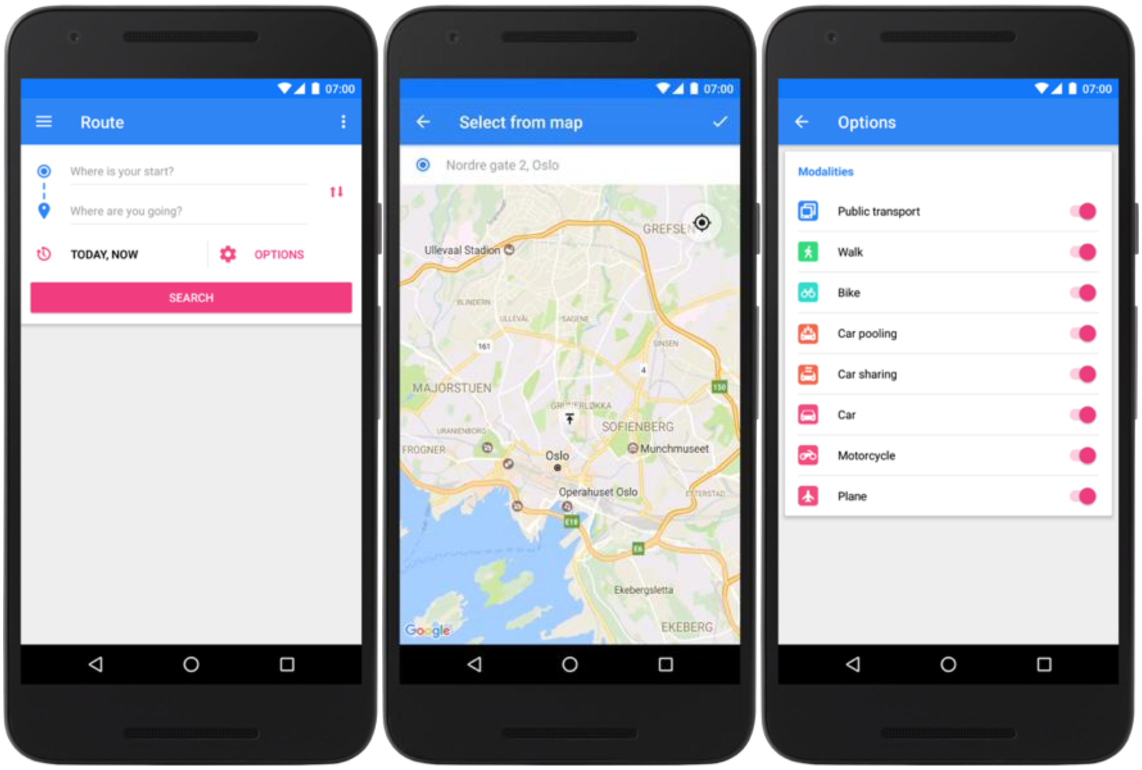

Figure 18. BONVOYAGE App - Route request and options

4.2.2 User Profiler Tool @CRAT

This prototype is managed by CRAT, in Rome.

Objective: show how global pre-trip plans vary on the basis of user's personalized parameters.

Brief Description: a user makes a query, for instance asking a trip between two European cities, for the first time, and receives a ranked list of multi-modal travel solutions. After being profiled, the same query, issued at a later time receives a (different, personalized) ranked list of travel solutions.

The prototype operates on the set of input data taken from Registration of User (age, gender, user category) and from User Query (source, destination, departure time, allowed transportation means, user preferences). The core of the User Profiler Tool is the User Centric Control System (UCCS), shown in Figure 19.

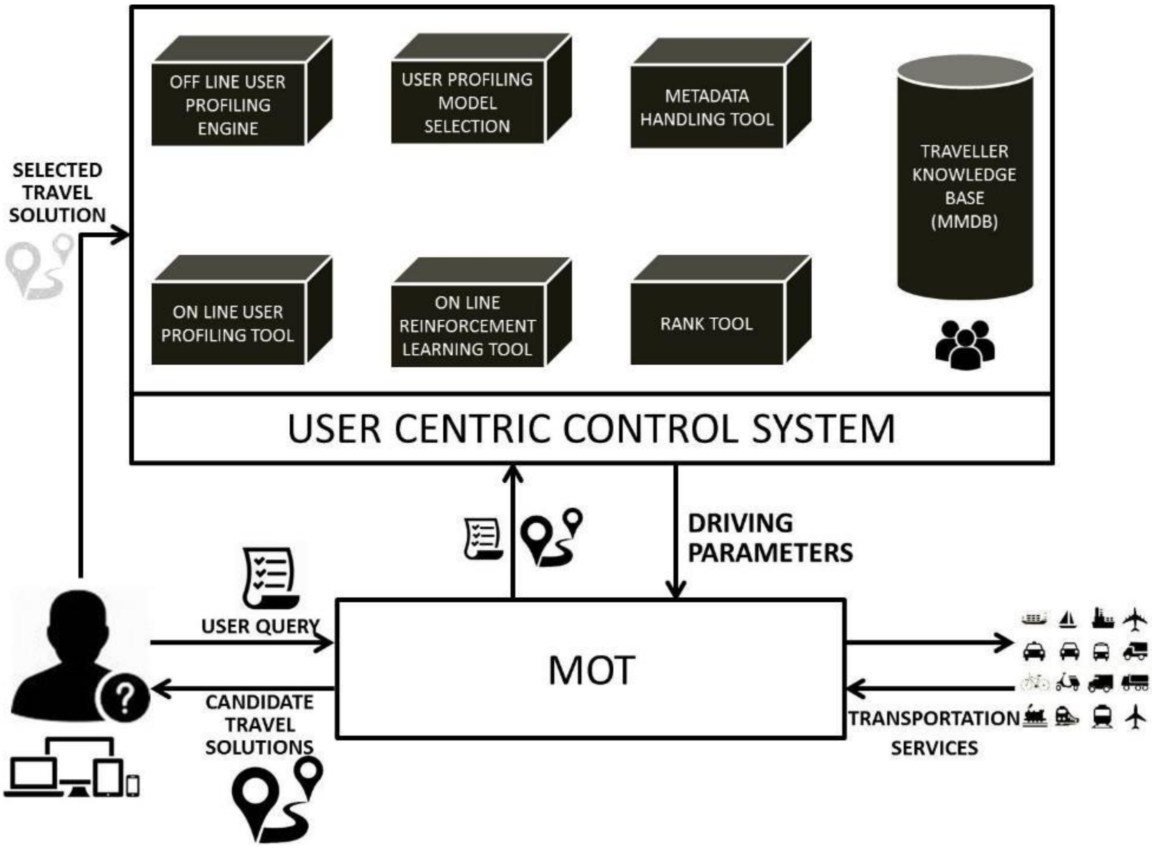

Figure 19. Multi-Objective Optimization Tool (MOT) and User Centric Control System (UCCS)

The prototype is able to take into account both user profiles and user history for personalization purposes. The User profile based personalization modules are:

- Off line User Profile Engine, in charge for identifying automatically a set of user profiles, each of them characterized by a subset of commons travel preferences and constraints; the user profiles we are interested in are conceived as the centroids of homogeneous clusters (or groups) of users showing similar behaves and preferences in terms of multimodal transportation means and services; once extracted the best partition of the users (according to the best parameters, see User Profiling Model Selection) the user profiles are indicative patterns in terms of travel preferences and constraints of a group of homogeneous, statistically relevant travellers;
- User Profiling Model Selection is the actual control panel of the User profile based personalization modules; the model selection is a very important task in any machine learning application, since once the learning algorithm is identified (in this case, the unsupervised, partitional k-means algorithm within the Off line User Profile Engine), the parameters controlling the effectiveness and the efficiency of the algorithm must be carefully adjusted in a suitable domain in order to allow the machine learning algorithm to extract useful information from the data analysis task;

- On line User Profiling assigns any user of the BONVOYAGE platform a user profile in terms of the most similar cluster (or group) and allows a complete characterization of the user from the travel preferences and constraints ' point of view; in particular, in case of new user interacting with the BONVOYAGE platform for the first time, the user profile assigned automatically by the On line User Profiling provides information about potential driving preferences and constraints that the user share with all the users belo nging to that specific user profile.

The User history based personalization modules are:

- On line Reinforcement Learning Tool, managing and updating different data structures according travel features automatically extracted from the interactions between the user and the BONVOYAGE platform; the main aim is providing driving parameters indicating the user 's preferences and constraints basing on his own past interactions with the BONVOYAGE platform;
- Rank Tool provides an ordering criterion in the family of (unordered) travel solutions according to the driving parameters identified automatically by the On line Reinforcement Learning Tool.

The Travel Knowledge Base is a portion of the Multimodal Mobility Data Base (MMDB) developed within WP5, and consists of all data managed and analysed by the Off line User Profiling Tool and the On line Reinforcement Learning Tool.

4.2.3 Personalization via sensors @CEA

This prototype is managed by CEA, in Grenoble.

Objective: infer, by aggregation of sensor data, specific user profiles, for instance that User A never rides a bike, User B never takes a plane; User C is stressed by the plane, User D is not stressed at all by the car; User E has a low carbon footprint.

Brief description: there are two prototypes, one performing real time assessment of user's transportation mode (UTM) from various sensors of his Android smartphone while he is on the move, and the other one providing the stress level of the user (USL) by analysing data from an Empatica E4 watch he is wearing.

Both prototypes are based on a common framework composed of the following modules: Datalogger App, Database, and feature extraction and classification algorithms exploiting them.

USL Datalogger App: The datalogger consists in acquiring physiological measurements together with information about stress. The Empatica E4 wristband presents several advantages: it is not very obtrusive; it allows collecting raw data of skin conductance, photoplethysmogram (PPG) and body temperature. The assessment of stress state is accomplished by the App shown in Figure 20. Data from Empatica E4 can be collected after the experiment by using the Empatica platform or online by the smartphone by using Empatica 's Android code.

USL Database: We have already collected several data in our prototype 's database:

- We use the MIT driver database available on Physionet[6].
- We use a database collected in a laboratory settings with well-known protocols generating stress: Trier Social Stress Test (TSST) which is designed to exploit the vulnerability of the stress response to socially evaluative situations, and the Socially Evaluated Cold-Pressor Test (SECPT), which is a physical stress protocol performed by immersing the hand into an ice water container, usually for three minutes, and measuring physiological changes. Its response is clinically indicative concerning vascular response and pulse excitability. We also use a less stressful task called d2 in which temporal constraints are introduced. For those experiments, 20 users are considered for each of the 3 experiments. The same users also performed control tasks, corresponding to the same activity without stress elements at different occasions.
- A stress database, which records interns presenting their work in real-life conditions, has also been created. For this, wearable sensors were used, together with questionnaires for perceived stress level.
- A stress database representing a workweek of different subjects, corresponding to real-life situations that typically appear in daily life, is used too.

[6] https://physionet.org/physiobank/database/drivedb

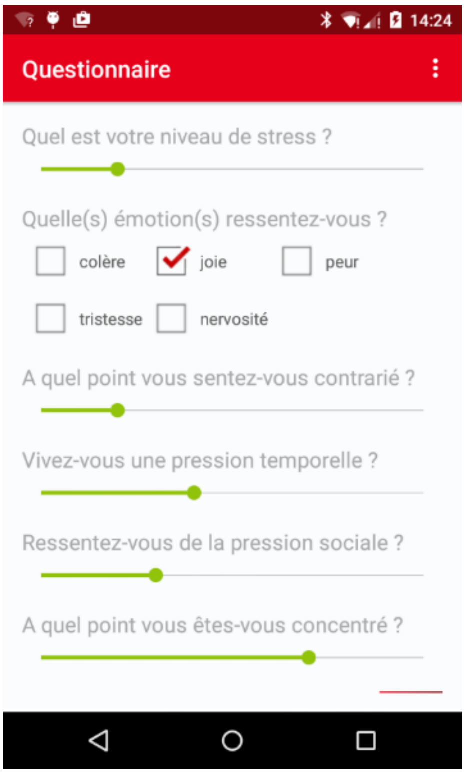

Figure 20. USL Datalogger front-end

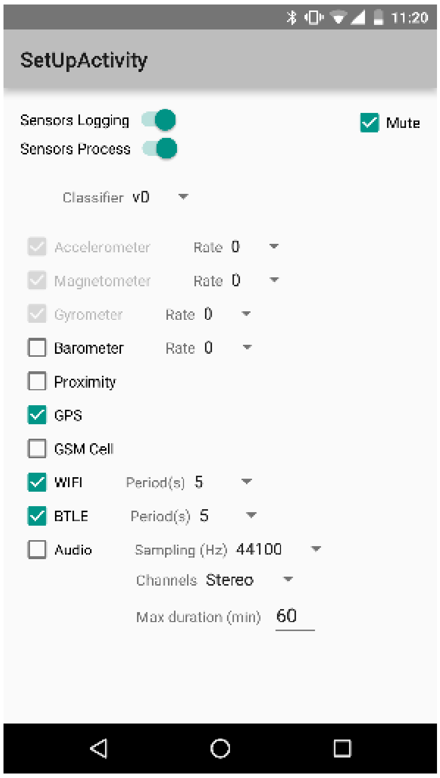

Figure 21. UTM Datalogger front-end

UTM Datalogger App: 15 modes have been pre-determined and wired into the App: still, walk, run, bike, electric bike (ebike), motorbike (moto), car, electric car (ecar), bus, electric bus (ebus), tramway, metro, train, plane and boat plus an additional class named "other" to manage data that are incorrectly classified in the pre-defined transport mode classes. This way other transport modes used by one user (for example: paragliding or windsurf board) can be taken into account. During acquisition, the Android app logs the information about the transportation mode and a set of chosen sensors available on the smartphone. The recorded files contain data from the sensors in the list below as well as the transportation modes annotated by the user and some technical information such as the version of the logging app. The sensors available for now are:

- Accelerometer,
- Magnetometer,
- Gyroscope,
- Barometer,
- Proximity sensor,
- GPS,
- Wi-Fi,
- BLE (Bluetooth Low Energy),
- Audio data.

We can set some parameters such as the sampling frequency or scanning frequency from the Set Up window shown in Figure 21. This Android logging app is used to create the necessary database to construct a transportation mode classification model.

UTM Database: The database was set up by making a call for volunteers among CEA employees, in Grenoble, France. Each user was taught how to use the datalogger. They were asked to use the datalogger during commute, business or leisure trip, and for the duration of one to several days. Once they returned, data stored in the smartphone were manually downloaded on the pc, via USB cable. A first quick manual analysis was done in order to check the user annotation and find potential important mistakes (such as the user forgot to notify in the app that he has changed transportation mode). At the end of September 2016, 22 users have participated, generating about 40 Gigabytes, 400 files, and representing 217 hours.

Both prototypes operate by invoking a chain of four sub-services in the following order:

- “Sensor reading” that reads raw data of different sensors of the and store them into buffers.
- “Features”: computes some relevant features from the previous buffers
- “Classifier”: calls M classifier(s) (= algorithm) with in input a subset of the previous features and give M predictions of the transportation mode.
- “Post-Classify”: Fuses the M predictions into one unique prediction.

4.2.4 The Multi-objective Optimization Tools @SINTEF

This prototype is managed by SINTEF, in Oslo.

Objective: this prototype constitutes the core MOT module of BONVOYAGE, and runs the Orchestrator.

Brief description: Various software components make up the MOT, and are under active development. Currently the array of software components is as follows:

- A simple directory service for the other services to find each other. This service will later in the project be replaced with an ICN service built on top of OGB.
- An orchestrator service that distributes routing requests to the individual routing services.
- A routing service hosting the routing algorithms. We already have an instance encapsulating/hosting the DYNAMO algorithm and another one hosting the Google routing service, thus proving that the concept of federation is feasible.
- A demonstrator client where we can produce route requests and receive and visualize the corresponding responses.
- A service control panel to launch services and see their statuses

Figure 22 below shows the MOT at work on a Grenoble-Bilbao request.

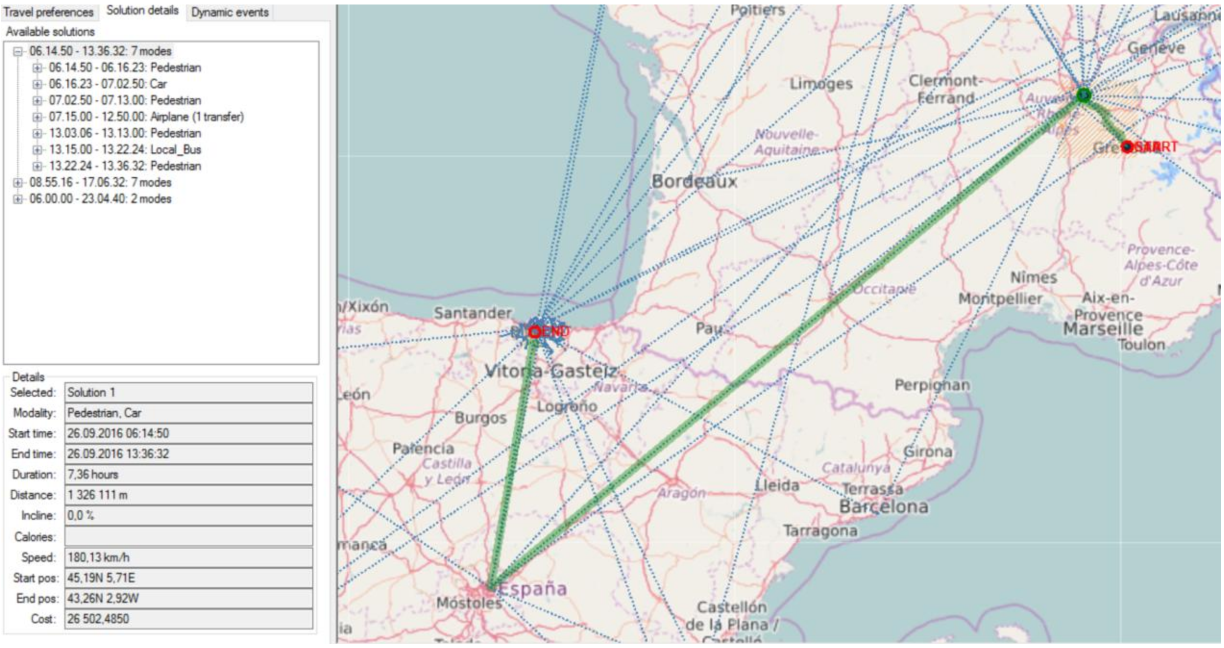

Figure 22. MOT at work on a Grenoble to Bilbao request

Routes from Grenoble to Bilbao are computed using car, public transport and flight networks and data coming from the following sources:

- Road data (Open street map)
- Public transport (GTFS – Bilbao local)
- Flights (QPX Express – only small extracts)

4.2.5 The prototype web application @CRAT

This prototype is managed by CRAT, in Rome.

Objective: to offer a test application for testing the platform.

Brief description: the CRAT web interface is able to call the Orchestrator @SINTEF and to include all of the personalization steps in the workflow, because it also offer a login interface and relies on the official BONVOYAGE MMMDB.

Figure 23 shows a solution provided by the planner from a location in Oslo ad one in Rome. It shows different intermodal solutions, which include biking, private car, carpooling, train, airplane, bus, etc. The proposed solutions are ranked according to the profile of the currently logged-in user.

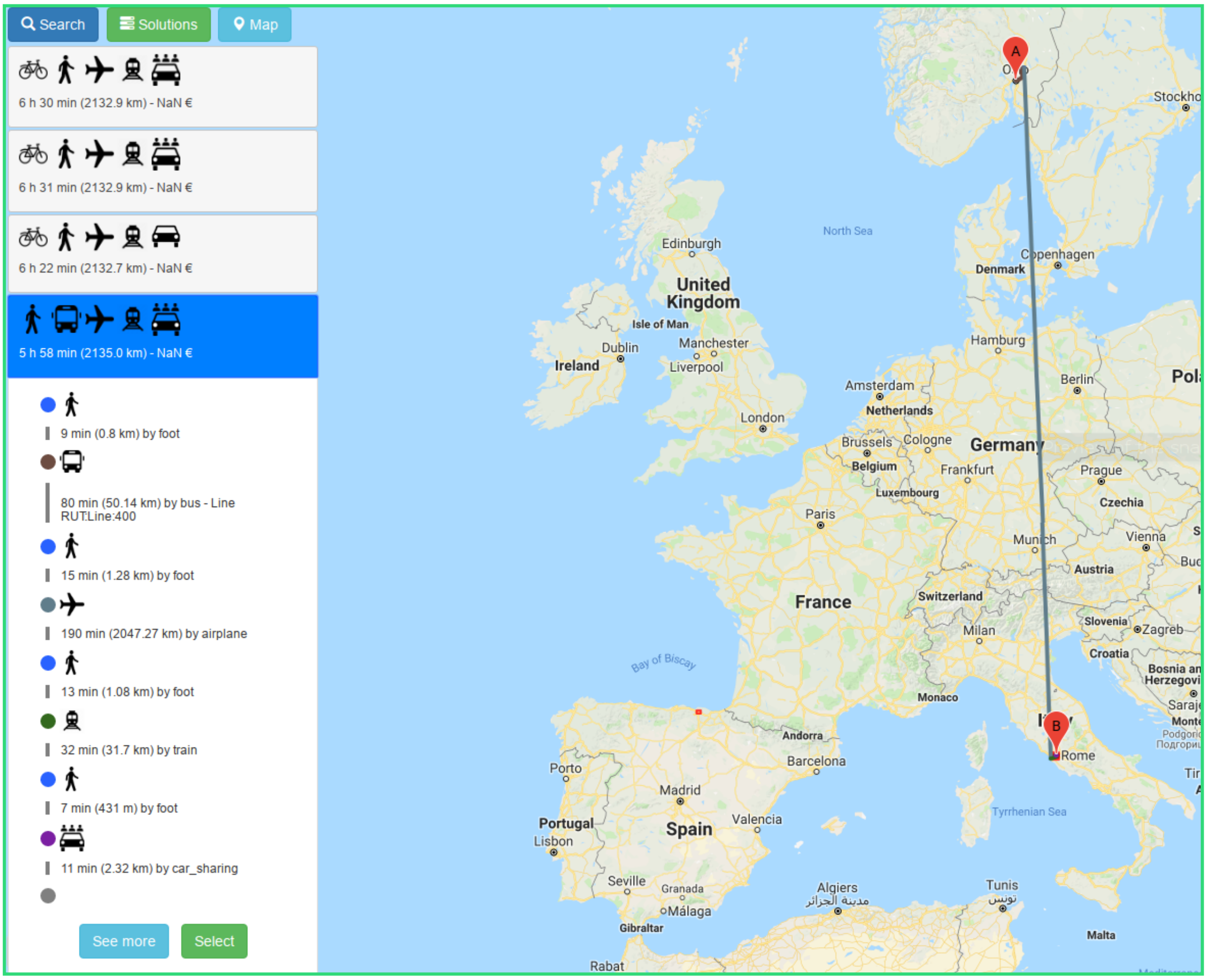

Figure 23. Door-to-door intermodal trip planning with the CRAT web interface

4.2.6 The prototype web application @CNIT

This prototype is managed by CNIT, in Rome.

Objective: to offer a different test application for testing the platform.

Brief description: the CNIT web interface is able to call the Orchestrator @SINTEF but does not o include all of the personalization steps in the workflow, because it was born as a supporting tool for the developers in testing the correctness of the resulting solutions when calling a specific end-point (and not the entire workflow).

It is totally stateless and offers a specific text box for entering the URL of the service to be invoked. It thus offers the possibility to either invoke the Orchestrator or to directly invoke any of the Soloists that have been deployed, bypassing the orchestration step.

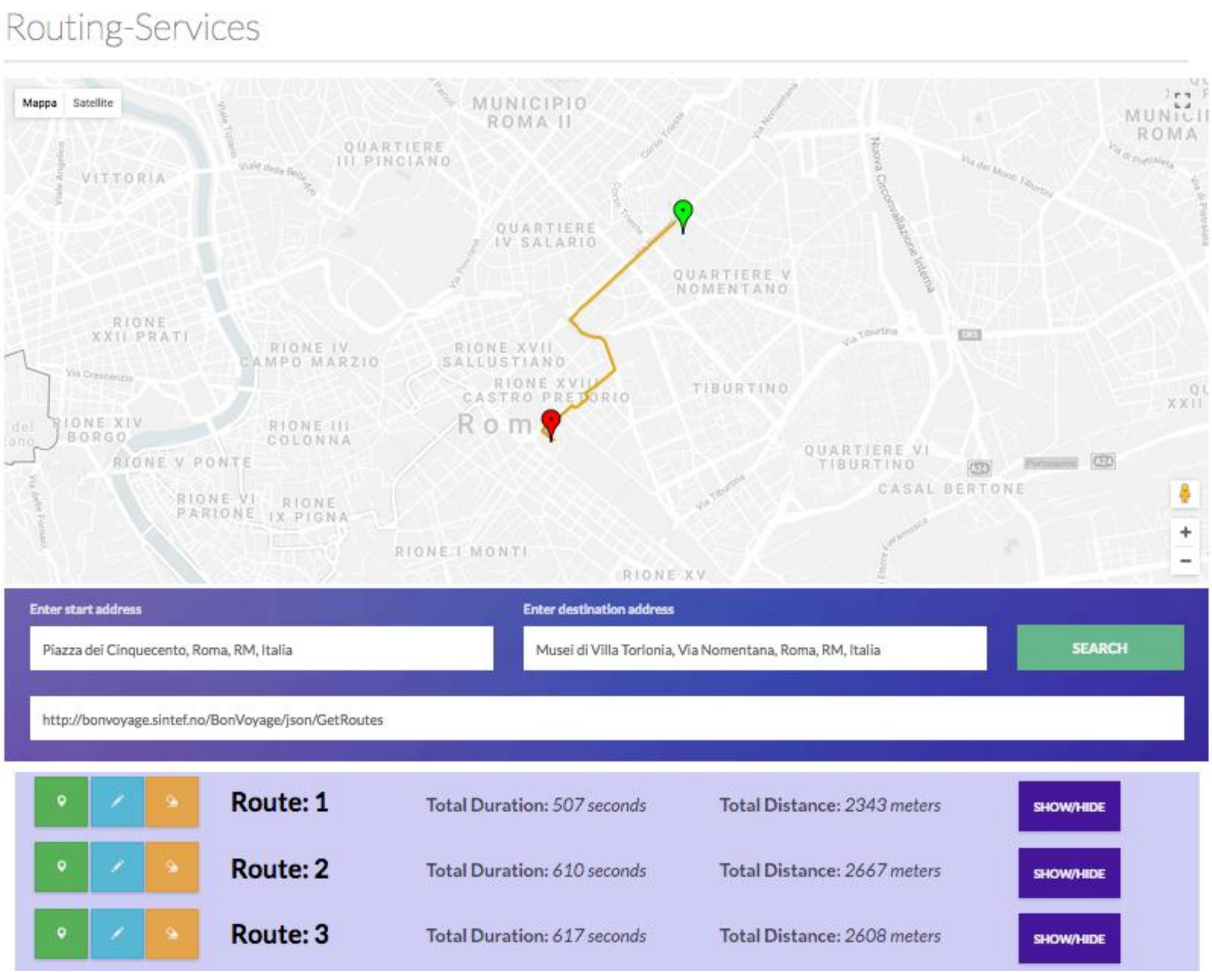

Figure 24. ***CNIT 's prototype*** web application for testing direct end-points

4.2.7 The urban soloist for car-pooling @CRAT

This prototype is managed by CRAT, in Rome.

Objective: This specific urban soloist is capable to offer carpooling in an urban road network and it easily integrates further transport modalities and smart mobility services.

Brief description: as shown in Figure 25, our urban soloist needs the following inputs to be initialized and to return optimal routes:

- Static input: all the data needed to set up the graph of the related area. These data are about the city map (streets, speed limits, road signs) and public transport infrastructures (stop locations, lines) and they change very slowly. For this reason, it is possible to consider them as static input for the algorithm and in BONVOYAGE it is possible to assume that they are updated periodically.

- Dynamic input: all the information that can change frequently as the traffic status, the public transport service availability, new ride-sharing offers and in general the detection of some event like accidents, strikes or breaks on public lines.
- Algorithm: a proper algorithm to solve the specific planning problem has to be selected.
- User query: this input represents the request of the user that want to find the best path according to his/her preferences on the graph built using static and dynamic inputs.

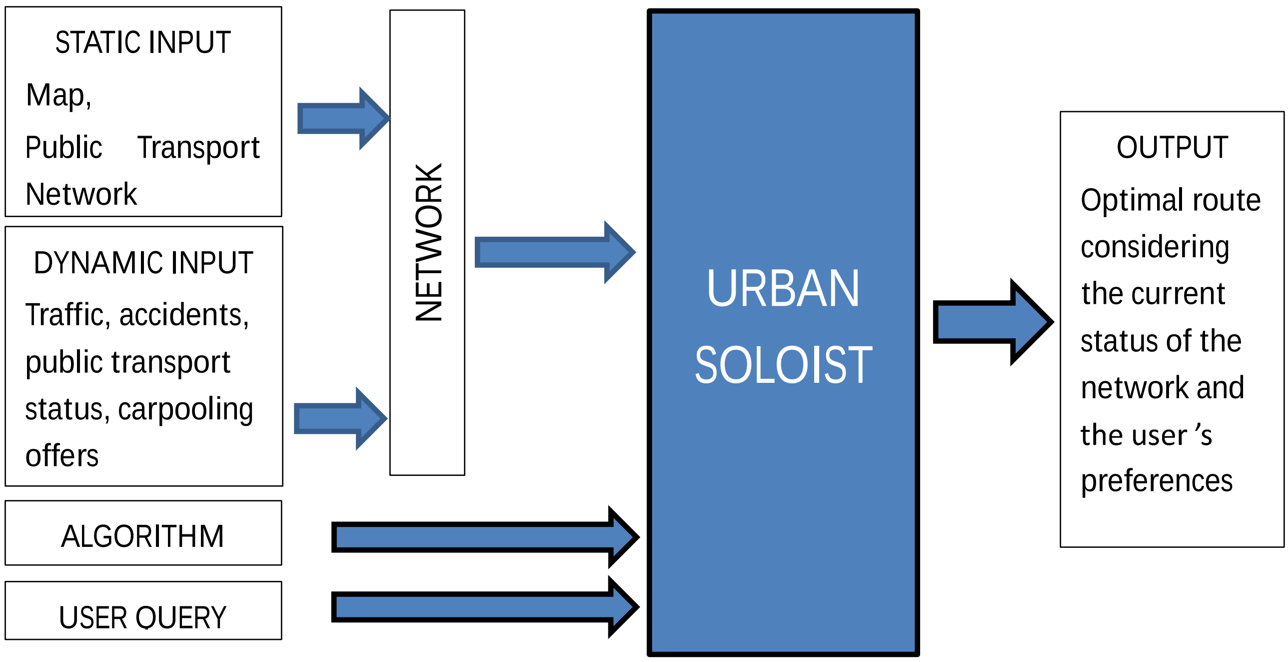

Figure 25. Urban soloist interactions

Static inputs are used to build the network that represents in a logical way the area covered by the urban soloist. In particular, the maps are downloaded from OpenStreetMap and the public transport infrastructures can be easily downloaded in GTFS format by using the OpenGeoBase of BONVOYAGE (exposed at bonvoyage2020.eu/travelcentricservices, see section 4.2.8).

For the purpose of the urban soloist, the transport network has been modelled as a multi-layered graph obtained as a superimposition of different layers, each one representing a transport means.

We provide an example of how the urban soloist is able to integrate the multi-modal trip planning with the car-pooling service. It is assumed that a user Alpha plans a trip from "Zamudio, Bilbao" to "Altzaga, Bilbao" for today at 19:00 pm, and the user intends to share the journey with other BONVOYAGE users. Figure 26 shows in red the itinerary that the user will follow with his/her car.

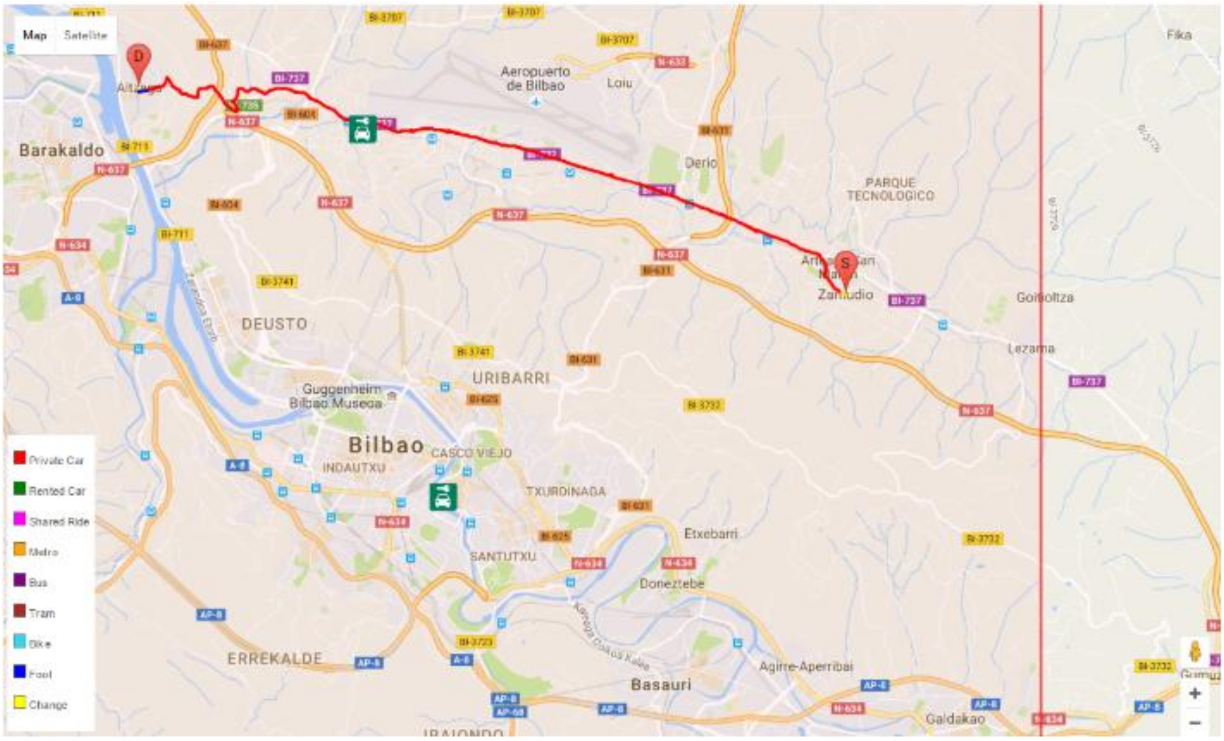

Figure 26. Car-pooling service: the driver shares a ride

Consider now that the orchestrator asks to the urban soloist to plan the journey for user Beta that intends to start at 18:50 pm from "Zamudio, Bilbao" (same source address of driver Alpha) and has to reach "Aeropuerto de Bilbao". User Beta wants to search if exists some driver available to share an itinerary useful to get him closer to the airport. this case, the urban soloist will return to the orchestrator the solution reported in Figure 27, where Alpha and Beta shares the first part of the itinerary (highlighted in purple) and after Beta will reach the airport by walking (dark-blue path).

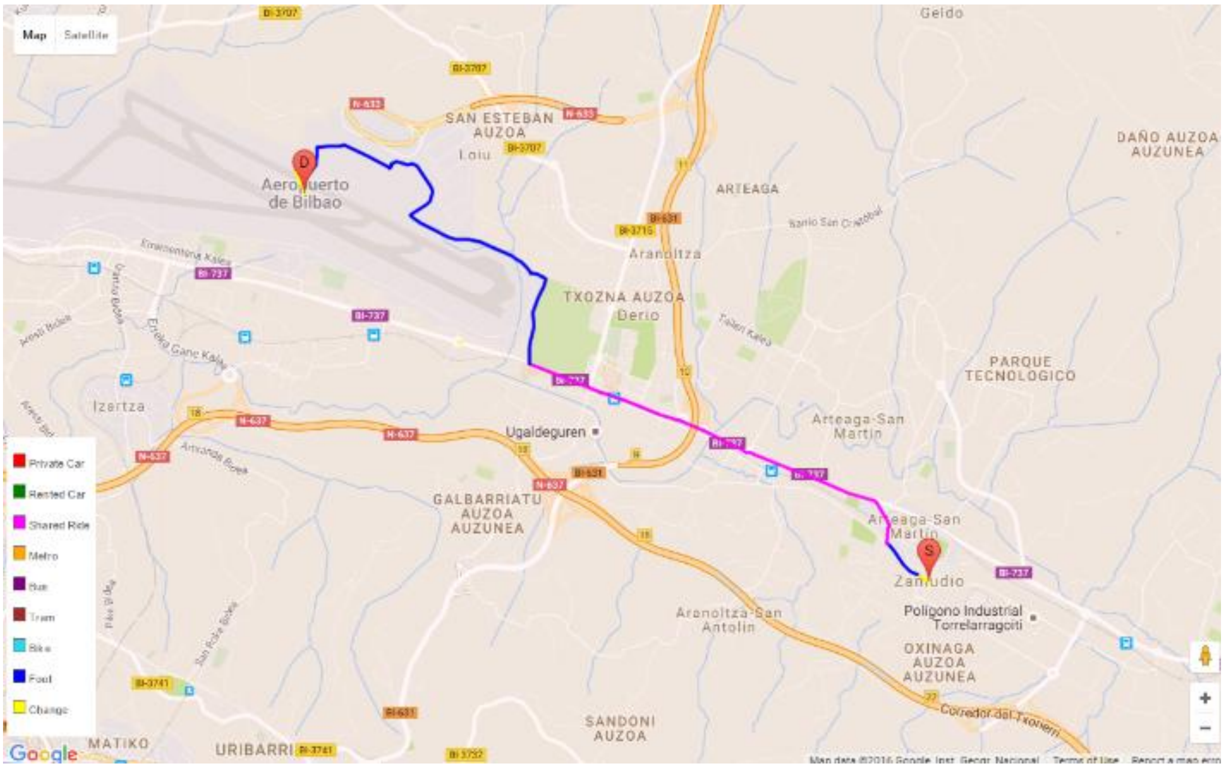

Figure 27. Car-pooling service: single source-multi destination solution example

Consider now a query coming from user Gamma that asks for a planning including all the available public transports and the car-pooling service. Gamma today at 19:00 pm should go from “Ola Bidea, Bilbao” to “Altzaga, Bilbao” using the bike or benefit from the car-pooling service. The urban soloist will return the solution shown in Figure 28, where Gamma reaches by bike Alpha (sky-blue path) in an intermediate node and then they will go to Altzaga sharing the ride.

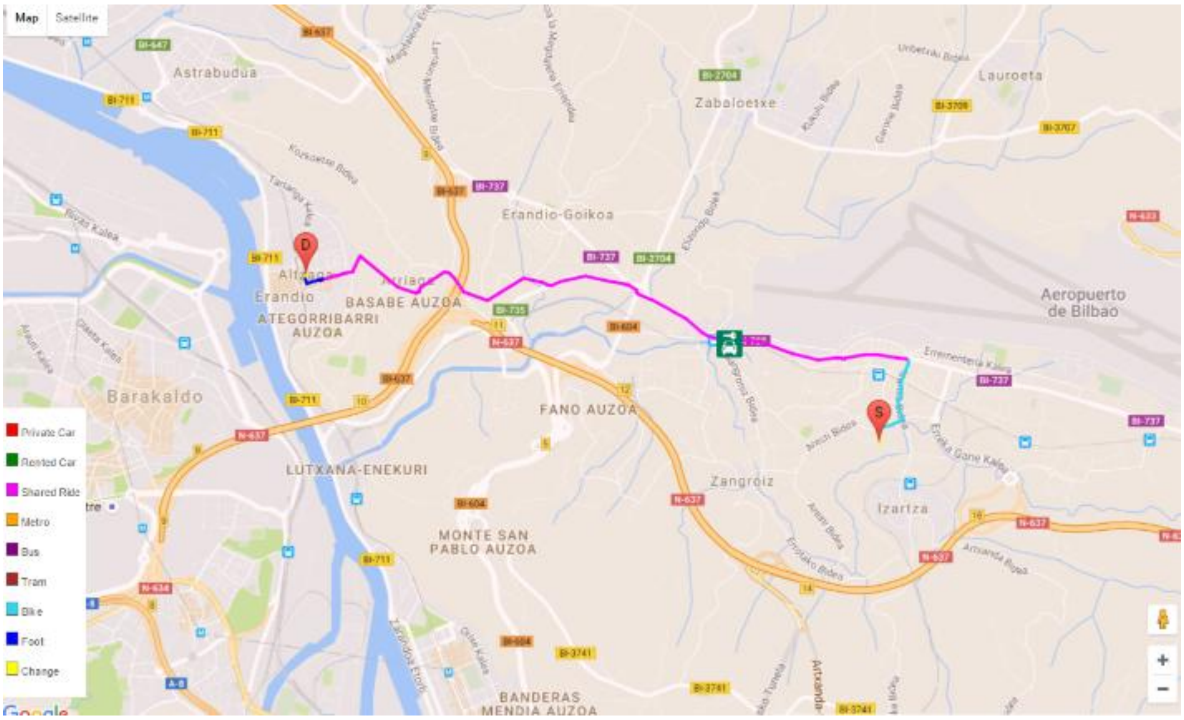

Figure 28. Car-pooling service: multi source-single destination solution example

Finally, in the case the orchestrator asks to the urban soloist to plan for the user Delta a trip from “Parque tecnologico, Bilbao” to “Indautxu, Bilbao” at 18:30, using only public transport and possibly the car pooling service as passanger, the subsolver will provide the solution shown in Figure 29, where passenger Delta goes by walk (dark-blue path) to an intermediate node where he will meet the driver Alpha and then they will reach togheter Altzaga (in purple is highlighted the polyline that join all the nodes visited by the car-pooling service). In the end, Beta will walk to the near subway station in Erandio and he/she will reach Santuxtu after six stops.

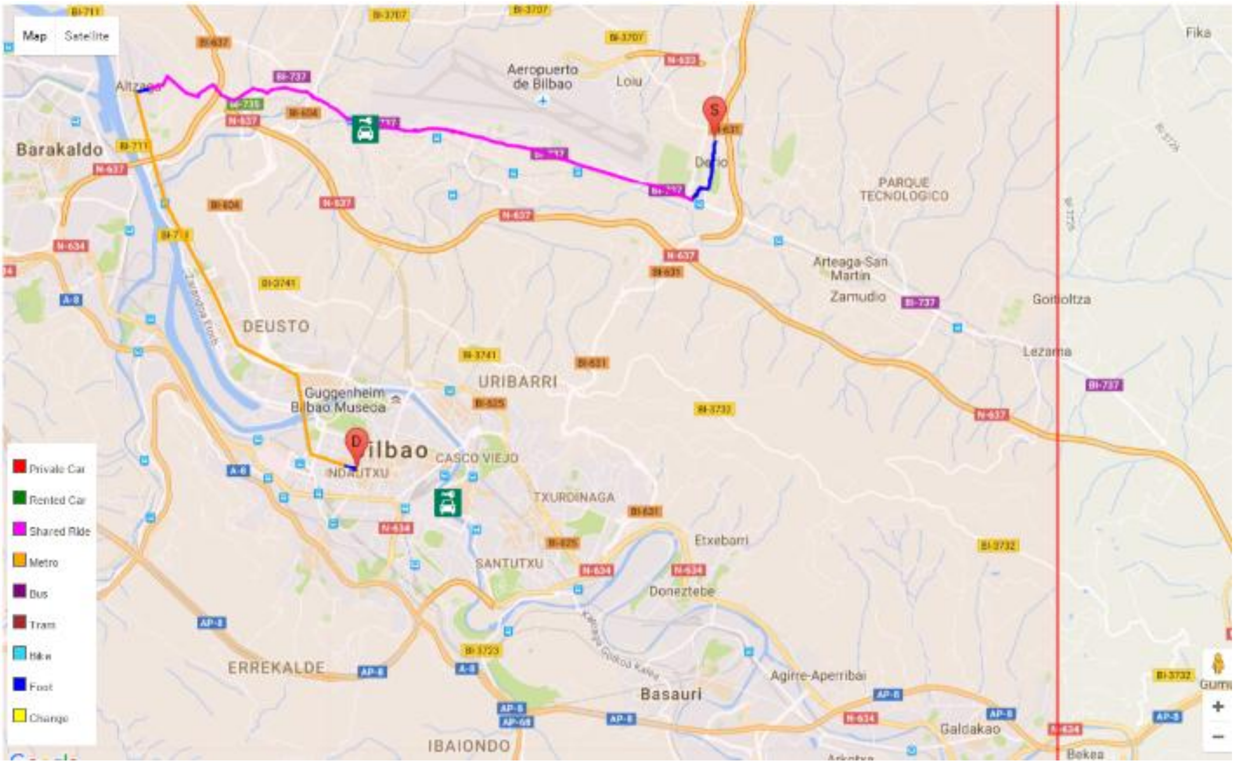

Figure 29. Car-pooling service: multi source-multi destination solution example

The car-pooling service integrated by the urban soloist allows to a passenger to take and leave a car in any intermediate node (including driver 's source and destination) compatibly with the time needed to reach these nodes. Obviously not all the rides offered by drivers and useful for a passenger can be considered by the urban soloist: in fact, certain constraints as the availability of seats and concerning some special needs (e.g. handi cap, extra luggage, animal) must meet between driver and passenger before to consider the ride as a 'candidate'.

The urban soloist includes also the possibility to share a ride added by a driver that will drive a rented car instead of a private car.

The testing phase of the urban soloist has been carried out using an Intel Core CPU i7-4710HQ 3.5 GHz, 16GB RAM computer, running MS Windows 10 Professional operating system has been used. The average execution time evaluated on five hundred random queries is about 400 milliseconds and it varies between a minimum of 350 milliseconds and a maximum of 500 milliseconds.

4.2.8 OpenGeoBase @CNIT

This prototype is managed by CNIT, in Rome.

Objective: discover information and data sources about travel that different providers offer within a specified geographical area.

Brief description: it is a discovery service of public transit data for software developers, transit agencies and more. The prototype is based on a multi-tenant distributed Discovery Service backend assigned to the "BONVOYAGE" tenant. Users (including Service Providers) can specify an area of interest (in terms of a GPS tile or other search criteria such as data type) and will get the URIs (HTTP and NDN) of the offered travel information. Users can then directly retrieve the data from the Transport Information Providers.

The backend of this prototype is based on OpenGeoBase: a distributed set of MongoDB database engines interconnected by the Internames Communication System of BONVOYAGE. Currently it has indexed about 1000 indexed GTFS files, retrieved from www.gtfs-data-exchange.com, transit.land and transitfeeds.com, as well as other publicly available GTFS data sources.

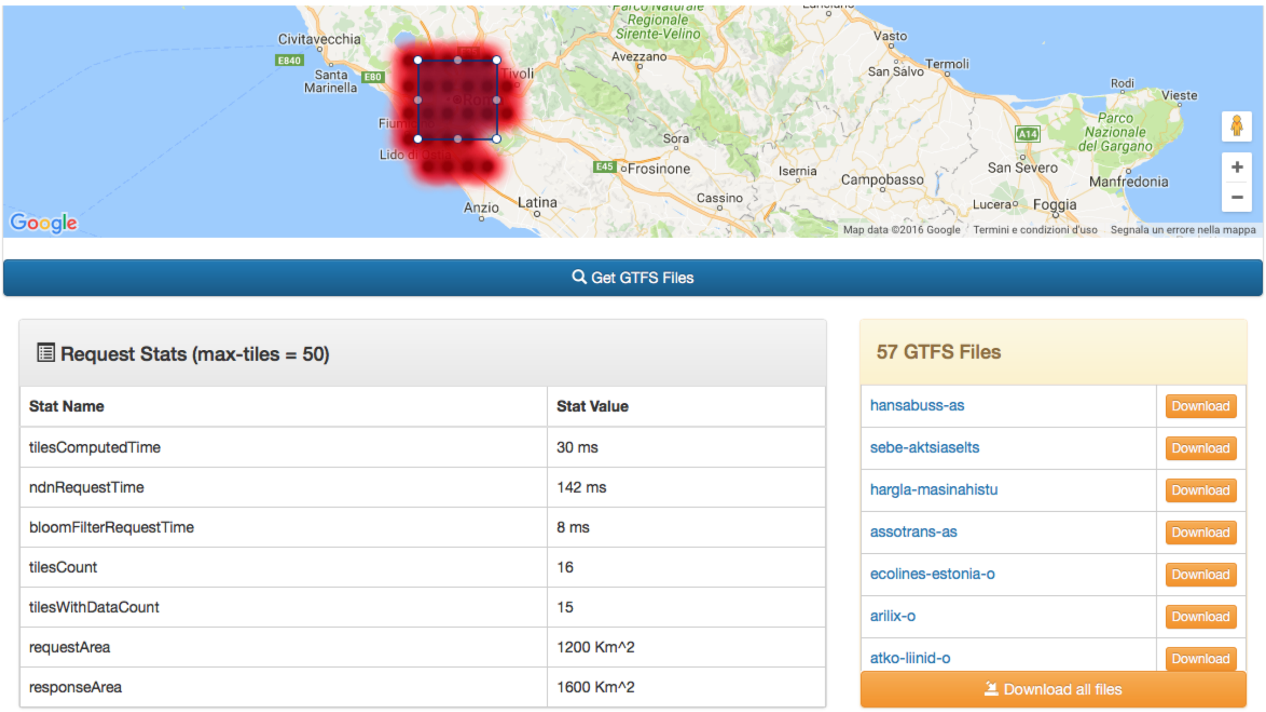

Figure 30. OpenGeoBase at work on a query around Rome

Figure 30 shows how OpenGeoBase responds to a query asking GTFS sources in an area of 1200 square kilometres.

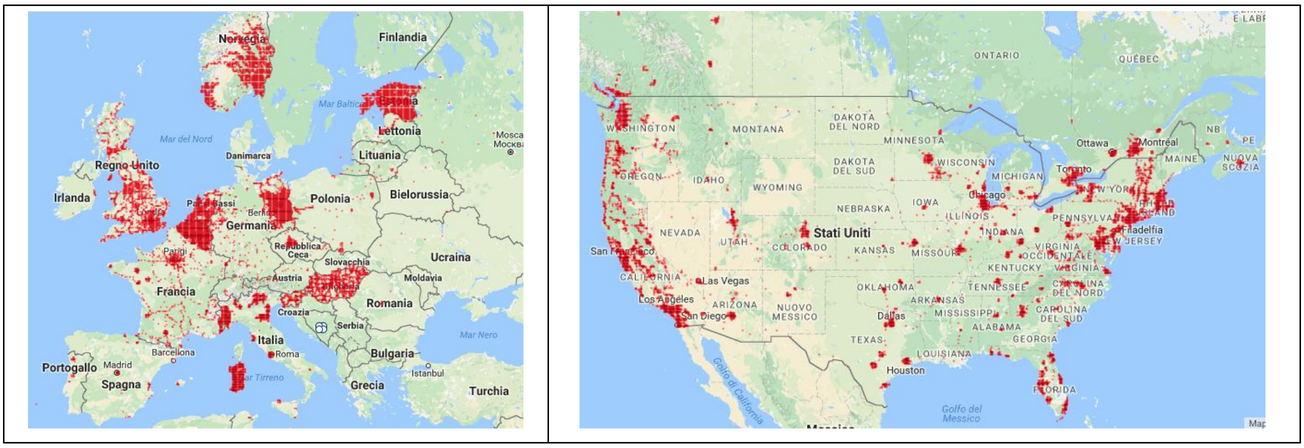

Figure 31. OpenGeoBase EU and US current coverage

Figure 31 shows current coverage of EU and US of OpenGeoBase, displayed as heat-maps.

So far, by indexing the publicly available GTFS files in our OpenGeoBase, the distributed database has 7 millions of entries. This integrated GTFS sources indexing effort is available at http://BONVOYAGE2020.eu/travelcentricservices.

Data is offered through a REST interface, which is better documented as a specific software component API, in deliverable D6.1.

4.2.9 Publish/Subscribe dissemination of real-time travel data @CNIT

This prototype is managed by CNIT, in Bari.

Objective: optimize the distribution of DATEX II real-time information through pub/sub.

Brief description: a user (for instance, a provider wanting to establish a novel ITS business) is able to receive continuous updates about real-time changes of select DATEX II information by: (a) selecting the area of interest; (b) obtaining a list of names; (c) making a subscription; (d) simply waiting for updates.

This prototype is able to simplify management of DATEX II data through pub-sub functionalities. Normal handling of DATEX II information from the NPRA server implies continuous download, processing, and selection of the whole huge, country-wide dataset.

The experimental testbed shown in Figure 32 takes an ICN approach to make distribution of travel data more efficient. A scenario was set-up where data crosses IP and NDN domains. Data source is the NPRA server at:

https://www.vegvesen.no/ws/no/vegvesen/veg/trafikkpublikasjon

Which includes:

- Road weather data: Data is automatically collected from 300 road weather stations along the national road network and include both observations and calculated predictions on certain routes.
- Travel times: Data is collected from AutoPASS OBUs and contain information about route, direction, time and present calculated travel time. Travel times are provided on main roads in Oslo, Bergen, Trondheim and Stavanger.
- CCTV (Closed circuit television): Images collected from a number of CCTV cameras along the national road network. Contain information about position, direction, time and a link to the CCTV image.
- Road and traffic information: Contain information about incidents, road works, road closures and driving conditions provided by 5 regional Traffic Information Centres.

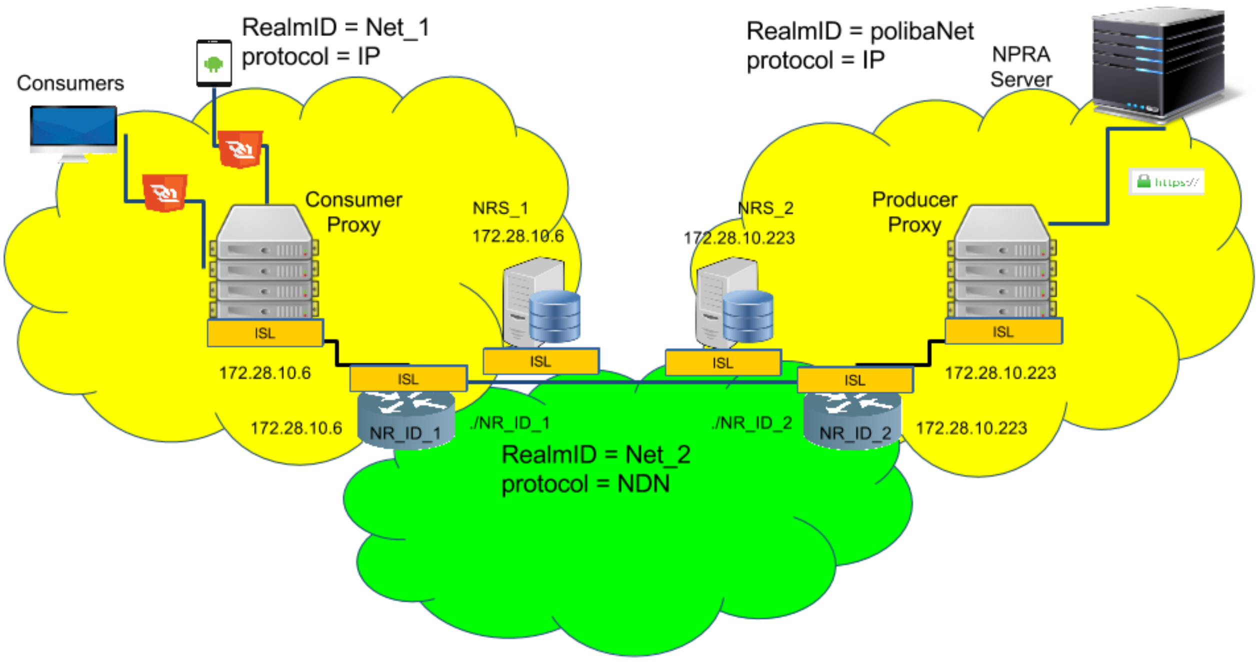

Figure 32. Pub/Sub testbed integrated with NPRA server

The prototype retrieves and then pushes to subscribers the travel-centric data and participatory sensing contents through request-response and publish-subscribe communication schemes over the heterogeneous network infrastructure. For example, the following name is automatically associated to a selected piece of information originated at NPRA:

n2n://polibaNet/bv/datexII/0758/40/GPS-ID/npra/cctv

It refers to the following naming structure, which is a realm-based, geo-referenced, hierarchical schema:

n2n://[realm ID]/bv/[standard]/[geo_info]/GPS-ID/<additional_info>

Any updates occurring to the selected piece of information (in the selected geographic area) are delivered to subscribers whenever a change occurs.

4.2.10 Green Score Policy @TRIT

This prototype is managed by TRIT, in Rome.

Objective: influence users mobility choices with the ultimate goal to reduce the environmental impact of the travel solutions selected by the users, pushing them to select travel solutions composed of means of transport with a low level of CO2 consumption.

Brief description: scores are assigned on the basis of the means of transport selected by the users and user has the possibility to use the scores to obtain prizes, awards and discounts.

Score is assigned to users if there is the availability of at least 2 possible alternative travel solutions to cover the itinerary (point of origin - point of destination).

User 's mobility behaviour is evaluated in two time periods:

- At Time 0 (T0): user eco-friendliness level is not defined. Score is assigned to all users based on the same rules.
- At Time 1 (T1): on the basis of the travel solutions and related means of transport selected by the user in T0, users eco-friendliness level is defined and users are distinguished into 4 different clusters (User Eco-friendliness Profile):
  - Eco-friendly User: user that chose between 76% - 100% of times the lowest CO2 consumption travel solution;
  - Quite Eco-friendly User: user that chose between 51% - 75% of times the lowest CO2 consumption travel solution;
  - Low Eco-friendly User: user that chose between 26% - 50% of times the lowest CO2 consumption travel solution;
  - Not Eco-friendly User: user who chose between 0% - 25% of times the lowest CO2 consumption travel solution.

The definition of the "User Eco-friendliness Profile", that entails the transition from Time 0 and Time 1, takes place after a pre-set number of travel solutions chosen by the users.

The number of the travel solutions after which "User Eco-friendliness Profile" is defined depends on the users travel frequency. Three different groups were defined on the basis of the travel frequency:

- Occasional Travellers: users who travel occasionally, for several reasons (e.g. pleasure trips, holidays or special events). For this group, User Eco-friendliness Profile is defined after 20 travel solutions selected by the user.

* Periodic Travellers: users who periodically travel for personal and / or working reasons (e.g. users who work away from home and come back for the weekend; users who like to travel for pleasure 1/2 times per week). For this group, User Eco-friendliness Profile is defined after 30 travel solutions selected by the user.
* Frequent Travellers: users who travel a lot for personal and / or working reasons (e.g. business travellers who have to go to work every day). For this group, User Eco-friendliness Profile is defined after 60 travel solutions selected by the user.

The number of travel solutions after which the User Eco-friendliness Profile is defined is:

* lower for users who travel less frequently, since they need more time to reach a threshold of travel solutions that enable to profile them;
* higher for those who travel more frequently because, as opposed to the first, they need less time to achieve an adequate number of travel solutions to be profiled.

4.2.11 Tariff Scheme design @CRAT

This prototype is managed by CRAT, in Rome.

Objective: The algorithm designs pricing rules that allow the transport operators that build the partnership to increase their profits; (ii) benefit passengers and (iii) reduce pollution.

Brief description: the prototype helps designing tariff schemes for multi-modal long-distance trips operated by a partnership between air transport and high-speed rail (hereafter, HSR).

In the following example we show how the prototype works on an exemplary route: Nantes-Saint Marteen. The baseline story is that Maria has to go from Nantes (rue Adolphe Moiti è, 19) to Philipsburg (Soualiga Road, 60). She is travelling for leisure purpose. She does not want to have more than one stop. Thus, she has two options:

1) Air France flight. This is a one-stop flight. Maria leaves from Nantes Atlantique Airport (NTE) and takes a flight towards Paris Charles De Gaulle Airport (CDG). Here she connects to a flight towards Princess Juliana International Airport (SXM).

Importantly, Maria does not want to switch from one airport to another one, when she has to make the interchange (i.e., the alternative in which Maria lands in Paris Orly, transfer to Paris Charles De Gaulle and then she takes the long distance flight, is not a feasible alternative).

2) TGVAir product offered by SNCF-Air France. This is a combined air-rail ticket. Maria leaves from Gare de Nantes (QJZ) and takes a high-speed ride towards Paris Charles De Gaulle Airport. The ride is offered by SNCF (Societ è Nationale des Chemines Francaises); once in Paris Charles De Gaulle Airport, she takes the flight towards Princess Juliana International Airport.

On the network, there are other people travelling from Nantes to Paris. They have two options:

1) Air France flight. This is a direct flight. People leave from Nantes Atlantique Airport and take a flight towards Paris Charles De Gaulle Airport.

2) High-speed rail ride. People leave from Gare de Nantes and take a ride towards Gare de Paris Montparnasse. The ride is offered by SNCF

Moreover, there are other people travelling from Paris to Philipsburg. They have one option: taking a direct flight from Paris Charles de Gaulle to Princess Juliana International Airport.

In this framework, Air France must decide how much should Maria be charged on the connecting flight or on the TGVAir product.

Benchmark scenario: The airline and the HSR are pure competitors. Only air transport is able to operate the route A-B. There is no partnership between air and rail and the two transport operators maximize their profits simultaneously and separately (Cournot Nash competition).

Partnership scenario: The airline and HSR form a partnership to operate market AB, involving integrating tickets, coordinating schedules, providing connections between airports and train stations and possibly streamlining baggage transfer or other valuable services (i.e., that increase relevant dimensions of quality identified in the survey). The partnership between the two modes can increase significantly the attractiveness of the air-rail product and travellers may consider it as a valid alternative compared to the connecting flight. In particular, we assume that the partnership is implemented through a vertical agreement. In other words, we assume that, first, the HSR operator sells seats on the train to the airline at a charge w; second, the airline decides how many seats to buy on the HSR train, and then sells a coordinated train-plane product in market AB (two-stage game).

As a baseline, operators should enable passengers to purchase a single ticket for the entire multimodal trip. In such a case, the airline and the HSR operator decide to share the same trip, and each operator can mark each segment of the journey with its own code, independent of whether the airline or the HSR is actually operating the service. This requires operators to integrate their information technology and computer reservation systems. More importantly, it requires operators to coordinate schedules between air and HSR services. In doing so, operators decide to take the risk associated with possible delays on one segment of the journey, and provide passengers with proper warranties. Operators can also consider offering coordinated baggage handling (so that passengers should not care about baggage transfer at the intermediate stop), and/or supplementary services on HSR trains similar to those offered on short-haul flights (e.g., dining).

We evaluate:

The profitability of the partnership: the transport operators will decide to build the partnership if and only if incremental profits gained are positive, net the (fixed) costs that would arise if they build the partnership, for the airline and the HSR respectively.

The effect on prices: if the partnership is built (i.e., there exists a two-stage Nash equilibrium) we provide resulting optimal prices for each leg.

Otherwise, if there exists an operator, which has no incentive to build the partnership, we show which operator is losing money.

4.3 Scientific and Technological impact

As regards scientific publications, BONVOYAGE is targeting top tier research conferences and journals. These leading venues shape future research in this area and as such provide maximum visibility for the project results. Several partners have an established presence and a strong track record in such venues.
The current list of publications is reported in http://bonvoyage2020.eu/results/dissemination.

Another important activity to exert impact is of course standards. Standards are a key way of ensuring that BONVOYAGE has a real impact. The standards process distils the best technical approach, as well as helping to ensure interoperability.

BONVOYAGE 's contributed to Internet and Transport Planning related standardization regulation activities as hereafter reported.

4.3.1 Internet related Standardization activities

The Internet Research Task Force (IRTF) focuses on longer term research issues related to the internet while the parallel organization, the Internet Engineering Task Force (IETF) focuses on the shorter term issues of engineering and standards making. The ICNRG 's main objective is to couple ongoing ICN research in the above areas with solutions that are relevant for evolving the Internet at large.
The BONVOYAGE project has been presented by CNIT at the interim meeting of the ICN Research Group (ICNRG) during the last IETF 93 meeting, held in Prague by Prof. Alfredo Grieco from CNIT. The target of the presentation was to illustrate the potential of the project as a framework to define vertical use cases on top of ICN communication technologies. The key concepts related to the Internames technology in BONVOYAGE have been also included in ad hoc standardization documents (IRTF Drafts) focusing on open challenges and middleware ICN-IoT architectures.

In addition to this physical project presentation, the following 5 Internet draft and RFC have been published:

1. **"ICN based Architecture for IoT – Requirements and Challenges"** Y. Zhang, D. Raychadhuri, L. A, Grieco, E. Baccelli, J. Burke, R. Ravindran, and G. Wang.
IRTF- ICNRG, IRTF Internet Draft, draftzhang-iot-icn-challenges-02, Aug 2015.

2. **"Requirements and Challenges for IoT over ICN"** Y. Zhang, D. Raychadhuri, L. Grieco, E. Baccelli, J. Burke, R. Ravindran, G. Wang, A. Lindren, B. Ahlgren, O. Schelen
IRTF-ICNRG, IRTF Internet Draft, draft-zhang-icnrg-icniot-requirements-00, Nov 2015.

3. IETF RFC 7933: Adaptive Video Streaming over Information-Centric Networking (ICN)
C. Westphal, Ed., S. Lederer, D. Posch, C. Timmerer, A. Azgin, W. Liu, C. Mueller, A. Detti, D. Corujo, J. Wang, M. Montpetit, N. Murray. August 2016.

4. **"ICN based Architecture for IoT"**, Y. Zhang, D. Raychadhuri, L. A, Grieco, S. Sabrina, H. Liu, S. Misra, R. Ravindran, G. Wang. IRTF-ICNRG Internet Draft, draft-zhang-icnrg-icniot-architecture-01, July 16, 2017.

5. **"Design Considerations for Applying ICN to IoT",** D. Raychadhuri, L. Grieco, E. Baccelli, J. Burke, R. Ravindran, G. Wang, A. Lindgren, B. Ahlgren, O. Schelen
IRTF-ICNRG Internet Draft, draft-zhang-icnrg-icniot-01, June 26, 2017

4.3.2 Transport planning related Standardization activities

BONVOYAGE partners put a strong effort in standardization and harmonization for the implementation of the DIRECTIVE 2010/40/EU on the "framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport".

NPRA has been strongly committed in this effort by contributing to standardization and harmonization work for transport planning as well as attendance in EC meetings for the regulation on multimodal transportation information services. This work has been influenced and inspired by knowledge gained from participation in the BONVOYAGE project, due to the fact that it was conducted from colleagues in the same unit of NPRA. In this respect, NPRA has given an effort to achieve cross-fertilisation between the development of the EU regulation for multimodal transport information services and the BONVOYAGE project.

The European Commission started work on the Delegated regulation on multimodal transport information services in 2014. The NPRA appointed experts has since then attended 8 of the 11 meetings until March 2016: on November 10th 2014, February 3rd 2015, April 28th 2015, June 2nd 2015, November 17th 2015, January 19th 2016, February 18th 2016 and March 18th 2016. At that point, a railway reform was carried into effect, and a part of the responsibility for public transport was switched from the NPRA to the newly established Norwegian Railway Directorate.

Since March 2016, they have attended at least two more meetings on the Delegated Regulation. Most of the content was developed in the period when NPRA attended the meetings with experts in close cooperation with our personnel in BOVOYAGE working in the same unit of NPRA.

The NPRA was also active in other harmonization and standardization work, such as the CEN working groups for the revision of the NeTEx and Transmodel standards, namely CEN/TC 278 WG3 SG9 and CEN/TC 278 WG3 SG4, as well as a subgroup of Interoperable Fare Management Standard (ISO 24014) called ISO/TC 204 WG8.

The particular views promoted by the NPRA in the above mentioned meetings, gathered also from the input from BONVOYAGE, have been the preparation of the European NeTEx profile, where we worked to include tariff data already in the first version. In addition, we had an active participant in the Transmodel "modelling meetings", and a national (former NPRA) project for a national travel planner has provided important input to the NeTEx standard, where we had close cooperation with the core group for NeTEx. In addition NPRA has tried to put emphasis on the need to harmonize the National Access Points (NAP) across Europe and to find innovative concepts o for discovering, accessing and linking these services. This will facilitate development and operation of end user services. It is also important in order to enhance attractiveness and user experience to cross-border information services. In our view BONVOYAGE offers such an innovative alternative.

For instance, the BONVOYAGE has submitted contribution to Urban ITS Standardization Mandate M/546 entitled "COMMISSION IMPLEMENTING DECISION C(2016)808 of 12.2.2016 on a standardizations request to the European standardizations organizations as regards Intelligent Transport Systems (ITS) in urban areas in support of Directive 2010/40/EU of the European Parliament" through the participation of NPRA to the mandate, both via email and via the face-to-face experts meetings. The standards where the project provided a contribution are:

1. Rc_MI22 "New standard development: To develop standard APIs and/or query/ data exchange format for interconnection of Journey Planning Systems in coherence with Transmodel v6 (as initially planned by CENTC278 WG3 SG8 Open Journey Planner Interface). (F.4.5)". BONVOYAGE suggested to consider also the interconnection of Journey Planning Systems among them and with National Access Points, providing information about the available national ITS data.
2. Rc_TM01 "A TM interface standard to enable exchange network performance data (Traffic conditions (LoS) and travel times) and planned and unplanned events/incidents (Roadworks, road/bridge/tunnel closures, bad weather and road surface conditions …) not currently covered by DATEX II. (E.4.3.2)". BONVOYAGE proposed to enhance the standard for DATEX II situation messages to more clearly be connected to the consequence for travel planning.

3. Rc_TM02 – "A coherent data model covering urban traffic control & management, such as traffic volume, occupancy rates, average speed travel times, traffic condition (LoS), events & incidents and circulation and traffic management plans (TMPs). (E.4.3.2) ", BONVOYAGE provided insights about for time-dependent travel speed profiles for cars - time of day and day of week.
4. Rc_MI01 – "To develop a standard reference data model for network topology for New Modes (car/cycle sharing areas, carpooling areas, battery recharging places) in coherence with Transmodel V6. (F.4.1) ". BONVOYAGE proposed to consider connection of network topologies for different travel modes (Rc_MI01).
5. Rc_MI24 – "Standard harmonization: To specify a unique solution for the models as developed by GDF and INSPIRE in overlapping areas: road, rail, waterway network, walking paths, administrative areas, named areas, etc.). (G.4.1)". BONVOYAGE provided suggestion for Infrastructure for Intermodal Spatial Information (Rc_MI24).

4.4 Market impact

At the time of writing, we can already claim that BONVOYAGE has had some market impact by observing the exploitable results, generated by the project, which are being used by the biggest industrial partner of the consortium, i.e. Trenitalia.

BONVOYAGE architecture requirements and functionalities are relevant for Trenitalia business in order to become an integrated, multi-modal and innovative mobility operator at national level.

Requirements and functionalities represent a solid basis for the future evolution of Trenitalia ICT services, so they may be possibly used to support the future development and realisation of a multi-modal fully integrated journey planner at Italian level. Trenitalia uses BONVOYAGE **architecture requirements and functionalities to implement its new App "ECE"** (Extended travel experience). This App is implemented as an end-to-end solution that will guarantee for TRIT the introduction of an extended travel experience tool. In particolar the BONVOYAGE architecture has been considered for the realization of the ECE platform, a multimodal platform for the complete integration of the customer experience, e-ticketing, e-wallet, extended Wifi, assistence and safety service. At the same time Integration of real time information functionalities of the App "ECE" has been implemented considering BONVOYAGE functionalities.

Score Policy: Trenitalia is interested in the development and implementation of Green Score Policy to analyze and reward environmentally friendly behavior of users. The logic of the Green Score Policy will be used in the new Trenitalia app.

Car pooling service integration: Trenitalia is doing an analysis on integration between usual multi-modality and new transportation services like social car.

Door to Door journey planner development Business Plan methodology: Trenitalia is interested in the exploitation of the Business Plan methodology definition elaborated for the BONVOYAGE platform in order to use it for the development of future Trenitalia role in ITS product that has the charateristics of a Door to Door journey planning.

In the research field, the papers that have been submitted have had an impact in their relevant areas, with some of the challenges posed providing new areas for investigation.