BONVOYAGE

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

Research and Innovation Action GA 635867

Deliverable D4.1:

Design of the Intelligent Transport Functionality

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Abstract:	The document reports design and preliminary development of the "Intelligent Transport Functionalities" offered by the BONVOYAGE platform, with particular attention to the personalization of the services by means of three distinct logic modules: User Profiler Tool, Multi-Objective Optimization Tool and Tariff Scheme Design Tool
Keyword List:	Intelligent Transportation System, service personalization, user profiling, trip planning, trip control, tariff scheme design, score policy, loyalty programme

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Abbreviations

ABBREVIATION	DEFINITION
API	Application Programming Interface
APP	Android software application
APTS	Advanced Public Transportation System
ATIS	Advanced Traveller Information System
ATMS	Advanced Transportation Management System
AUTS	Advanced Urban Transportation System
AVM	Advanced Vehicle Management
BLE	Bluetooth Low Energy
BVM	Business Vehicle Management
CBR	Case Base Reasoning
CO_2	Carbon Dioxide (chemical formula)
CPU	Central Processing Unit
D2	Less stressful task
ebike	Electric bike
ebus	Electric bus
EC	European Commission
ecar	Electric car
ER	Entity Relationship
EU	European Union
FEV	Fully Electric Vehicle
GPS	Global Position System
ICT	Information and Communication Technology
IT	Information Technology

ITS	Intelligent Transportation System
JSON	JavaScript Object Notation
MDA	Model Driven Architecture
MOT	Multi-Objective Optimization Tool
MTP	Multimodal Trip Planning
OCR	Optimality CRiteria
POC	Personalized Optimality Criteria
PoI	Point of Interest
PPG	Photoplethymogram
SECPT	Socially Evaluated Cold-Pressor Test
SQL	Structured Query Language
TDT	Tariff scheme Design Tool
TLC	Telecommunication
TSST	Trier Social Stress Test
UDM	User Data Model
UIML	User Interface Markup Language
UPT	User Profiler Tool

Table 1 - Abbreviations

1 Introduction

1.1 Deliverable Rationale

Work Package 4 (WP4) is one of most important technological work packages in BONVOYAGE. The work package is in charge of designing and developing the so-called "intelligent" functionalities identified since the proposal (summer 2014) as distinctive features of the BONVOYAGE platform. In the meanwhile, these functionalities have been evolved and adjusted over the years since the beginning of the project (spring 2015). In light of advancements gained through multidisciplinary research and technological innovations in the field of Intelligent Transportation Systems (ITS), the scientific contributions given by the partners involved in BONVOYAGE can be easily evaluated on the basis of concrete advancements with respect to the state of the art and their potential impacts on the reference markets. The main impacts are in terms of enhancement of the ITSs, here conceived as smart applications for planning, control and reaction to real time unforeseen events. Due to heterogeneity and technological complexity of different research fields involved in WP4, the Work Package has been structured in three main Tasks:

- Task 4.1 User Profiler Tool
- Task 4.2 Multi-Objective Optimization Tool
- Task 4.3 Tariff Scheme Design Tool

Each task is organized in subtasks providing different outputs and expected results, as explained in Section 1.3.2. Deliverable D4.1 reports all methodological and algorithmic references for the development of the intelligent functionalities developed within the above-mentioned Tasks in the reference period M6-M18. The document is organized as described in Section 1.3.1, where the way the intelligent functionalities cooperate each other is briefly outlined. For the moment being, the cooperation among intelligent functionalities is still under investigation and the complete details about cooperation among intelligent functionalities will be reported in Deliverable D4.2.

The report is in line with the preliminary, intermediate document I4.1 reporting the work carried out in the reference period M6-M12 and submitted to EC on April 2016. The main achievements from the scientific contributions provided by all partners involved in WP4 are perfectly in line with the technological advancements described in the Description of Action (DoA) of the project and, in the most of cases, have already been disseminated by means of scientific publications.

1.2 Quality review

The internal Review Team responsible of this deliverable is ATOS (Ignacio Gonzalez Fernandez).

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0.7.3	Contributions to section 5	Raffaele Gambuti, Lorenzo Ricciardi Celsi, Francesco Liberati (CRAT)	10/10/2016
0.7.4	Executive summary and conclusions review	Silvia Canale and Manlio Proia (CRAT)	11/10/2016
0.7.5	Reinforcement learning contribution to section 5	Federico Lisi, Manlio Proia (CRAT)	13/10/2016
0.7.6	Clustering based approach and model selection review in section 4	Silvia Canale, Vincenzo Suraci, Francesco Delli Priscoli and Vittorio Palmisano (CRAT)	13/10/2016
0.7.7	Score policy definition and design in section 6.2	Flavio De Trane and Francesco Sorvillo (TRIT), Stephan Strodl (FLUID)	14/10/2016
0.8	Appendixes A-E,	Silvia Canale, Francesco Delli Priscoli, Antonio Pietrabissa,	14/10/2016

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0.9	Internal review	Ignacio González Fernandez (ATOS)	24/10/2016
1	**Final deliverable D4.1**	**Silvia Canale (CRAT)**	**28/10/2016**

Table 2 - BONVOYAGE Quality review

1.3 Executive summary

The deliverable D4.1 describes the goals achieved within Work Package 4 (WP4) "Intelligent transport functionalities" in the period October 2015 – October 2016 (M6-M18). A draft of the deliverable has made available to the EC on April 2016 (M12) as Intermediate deliverable I4.1. Intermediate deliverable I4.1 contains a draft version of preliminary results from activities completed by M12 within WP4. The aim of this document is that of reporting the main definitions, objectives and results concerning the so-called "intelligent" functionalities with respect to the BONVOYAGE platform. Starting from the reference functional architecture of the BONVOYAGE platform (reported in deliverable D2.2) and following the seminal results achieved during the fundamental tasks related to system requirement and functionality definition, the document lead the reader through the driving requirements and the target functionalities dedicated to personalization of a number of services offered by a multi- and inter-modal transportation platform. The main mathematical models and algorithms developed in BONVOYAGE for user profiling, multi-objective optimization and tariff scheme design are reported as results of WP4. For the complete organization and structure of the main tasks, we refer to Sections 1.3.1 and 1.3.2.

1.3.1 Deliverable description

This document is organized according to inner structure of the tasks of WP4. In particular:

- Section 1 describes and summarizes the deliverable organization.
- Section 2 describes how starting from the functional requirements we figure out the intelligent functionalities from three main points of view: user profiling, multi-objective optimization and tariff scheme design (one for each main task).
- Section 3 summarizes the connections between WP4 and other important WPs in the BONVOYAGE project, with particular attention to WP2, WP5, WP6, WP7 and WP8. Moreover, the section briefly outlines how the main components in charge of WP4, namely the User Profiler Tool, the Multi-Objective Optimization Tool and the Tariff Scheme Design Tool, are supposed to cooperate each other and to jointly support the most technologically advanced functionalities of the BONVOYAGE platform. As said

before, the complete cooperation scheme involving all intelligent functionalities is still under investigation and the final version will be reported in Deliverable D4.2.

- Section 4 presents the main methodologies and technologies investigated and developed within Task 4.1 – User Profiler Tool dedicated to user profile based service personalization. Please consider that personalization is a set of functionalities providing useful information about the user and his interaction with the BONVOYAGE platform. Therefore, personalization is a preliminary task with respect to intelligent functionalities developed in Tasks 4.2 and 4.3. In particular, this section describes the concept of user feedback, including both explicit and implicit feedback.
    - The *explicit feedback* is explicitly given by the end user and the user feedback personalization functionalities are reported in Section 4.1. In this case, the functionalities rely on the analysis of data coming from user interacting with the BONVOYAGE platform and allow extraction of useful information in *pre-trip interaction* between the user and the BONVOYAGE platform in terms of driving parameters for trip planning functionalities (see Section 4.1.3) and for ordering travel solutions to be returned to the user (see Section 4.1.4).
    - The *implicit feedback* is estimated by means of distributed sensors and sensor based feedback personalization functionalities are reported in Section 4.2. In this case, the functionalities rely on the analysis coming from different sensors and allow extraction of useful information in *on-trip interaction* between the user and the BONVOYAGE platform in terms of user stress level recognition (see Section 4.2.1) and user transportation mode identification (see Section 4.2.2).
- Section 5 presents the BONVOYAGE ambition to solve the problem of journey planning in very large areas, door-to-door, by introducing the multi-objective optimal trip planning service developed in Task 4.2 – Multi-Objective Optimization Tool. The solution strategy relies on a hierarchical approach based on one Orchestrator (see Section 5.2) and several trip planning services covering from international to urban subnetworks. Particular attention is given to integration of innovative, collective private transportation services (e.g., car pooling) in urban and regional scenarios (see Section 5.3, 5.4 and 5.5).
- Section 6 presents the impact of an appropriate intelligent functionality dealing with Membership Management functional module and allowing us to overcome the state of the art within Task 4.3 – Tariff Scheme Design Tool. Two fundamental membership functionalities are described this section: the score policy (see in Section 6.2) and the loyalty programme (see Section 6.3).
- Section 7 describes how the tariff schemes well designed, within Task 4.3 – Tariff Scheme Design Tool, might help and create new business opportunities by including partnership among transport operators according to different markets and scenarios.
- Section 8 summarizes the work developed within this document, introducing possible future work starting from the research activities obtained in this document.

- Section 9 contains the references.

For sake of readability, some of the technical documents issued by the WP4 have been summarized and reported in a number of appendices of this deliverable. In particular,

- Appendix A includes the description of the User Data Model developed with the aim of designing a customize system for user's specific needs. The document has been presented in a very preliminary version since the beginning of the WP during the First WP4 Physical Meeting in Rome (November 2015). It is still a working document and is currently begin updated in order to meet the algorithmic needs. The version reported in User Data Model is a stable version, at the moment being under review for integration purposes and development of inner and outer interfaces.
- Appendix B includes the description of the official “BONVOYAGE Questionnaire” created to investigate main users’ preferences and constraints for mobility services and aimed at collecting a knowledge base about user behaviours in terms of long distance, multimodal travels. The data collected by this important questionnaire have been analysed within Task 4.1 in order to test the clustering based user profiling tool (see Section 4.1.3).
- Appendix C includes the description of an additional “BONVOYAGE Questionnaire 2nd” created to investigate passengers’ preferences in long-distance trip chains in order to develop the Tariff Scheme Design Tool, with particular attention to the multi part tariff aspects, as explained in Section 7.
- Appendix D includes the description of the Market Studies carried out in the first subtask of Task 4.3 – Tariff Scheme Design Tool. It represents the analytical basis for developing all functionalities in the task and reported in Sections 6 and 7.
- Appendix E includes the BONVOYAGE WP4 Glossary concerning preliminary ideas and basic concepts shared by all partners involved in WP4, and then evolving in more technical documents (e.g., User Data Model reported in Appendix A). As Appendix A, this document has been conceived since the beginning for all research activities in order to favour the comprehension of the most important concepts and, above all, to harmonize the different research activities among them.

1.3.2 *Summary of results*

As mentioned in Section 1.1, work package 4 (WP4) is organized in three main tasks: User profiling tool (Task 4.1), Multi-Objective Optimization Tool (Task 4.2) and Tariff scheme design tool (Task 4.3). As mentioned in Section 1.1, work package 4 (WP4) is organized in three main tasks: User Profiler Tool (Task 4.1), Multi-Objective Optimization Tool (Task 4.2) and Tariff Scheme Design Tool (Task 4.3). The results obtained within WP4 and reported in the deliverable are the output of research activities involved in each task of WP4. Each task has been organized in several different subtasks, according to an activity plan proposed by each task leader and discussed among all partners involved in the task. The complete activity plan for each task is summarized in the Table 4, Table 5 and Table 6. For each subtask, the expected results

SUBTASKS	CONTRIBUTION BY CEA	CONTRIBUTION BY CRAT	CONTRIBUTION BY ATOS	CONTRIBUTION BY TRIT	CONTRIBUTION BY FLU	EXPECTED RESULTS	SCHEDULE	WHERE REPORTED
4.1.1 User data model definition	Definition of data model describing the main entities involved in BONVOYAGE's service personalization, with particular attention to **features coming from real time sensors** (e.g., global mean user stress level, mean user stress level for plane, for car, etc.)	Definition of data model describing the main entities involved in BONVOYAGE's service personalization with particular attention to **features coming from real time user feedback** and to **impacts on Multi-Objective Optimization Tool (Task 4.2)**	Logical design of data structure (**back end perspective**) on the basis of the data model describing the main entities involved in BONVOYAGE's service personalization	Definition of data model describing the main entities involved in BONVOYAGE's service personalization with particular attention to features coming from historical data about travelling and to impacts on the Tariff scheme design tool (Task 4.3)	Logical design of data structure (**front end perspective**) on the basis of the data model describing the main entities involved in BONVOYAGE's service personalization	User Data Model	**Oct 2015 - Dec 2015** (M6 - M8) Review period: **Feb 2016 - Apr 2016** (M10 - M12)	**D4.1 APPENDINX A**
4.1.2 Statistical inference for monitoring the Level of user Stress (LS) and the User transportation mode (UTM)	Definition and development of data fusion and machine learning algorithms for statistical inference for monitoring LS and UTM (**both back end and front end**) including the following subtasks: (i) development of a datalogger;				Definition of software requirements for the full integration of data fusion and machine learning algorithms for statistical inference for monitoring LS and UTM in the BONVOYAGE **front end**	User stress level module and user transport module	**Oct 2015 - Oct 2016** (M6 - M18): (i) datalogger, (ii) database set up **Nov 2016 - Jun 2017** (M19 - M26): (iii) features	**D4.1 (see Section 4.2)**

	(ii) database set up; (iii) feature selection.						definition, machine learning algorithm, tests, performance	
4.1.3 User feedback analysis for service personalization	Definition of the user feedback based personalization system in BONVOYAGE (**user requirements perspective**)	Definition of the user feedback based personalization system in BONVOYAGE (**Future Internet perspective**)	Definition of the user feedback based personalization system in BONVOYAGE (**back end perspective**)		Definition of the user feedback based personalization system in BONVOYAGE (**front end perspective**)	Concept and algorithms for service personalization in BONVOYAGE	**Jan 2016 - Oct 2016** (M9 - M18)	**D4.1 (see Section 4.1.2)**
4.1.4 Machine learning techniques for user behavioural profile identification		Definition of machine learning based algorithms for user behavioural profiling (**both back end and front end**)				User profile based driving parameters definition	**Jun 2016 - Dec 2016** (M14 - M21)	**D4.1 (see Section 4.1.3 and 4.1.4)**
4.1.5 Pre/on-trip user profiling and user profile evolution		Definition of user profiling procedure (**both back end and front end**)				User profile based on trip personalization algorithms	**Nov 2016 - Jun 2017** (M19 - M26)	**D4.2**

Table 3 - Task 4.1 User Profiler Tool

SUBTASKS	**CONTRIBUTION BY SINTEF**	**CONTRIBUTION BY CRAT**	**CONTRIBUTION BY FLU**	**EXPECTED RESULTS**	**SCHEDULE**	**WHERE REPORTED**
4.2.1 Evaluation of use cases, requirements, architecture, reference scenarios	Evaluation of use cases, requirements, architecture, reference scenarios with particular attention to requirements regarding the design of the optimization algorithm.	Evaluation of use cases, requirements, architecture, reference scenarios with particular attention to requirements regarding the design of the control algorithm and requirements regarding the tariff schemes and the user profiler tool. Review of the state of the art.	Evaluation of use cases, requirements, architecture, reference scenarios with particular attention to requirements regarding the design of internal interfaces and the service adaptation mechanism --> should be extended until end of February due to dependency on WP2	In-depth evaluation aimed at determining the best approach to implementing the Multi-Objective Optimization Tool (in particular, analysis of the car pooling related use case and alternative flows)	**Oct 2015 - Jan 2016** (M6 - M9)	**D4.1 (see Sections 2.2 and 6.2)**

4.2.2 Definition of inputs of interests and outputs to be provided	Define inputs of interests and outputs to be provided with particular attention to the inputs needed by the inter-modal routing algorithm and the interaction with the multi-modal mobility database.	Define inputs of interests and outputs to be provided with particular attention to the inputs needed by the control algorithm and outputs required by the travel option purchase service.	Define inputs of interests and outputs to be provided with particular attention to requirements regarding the design of internal interfaces and the service adaptation mechanism.	Determination of inputs and outputs for the routing/control algorithm, for the underlying Internames structure and for the service adaptation mechanism	**Dec 2015 - Feb 2016** (M8 - M10)	**D4.1 (see 6 and Appendix A)**
4.2.3 Problem definition, mathematical formalization and algorithm design	Define the optimization problem as a mathematical formulation and design the pre-trip and on-trip algorithm.	Define the control problem and design the on-trip algorithm.		Establishment of a collaborative architecture relying on an orchestrator plus distributed local solvers embedding resource constrained shortest-path algorithms	**Mar 2016 - Oct 2016** (M11 - M18)	**D4.1 (see Section 5)**
4.2.4 Algorithm development and validation	Development, implementation and assessment of the different optimization algorithms formulated in subtask 4.2.3. Validate the algorithms with respect to the adherence to static and real-time constraints and to the overall quality of the solutions.	Develop, implement and compare the possibly different control algorithms formulated in subtask 4.2.3. Validate through simulations the algorithms with respect to the personalized user profiles and with respects of the use cases defined in WP2.		Development and implementation of the Travel Solution Management Module (and of its two submodules, i.e.., the Global Travel Solution Management Module and the Local Travel Solution Management Module)	**Nov 2016 - Jun 2017** (M19 - M26)	**D4.2**

Table 4 - Task 4.2 Multi-Objective Optimization Tool

SUBTASKS	CONTRIBUTION BY TRIT	CONTRIBUTION BY CRAT	CONTRIBUTION BY FLU	CONTRIBUTION BY AZK	CONTRIBUTION BY COB	EXPECTED RESULTS	SCHEDULE	WHERE REPORTED
4.3.1 Benchmark study of existing tariff models/trends and highlight of possible evolutions to strengthen the Tariff Scheme Tool innovation features	Study and analysis of existing tariff models implemented or under discussion by different passenger transport operators across EU and in other non EU countries. The study is aimed to identify relations between specific aspects/variables of tariff models and passengers mobility choices (that is: which tariffs, tax policies, score rules can "push" passengers to prefer specific transport modes/solutions). The study to be	Study and analysis of existing tariff models implemented or under discussion by different passenger transport operators across EU and in other non EU countries. The study is aimed to identify relations between specific aspects/variables of tariff models and passengers mobility choices (that is: which tariffs, tax policies, score rules can "push" passengers to prefer specific transport modes/solutions). The study to be carried out can be selected among the 5 options listed in column G, according to the partner's research/business interest.		Study and analysis of existing tariff models for freight transport implemented by different freight transport operators (in Spain and/or other EU and non EU countries).	- Study and analysis of City of Bilbao current tariff model. The analysis shall point out existing factors/relations indicated in studies a, b, c, d and e in column G. - Study and analysis of existing tariff models implemented by other municipalities across EU and in other non EU countries.	Detailed analysis of the mainly used tariff models and urban mobility polices	**Jan 16** M9	**D4.1** **(see APPENDIX D)**

	carried out can be selected among the 5 options listed in column G, according to the partner's research/business interest.							
4.3.2 Analysis of factors pushing the user towards socially desirable mobility solutions	- Joint selection of one study for further investigation (investigation will be carried out through a survey questionnaire in order to: verify/confirm the identified relations between specific tariff models and passengers mobility choices; identify additional factors/variables that shall be included in the Tariff Scheme algorithm). - Preparation of	- Joint selection of one study for further investigation (through a survey questionnaire in order to verify/confirm the identified relations between specific tariff models and passengers mobility choices; identify additional factors/variables that shall be included in the Tariff Scheme algorithm). - Preparation of the survey to be carried out for data gathering and analysis; - Survey implementation, results collection: distribute survey among CRAT employees; gather answers; - Survey results analysis: integrate all answers stemming from surveys carried out by the TRIT, CRAT, AZK and COB; analysis		- Joint selection of one study for further investigation through a survey in order to verify/confirm the identified relations between specific tariff models and passengers mobility choices; - Survey implementation and results collection: distribute survey among AZK employees; gather and share received surveys with CRAT.	- Joint selection of one study for further investigation through a survey in order to verify/confirm the identified relations between specific tariff models and passengers mobility choices; - Survey implementation and results collection: distribute survey among COB employees; gather and share received surveys with CRAT.	Survey prepared by CRAT and TRIT	Survey Preparation M9–M10(mid Jan. '15 – mid Feb. '16) Survey Submission M10-M11(mid Feb.'16-mid Mar.'16) Results collection and analysis M11-M12(mid Mar. '16 - mid Apr. '16)	**D4.1** **(see APPENDIX B and C)**

	the survey to be carried out for data gathering and analysis; - Survey implementation and results collection: distribute survey among Trenitalia employees; gather and share received surveys with CRAT.	of results arising from the survey; draw conclusions; compare survey evidence to the relations identified within the study and identify variables to be provided to the Tariff Scheme algorithm.						
4.3.3 Analysis and definition of Tariff Scheme Tool proposals, with identification of respective advantages/disadvantages	- Selection of BONVOYAGE "intelligent functionalities" impacting on the Tariff Scheme and to be developed beyond the state-of-the-art. Identification of functionalities impacting on the Tariff Scheme and that will be specified only (which will remain at the state-of-the-art).	- Selection of BONVOYAGE "intelligent functionalities" impacting on the Tariff Scheme and to be developed beyond the state-of-the-art. Identification of functionalities impacting on the Tariff Scheme and that will be specified only (which will remain at the state-of-the-art). - Tariff Scheme Design: drafting of a proposal for BONVOYAGE Tariff Scheme, that is: identification of input from User Profile and Multi-Objective Optimisation Tool	Providing feedback and suggesting modifications to the proposal for BONVOYAGE Tariff Scheme, concerning: identification of input from User Profile and Multi-Objective Optimisation Tool (user profile; transport operator tariffs; travel itinerary selected by the passenger, etc.); identification of the factors/relations to be taken into account by the Tariff Scheme in	Providing feedback and suggesting modifications to the proposal for BONVOYAGE Tariff Scheme, concerning: identification of input from User Profile and Multi-Objective Optimisation Tool (user profile; transport operator tariffs; travel itinerary selected by the passenger, etc.); identification of the factors/relations to be taken into account by the Tariff Scheme in order to calculate the final price or scores to be awarded; identification of the output that the Tariff Scheme shall	Providing feedback and suggesting modifications to the proposal for BONVOYAGE Tariff Scheme, concerning: identification of input from User Profile and Multi-Objective Optimisation Tool (user profile; transport operator tariffs; travel itinerary selected by the passenger, etc.); identification of the	Tariff scheme proposal	**Jan.16 - Apr. 16** M9 - M12	**D4.1** **(see Section 6 and 7)**

	- Tariff Scheme Design: drafting of a proposal for BONVOYAGE Tariff Scheme, that is: identification of input from User Profile and Multi-Objective Optimisation Tool (user profile; transport operator tariffs; travel itinerary selected by the passenger, etc.); identification of the factors/relations to be taken into account by the Tariff Scheme in order to calculate the final price or scores to be awarded; identification of the output that the Tariff Scheme shall provide to the passenger (customised tariffs prioritised	(user profile; transport operator tariffs; travel itinerary selected by the passenger, etc.); identification of the factors/relations to be taken into account by the Tariff Scheme in order to calculate the final price or scores to be awarded; identification of the output that the Tariff Scheme shall provide to the passenger (customised tariffs prioritised according to user preferences).	order to calculate the final price or scores to be awarded; identification of the output that the Tariff Scheme shall provide to the passenger (customised tariffs prioritised according to user preferences).	provide to the passenger (customised tariffs prioritised according to user preferences).	factors/relations to be taken into account by the Tariff Scheme in order to calculate the final price or scores to be awarded; identification of the output that the Tariff Scheme shall provide to the passenger (customised tariffs prioritised according to user preferences).			

	according to user preferences).							
4.3.4 Definition of the Tariff Scheme working methodology (models, methods and algorithms)		Definition of the mathematical algorithm establishing how all inputs, outputs and relations underlying the Tariff Scheme work together.	Definition of the mathematical algorithm establishing how all inputs, outputs and relations underlying the Tariff Scheme work together.			Definition of an algorithm capable of pushing the BONVOYAGE "intelligent functionalities" beyond the state-of-the-art.	**May 16 – Oct. 16** M13 – M18	**D4.1** **(see Section 6 and 7)**
4.3.5 Tariff Scheme methodology implementation			Development of functionalities impacting on the Tariff Scheme and definition of Tariff Scheme functional specifications (with respect to BONVOYAGE "intelligent functionalities" and those that will remain at the state-of-the-art).			Functionalities development and identification other related domain (e.g., input/output relationships among Tariff Scheme, the User Profile and the Multi-Objective Optimization Tool.	**Nov 16 – Jun 17** M19– M26	**D4.2**

4.3.6 Off-line Tariff Scheme Tool simulation	Feedback on simulation put in place by CRAT and FLU.	Simulation implementation.	Simulation implementation.	Feedback on simulation put in place by CRAT and FLU.	Feedback on simulation put in place by CRAT and FLU.	Simulations	**Nov. 16 – Jun. 17** M19– M26	**D4.2**

Table 5 - Task 4.3 Tariff Scheme Design Tool

2 From requirements to intelligent functionalities

This section explains which requirements have driven the design of the target functionalities considered in WP4. The target functionalities are the subset of the functionalities addressing the driving requirements and, accordingly, selected as of interest within the work package after a careful analysis of the state of the art and comparison with current both research and commercial similar projects. Here we will refer to main results reported in Deliverable D2.2 in terms of user needs, functional and non-functional requirements, functional modules and system functionalities so as they have been identified and developed in WP2.

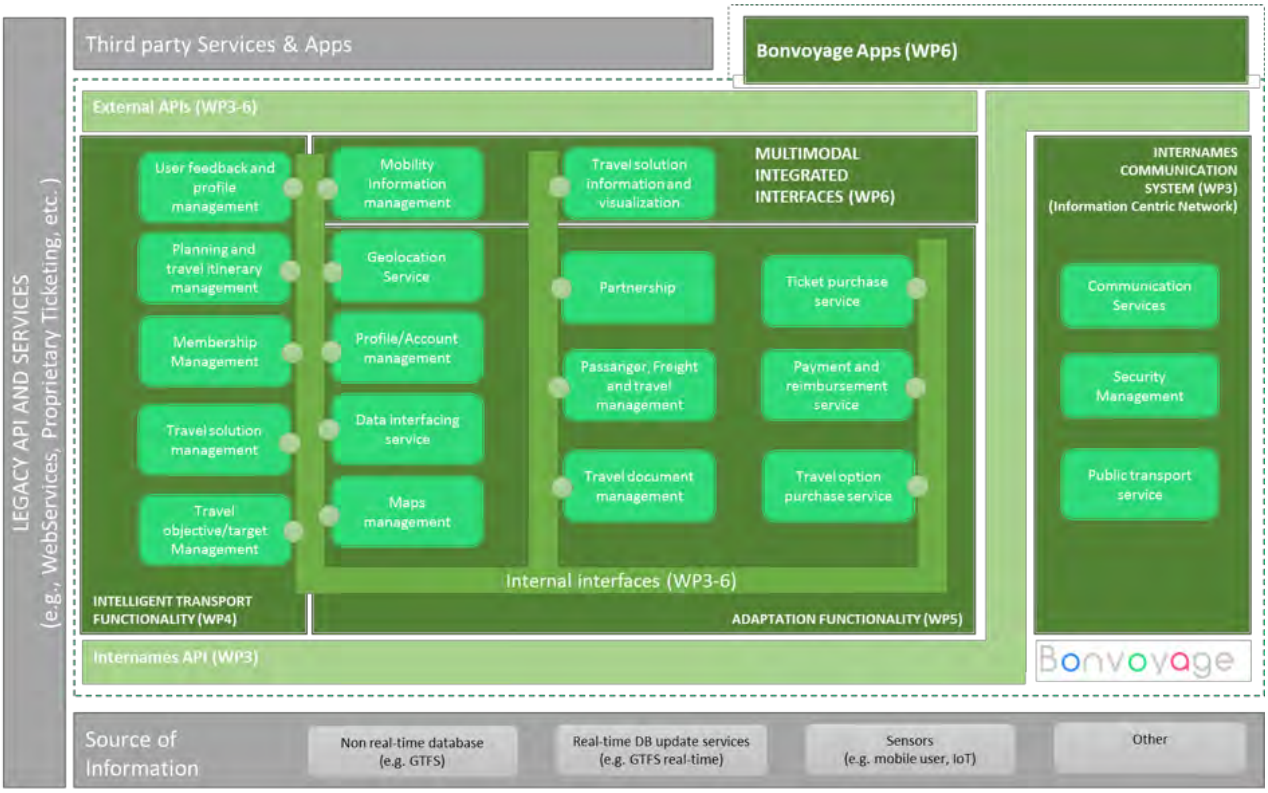


Figure 1 - BONVOYAGE reference architecture

The section is organized according to three tasks in WP4: User profiler tool (Section 2.1), Multi-Objective Optimization Tool (Section 2.2) and Tariff scheme design tool (Section 2.3). Target functionalities are described and analysed from both methodological and functional point of view. State-of-the-art and currently available solutions are summarized and compared with respect the driving requirements in the following sections, respectively Section 4 for as concerns the User profiler tool, Section 5 the Multi-Objective Optimization Tool and Sections 7 and 8 for Tariff Scheme Design Tool. For sake of readability, we report in Figure 1 the *BONVOYAGE reference architecture* so as developed in Task 2.2.

2.1 User Profiler Tool

A number of requirements collected within Task 2.1[1] in the BONVOYAGE project mentioned possibilities and capabilities dealing with personalization of different services that, nowadays, are offered by the most of advanced ITS available on the market.

In particular, in Table 6 the main requirements affecting personalization aspects are identified. After identifying the most important requirements, all partner involved in Task 4.1 selected the logical functionalities and related functional modules, among the ones identified in Task 2.2[1], in charge of offering the set of basic services allowing the BONVOYAGE platform to meet the requirements identified in the project. A considerable effort has been devoted to develop the *concept* behind the BONVOYAGE functional architecture. The target was that of figuring out how the platform will practically meet expectations and needs manifested not only by end users, but also by transport operators, who are considerably interested in extracting useful information about their customers' behaviour and needs as well as in estimating the quality of experience perceived by their customers with respect to offered travel services.

REQUIREMENTS ID	DESCRIPTION	STAKEHOLDER
BU10	Mandatory registration required: Access only with BONVOYAGE credentials (at least in the initial phase - to assess future BONVOYAGE *super partes* that integrates access credentials with other App). 1) Registration required "simple" (only email, password) and authorization to geolocation. 2) Name; Surname (required) + nickname (optional), default preferred language, profile picture (optional) + icon (optional) 3) Adding optional information on user category (few options with ability to click multiple), with the possibility of skipping. Categories will include: Bike lovers; Heavy Vehicles drivers (including both truck drivers as well as bus drivers); Luxury (5 star tourists looking for luxury travel conditions); Backpacker (hostel tourists); Low cost; Families; - Business; Schools (students groups); Eco-friendly (CO2 saving and naturalistic itineraries); Groups (tourists groups); Religious groups (religious tourism); Romantic (romantic travels for couples, scenic tours); Single; Adventure (adventure travels); Disabled travellers (with disabilities - also specifying the kind of disability); Food (wine and food travels); Art and culture (artistic itineraries); Music (itineraries for music events); Sport (itineraries for sporting events); Pregnant; Elderly; Day tripper (one day round trip); Special needs. This information shall be provided according to EU privacy regulation. 4) Adding additional data (e.g., tax code, VAT number) required to make the payment with billing. 5) Possibility to link the account to the social networks (e.g., Gmail).	*Users*
BU251	Possibility for the user to require and receive road side assistance (if necessary) through BONVOYAGE platform. The user can send a request for assistance simply pushing a button on the BONVOYAGE App	*Users*

[1] V. Suraci, L. Ricciardi Celsi, F. Lisi et al., Deliverable 2.2 - BONVOYAGE Architecture, BONVOYAGE Project (2016)

REQUIREMENTS ID	DESCRIPTION	STAKEHOLDER
BU321	Feasible solutions are found and ranked according to selection criteria - The best k solution (with k fixed) are returned - Identification of the preferred solution among the k returned	*Users*
BU960	- Possibility of sending notifications on possible problems the App (e.g.: problems with maps, places missing; feedback if misplaced); - Possibility to send feedback on how to improve the App; - Evaluation of using experience the App (cities, companies of mobility and transport supported by the JPA, information provided from the app, accuracy estimated time of arrival at destination, accurate arrival times for public transport, correct information on location and online, finding points of interest, suggestions).	Users
BU961	- Possibility for the user to insert and share his feedback on the travel solution he obtained for a specific itinerary; - Possibility for users to display feedback on a specific travel itinerary uploaded and shared by other users. Feedback can be provided by the user only if he has concretely experienced a travel solution. Feedback can be provided in two ways: - By the user in a proactive way; - Upon request of BONVOYAGE system (BONVOYAGE sends the user - through email - a request to evaluate his travel experience).	Users
BU970	- Receiving assistance during journey to deliver an opinion and satisfaction degree on development of the trip concerning the overall travel solution and/or each single monomodal step (e.g., during the travel, when a change of vehicle happen; on-line support). - Receiving assistance by activating the function of rescheduling with the possibility of providing a negative feedback if applicable. - Possibility to enable indoor and outdoor maps visualisation (based on requirement BU261).	***Users***
BU980	- Possibility to send requests for help to re-plan trip in case of unforeseen circumstances; - Possibility to receive support to re-plan of the travel itinerary (hint alternative route) - requirement ambitious, through the intervention of a virtual assistance. Virtual assistance can be activated in any moment by the user, except when it acts in a proactive way (as described in requirement BU961). Virtual assistance is always active by default for the heavy vehicles category.	***Users***
BU1370	Once the freight has been delivered, BONVOYAGE platform asks the user to qualify each of the Freight services (quality, reliability, usability, user experience…) providing a feedback on: - Package delivery - Subcontract a driver - Freight Exchange - Optimized route	***Users***
BU1380	Possibility for a transport operator which subcontracted a driver via BONVOYAGE to insert and share a feedback about him and the provided service	***Users***
BU1390	Capability of BONVOYAGE platform to keep track of transports made by a single freight transport operator (both company and single driver) and of related results (e.g., volumes). Freight transport operator features (e.g., number of tracks, past experiences) and feedback are shown as results of the research a user has made on available freight services.	***Users***
BU1400	Possibility for a transport entity, which has already performed the transportation of the available freight found in BONVOYAGE, to insert and share a feedback about the responsible person of the freight	***Users***
BU1410	Possibility for the responsible person of a freight published in BONVOYAGE and which has contracted a Transport Operator via BONVOYAGE to insert and share a feedback about him and the provided service	***Users***

REQUIREMENTS ID	DESCRIPTION	STAKEHOLDER
BSP50	Capability of BONVOYAGE platform to interact with external service providers to provide them customer personal data. [For this requirement, it is necessary to understand if it is compatible with privacy legislation. Besides, data enriches a system like BONVOYAGE, so it shall evaluate if BONVOYAGE data shall be shared with external entities. In any case, this data shall not include user profile data].	Service providers
BT10	Capability of BONVOYAGE platform to manage authorizations for different profiles of system users operating on different channels. [System users refer to transport, travel operators and other service providers connecting to BONVOYAGE platform]	Technology providers
BT20	Capability of BONVOYAGE platform to include a new user travel profile to be used for travel solution research and travel document purchase.	Technology providers
BT30	Capability of BONVOYAGE platform to define rules to grant bonus through the combination of a pre-defined set of parameters/rules.	Technology providers

***Table 6 -** Requirements related to user feedback and profile management*

FUNCTIONALITY NAME AND ID	DESCRIPTION	INPUT PARAMETERS	OUTPUT PARAMETERS	MODULE
UPLOAD_TRAVEL_PROFILE **UPL_TPR**	Update of the user profile based on its last choices (source and destination of the trip)	USER_ID - User Identifier CURRENT_USER_PROFILE - User Profile (Travel Profile) TRIP_PLANNING – From departure location to arrival location	UPDATE_USER_PROFILE- New User Profile Updated	User feedback and profile management
PUT_TRAVEL_CHUNK_USER_FEEDBACK **TCH_UFB**	This functionality allows the end user to insert his feedback on the travel chunk (that is a sub-part of the overall travel solution) he obtained for a specific itinerary; Feedback can be provided by the user only if he has concretely experienced a travel solution.	USER_ID - the user identifier TRAVEL_SOLUTION_ID CATEGORY - the category to which the feedback refers to MOS - a 1 to 5 score to evaluate the feedback COMMENT - a text free string TRAVEL_CHUCK_ID - represents the id of travel solution sub-part [OPTIONAL] CURRENT_USER_PROFILE - current user profile	ACK - True if the feedback has been registered, false otherwise. ERROR - Error message, in case ACK is false.	User feedback and profile management

***Table 7 -** Functionalities related to user feedback and profile management*

2.2 Multi-Objective Optimization Tool

Even if many requirements and functionalities may influence the input and output to and from the optimization engine, we focus here only on those requirements and functionalities with a direct impact on the methods to be implemented within Task 4.2.

Requirement Id	Description	Stakeholder
BU 320	Planning travel solution Settings	User
BU 330	Planning travel solution through filter	User
BU 340	Trip planning and visualisation	User
BU 350	Additional information about the trip	User
BU 360	Search stops and public transport routes	User
BU 370	Travel time calculation (before and during the journey)	User
BU 440	Define searching engine for travel solutions	User

BU 810	Addition of passengers to a pre-identified travel solution.	User
BU 820	Travel Extension: addition of a new travel solution to a pre-identified travel,	User
BU 1320	Modifying the optimized route	User

***Table 8** - Requirements related to trip planning and control*

FUNCTIONALITY ID	DESCRIPTION	INPUT	OUTPUT	MODULE
TRAVEL_SOLUTION_EXTENSION	This functionality, is used to modify a travel solution with additional info regarding the whole travel	The solution to modify, the modified input and all inputs to Function SEARCH_ENGINE.	The best travel solution extending the original solution	Travel solution management
UPDATE_OPTIMIZED_ROUTE	This function allows the user to modify a created optimized route by changing some parameters and recalculating it	The solution to modify, the modified input and all inputs to function SEARCH_ENGINE.	The best travel solution satisfying the new parameters	Travel objective and target management
CALCULATE_TRIP_SOLUTION	This function computes a family of optimal or near-optimal route alternatives from a given origin to one or more destinations. The function takes into account a number of query parameters, user constraints, and user commitments and uses these as constraints in the search. The user objectives are instead combined in the objective function to determine the quality of the solutions. The alternatives returned must be sufficiently different from each other, according to some predefined indicators	All data relevant to the search, depending on the specific user, i.e. origin, destination, user profile, time windows, mode preferences, via point, etc.	A bunch of alternative routes or travel solutions, ranked according to their objective function, satisfying all search criteria	Planning and travel itinerary management
CONTROL_TRIP_SOLUTION	This function receives a set of routes to monitor and the occurring dynamic events and decodes whether one or more such routes are "sufficiently" affected by the events. In which case, it will return a request to the affected user(s) whether to calculate a new set of route alternatives. During the processing phase, monitored routes that are sufficiently affected by the dynamic events are identified: a. Routes that are not possible anymore b. Routes that will be delayed c. Routes that can be improved	The set of routes to monitor, the set of dynamic events	The set of routes to be updated.	Planning and travel itinerary management

***Table 9** - Functionalities related to trip planning and control*

2.3 Tariff Scheme Design Tool

This section provides a detailed overview of the state-of-the-art of functionalities related to the Tariff Scheme and to be implemented within Task 4.3 Tariff Scheme Design Tool**.** Therefore, the present section illustrates requirements and functionalities belonging to the following modules:

- **Membership management**;
- **Travel solution management (only sub-cluster Tariff promotion/modification);**
- **Travel objective/target management**.

Requirements and functionalities are shown, respectively, in Table 10 and Table 11 below.

Based on work performed in subtask 4.3.3 (intelligent functionalities selection, see Section 1.3.2) a distinction has been made between:

- **intelligent functionalities** that will be developed beyond the state-of-the-art;
- **non-intelligent functionalities** that will only be specified.

Identified intelligent functionalities are: SET_SCORE_POLICY and BUILD_PRICE showed in Table 11. For intelligent functionalities, existing "criticalities" (including limits and aspects to be improved) will be highlighted (the "solution" to criticalities and functionality progress will be described in Section 7).

Requirement Id	Description	Stakeholder
BU1000 Score visualisation	Capability of BONVOYAGE platform to allow the user to check his score, with his list of purchases/points earned, and his position in the ranking. Possibility to view the ranking of the other users (general rank and weekly rank) to determine "reliability" user.	User Requirements
BU1010 Award	Capability of BONVOYAGE platform to allow the user to obtain awards (e.g., transports or car-sharing, bike sharing free tickets). Awards proposition to the user will be based on these preferences (where possible). Possibility for the user to receive an award as BONVOYAGE scores from external services providers having a partnership with at least one of the BONVOYAGE partner operators.	User Requirements
BU990 Collecting score	Capability of BONVOYAGE platform to allow the user to gather points/scores based on: - Travel solutions purchased (e.g., based on low environmental impact of the purchased travel solution); - Quantity and type of information mobility shared with other users; - Achievement of objectives. - Possibility to gather scores from external services providers having a partnership with at least one of the BONVOYAGE partner operators.	User Requirements
BU30 Base account definition/setting	In every moment after completion of the initial basic registration, capability of BONVOYAGE platform to allow the user to update his account with the following additional, optional information: - name - mobile phone number - nickname, photo, icon identification - insertion and save of addresses/favourite places - list favourite events/favourite places - fidelity programmes of BONVOYAGE transport operators and service providers (e.g., Star Alliance awards) - age range - employment Account update can be done whenever the user wants to. Information shall be sided by a box explaining why that information is required and how BONVOYAGE will use that information to determine the most suitable solution for the user (e.g., personalised discounts/promotions). In his account page, the user will have the possibility to display fidelity points accumulated.	User Requirements
BU690 Discounts/Promotions	Capability of BONVOYAGE platform to allow the user to visualise discounts/promotions available and buy it. The list of possible promotions shall be ranked according to user profile defined as the commercial profile assigned at the registration moment or the behavioural profile emerged by analysing data about the user and the feedbacks provided.	User Requirements
BU450 Defining objectives to be achieved in a given time interval	Capability of BONVOYAGE platform to allow the user to define a target: calories, emissions, money. Each target reached allows the accumulation score/points (e.g., more heat = more points; less emissions = more points, more money saved = more points). It is a preferential requirement.	User Requirements
BU460 Mission/Travel monitoring	Capability of BONVOYAGE platform to allow the user to track and visualise information on: - progress towards achieving the objectives; - time remaining at the end of the time pre-set for the achievement of. It is a mandatory requirement.	User Requirements
BU470 Mission/Travel cancellation	Capability of BONVOYAGE platform to allow the user to delete the objective (of the mission).	User Requirements

BTIP50 Upload tariff profile offers and promotions	Capability of BONVOYAGE platform to receive from transport operators information on tariff profile, offers and promotions targeting different users and/or internalising negative externalities such as pollution and congestions. BONVOYAGE acquires rules defined by the transport operator for tariffs range to whom offers relate.	Transport information provider requirements
BTIP60 Cancel tariff profile offers and promotions	Capability of BONVOYAGE platform to receive from transport operators instructions on tariffs profile, offers and promotions to be deleted.	Transport information provider requirements
BTIP70 Modify tariff profile offers and promotions	Capability of BONVOYAGE platform to receive from transport operators instructions on tariffs profile, offers and promotions to be modified (according to modifications decided by transport operators), while tracking all the operators involved in the process.	Transport information provider requirements
BTIP80 Define type of pricing (e.g., OD, per km, zone)	Capability of BONVOYAGE platform to receive from transport operators rules to be followed for price building, based on necessary elements for tariffs, offers and promotions definition. All prices modifications shall be validated by the interested transport operator before operating.	Transport information provider requirements
BU1020 Receiving and obtaining promotions/discounts	BONVOYAGE platform gives to the user the possibility to: - receive promotions from the partners of BONVOYAGE, associated with specific classes of users (e.g., over 60); - receive offers from the partners of BONVOYAGE, for sites designated as favourites. - obtain reductions for TLP (e.g., older passengers (over 60) discount). - receive promotions/discounts according to the profile (commercial and/or behavioural) associated to the user; - disable the promotion receptions (through a specific settings functionality); - receive promotions/discounts or buy (at full price) tickets for events (e.g., museums, tourist tours).	User requirements

Table 10 - *Requirements related to membership and tariff scheme management*

Functionality Id	Description	Input parameters	Output parameters	Module
SET_SPL SET_SCORE_POLICY	This function sets the score assignment policy.	SCORE_PL - Score assignment policy (e.g., linear, exponential, etc.).	List of static score assignment rules	Membership management
BLD_PRC BUILD_PRICES	This function designs non-linear tariff schemes for multimodal transport networks to promote dynamically the use of socially desirable mobility services (e.g., those with low environmental impact) and to incentivize the adoption of the most efficient (e.g., in terms of congestion externalities given the load capability) bundle of travel options.	USER_PROFILE - User Profile List of feasible travel solutions (Departure location; Expected departure time, Arrival location, Possible intermediate locations, Special needs, Total travel time (hour, minutes), Travel path (set of uni-modal link(s)), Set of exchange nodes, Number of passengers, Points of interest for the user, Environmental impact (CO2 grams emitted), Contribution to the user pre-defined mission (how many calories the user will burn/how many CO2 grams, Comfort, Heat, Available capacity, Access/Egress Time) UNIMODAL TRAVEL LINK LIST of available discounts and promotions TICKET PRICES LIST - List of existing ticket prices associated to each transport mode and passengers category (provided by a specific transport operator) LIST of available mobility services that can be associated to the travel solution LIST of available leisure/local services that can be associated to the travel solution COMMERCIAL_INFO - Applicable commercial conditions (e.g., refund, compensation) connected with the resolution of transit acquired. LIST of available partners services that can be associated to the travel solution List of SCORE_ID List of SCORE_VALUE List of gifts The PROGRESS of the objective TIME_REMAINING	Table of PRICES	Travel solution management

Table 11 *- Functionalities related to membership and tariff scheme management*

3 Relation inter and intra work packages

3.1 Relation inter work packages

With respect to very high level architecture proposed for the BONVOYAGE platform and reported in Figure 2, the role of WP4 is crucial from the technological point of view and very close to all important WPs in the project.

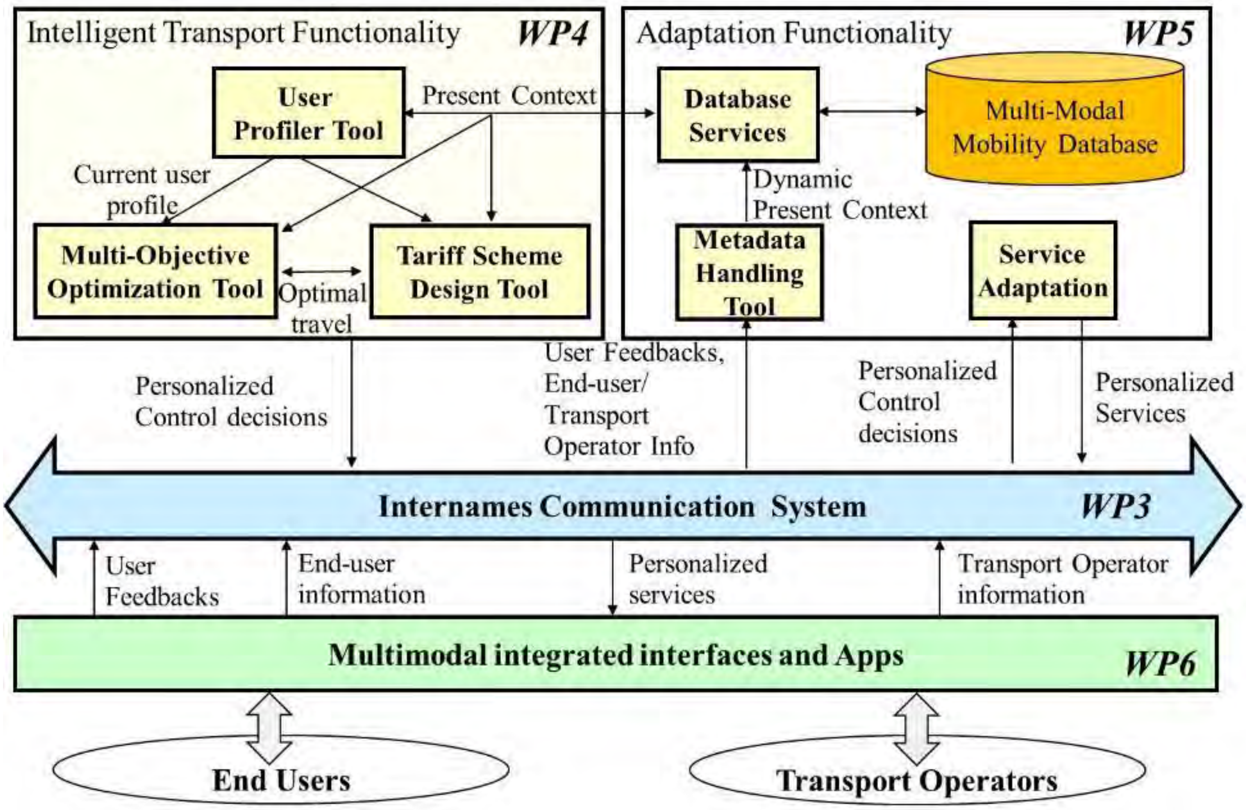


Figure 2 - BONVOYAGE logical scheme

In fact, the work developed within WP4 has a central role in BONVOYAGE, in the sense that it is in charge for developing the most innovative and challenging functionalities to support advanced services offered by the BONVOYAGE platform. Accordingly, WP4 has very strong connection with other technological work packages of the project, as it can be easily seen from Figure 2. In the following the main connections with other WPs are outlines. Please consider that the most of these WPs are still ongoing at M18 and, hence, connections here depicted are still subject to modifications until the end of WP4. In particular,

- WP2 provided fundamental inputs to WP4 for as concerns requirements as well as functionalities and use cases[2], as reported in Section 2 and recalled in several sections dedicated to scientific contributions (e.g., Section 4.1.3).
- WP5 offers functionalities highly coupled with the ones developed in WP4; in fact, data acquired and stored in the Metadata Handling Tool are made available with the "Dynamic Present Context" and then delivered to the WP4 tools as "Present Context"; accordingly, the User Data Model developed within WP4 (see Appendix A) is in line with the data structure of the "Databases services". The definition of "Present Context" covers both data object coming from Metadata Handling Tool and analysed by User Profiler Tool back end side (as detailed in Sections 4.1.2, 4.1.3 and 4.1.4) and data object coming from sensors and analysed by User Profiler Tool front end side (as detailed in Sections 4.2.1.4 and 4.2.2.3). The definition of "Current user profile" covers both data object issued by User Profiler Tool back end side (as detailed in Sections 4.1.3 and 4.1.4) data object issued by User Profiler Tool front end side (as detailed in Sections 4.2.1 and 4.2.2).
- WP6 is in charge for the development of the end user BONVOYAGE Application, strongly coupled with personal information provided by the end users (e.g., User Feedback, End-User travel information); personal information can be captured to enrich the user profile by means of the "Present Context" feeding the User Profiler Tool. Furthermore, the "Personalized Control decisions" computed within WP4, in terms of Candidate Travel Solutions (see Section 5) and User Score (see Section 6.2) are delivered and made available to platform in order to provide personalized services by the end user BONVOYAGE Application. Please consider two important contributions here reported: (*i*) contribution given by Task 6.1 to the Set Score Policy functionality described in Section 6.2.3 and (*ii*) integration of the front-end applications in charge of collecting data for user stress level (see Section 4.2.1) and transportation mode (see Section 4.2.2) assessment in the end user BONVOYAGE Application within Task 6.2.
- All partners involved in WP4 have delivered the main useful information to WP7 to enable the integration; in particular, the main components identified so far in WP7 and developed within WP4 are: User Profiling Tool (front-end), namely UPT-FE, including the user stress level (see Section 4.2.1) and transportation mode (see Section 4.2.2) assessment functionalities developed in Task 4.1; User Profiling Tool (back-end), namely UPT-BE, including the On line User Profiler (see Section 4.1.3) and the Rank Tool (see Section 4.1.4) developed in Task 4.1; Multi-Objective Optimization Tool, namely MOOT, including the Orchestrator (see Section 5.2), the Urban Soloist (see Section 5.3) and the Passenger

[2] V. Suraci, L. Ricciardi Celsi, F. Lisi et al., Deliverable 2.2 - BONVOYAGE Architecture, BONVOYAGE Project (2016)

Aggregator (see Section 5.5) developed in Task 4.2; Tariff-Scheme Design Tool, namely TSDT, including the Set Score Policy functionality (see Section 6.2)developed in Task 4.3.

- As concerns WP8, partners involved in WP4 are very active both in terms of dissemination and of exploitation; in particular, a huge effort by WP4 partners has been made with several different scientific publications. Some of scientific papers reporting the results achieved within WP4 in the reference period M6-M18 are cited in Section 9 (see [1]–[4]). A number of journal papers are expected to be submitted in the very next months in order to publish both methodological and algorithmic contributions (the most of them reported in this deliverable) and experimental results (expected to be reported in deliverable D4.2). We refer to deliverable D8.1 for the project dissemination plan and the complete list of dissemination activities.

3.2 Interdisciplinary functionalities

Besides outer strong connections between WP4 and other technological WPs in the BONVOYAGE project, as explained in Section 3.1, there are very strong inner connections among the three main tools designed and developed in WP4. In order to briefly explain these connections, we will refer to focus on WP4 as depicted in Figure 3.

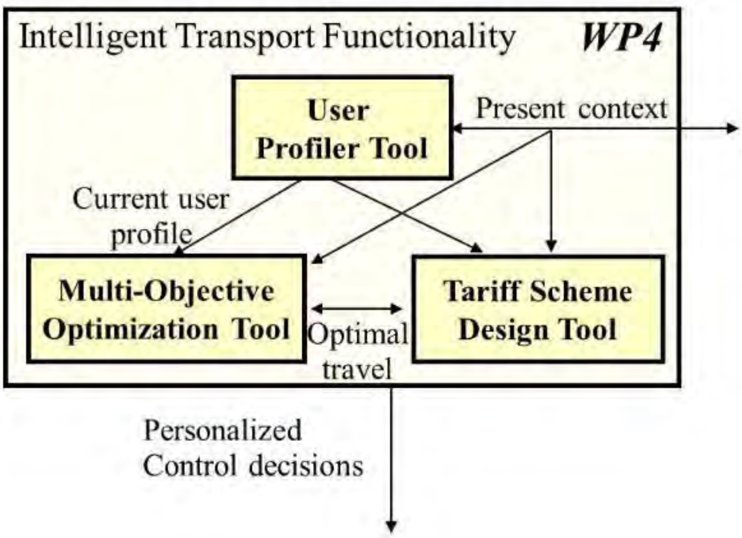


Figure 3 - Inter module relations

3.2.1 User profiler based trip planning

The main idea is that of using the data contained in the so called "Present Context" (according to definition of User Data and User Query given in Sections 4.1.2, 4.1.3 and 4.1.4 and the description of the features detailed in Section 4.2.1.4 and 4.2.2.3) in order to extract useful information about user behaviours in terms of implicit preferences to be taken into account both during the pre-trip planning and the on-trip control. The User Profiler Tool will play the role of controller of the Multi-Objective Optimization Tool in the sense that user profile based driving parameters will be provided to the trip planning and the trip control modules within the Multi-Objective Optimization Tool in order to guide the optimal solution selection process (please see Section 4.1.2). In this sense, the "Current user profile" will provide both data object issued by User Profiler Tool back end side, in terms of User profile based DRIVING PARAMETERS (see Sections 4.1.3) and of User history based DRIVING PARAMETERS (see Section 4.1.4), and data object issued by User Profiler Tool front end side, in terms of User stress level assessment (see Section 4.2.1) and User transportation mode assessment (see Section 4.2.2). The driving parameters extracted from the "Present context" constitute important and useful information extracted by analysing huge amount of data and taken into account to drive the functionalities developed within the Multi-Objective Optimization Tool. In particular, as explained in Section 4.1.3, User profile based DRIVING PARAMETERS provides the Personalized Optimality Criteria driving the Orchestrator (see Section 5.2) as well as specific Soloists (e.g., the Urban Soloist described in Section 5.3) in searching the set of optimal solutions to be provided to user according to his travel query, that is the "Travel Solutions" described in Section 4.1.2 (see Figure 7). Once the set of Travel Solutions has been calculated by the Multi-Objective Optimization Tool, the Travel Solutions are ranked by the Rank Tool (see Section 4.1.4) and returned as "Candidate Travel Solutions" to the user. In this way, the user receives back a list of preferred and ordered travel solutions (preferred according to User profile based DRIVING PARAMETERS and ordered according to User history based DRIVING PARAMETERS). Other important information concerning the user during the trip is extracted by User stress level (see Section 4.2.1) and User transportation mode (see Section 4.2.2). This data will be fundamental in the on-trip phase.

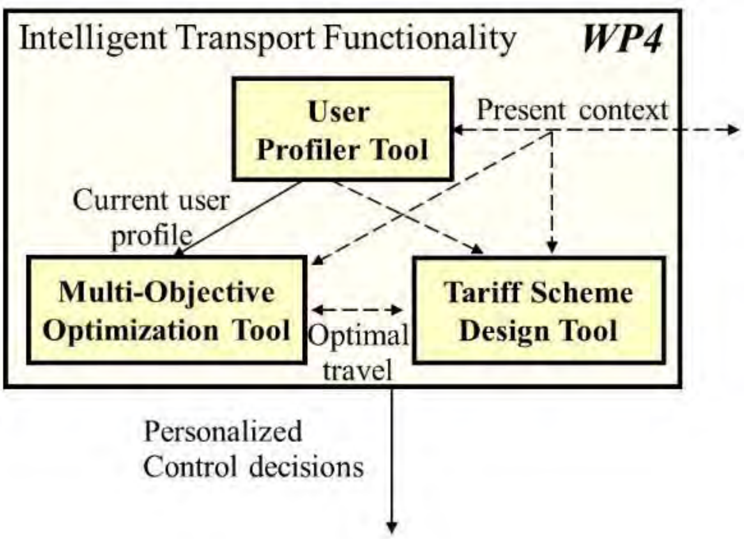


Figure 4 - Inter module relations, focus on Tasks 4.1 and 4.2

3.2.2 *User profiler based travel-centric tariff scheme design*

Similarly, useful information implicitly extracted by analysing data about user travel preferences and constraints would be of a certain interest from the tariff scheme design point of view. In fact, by analysing actual behaviours, the most interesting features from the end user's point of view will be the score policy functionality (see Section 6.2) and tariff scheme design (see Section 7). The connection between the User Profiler Tool and the Tariff Scheme Design Tool is still an open point though preliminary results can be found in Sections 6 and 7.

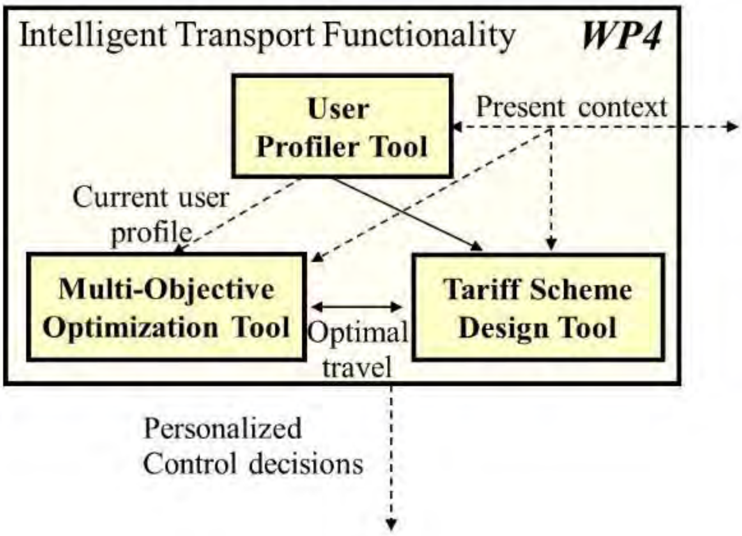


Figure 5 - Inter module relations, focus on Tasks 4.1, 4.2 and 4.3

4 Personalization by user profiling

This section summarizes the research work performed in the field of service personalization in Intelligent Transportation Systems (ITS) within Task 4.1. Personalization in service and customer care is one of the keys to providing services and products being closer and closer to client's expectations. In this respect, the customer experience plays a crucial role for driving service customization and targeted marketing initiatives. Though since the beginning considered a topic characterizing management science barely, in the last decade many fields in engineering have been more and more deeply interested in the technical, quantitative aspects behind the fulfilment of user's expectations with respect to general services, with particular attention to those offered by service network connecting huge amount of users, e.g., TLC networks. For as concerns transportation systems, recently decision making support systems have been conceived and developed on the adoption of suitable recommendation systems for transportation environment. Some of these recommendation systems rely on the availability of some user feedback and perform user experience analysis based on (i) the user behaviour and (ii) the present context.

In this respect, there are two user centric, fully data driven approaches adopted in the BONVOYAGE project. The former aims at identifying specific, user profile based travel preferences in order to drive the Multi-Objective Optimization Tool (MOT) and the Tariff scheme design tool (TDT), both in the pre-trip and on-trip phase, as mentioned in Section 4. The latter relies on data coming from general purpose sensors and here used in order to extract useful information about the user stress level and actual transportation mode during the travel (on-trip phase). The section is organized as follows.

Section 4.1 reports (i) the basic concepts and ideas for actual development within Task 4.1, coming from scientific literature and reference market; (ii) the preliminary results obtained in terms of beyond state of the art from the methodological and architectural point of view. Moreover, this section reports the main methods and algorithms for user feedback based user profiling. In particular, Sections 4.1.3 and 4.1.4 explain the role of user feedback provided explicitly by the user. This contribution is mainly due to CRAT within Task 4.1.

Section 4.2 is fully dedicated to sensor based user profiling aiming at providing accurate and reliable estimation of the user stress level experienced by the user on trip and the actual transportation mode used by the user on trip. This contribution is mainly due to CEA within Task 4.1.

4.1 Personalization in BONVOYAGE by user feedback

In this section, we present the reference scientific framework concerning data driven personalization in ITSs. The presentation is given from a twofold perspective. From one side, the focus is on methodologies proposed in literature and partially implemented in commercial applications (reported in Section 4.1.1). From the other side, we analyse what is still missing and how advanced ICT framework can favour new services in ITS (reported in Section 4.1.2), with particular attention to the innovative contributions given by BONVOYAGE. Sections 4.1.3 and 4.1.4 provide the original material for understanding the main algorithms and services developed within Task 4.1 User Profiler Tool in order to support the advancements illustrated in Section 5.1.2.

4.1.1 State of the art

In [5] a real world application is described where a PErsonalized mobile CIty Transport Advisory System (*PECITAS*) is designed, implemented and tested for both citizens and guests of the city of Bolzano [6], in northern Italy. The optimal routing problem in transit network[3] is presented as a

[3] A transportation network where more than one transport mean is allowed simultaneously (e.g., bus, metro, car, etc.)

personalization depending service. The two dimensions of personalization are the user's preferences, explicitly pointed out by the user, and the user profile, namely a behavioural profile indicating specific objectives and additional constraints to be considered in the optimal routing problem. The user's preferences are expressed with respect to walking, bus changes, arrival at destination and sightseeing, while the so called "travel profiles" have been categorized in five static types, decided a priori according to past experience.

In [7], starting from the idea that the available appropriate information, according to the user's preferences, might be null in consideration of the first interaction between the user and the system, in order to collect the relevant and appropriate information for this "unknown" new user, it might be used the collaborative or social filtering based on a similarity among users. They introduced the multi-criteria decision-making with a method based on partial aggregation category inspired to the known ELECTRE. The considered criteria include price, duration, distance, etc. They introduced the ELECTRE method with their implementation/approach: (i) User Profile and (ii) Personalization Multi Criteria Method. The validation of its proposal approach aims at searching suitable itinerary from a given point "A" to a given point "B" in a multi-modal network basing on a certain criteria of selection (cost, distance, trip duration and walk). The paper shows that the precision of the pertinent solutions increases with an elevated number of requests, since the system learn better the user's preferences.

In [8] a Model Driven Architecture (MDA) approach is introduced to address the problem of generating personalized user interface. In order to achieve this goal, they explicitly define a context model mapped to a specific domain ontology that captures the knowledge of an application domain. Roughly speaking, the proposed approach takes into account content personalization in the interactive applications (mapping information in real time) and outlines a method to generate UIML (User Interface Markup Language) code that could be rendered in order to produce a final interface for specific platforms.

In [9] the authors presented an approach for personalization in journey search in order to manage urban movements of specific travel category (e.g., freight), aimed to reduce the congestion in transport system. Such approach provided integration among ontology concept, multi-criteria technique and Case Base Reasoning (CBR). The combination between ontology and CBR system provides the possibility to overcome information retrieval problem obtaining several advantages as efficient and interactive information search operation. In the proposed approach, a new source of external knowledge is considered, so to obtain a process of personalization with a method based on SWRL rules. The combined use of these two techniques (ontology and CBR tool) is aimed to support the Web Ontology Language (OWL) and rules by Semantic Web Rule Language (SWRL) for a better process of personalization.

In [10] a Multi-Agent Personalized Information System (MAPIS) is introduced to address the problem of providing personalized information for customized solutions to individual user requests. The main contribution is the multi-agent system provided with a sort of social abilities that might be capable to offer each user personalized information based on the interaction among users. MAPIS can be viewed as distributed entities. The system shares information and task coordination and is integrated in a pre-trip travel information system named AgenPerso, by obtaining personalization information for multimodal transportation.

In [11] a framework for personalized multimodal travel information is presented where the system is in charge of learning the user's preferences and of monitoring the user's activity patterns. The system provides a personalized routing service based on the real-time public transport information. Once the user provides the system with a list of activities to plan for a specific day, the system advices the user by pointing out the optimal sequences of activities as well as associated travel plans. The system supplies the travel plan by multimodal transportation vehicles (e.g., private car, public transportation, etc.) that might include up to several switches. During the travel, the users can accept or reject advices, so that the system can learn user's preferences and can adjust the user profiles.

In [12] an approximation method based on Bayesian inferences is introduced in order to realize a traveller information system. The system learns the users' preferences incrementally, by capturing the experience of the user using the system and by monitoring every single choice made by the user. The mechanism behind the system consists on the user's choices ("beliefs"), when planning a travel. Every user's choice is then used by the system in order to identify future and more personal advice.

From a completely different point of view but keeping in mind the most recent advancements in personalization for the so called Future Internet, a cognitive approach concerning the personalization by suitable identification of the driving parameters is introduced in [13]. In this respect, the concepts of Future Internet (FI) and Quality of Experience ([14] can be highly brought back and adopted within ITS, in particular using the Quality of Experience Control (see [15] and [16]), in order (i) to identify specific driving parameters to control the journey planning service in the pre-trip phase (see Section 4.1.2); (ii) to extract useful information in terms of user profiles (see Sections 4.1.3 and 4.1.4); (iii) to control the user Quality of Experience during travel.

During our research activities, several different projects, both research and commercial projects, have been investigated concerning methodologies and technologies offering added value services in ITS. Among them, we cite the EU Mobis[4] project and the Rome2Rio service platform[5].

[4] http://www.mobis-euproject.eu

[5] http://www.rome2rio.com

4.1.2 Beyond the state of art and contributions gathered within BONVOYAGE

In this section, we summarize the contributions given by partners involved in Task 4.1 with respect to the state of art reported in Section 4.1.1.

With respect to personalization of the services offered by ITS, in the BONVOYAGE project we propose a *User Profiler Tool* (UPT) whose key difference, with respect to previous control and/or learning based approaches for ITS (see Section 4.1.1), consists in *jointly* taking into account the user request submitted to the MOT module and the actual choice carried out by the user as one or more *Candidate Travel Solutions* are returned (namely, the user feedback, see Section 4.1.3 and 4.1.4). As a matter of fact, these choices are elaborated by UPT in order to refine the user behavioural profiling and eventually producing the so-called *Personalized Optimality Criteria* which drive MOT to provide personalized travel solutions representing the *Personalized Control Decisions* as explained in Sections 4.1.3[6] and 4.1.4. UPT is expected to *extends* traditional ITS functionalities by automatically learning user preferences from the user implicit behaviour in terms of interaction with the BONVOYAGE platform, even in the case the user preferences are in contrast with the ones explicitly declared.

The core of UPT is the *User Centric Control System* (UCCS) consisting of a control system explained in this section. In this perspective, we consider the following outer elements interfacing with UPT:

- **User**: private traveller, possibly member of a group of travellers, with or without owned transportation mean;
- **Transport operators**: private and public, individual and collective transportation service provider;
- **User Query**: elementary query in the interaction between the user and the BONVOYAGE platform;
- **Candidate Travel Solution**(s) returned by the journey planning service running in the MOT.

In a very schematic representation, the actors User and Transport operators interact with the MOT by means of a generic, service independent, User Query. MOT returns a Travel Solution (or a family of Travel Solutions) for each User Query. We name the Travel Solutions "Candidate Travel Solution" in order to stress the fact that these travel solutions are tailored on the user's preferences (according to some user profile) and are ranked (according to past history of user's selections) so that the highest candidate travel solutions are the most likely preferred ones.

With respect to this basic interaction, we introduce UCCS in terms of a control system of the process involving the User and the BONVOYAGE MOT, as illustrated in Figure 6. UCCS consists of the following main modules:

[6] Part of the work reported in this section has been accepted as scientific publication ([1]).

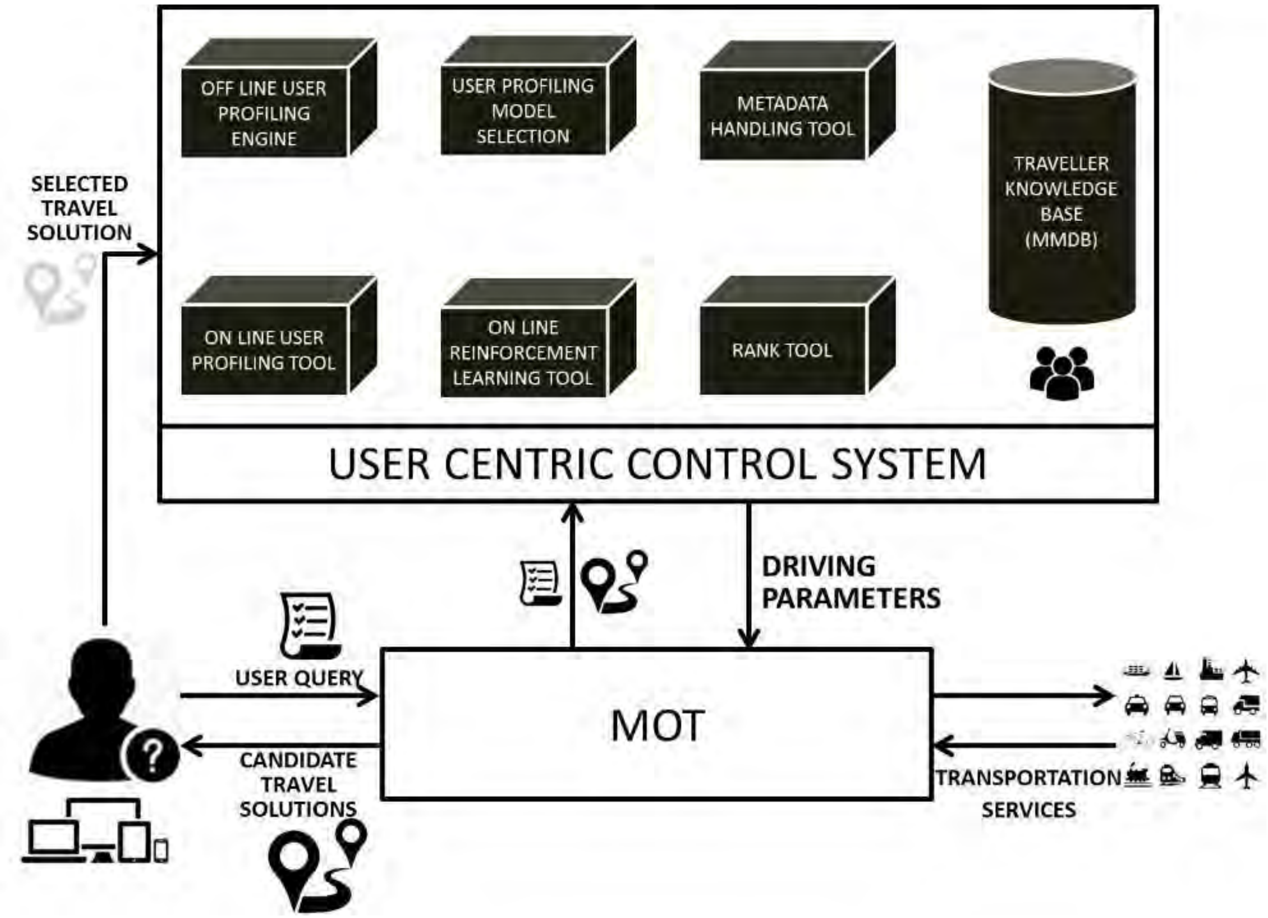


Figure 6 - Multi-Objective Optimization Tool (MOT) and User Centric Control System (UCCS)

- *User profile* based personalization modules (described in Section 4.1.3, [1]), namely:
  - **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 belonging to that specific user profile.
- *User history* based personalization module (described in Section 4.1.4), namely:
  - **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.
- **Travel Knowledge Base** represented by a portion of the Multimodal Mobility Data Base (MMDB) developed in the BONVOYAGE platform within WP5 (Task 5.1), consists of all data managed by the Metadata Handling Tool and analysed by the Off line User Profiling Tool and the On line Reinforcement Learning Tool.
- **Metadata Handling Tool** is the family of inner software interfaces for (i) switching the messages and data that come from other functional modules, external to the user profile and user history based personalization modules, and (ii) remodelling some data for further uses.

As explained in WP2 (Task 2.2, see Section 6.2.5 of [17]), the Metadata Handling Tool is the component using Internames to get dynamic information from transport operators. This information changes in a very dynamic environment and is provided in a specific format by stakeholders and transport operators (e.g., public data sources, like road traffic dynamic data, public transport stops and schedules, charging points for electric vehicles, and so on). Besides providing external software interfaces, this component offers a family of inner interfaces managing different data format and orchestrating the User profile and User history based personalization modules.

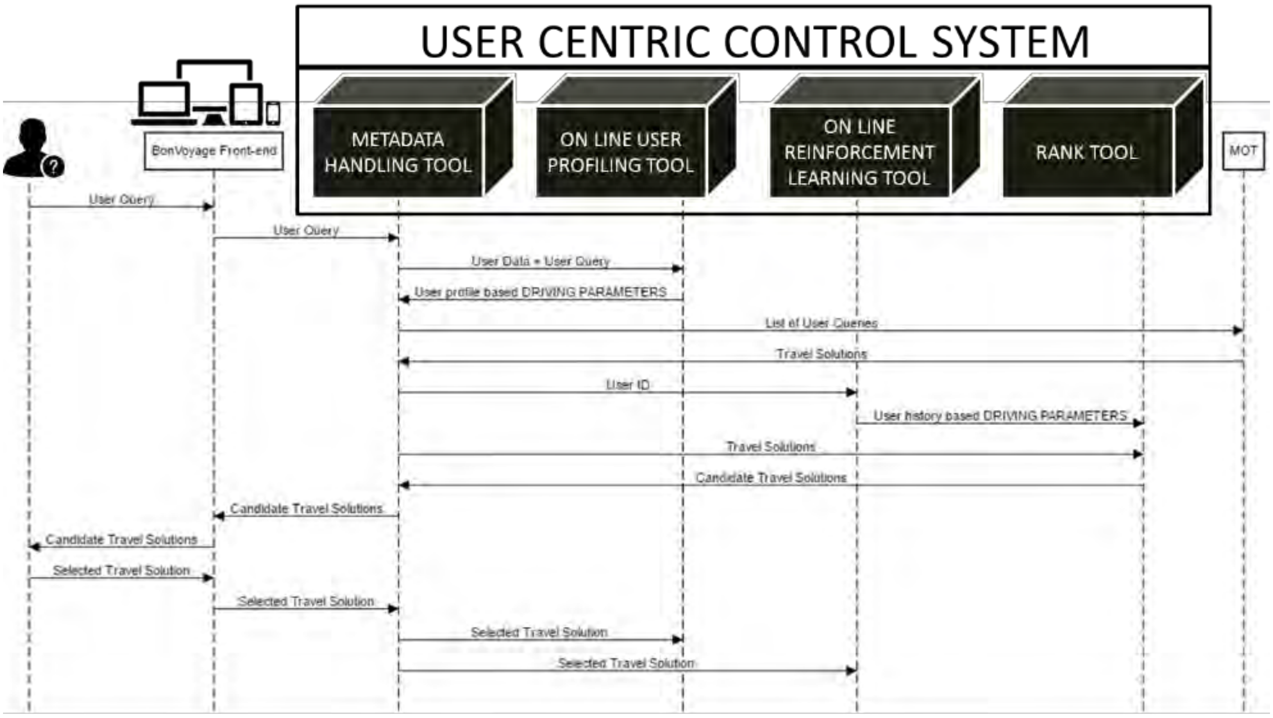


Figure 7 - UCCS and MOT - Message Sequence Chart

Since the algorithmic description of the procedures designed within the *User profile* based and *User history* based personalization modules can be of difficult readability, we report in Table 12 the complete list of symbols adopted in the rest of this section.

Symbol	***Description***	***Type***
u	User identifier	Integer
a	Source Location	GPS
b	Destination Location	GPS
t_a	Begin travel time	Integer
y(u)	Year of birth of user *u*	Integer
g(u)	Gender of user *u*	Boolean
TC(u)	Travel category declared by user *u*	$\{0,1\}^T$
UD(u)	User Data of user *u*	
UC(u,a,b,ta)	Owned transport means (Yes or No)	Boolean
	Fidelity Program (Owned or not)	Boolean
	Reasons for Travelling (Business or Other)	Boolean
	Number of passengers	Integer
	Maximum number of transit nodes	Integer
	Requested return (Yes or no)	Boolean
	Vector of allowed types of transport mean	$\{0,1\}^M$
	Preferred class category	Integer
	Maximum allowed overall price	Real

	Allowed total travel time (in seconds)	Integer
	Vector of special travel requests	$\{0,1\}^S$
UP(u,a,b,ta)	Minimize the overall *travel time*	Boolean
	Minimize the overall *travel cost*	Boolean
	Maximize *comfort level*	Boolean
	Maximize the *class category*	Boolean
	Minimize *CO_2 emissions*	Boolean
	Minimize the number of *transit nodes*	Boolean
	Minimize the *walking distance*	Boolean
	Minimize the number of distinct *modality means*	Boolean
Q(u)	User query	Vector
POC(*Q*(*u*))	Personalized Optimality Criteria for *Q*(*u*))	$\{0,1\}^P$
ocr(*s**(*Q*(*u*)))	Optimality Criterion explicitly selected by user *u*	$\{0,1\}^P$
f_i	Individual users' travel features	Vector
c_j	Individual components for each feature	Vector

Table 12 - List of symbols within Sections 4.1.3 and 4.1.4

4.1.3 Clustering based user profiling

As explained in Section 4.1.1, many personalization approaches proposed in ITS services for mobility takes into account data analysis based approach. In the most of cases, user feedback about ITS services is only partially, and *a posteriori*, taken into account off-line and in supervised way. In this section, we explain how the UPT will allow for actual service personalization by closing the loop between the end user and the BONVOYAGE platform. The complete description of the reference framework and main methods have been published as results of the BONVOYAGE project in the scientific paper [1].

With reference to Figure 6, we depict a cognitive scenario offering advanced features with respect to current trip planning services. Just for presentation purpose, we consider an ideal ITS integrating the so-called *Advanced Travel Information System* (ATIS) and the MOT playing the role of journey planner. The main task of ATIS is that of setting up and keeping updated the transportation network model, according to specific features of distinct layer of transportation means (railway, airway, etc.). Typically, Transport Operators directly provide real-time mobility data. In what follows, we assume that *U* users (*i*) registered themselves in ITS platform and (*ii*) have subscribed the trip planning service. User *u* submits a travel request to ITS whenever *u* needs to plan a *door-to-door* travel from a specific source location *a* to a target destination *b*. We indicate by $d_0(a,b)$ the Euclidean distance between two dimensional vectors of GPS coordinates corresponding to physical locations *a* and *b*. We assume that *u* can indicate a time t_a for travel to begin. Additionally, *u* is expected to provide a set of constraints, like specific special needs, allowed transportation means or simply the number of people travelling with *u*[7]. We denote this set as the family of *User Constraints* and indicate by $UC(u,a,b,t_a)$ since constraints are specific for the travel from *a* to *b* starting at time t_a. Moreover, we assume that user *u* can indicate an explicit set $UP(u,a,b,t_a)$ of *User Preference Criteria* about the desired travel. As customary in current trip planning services, the set $UP(u,a,b,t_a)$ typically contains one preference criterion and is used to explicitly guide the MOT in proposing the most suitable travel solutions. In [1] we proposed a set of eight reference preference criteria representing just a particular subset of a general set of *Optimality Criteria,* that we denote by $OCR = \{oc_1,...,oc_P\}$ of cardinality *P*.

User Query $Q_i(u)= (u,a,b,t_a,UC,UP)$ is the *i*-th query submitted by user *u* planning a travel from *a* to *b* starting at time t_a by satisfying User Constraints $UC(u,a,b,t_a)$ and by optimizing according to User Preference Criteria $UP(u,a,b,t_a)$. The MOT returns a travel solution $s(Q(u))$ in line with query $Q(u)$: we denote each travel solution by $s(Q(u))$. We will refer to $s(Q(u))$ as Travel Solution, in the sense that $s(Q(u))$ is a travel solution that can be chosen by user *u*.

Because of processing time and resource constraints, MOT cannot consider all possible Optimality Criteria in $\{oc_1,...,oc_P\}$, even in the case *P* is very low. Alternatively, MOT can select a suitably selected subset of $\{oc_1,...,oc_P\}$ including, sometimes only, $UP(u,a,b,t_a)$. With respect to Figure 6, we can consider two distinct working modes: the *Basic Mode* and the *Cognitive Mode*. Both working modes allow each user *u* to submit a query $Q(u)$ in the pre-trip phase to the MOT and request the MOT to select and to return a family of Candidate Travel Solutions for user *u*. The MOT performs such selection on the basis of $Q(u)$ and information provided by Transport Operators according to mobility information. The Basic Mode, differently from the Cognitive Mode, does not make use of the User Centric Control System (UCCS). Conversely, the Cognitive Mode makes use of the UCCS including five fundamental functionalities being in charge for the actual personalization of mobility services: (*i*) the *Off Line User Profile Engine* functionality, strictly cooperating with (*ii*) the *User Profiling Model Selection*; (*iii*) the On Line *User Profiling* functionality providing real time information about the actual behavioural profile assigned to user *u*; (*iv*) the *On Line Reinforcement Learning* functionality controlling the *Rank Tool*. Functionalities (*i*)-(*iii*) are described in the remaining of the section, while functionality (*iv*)-(*v*) are described in Section 4.1.4.

With reference to Figure 7, in the Cognitive Mode User Query $Q(u)$ is forwarded to UCCS. The Metadata Handling Tool enriches $Q(u)$ with User Data. In BONVOYAGE the only user data analysed by UTP are: user's year of birth $y(u)$ of *u*, user gender $g(u)$, travel categories $TC(u)$ selected by user *u* at the registration time. In BOVOYAGE, user can select a subset of travel

[7] We refer here to the work concerning the BONVOYAGE functionality definition, as carried out in WP2, Task 2.2, and reported in D2.2. See also Table 9 (functionality CALCULATE_TRIP_SOLUTION)

categories[8] in the following domain: Bike lover, Heavy vehicle driver, Luxury, Backpacker, Low cost, Family, Business, School, Eco-friendly, Group, Religious, Romantic, Single, Adventure travel, Disable traveller, Food lover, Art and culture fan, Music fan, Sport lover, Pregnant, Elderly, Day commuter, No travel category.

The Metadata Handling Tool provides the On Line User Profiling Tool with a vector, composed by User Data $UD(u)=\{y(u), g(u), TC(u)\}$ and by User Query $Q(u)$. The On Line User Profiling Tool identifies, in real-time, the User Profile $prl(u)$ which user u belongs to in the set of k possible User Profiles. The identification of optimal k and, accordingly, the optimal partition of travellers in the Traveller Knowledge Base in k profiles is the machine learning task demanded, off line, to the Off Line User Profiling Engine. Then the On Line User Profiling Tool identifies, via the $prs(prl_k)$ function when $prl_k = prl(u)$, the *Personalized Optimality Criteria* $POC(Q(u))$, associated to the User Profile $prl(u)$. In order to do that, the On Line User Profiling Tool associates the User Profile $prl(u)$ the most representative optimality criteria in the group of travellers sharing the same User Profile with user u. Roughly speaking, the On Line User Profiling Tool generalizes in the optimality criteria, in the sense that it associates to user u the optimality criteria selected by the travellers being closer (more similar) to u. In fact, in each group of homogeneous travellers, the presence of the most representative optimality criteria provides a natural ordering over the family all possible Optimality Criteria in $\{oc_1,...,oc_P\}$. The On Line User Profiling Tool associates this natural ordering to each user u and provides Metadata Handling Tool with a family of weights (one for each Optimality Criteria) measuring the relevance of the Optimality Criteria in the User Profile $prl(u)$. We refer to these weights as the User Profile based DRIVING PARAMETERS and denote them by $\{ow_1,...,ow_P\}$. The On Line User Profiling Tool returns these parameters to the Metadata Handling Tool. Please consider that the profiling based association is performed on the basis of user u and User Query $Q(u)$. Therefore, one user u can be profiled in distinct ways depending to distinct User Queries $Q_1(u)$,…, $Q_z(u)$.

The User Profile based DRIVING PARAMETERS $\{ow_1,...,ow_P\}$ are then used in order to properly control the trip planner in proving suitable, personalized travel solutions. With reference to Figure 7, the Metadata Handling Tool provides the MOT with List of User Queries. Basically, this list consists of (*i*) the User Query $Q(u)$ requested by the user and (*ii*) the User Query $Q(u)$ where the User Constraints $UP(u,a,b,t_a)$ are replaced by the optimality criteria weighted according to the User Profile based DRIVING PARAMETERS $\{ow_1,...,ow_P\}$ related to of the User Profiler $prl(u)$. Then, MOT calculates the family of Travel Solutions with respect to not only the *explicit* User Preference Criteria $UP(u,a,b,t_a)$ (as in the Basic Scenario), but also to the *implicit* User Profile based DRIVING PARAMETERS $\{ow_1,...,ow_P\}$. In this sense, MOT considers both preferences

[8] We refer here to the work concerning the BONVOYAGE system requirement definition, as carried out in WP2, Task 2.1, and reported in D2.2. See also Table 6 in Section 2.1 (requirement ID BU10).

explicitly indicated by user *u* in *Q*(*u*) and the optimality criteria selected by the UCCS as User Profile based preferences *implicitly* inducted by the machine learning based approach. The family of Travel Solutions is returned to Metadata Handling Tool. As explained in Section 4.1.4, the Metadata Handling Tool asks the Rank Tool to order the Travel Solutions provided by MOT and return the (ordered) Candidate Travel Solutions to user *u*. At this point, if user u selects one travel solutions in the set of Candidate Travel Solutions, we denote by $s^*(Q(u))$ the Selected Travel Solution, that is returned to the Metadata Handling Tool by the BONVOYAGE Front-end. Please consider that this a key, distinctive features of the BONVOYAGE platform with respect to current ITS, since the selection operated by user *u* is received by UCCS as the actual, *explicit* user feedback with respect to the set of proposed Candidate Travel Solution. This information is analysed by UCCS in order to improve the performance in the personalization process, as described in the remaining of this section and in Section 4.1.4.

With respect to the functionalities identified in Section 2 (see Section 2.1 and 2.2), the User profile based personalization modules described in this section as part of the UCCS allow for a complete profile based personalization of the functionality CALCULATE_TRIP_SOLUTION (see Table 9). In fact, the User profile based Driving Parameters provides the exact weights related to different optimality criteria considered in the functionality CALCULATE_TRIP_SOLUTION, besides the ones explicitly indicated by the user $UP(u,a,b,t_a)$. In this sense, we consider that the UCCS allows MOT to provide more detailed, personalized travel solutions, since the identification of optimal trip is driven by the analysis of Traveller Knowledge Base incrementally gathered by the BONVOYAGE platform. The methodological and algorithmic framework developed UCCS has been partially published in 2016 [1] while additional two journal papers are in preparation and will be submitted in the next weeks.

Off line User Profile Engine

Our main goal is defining the most suitable number *k* of User Profiles with respect to the Traveller Knowledge Base. Each User Profile describes a general, but recurrent, *pattern* of user behaviours. In particular, we are interested in characterizing each User Profile by the one travel solution effectively selected by users sharing the same User Profile when choosing one among a number of possible Candidate Travel Solutions (for a complete definition of Candidate Travel Solution, please refer to Section 4.1.4). More in general, in the Traveller Knowledge Base we consider a pattern characterized by the possible users' travel choices, preferences, and optimality criteria. Each interaction between users and UCCS (see Figure 7) provides useful data that can be automatically acquired and stored in the Traveller Knowledge Base.

The Off line User Profile Engine performs cluster analysis on data consisting of User Data $UD(u)=\{y(u), g(u), TC(u)\}$ and User Query $Q_i(u)= (u,a,b,ta,UC,UP)$. From now on, we denote by

$$UQ_i(u) := <UD(u), Q_i(u)>$$

the vector of User Data $UD(u)$ and i-th User Query $Q_i(u)$ as defined at the beginning of the section. The Traveller Knowledge Base stores data in the form $UQ_i(u)$ and, for each $UQ_i(u)$), the User Feedback $ocr(s^*(Q_i(u)))$ is stored as the optimality criterion of the one Candidate Travel Solution actually selected by user u after submitting the User Query $UQ_i(u)$. The cluster analysis is performed by a partitional data clustering algorithm returning a partition set of the Traveller Knowledge Base's queries $UQ_i(u)$. In this respect, several partitional clustering algorithms, both supervised and unsupervised algorithms, have been proposed in literature, and some of them are designed for numerical attributes or for mixed attributes. We adopt the well-known k-means algorithm [18], a very efficient though heuristic unsupervised machine learning algorithm. The algorithm returns k clusters (or partitions) of non-overlapping, homogeneous user queries $UQ_i(u)$ by minimizing a homogeneity criterion, namely the Within-Cluster Sum of Squares (WCSS) of the partition, given by the summation of the intra-cluster distance of each cluster. The intra-cluster distance of a cluster C_j is defined as the squared sum of the Euclidean distance of each $UQ_i(u)$ and the centroid c_j of the cluster C_j. The k-means algorithm strengths include ease and high scalability. However, it has two major drawbacks: (*i*) the number k of clusters must be known *a priori* and (*ii*) the solution algorithm is a heuristic and, accordingly, the method is very sensitive to the provided initial solution. Both the issues will be discussed in the paragraph dedicated to User Profiling Model Selection.

Given a number k of clusters, the k-means algorithm provided k User Profiles minimizing the WCSS criterion. They are stored in the Traveller Knowledge Base as well as the User Queries $UQ_i(u)$. Each cluster C_j is identified by its centroid c_j, defined as the mean point amongst the User Queries $UQ_i(u)$ assigned to cluster C_j. Since a record in the Travel Knowledge Base includes the User Query $UQ_i(u)$ as well as the User Feedback $ocr(s^*(Q_i(u)))$, it is possible evaluating two statistical measures of the homogeneity of the set of k User Profiles returned by the k-means algorithm: precision and recall. In the case of the Travel Knowledge Base, the *precision of cluster* C_j with respect to optimality criterion oc_v in $\{oc_1,...,oc_P\}$ is defined as the ratio between the number of $UQ_i(u)$ in C_j that actually selected the optimality criterion oc_v (i.e., oc_v is in $ocr(s^*(Q_i(u)))$ with $UQ_i(u)$ in C_j) and the total number of $UQ_i(u)$ in C_j. The *recall of cluster* C_j with respect to optimality criterion oc_v in $\{oc_1,...,oc_P\}$ is defined as the ratio between the number of $UQ_i(u)$ in C_j that actually selected the optimality criterion oc_v (i.e., oc_v is in $ocr(s^*(Q_i(u)))$ with $UQ_i(u)$ in C_j) and the total number of $UQ_i(u)$ in the Travel Knowledge Base that actually selected the optimality criterion oc_v (i.e., oc_v is in $ocr(s^*(Q_i(u)))$ with $UQ_i(u)$ in the Travel Knowledge Base).

In this Project, we compared a MapReduce approach and a Spark implementation of the k-means algorithm in order to boost efficiency. Preliminary experimental results conducted on large scale data sets show that Spark implementation is more performant than the MapReduce approach.

The complete report of the experimental results will be detailed in Deliverable D4.2. In order to assess the effectiveness of the proposed approach, the Traveller Knowledge Base we consider for the assessment has been provided by the knowledge base collected by the BONVOYAGE consortium by promoting the BONVOYAGE Questionnaire (see Appendix B) among different social and professional network. Over a family of more than 350 questionnaires, we consider a subset of the Traveller Knowledge Base as the training set (326 instances) and the remaining as the test set (26 instances). Therefore we applied the k-means implementation in the Off line User Profile Engine generating the optimal user profiles identification (supported by the User Profiling Model Selection too, see next paragraph) and the On line User Profiling validating the identified user profiles on the test set.

User Profiling Model Selection

As introduced in the previous paragraph, the two major drawbacks of *k*-means algorithm are the initial centroids selection and the optimal value of parameter *k*, known and provided a priori. A careful seeds selection can be carried out by means of the *k*-means++ algorithm, whose parallel implementation is also built-in in Spark. The Offline User Profile Engine runs independently, in background, in the BONVOYAGE platform. From one run to the following, as more and more User Queries $UQ_i(u)$ are gathered and collected in the Travel Knowledge Base, as well as the User Feedback ($ocr(s^*(Q_i(u)))$), the optimal value of parameter *k* can as well change. In fact, the number of User Profiles depends on the Travel Knowledge Base. Therefore, a model selection phase is important and is to be applied preliminarily with every run of the algorithm.

The model selection phase revolves around the Elbow Plot heuristic [19] this method consists in plotting the WCSS as function of number of clusters, i.e. as the value of parameter *k* increases. The optimal value of parameter *k* is where an *elbow* appears in plot, meaning that introducing an additional cluster (i.e., $k: = k+1$) would not improve data modelling in terms of homogeneity of data partition. This heuristic approach has the major drawback that, depending on the dataset at hand, sometimes an elbow cannot be clearly identified. That is the reason why we allow the User Profiling Model Selection adopting the first order derivative of WCSS and considers a first order criterion to select the elbow in the case it is not so clearly shaped in the natural plot. In this sense, the User Profiling Model Selection controls the Off line User Profiling Engine and collects the value of the Elbow Plot by recalling the *k*-means algorithm several times in order to select the best value of parameter *k* by applying the first order criterion.

Preliminary results show that for the Traveller Knowledge Base collected so far by means of the BONVOYAGE Questionnaire (please see Appendix B), the optimal number of User Profiles according to the Elbow Plot heuristic is between 6 and 8.

On line User Profiling

The two major functions offered by the On line User Profiling are: *prl* and *prs*. The former is defined as *prl*: $u \rightarrow \{prl_1, ..., prl_k\}$ and assigns each user *u* the User Profile *prl*(*u*) in the set of *k* User Profiles identified by the Off line User Profile Engine supported by User Profiling Model Selection. This function simply evaluates the Euclidean distance (the same adopted in the WCSS) between the User Query *UQ*(*u*) provided by u and the centroids $\{c_1,...,c_k\}$ of the clusters $C_1,...,C_k$, so as returned by the Off line User Profile Engine once the User Profiling Model Selection provides the optimal value of parameter *k*. The User Profile C_j associated to user *u* is the one corresponding to the minimum Euclidean distance, i.e. the closest centroid to *u*.

The latter is defined as *prs*: $prl_k \rightarrow \{0, 1\}^P$ and derives for User Profile prl_k the subset of Optimality Criteria being well represented in the cluster C_k associated to User Profile prl_k. By analysing the centroid c_k associated to User Profile prl_k, the On line User Profiling defines the User Profile based DRIVING PARAMETERS $\{ow_1,...,ow_P\}$ to be returned to the Metadata Handling Tool as follows. For each optimality criterion oc_j such that $prs(prl_k)_j = 0$, related ow_j is 0. Otherwise, oc_j is the percentage of User Queries $UQ_i(u)$ in the cluster C_k of such that oc_j is in $ocr(s^*(Q_i(u)))$. In this sense, the distribution of optimality criteria actually chosen by the User Query in the cluster affect the User Profile and allow the personalization of the Travel Solutions returned by MOT, as explained above.

4.1.4 Reinforcement learning based user profiling

The prominent interaction between human being and machine, in terms of real users' choices, allows to accomplish a cognitive model-free approach in charge of learn individual users' behavioural profile, such estimating **individual users' travel preferences**. In this section, we consider specifically one user *u* and his interaction with the BONVOYAGE platform, instead of considering clusters of travellers being similar to user *u*.

On Line Reinforcement Learning Tool

The learning process occurs when the users are induced to choose for travel solutions (explicit feedback), as consequence of travel queries. In particular, when the users select their travel solution **the system learns specific travel features**. The algorithm used to learn the **individual users' travel features**, based on users' travel choice, is a Reinforcement Learning algorithm (i.e., Q-Learning algorithm [20].

The *M* individual travel features f_i (with i=1, …, *M*), that the Q-Learning algorithm is in charge for learning in this context are:

1) *Number of transit nodes*: This feature allows to learn the number transport modalities that user is available to change during each journey (e.g., 1, 2, 3, etc.).
2) *Used transport means*: This feature allows learning the most used transport means during the overall user's history (e.g., *Car*, *Metro*, *Bike*, etc.)
3) *Private service cars*: This feature allows learning the most preferred private service car (e.g., *Taxi*, *Car sharing*, *Car pooling*).
4) *Preferred class category*: This feature allows learning the most preferred class category for each travel (e.g., *First class*, *Second class*).
5) *Total travel time global travel*: This feature describes the total travel time most used by each user for journey in European area.
6) *Special request*: This feature allows learning the most requested ancillary service for each user in his/her journey history (e.g., *Wi-Fi connection*, *Pet allowed*, *Smoker*, etc.).
7) *Walking distance during travel*: This feature allows learning the preferred maximum distance that each user is available to make.
8) *$C0_2$ emissions*: This feature describes the sensibility of each user to the $C0_2$ emission, basically if each user is careful to choose travel solutions taking into account the $C0_2$ emission.
9) *Comfort level*: This feature allows learning the most preferred comfort level of each user during each journey.
10) *Range hour travel*: This feature allows learning the most preferred departure time.
11) *Range price travel*: This feature allows learning the willingness to pay for each travel.

For each travel feature f_i is considered a set of distinct components c_j (where j=1, …, N), the components c_j are specific attributes (e.g., *Car*, *Metro*, *Bike*, etc.) of each feature. When user submits his/her first travel request, as described in Section 4.1.3 the user falls into a cluster and exploiting the clustering based information the Metadata Handling Tool has the task to initialize[9] the weights of each c_j in each f_i, considering the weights associated to each components of each feature within the cluster, if the user is in his/her first query.

For every cluster it is possible to retrieve the components distribution (histogram) for every feature within the cluster (i.e., considering only travel requests associated to said cluster). After normalisation with respect to the sum of the bins, each feature f_i will have a vector whose length is $card\{A(f_i)\}$, whose elements are in range [0,1] and whose sum is 1.

While if the user has already submitted his/her first query the Metadata Handling Tool provides to the On Line Reinforcement Learning the User ID (known user), as it can interact with the Rank Tool.

[9] The Metadata Handling Tool initializes the weights for each user, just for his/her **first** travel request within the system.

Once the user has selected his/her suitable travel solution, the system extracts the useful components, as they have been modelled in the travel features, from the selected travel solution. Considering the components extract, the algorithm updates the weights (i.e., user history based Driving Parameters) of each component c_j, following the Q-Learning Learning update rule [20]. If a user doesn't select his/her suitable travel solution (absence of explicit feedback), the algorithm doesn't update the weight leaving the learning process unchanged.

The set of proposed features f_i is only one of the ways of how we can model the algorithm, in fact the learning algorithm can be considered as model-free or data independent, in the sense that the modelled features f_i and the components c_j can be chosen according to the characteristics that we have intention to learn.

Rank Tool

The acquired individual weights, for each component c_j in each travel feature f_i, will used to provide a suitable list of ranked travel solutions, exploiting an appropriate **rank algorithm properly designed for this scope**.

The **Rank Tool** receives in input the individual weights (user history based Driving Parameters) learned by Q-Learning algorithm, and the un-ordered list Travel Solutions (led by the Metadata Handling Tool) computed by the MOT. The rank algorithm evaluates the travel solutions relying on the individual weights and then returns an **individual ordered list of travel solutions** to the Metadata Handling Tool (Figure 7). The Metadata Handling Tool provides the list of Candidate Travel Solutions to the user u via BONVOYAGE Front-End.

The *Selected* Travel Solution $s^*(Q(u))$, chosen by the user u, is provided by the BONVOYAGE Front-End to the Metadata Handling Tool. For as concern the learning process the $s^*(Q(u))$ represents the explicit feedback, since it contains the implicit preferences chosen by the user selecting the $s^*(Q(u))$. It is fundamental noting that the $s^*(Q(u))$ is provided to both (*i*) On Line User Profiling Tool and (*ii*) On Line Reinforcement Learning Tool, in order to be used as a feedback of paramount importance in the machine learning algorithms embedded UCCS (Figure 7).

The algorithms presented above (i.e., Q-Learning algorithm, rank algorithm) are in line with the implementation of the functionalities:

- UPL_TPR (described in Table 7) when the Q-Learning algorithm learns users' preferences updating the weights of each feature relying on the selected travel solutions.

- CALCULATE_TRIP_SOLUTION (described in Table 9), when the rank algorithm according to *some indicators* (i.e., individual features' weights) properly order the travel solutions.

Results

The Rank Tool algorithm has been tested with several different users (about hundreds of users). Here we report a very simple example, for sake of simplicity, in order to show what the algorithm learns about individual preferences described by travel features.

Two real users (User A and User B) have made two similar travel requests within the urban area of Bilbao. By exploiting the urban soloist (described in Section 5.3), the On line User Profiling Tool (immediately after users' travel requests) has classified both users as similar users, since they belong to the same cluster (as described in Section 4.1.3).

Once the On line User Profiling Tool has profiled User A and User B, the Metadata Handling tool initializes the individual weights of the components in each travel feature for each user. Since the users belong to the same cluster they have the same components' weights.

User A and User B have used the urban soloist and have made ten different travel requests (for each travel request by a user, the urban soloist returns *n* different travel solutions by considering the combination of all allowed transport modalities, as described in 5.3) and then by choosing ten times their suitable travel solutions for their respective travel requests.

Therefore, for each interaction (i.e., choosing the trip) the Q-Learning algorithm has updated the components c_j within each feature for each user, taking into account each selected travel solution.

During the selection of travel solutions, the two users have had different behaviours, since they chose travel solutions having different transport modalities.

Figure 8 and Figure 9 show how dependently by the transport modalities the individual components' weights (ordinate axis) change for the two users. Even if the two users were classified as "similar", their different behaviours have been learned, during the selection of the travel solutions, by the Q-Learning algorithm. For instance, Figure 8 and Figure 9 figure out how for User A (in light grey) the preferred transport modalities, after ten selected travel solutions, for urban area detected by the algorithm are *Motorbike* and *Car sharing*, while for User B (in dark grey) the preferred transport modalities, after ten selected travel solutions, are *Private Car* and *Taxi*.

In this way, for future request, the rank algorithm will suggest, in the first positions the travel solutions having the more weighted transport modalities.

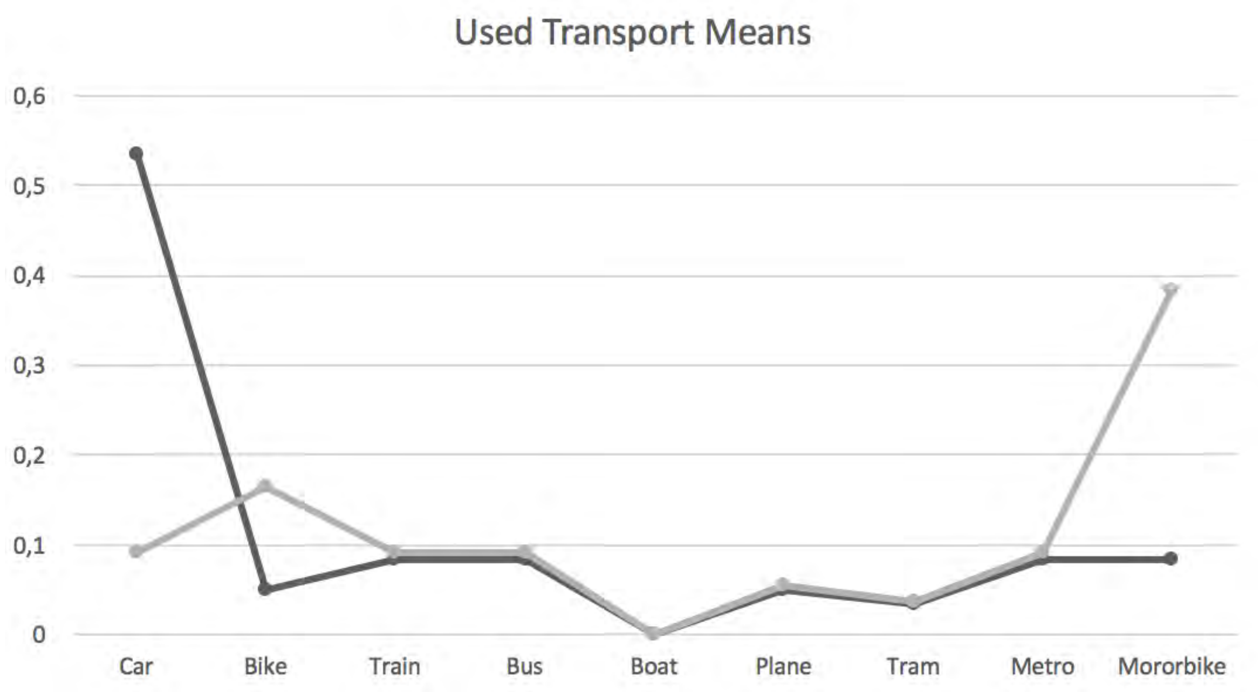


Figure 8 - Used Transport Means, User A (light grey) User B (dark grey)

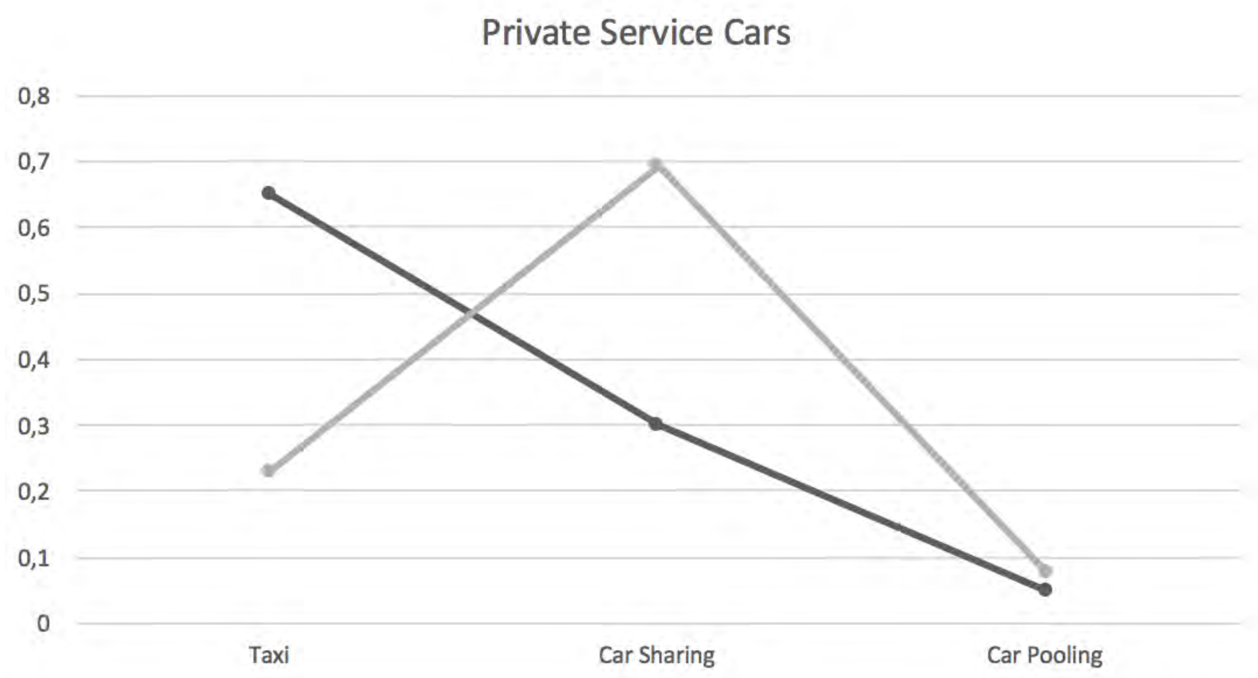


Figure 9 - Private Service Car, User A (light grey) User B (dark grey)

4.2 Personalization in BONVOYAGE by sensors

4.2.1 Implicit feedback and Stress Level assessment

4.2.1.1 Introduction

The recent development of wearable devices measuring physiological parameters allows to imagine new quantify self-application that can be used in several applications of practical interest. For the BONVOYAGE project, we develop a new functionality that will estimate the stress level of the user during his travels. This new functionality will allow providing information during the trip about particularly stressful events, which could be used to propose an alternative travel solution. But the main use of this functionality will be personalizing future travels solutions, which will be proposed by the BONVOYAGE platform. For example, the platform will foster solutions that are less stressful for the user. As there is no physical model linking physiological measurements to stress levels, we use a machine learning approach. For that, we use databases of physiological and accelerometer data together with stress level knowledges during the acquisition. To acquire those databases a datalogger is necessary.

4.2.1.2 Datalogger

The datalogger consists in acquiring physiological measurements together with information about stress. After a state of the art comparing several sensor systems, we decided to use Empatica E4 wristband. This system presents several advantages: it is not very obtrusive; it allows collecting raw data of skin conductance, photoplethysmogram (PPG) and body temperature. We also use the assessment of stress state by using a questionnaire like the one below implemented in the smartphone. 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 codes.

Figure 10 - Stress Level Questionnaire

4.2.1.3 Database

In order to develop a good estimator of stress level during daily life several technological issues have to be considered:

- Cause of stress: most of the experiments that have been conducted for developing stress level estimators are based on one specific stressor. They are not generalizable to several kinds of stressor. We consider social, physical and temporal stressors.
- Inter-individual variability: the system should be robust to several users. We use databases with several users. – The individual calibration should be as simple as possible
- Motion disturbances: motion generates errors in the sensor measurements. Moreover, the autonomous nervous system is affected by physical activity as well
- In daily life, several causes can influence the physiological state of the user that are not only due to stress
- It is difficult to obtain the ground truth about the stress level

We have already collected several data in our studies:

- We use the MIT driver database available on Physionet[10].
- 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 recording 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 is also being created, corresponding to real-life situations that typically appear in daily life. For recording perceived stress level, the Figure 11 is used.

4.2.1.4 Features extraction

This is the next step of development scheduled in BONVOYAGE project for stress level assessment. It consists in extracting relevant information from sensors data stored in the database (as previously described) for classification algorithms. To find relevant features, previous studies have been analysed, in combination with visual inspection of the data in order to identify what signal properties that differ between stress states and stress-free activities. These features can be calculated on signal segments (time windows) of five seconds up to five minutes. An example of features for wearable stress estimation applications can be found below:

- Time-domain heart rate variability (HRV) features:
    - Mean heart rate
    - Standard deviation of heart rate
    - Standard deviation of heart rate divided by mean heart rate
    - Root mean square of successive differences of heart rate
- Frequency-domain heart rate variability (HRV) features:
    - Total energy in interbeat intervals
    - Sum of energy in ultra low frequency (ULF) band (0 – 0.003 Hz)

[10] (https://physionet.org/physiobank/database/drivedb/)

- Sum of energy in very low frequency (VLF) band (0.003 – 0.04 Hz)
  - Sum of energy in low frequency (LF) band (0.04 – 0.15 Hz)
  - Sum of energy in high frequency (HF) band (0.15 – 0.5 Hz)
  - Ratio between energies in LF and HF bands
- Skin conductivity features:
  - Mean of skin conductance level (SCL)
  - Mean of positive derivative
  - Number of local maxima
  - Sum of skin conductance responses (SCR) width multiplied with prominence
  - Mean SCR width
  - Sum of area under SCRs
  - Standard deviation of SCRs
- Skin temperature features:
  - Mean skin temperature
  - Mean skin temperature derivative
- Accelerometer features:
  - Mean accelerometer deviation from rest
  - Accelerometer signal power

To select the most relevant features for assessment of driver stress, an exhaustive sensor-wise feature selection was performed on the MIT driver stress database [4]. The same method was also applied to laboratory stress data. The selection consisted of, firstly selecting the most relevant within each sensor, to find the most performant representation of it. Then these subsets were combined, to find the best sensor combination. The selection criterion was the highest classification performance, but filter/scoring methods were also applied. The results on these databases indicate that heart rate features are most relevant, in combination with derivative-based skin conductivity features and respiratory measures.

Furthermore, in order to validate that features that origin from wearable sensors can be considered as performant as features that origin from laboratory sensors for detecting stress, a validity study has been performed, comparing different sensor systems and their features. This study will be presented at the IEEE Systems, Man & Cybernetics conference in Budapest on October 10, 2016 (A Comparison of Wearable and Stationary Sensors for Stress Detection).

The performed feature selection and validity studies will serve as a base for developing the final User Stress Level estimation algorithm.

4.2.1.5 Classification algorithms

The User Stress Level estimation algorithm has to learn to classify data in different pre-defined classes on a well-known dataset before being able to analyse in real time new data. This step consists in building a mathematical model for classification. Classification algorithms are the final step of user's stress level assessment. Output from classification algorithms will feed in the User profiler tool through the Metadata Handling Tool. Different classification algorithms will be tested (performance, complexity, computing cost, etc.). Classification algorithms that have been explored so far include naïve Bayes, support vector machines, decision trees, neural networks, least square classifiers, and k-nearest neighbour algorithms.

4.2.1.6 Regressive algorithms

An option to using predefined number of classes (e.g., rest, activity, and stress), is to introduce a continuous variable that represents the stress level. In this case, the perceived stress level serves as ground truth, indicating the stress level related to the time windows. A possible algorithm is for example linear regression. This allows for a more refined stress level assessment, but it has the weakness of relying on user perceived stress level questionnaires, which do not necessarily correspond to the ground truth.

4.2.2 User transportation mode assessment

4.2.2.1 Introduction

Detecting transportation modes has gained an increasing attention in recent years thanks to the widespread of smartphones and wearable devices with new sensors and increasing computing power. Thus, the correct recognition of this particular dimension of a person's context has applications in various fields such as the automation of mobility surveys, assistance during travels, the estimation of transportation's environmental impact and health/fitness applications.

In the context of BONVOYAGE Project, estimating the transportation mode of a user is very interesting to understand how the user is likely to move: for example, we can discover that a user never uses a bike, or never takes a plane, and so on. This is therefore very helpful for the personalization aspect of the project, both in pre-trip and on-trip phase.

Transportation mode recognition is a machine-learning problem and therefore follows a general scheme:

- The first step is the acquisition of sensor data annotated by the user. The annotation is the effective transportation mode. This step leads to an annotated database (see Section 4.2.2.4). In order to be able to record these annotated sensor data, we need a datalogger (as described in Section 4.2.2.2), i.e. a smartphone application that allows to record and annotate travels;
- The second step is the processing of raw data and the extraction of relevant features (see Section 4.2.2.3).

Third step is the building of classification algorithms that estimates transportation mode from the previous features. Finally, this estimation can be improved by a post-processing step that filters erroneous classifications, delivering the final estimate of the user's context (see Section 4.2.2.4).

4.2.2.2 Datalogger

Acquiring an important and well-balanced database is the first step in constructing a good model recognizing and assessing transportation modes. In order to create this database, we developed an Android application ("app") that acquires and stores raw data from several smartphone sensors.

The main functionalities of the developed Android app are shown in Figure 11 and Figure 12. The app records the raw data from the sensors as well as the transportation mode annotated by the user. In Figure 11 we can see the main window of this app through which the user can begin the logging of the data and can provide the transportation mode. We can see that 15 modes have been pre-determined: 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 correctly classified in the pre-defined transport mode classes. This will enabled one to take in charge other transport mode which could be used by one user (for example: paragliding or windsurf board).

Figure 11 - Main window of the Android app

During an acquisition, the Android app logs the information about the transportation mode and a set of chosen sensors available on smartphones. 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 12.

Figure 12 - Set up window of the logging Android app

This Android logging app is used to create the necessary database to construct a transportation mode classification model based on features extracted from smartphone sensors.

4.2.2.3 Features extraction

This is the next step of development scheduled in BONVOYAGE project for transport mode recognition. It consists in extracting relevant information from sensors data stored in the database (as previously described) for classification algorithms. Indeed, this kind of algorithm has to learn to classify data in different pre-defined classes on a well-known dataset before being able to analyse in real time new data. This step consists in building a mathematical model for classification

4.2.2.4 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. He was asked to use the datalogger during commute, business or leisure trip, and for the duration of one to several days. Once he 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.

The next figure shows the split of the database with respect to the class. For each class, the size is given in number of instances, seconds and hours. In our case, one instance is made of consecutive 5 seconds of signal.

DB size	Total	still	walk	run	bike	ebike	motor bike	car	ecar	bus	ebus	tram	subway	train	plane	boat	other
# instances	156303	15196	17718	2174	11242	136	0	20033	309	11441	515	4758	958	42129	22752	5316	1626
# sec	781515	75980	88590	10870	56210	680	0	100165	1545	57205	2575	23790	4790	210645	113760	26580	8130
# hours	217.1	21.1	24.6	3.0	15.6	0.2	0.0	27.8	0.4	15.9	0.7	6.6	1.3	58.5	31.6	7.4	2.3

Figure 13 - Number of instances and duration per class

The next figures point out that, despite our efforts, database is still unbalanced. In fact, if we define a “representative threshold” of 3900 instances (representing approximatively 5.5 hours), only 9 out of the 16 defined classes are represented: still, walk, bike, car, bus, tram, train, plane, boat. Several reasons explain this result:

- Users are voluntary and can’t be forced to use a specific transportation mode;
- Three modes are not widespread in Grenoble: electric bike, electric car and electric bus.

Moreover, some mode does not exist in Grenoble, such as subway and boat.

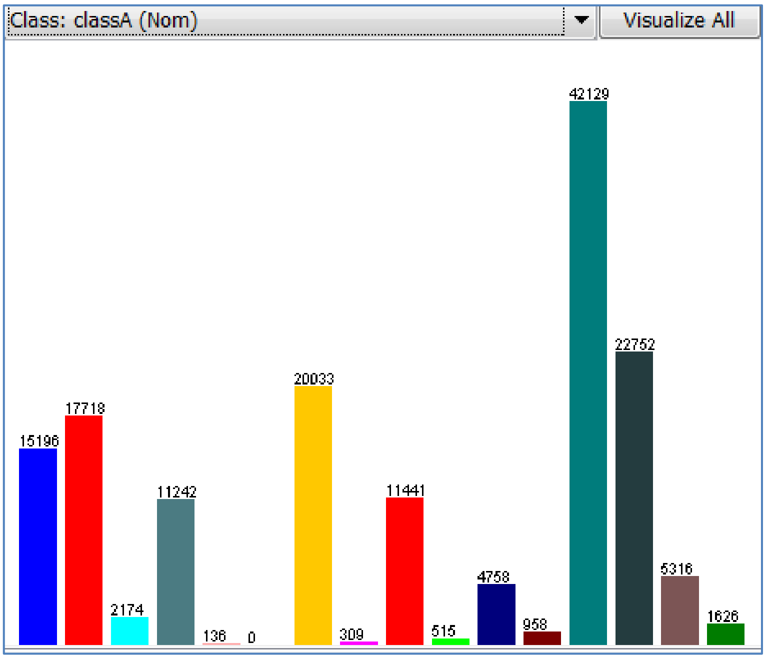


Figure 14 - Number of instances per class

It is also interesting to look at the number of instances with respect to the user (see next figure). We can notice that some users had logged very few data. This is often due to some dysfunction of the user's phone, such as a sensor that does not work.

Therefore, if we use the same previous "representative threshold" of 3900 instances, among the 22 users, 9 have mainly participated.

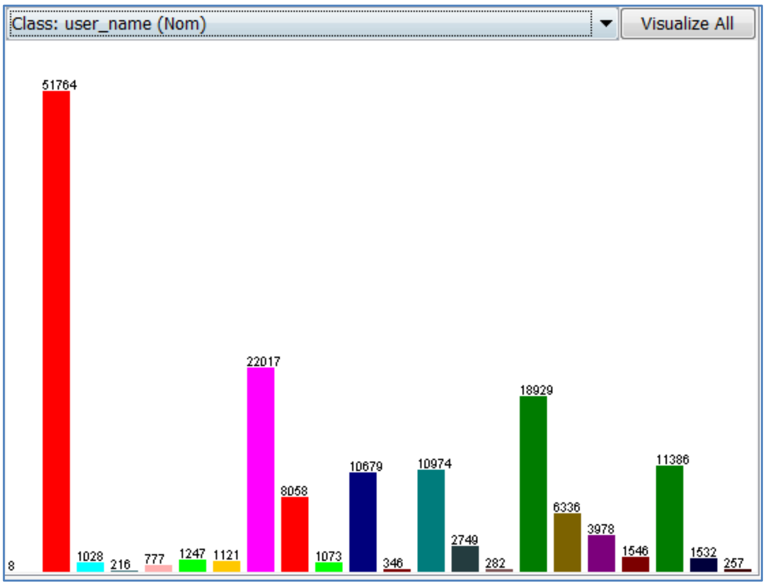


Figure 15 - Number of instances per user

A last interesting graph concerns the diversity of devices used (see next figure). 12 devices were used, but the majority of data were acquired with 5 of them.

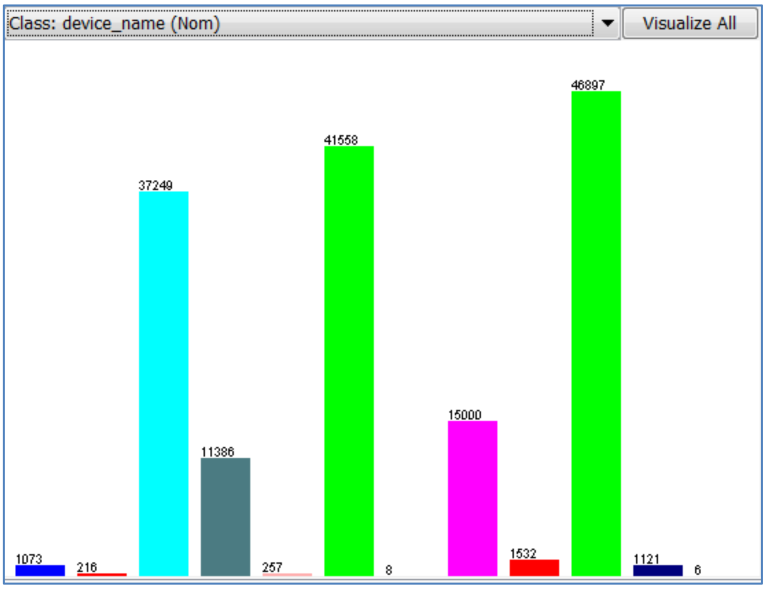


Figure 16 - Number of instances per device

To conclude, we have at our disposal a very rich database with 9 different transportation modes, set up by 9 different users, using 5 different phones, which represent 217 hours of recording, 400 files and 40 Gigabytes.

It is interesting to compare our database with respect to the State of the Art ([21], [22], [23], [24] and [25]) discarded many papers because of their very poor database (single user, single device, only few hours or record, e.g., see [26]), and we have kept only the biggest databases.

Next table summarizes different databases in terms of Classes, Sensors, #Users, #SP and #Hours.

	Classes												#Classes	Sensors						Database		
	Still	Walk	Run	Bike	Car	Bus	Train	Metro	Tram	Moto	Plane	Boat		GPS	ACC	GIS	BT	MAG	GYR	#Users	#SP	#Hours
MA10	1	1		1	1	1	1	1		1			8		1					?	1	?
WA10	1	1		1	1	1		1					6		1					7	?	12
YU13	1	1	1	1			*1*						5		1					74	?	1000
YU14	1	1	1	1			*1*						5		1			1	1	224	?	8300
HE13	1	1			1	1	1	1	1				7		1					16	3	152
RE10	1	1	1	1		*1*							5	1	1					16	?	120
ZH10		1		1	1	1							4	1						65	?	2036
CEA16	1	1		1	1	1	1		1		1	1	9	1	1		1	1	1	9	5	217

Figure 17 - Comparison of our Database w.r.t. State of the Art

From this table, we notice that our database presents a very good compromise between diversity (#Sensors, #Classes, #Users) and quantity (#Hours) of the data.

4.2.2.5 Classification algorithms

Classification algorithms are the final step of user's transport mode recognition. Output from classification algorithms will feed in the User Profiler Tool. Different classification algorithms will be tested (in terms of performance, complexity, computing cost, etc.) and experimental results will be reported in D4.2. The classification algorithm that well meets BONVOYAGE requirements will be implemented.

5 Trip planning by multi-objective optimization

This section summarizes the research work performed in the field of intelligent inter-modal trip planning in intelligent transportation systems. In particular, the research focused on the definition of the methodological approach, implemented in BONVOYAGE, in order to realize the functionality CALCULATE_TRIP_SOLUTION defined in Table 9.

5.1 Overview

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.*

5.2 The Orchestrator

The orchestrator is a *decomposition approach* to solve the routing problem on a multimodal network *N*. It orchestrates a set of solution algorithms (*solvers*) acting on different multi- or single-mode subnetworks of the original network *N.* 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. For instance, if the request regards a trip from city A to city B, the orchestrator may invoke a solver in charge for city A, a solver in charge city B and a solver capable to find extra-urban path from the boundary of city A to the boundary of city B. Another example of such orchestrating approach regards the matching of two different trips in freight transportation scenarios, or the identification multimodal trips through successive and coordinated invocations to single-mode solvers.

The major features of the orchestrator approach are:

- The decomposition allows for significant speed-ups in answering queries;
- The different solvers operating on the subnetworks and made available for the BONVOYAGE platform may be designed and implemented by different organizations;
- The decomposition is *metric-independent* so it can be used in conjunction with different objective functions. The only required property is that such functions are separable in terms which may be associated with the components of the decomposition.

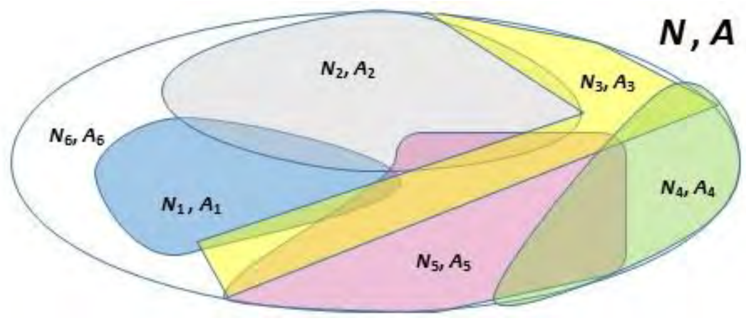
As we will discuss later on, our technique is inspired by some recent developments in decomposition approaches for route planning. In particular, in [27], the authors advocate the use of separator-based methods to compute optimal paths in large networks. These methods are based on a pre-processing phase in which the *topology* of the network is exploited in order to define a suitable decomposition into subnetworks; and a *metric-dependent customization* in which the best solution to the current query is computed and returned. According to [27], this approach outperforms all other techniques on complex, realistic scenarios. Alternative techniques may actually perform better when tackling problems with fixed metric (e.g., shortest time) or other simplified scenarios. For example, contraction hierarchies which may be efficiently efficient for certain problems show a poor behaviour against user preferences (see [28]). In contrast, separator-based methods can tackle multiple metrics, consider U-turns, avoid left-turns, consider multiple restrictions, include real-time information, road closures, etc. All this is crucial to tackle BONVOYAGE target scenarios. Also, one major feature of the BONVOYAGE approach is to allow *personalized metrics*, which implies that the number of different objective functions can grow as large as the number of users (and more). As we will see later, however, such objective functions will still be separable, that is they can be expressed as the sum of non-negative components each associated with an edge.

Another interesting property of separator-based methods is that they can take into account *time-dependent* edge costs – that is the cost $l(u,v)$ associated with the directed edge (u,v) depends on the time when the edge is actually *reached* during the route.

In the next sections, we introduce a formal version of the orchestrator concept. However, the current implementation of the orchestrator will contain some limitations with respect to the full concept due to speed requirements.

5.2.1 The orchestrator: basic definitions

The orchestrator 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.*



A *multi-modal network* is a graph $N = (V, E)$ where V is a set of nodes and E is a multiset of directed edges (i.e. ordered pairs of nodes). Each edge is associated with a single modality. So, for instance, if the nodes represent crosses in the road map of a city, then an edge between two crosses 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.

To perform its task, the orchestrator relies on a set of solvers A_1, …, A_q to compute an optimal route in a corresponding multi- or single-mode subnetwork N_1, …, N_q with the property that $N_1 \cup \ldots \cup N_q = N$. In other words, the subnetworks provide a coverage of the original network and they are not necessarily disjoint. Solvers may correspond to different algorithms but also different implementations of the same algorithm.

The pair (N_i, A_i) is a *soloist*. Observe that:

- Different soloists (N_i, A_i), (N_q, A_q) may share the same solver. For example, we may have N_i = Bilbao Road, N_q = Grenoble Road, A_i= A_q = Dijkstra, implemented by Arturo Toscanini (*Ver 3.2*).
- Different soloists (N_i, A_i), (N_q, A_q) may share the same network. For example, we may have N_i = N_q = Grenoble Road, A_i= *Dijkstra* (implemented by Arturo Toscanini (*Ver 3.2*)) A_q = *A**, implemented by Herbert von Karajan.
- Different soloists (N_i, A_i), (N_q, A_q) may share the same network and the solvers may implement the same algorithm but different implementations. For example, we may have N_i = N_q = Grenoble Road, A_i= *Dijkstra* (implemented by Riccardo Muti (*Ver 3.2*)) A_q = *Dijkstra*, implemented by Zubin Mehta.

Whenever a soloist is available for the BONVOYAGE platform after a registration protocol, the orchestrator may decide to engage it.

Note that new soloists can be made available at any time.

Once a query is submitted to the orchestrator *N, A* it will

1. Identify a suitable collection of *soloists* to answer the query;
2. Construct the proper query for each soloist;
3. Collect answers from soloists;
4. Compose a unique solution.

5.2.2 On overlay graphs

The orchestrator takes its inspiration from overlay graphs decomposition [29] which, according to the recent paper by [27], is the most competitive approach when the performance metric can change with the query. We will introduce here the basic concepts, which will help to introduce the orchestrator decomposition presented in the next sections. The general technique makes use of *multilevel nested partitions* of the nodes V of a directed graph $G(V,E)$. However, for our purposes it is enough to consider a 2-level partition, where the first level is simply given by singletons (i.e. the original nodes), whereas the second level will be $Q = \{C_1, \ldots, C_q\}$. The classes in the partition are called *cells*. A *boundary edge* is an edge with endpoints in different cells. The endpoints of a boundary edge are called *boundary nodes*. We let $S \subseteq V$ be the set of all boundary nodes and we let S_i be the boundary nodes in class C_i (so $\{S_1, \dots, S_q\}$ is a partition of *S*).

In the remaining, for each $e \in E$ we are given its length $l_G(e)$. An *overlay graph H* = (*S,F*) is associated with G and the partition *Q*. The nodes if *H* are the boundary nodes *S*. Let $u, v \in S$ be distinct nodes of *S*. If u, v belongs to the same cell S_i then $(u, v) \in F$ and its length $l_H(u, v)$ will be the length of a shortest path from *u* to *v* in *G* using only edges in the subgraph induced in *G* by cell S_i. If u, v belongs to different cells then $(u, v) \in F$ only if $(u, v) \in E$ and its length $l_H(u, v) = l_G(u, v)$.

One fundamental property of this representation is that a shortest path from *x* to *y* in *H* of length $L_H(x, y)$ corresponds to a shortest path from *x* to *y* in *G* of length $L_G(x, y) = L_H(x, y)$. So we can compute a shortest path P_H in *H* and then derive from P_H the shortest path P_G in *G* (of equal length). Without going into details, the interesting property of this transformation is that the distances in the cliques $S_1, \dots, S_q$ induced in *H* by the nodes in a same cell can be pre-computed off-line. When a query comes a shortest path can be quickly computed in *H* and the solution is extended in real-time with the remaining nodes in *G*. Our orchestrator somehow generalizes this idea to *soloists* rather than cells.

5.2.3 From multi-modal networks to soloists representation

As mentioned, the orchestrator generalizes the ideas in the overlay graph decomposition approach to routing. The crucial differences are that

1. The reference graph *N* = (*V,E*) is a *multi-modal* network and may be partly unknown
2. The elements in the decomposition are not simple cells identified by a set of nodes, but they are (potentially multi-modal) subnetworks of *N* along with a solution algorithm, namely soloists (N_1, A_1), …, (N_q, A_q).
3. The concept of *boundary nodes* is replaced by that of *connection nodes*. Connection nodes represent entry and exit points of the subnetworks associated with soloist. They may and may not coincide with (a subset of) the boundary nodes of the subnetwork (defined as for overlay graphs). The may or may not be geographically localized. Observe that connection nodes may actually correspond to extended areas within the associated subnetworks. In general, connections nodes must be chosen carefully at the registration of a new soloist into the BONVOYAGE platform. Again, we denote by $S_i$the set of connection nodes in subnetwork N_i.
4. The overlay graph is replaced by the *orchestrator graph H* = (*S,F*). The nodes of the graph are the connection nodes. Each set S_i induces a clique in *H*, i.e. for every ordered pair of distinct nodes $u, v \in S_i$ there is an edge $(u, v) \in F$, called *connection* edge. With every connection edge (u, v) we also associate a distance $l_H(u, v)$ representing a lower bound

on the minimum distance from u to v. in the subnetwork. Distances are evaluated according to one or more pre-defined metrics.

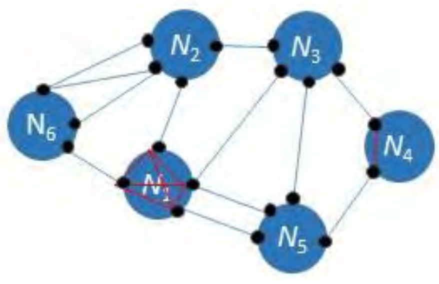


Figure 18 - The orchestrator graph. The black nodes are connection nodes. The connection nodes belonging to the same subnetwork induce a clique in the orchestrator graph

5. If nodes $u, v \in S$ belong to different subnetworks, there is an edge (*u*,*v*) in *H* only if it is possible to "transfer" from *u* to *v*. The length $l_H(u, v)$ 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.
6. When a request for a route from A to B is received, the orchestrator looks for one or more shortest routes in the orchestrator graph. Once the route(s) is identified, the actual value is computed with the current lengths. Observe that since pre-computed distances are not necessarily exact – in general they are *lower bounds* – and in addition they are computed before they are actually used, the resulting solutions are not necessarily optimal.

5.2.4 Registering a new soloist to the BONVOYAGE platform

A new soloist registering to the BONVOYAGE platform must inform the orchestrator about its capabilities. In particular:

- The area of interest. This will be given as a polygon – vertices will be indicated by geographical coordinates.
- The modalities available. This is a subset of the orchestrator public set of permitted modalities. For example, "car" and "walk".
- The potential modality transitions, along with the connection points. For instance, one can go to "airplane" if the area of interest contains an airport. Connection points or area can be also expressed.
- Potential objectives. This can be "time" or "cost" or a weighted combination.
- Other characteristics that can be expressed.

A sketch of a potential json scheme is given below.

```
{
```

```
    "schemaVersion": "1.0",
    "boundaryDescrition": "The 'boundary' describes the geographical area
within which the service most likely can handle travels.",
    "boundary": {
          "geometry": {
                "type": "Polygon",
                "coordinates": [
                      [
                            [ 10.0, 10.0 ],
                            [ 10.0, 20.0 ],
                            [ 20.0, 20.0 ],
                            [ 20.0, 10.0 ],
                            [ 10.0, 10.0 ]
                      ]
                ]
          }
    },
    "modalitiesDescrition": "The 'modalities' lists the modes that can be
part of a route returned from the service.",
    "modalities": [

          "OwnCar",
          "Motorcycle",
          "OwnBicycle",
          "Foot"
    ],
    "transitionsDescrition": "The 'transitions' lists the possible entry
(from) and exit (to) mode of travel. Each entry has an optional geometry.",
    "transitions": [
          {
                "fromTo": [ "Airplane" ],
                "geometry": {
                      "type": "MultiPoint",
                      "coordinates": [
                            [ 4.0, 4.0 ],
                            [ 6.0, 4.0 ]
                      ]
                }
          },
          {
                "fromTo": [ "Bus" ],
                "geometry": {
                      "type": "Polygon",
                      "coordinates": [
                            [
                                  [ 10.0, 10.0 ],
                                  [ 10.0, 20.0 ],
                                  [ 20.0, 20.0 ],
                                  [ 20.0, 10.0 ],
                                  [ 10.0, 10.0 ]
                            ]
                      ]
                }
          },
          {
                "to": [ "Bus", "Tram" ]
          }
    ],
```

```
    "characteristicsDescrition": "additional properties that describes the
service that the orchestrator may use for the overall system to perform
better",
    "characteristics": [
          { "responceTime": "Medium" },
          { "solutionQuality": "Heuristic | Optimal" },
          { "multiSolution": "true" }
    ]
}
```

5.2.5 An example: from Grenoble to Bilbao

In order to demonstrate the potentiality of the orchestrator approach developed in BONVOYAGE, we will implement a number of "soloists". Such soloists will be then exploited to demonstrate a number of scenarios, covering the main requirements and many innovative features offered by the BONVOYAGE platform. In a first scenario, a specialist is travelling from Grenoble to Bilbao for business. This scenario requires the exploitation of different transport modalities in differ European region.

Assume that the orchestrator graph is the following one (we only show the part of subnetwork which may be affected by a query):

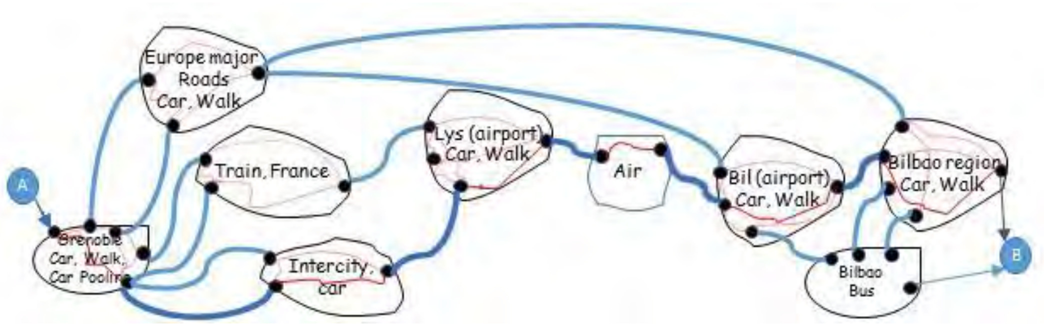


Figure 19 - Example of (partial) orchestrator graph and chosen path (in bold)

When a request for routing from an origin A to a destination B, the orchestrator first assign A and B to one or more soloists, according to the coordinates and possibly other information (as the wanted modalities).

At invocation, the orchestrator search for a promising path from A to B in the orchestrator graph (*orchestrator path*). The nodes of such path belong to a subset of subnetworks, in turn corresponding to specific soloists. For example, in Figure 19 the path in bold is the path chosen by the orchestrator.

The orchestrator path identifies the subset of soloists. Such soloists in this path will be invoked in the sequence represented by the oriented path from A to B. Each soloist returns the segment of route between its two connection points involved in the orchestrator path.

5.3 Soloist example: an "urban" soloist

In our reference scenario, one of the transport modes will include urban car pooling. Any potential solutions will require so the activation of a soloist capable to offer car pooling in an urban road network. In what follows, we describe in detail a possible implementation of an urban soloist with car pooling services.

5.3.1 Definition of an urban soloist

The BONVOYAGE example of urban soloist aims at providing an integrated planning service to the end-user where multimodality, real-time information and car pooling services are considered jointly to provide a custom solution.

There are many studies in the scientific literature focusing on the trip planning for end-users trying to solve the problem focusing on a specific aspect as the real-time traffic data integration [30], battery constraints for electric vehicles [31], time dependency in multi-modal networks [32] and the extension to include the car pooling [33]. The multitude of scientific researches in the domain of urban mobility is flanked by a multitude of commercial solutions available as web services or mobile Apps. Just to mention some of these services, it is possible to cite Google Maps, Waze, EVTripPlanner , Moovit and Lyft[11].

This specific urban soloist includes car pooling and it has been conceived flexible by design in order to easily integrate further transport modalities and smart mobility services.

As shown in Figure 20, our urban soloist needs the following inputs to be initialized and to return optimal routes:

- Static input: it is possible to refer as static input to 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.

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[11] www.google.it/maps

www.waze.com

https://evtripplanner.com/planner

http://moovitapp.com

https://www.lyft.com

https://www.openstreetmap.org

- 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.

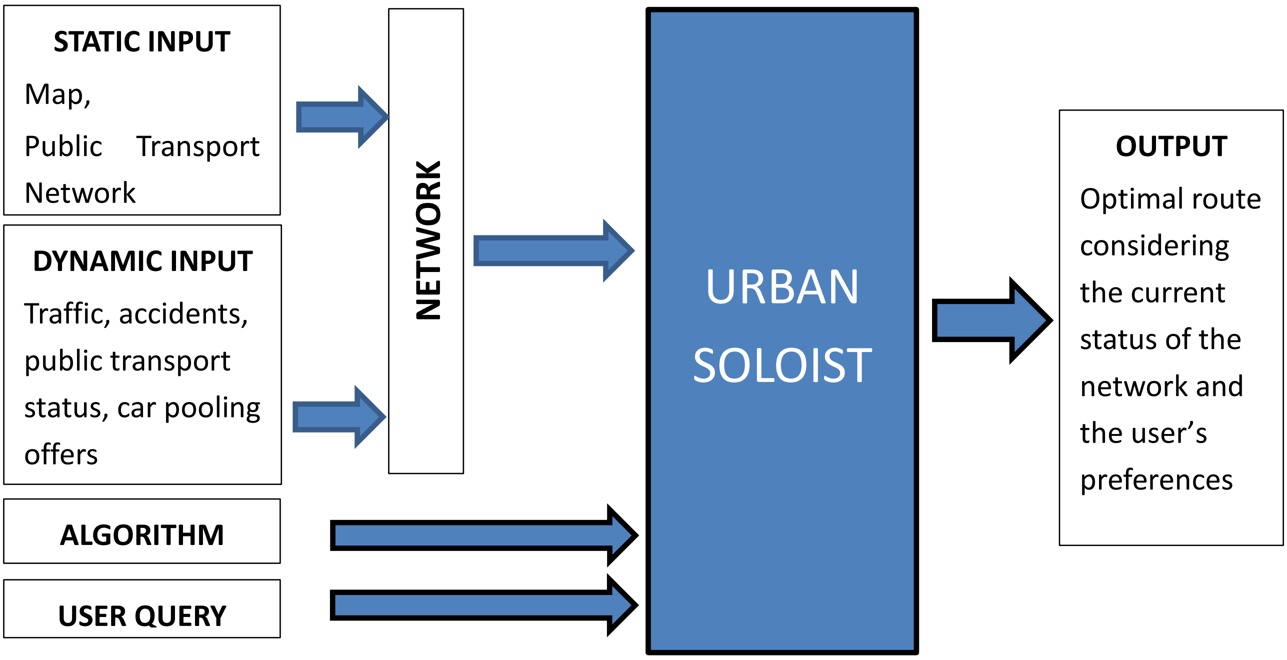

Figure 20 - Urban soloist interactions

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 by OpenStreetMap[12] and the public transport infrastructures can be easily downloaded in GTFS format by using the BONVOYAGE service exposed at bonvoyage2020.eu/travelcentricservices. All these data are processed in order to build the integrated transport network that allows to define feasible solutions including both private and public transport means. 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.

Hereinafter our urban soloist (N_U, A_U) is detailed in order to highlight how BONVOYAGE calculates the best route on a multi-modal network integrating also the car pooling service.

Let N_U be a graph representing the interconnection of different urban mobility networks modelled as follow:

[12] https://www.openstreetmap.org

- Road graph $G_R = (V_R, E_R)$: this graph is a model of the road network where each directed edge in E_R represents a street accessible by vehicles (i.e. footways and cycleways are excluded) and each node in V_R represents a crossroad (generally a junction of two or more streets). Figure 21 shows highlighted in red the $G_R = (V_R, E_R)$ obtained as an abstraction of the Bilbao road network.

Figure 21 - An example of road graph

- Pedestrian graph $G_P = (V_P, E_P)$: the pedestrian graph is similar to the road graph, with the only difference that $G_P = (V_P, E_P)$ includes also the exclusively pedestrian streets (e.g pedestrian areas, footways, stairs), it doesn't represent the roads where is not possible to walk (e.g., highways, motorways) and lastly all the edges in E_P are considered undirected. Figure 22 shows in blue an example of graph $G_P = (V_P, E_P)$.

Figure 22 - An example of pedestrian graph

- Bicycle graph $G_B = (V_B, E_B)$: as for the pedestrian graph, also the bicycle graph is a different abstraction of the road network. Bicycle graph is very similar to the pedestrian graph excepting for the stairs that represent edges in E_p but not in E_B, and cicleways that represent undirected edges in E_B but they are not included in E_P. An example of $G_B = (V_B, E_B)$ is reported in Figure 23.

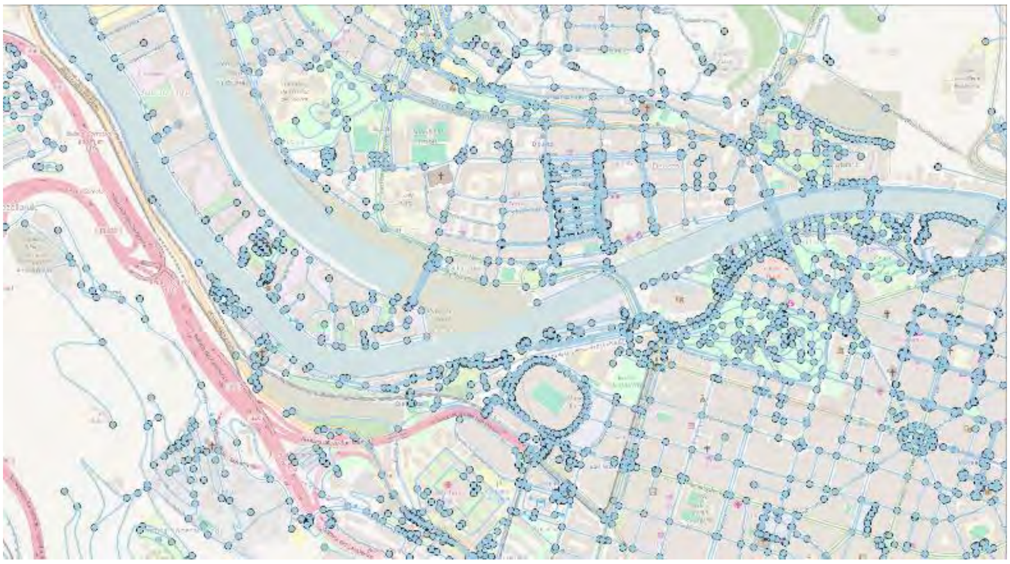

Figure 23 - An example of bicycle graph

- Subway graph $G_S = (V_S, E_S)$: this graph is a representation of the subway network. Each node in V_S represents a subway station and each edge in E_S represents a link between two consecutives subway stations as highlighted in orange in Figure 24. Following the same rationale used to define $G_S = (V_S, E_S)$, it is possible to define graphs for bus and tram networks.

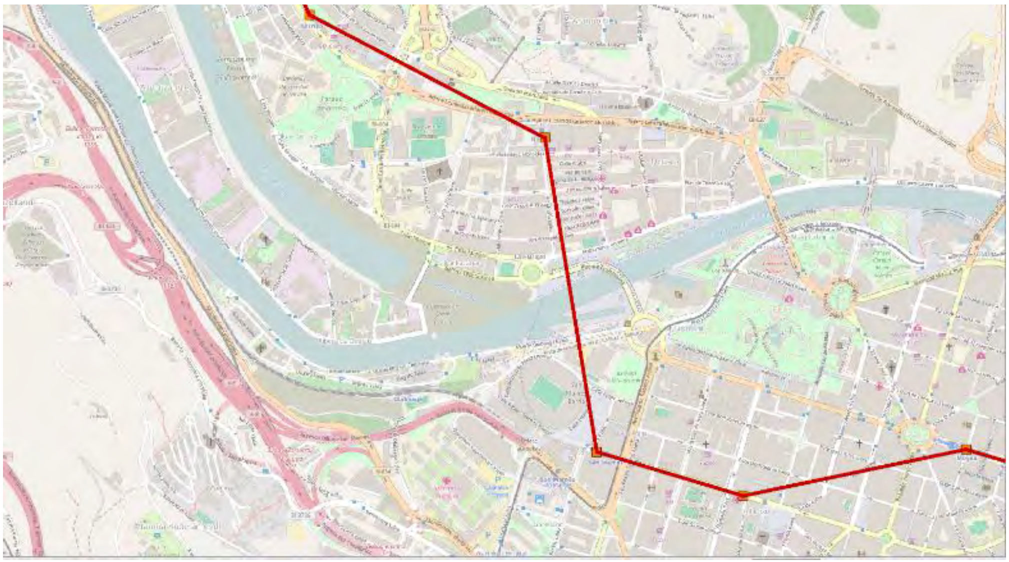

Figure 24 - An example of subway graph

- Car-Rental graph $G_{CR} = (V_{CR}, E_{CR})$: this graph represents the locations where it is possible to rent a car. For this reason, it is possible to consider V_{CR} the set of all the car rental locations whereas E_{CR} is an empty set. In fact, after the user has rented a car he/she will drive on the road network already modelled as $G_R = (V_R, E_R)$. It is important to notice that in the same way it is possible to model also other transport modalities like bike rental, bike sharing. Also car sharing service follows the same approach but the main difference with the car rental is the fact that the vehicle is available not in a fixed location and for this reason the car sharing can be considered only to plan a trip that the user immediately afterwards will start to follow.
- Car Pooling graph $G_{CP} = (V_{CP}, E_{CP})$: the car pooling graph is considered in BONVOYAGE similarly to the graph defined for a public transport modality (e.g., $G_S = (V_S, E_S)$) but its topology changes faster than the other graphs due to the fact that frequently new rides are offered and old offered rides become obsolete and should therefore be removed. In fact, when a user communicates to BONVOYAGE that he wants to share his vehicle for a specific itinerary, all the nodes and the edges belonging to $G_R = (V_R, E_R)$ and crossed by the driver (according to the planning) are added to the car pooling graph including the information about the expected time when each node will be visited. When a user asks BONVOYAGE for a planning including the car pooling service with the role of passenger, the urban soloist includes in the search also all the rides offered by the drivers, compatible with the passenger's start time and preferences (e.g., number of seats available, special needs). At this stage, the routes followed by the drivers are considered fixed and they are not modified to council with the passenger's itinerary, but a passenger

aggregation algorithm is performed offline in order to define pool of affine users including also the possibility to have a detour from the individual itinerary to optimize a common metric (e.g., to reduce time, cost, distance). More details about the passenger aggregation algorithm are reported in Section 5.5.

- Logical graph $G_L = (V_L, E_L)$: graph G_L is a representation of the existing interconnections among different transport modalities. The set of nodes V_L is an empty set whereas E_L contains edges linking two nodes belonging two different graphs such that:
  - $e(v_r,v_p) \in E_L$ with $v_r \in V_R$ and $v_p \in V_P$ such that v_p is the nearest node to v_r (meaning that the coordinates of the two nodes minimize the Euclidean distance) if it is possible to park the car in node v_r
  - $e(v_b,v_p) \in E_L$ with $v_b \in V_B$ and $v_p \in V_P$ such that v_p is the nearest node to v_b if it is possible to leave the bike and continue by walk
  - $e(v_s,v_p) \in E_L$ and $e(v_p,v_s) \in E_L$ for each $v_s \in V_S$ and $v_p \in V_P$ such that v_p is the nearest node to v_s . These edges allow to enter in the subway stations and to exit from them.
  - $e(v_p,v_{cr}) \in E_L$ for each $v_{cr} \in V_{CR}$ and $v_p \in V_P$ such that v_p is the nearest node to v_{cr} . These edges allow to enter in a car rental and to take a vehicle.
  - $e(v_{cr},v_r) \in E_L$ for each $v_{cr} \in V_{CR}$ and $v_r \in V_R$ such that v_r is the nearest node to v_{cr} . These edges allow to exit from a car rental office and to drive on the road network.

In Figure 25 reported below, the logical edges that allow to change transport modality in a certain node are depicted in yellow. In general, it is always allowed to pass from a graph to a different one (e.g., leave the bike and continue by walk) but in certain node it is possible only to continue using the current transport modality (e.g., on highways as depicted by the red nodes belonging to V_R in the left side of Figure 25).

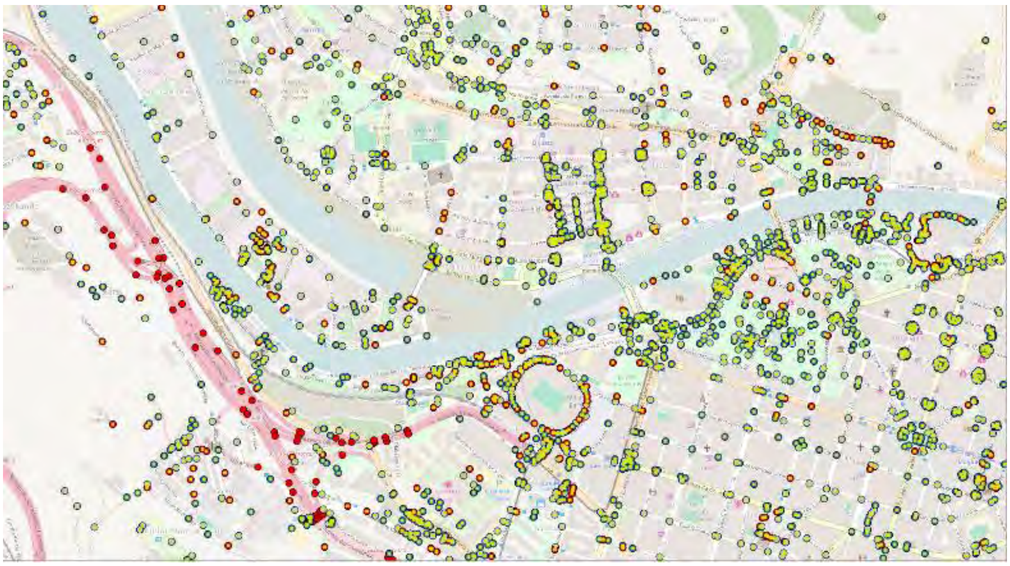

Figure 25 - An example of logical graph

So the network of the urban soloist can be defined as

$$N_U = G_R \cup G_P \cup G_B \cup G_S \cup G_{CR} \cup G_{CP} \cup G_L$$

Modelling the transport network as described above allows to use real time data to modify the solutions set. In fact, to each edge belonging to N_U it is possible to associate multiple weights: some of these weights are static and independent from the transport mean (the length of the street for example), other can be considered static but they depend on the mean of transport used to cross the link (e.g., CO2 emissions, cost) and other metrics change dynamically and depend on the mean (e.g., time needed to cross the link). As already detailed in Section 5.2.4, each trip planning query can ask to optimize one of these metrics or a combination of these ones according to the user's profile. Moreover, the approach used to model the network is extremely flexible and it can be easily extended to each urban area, including also additional transport modalities (e.g., taxi, Uber service).

For as concerns the choice of the algorithm A_U, it is possible to use any state of the art algorithms and implementation to solve the shortest path problem (Dijkstra, A*, ALT, contraction hierarchy, bidirectional Dijkstra).

In particular, for the urban soloist BONVOYAGE implemented the Dijkstra algorithm to solve the shortest path problem.

5.3.2 Urban soloist testing in a real world scenario

In this section are described some preliminary results obtained on a real world scenario. The scenario considers the city of Bilbao, and precisely an area of 20Km x 15Km as shown in Figure 26 delimited by the red box.

Figure 26 - The area used for testing the urban soloist

The urban network obtained modelling this geographical area consists of a graph with 63351 nodes and 121631 edges, distributed among the different sub-graphs as follow:

- Road graph $G_R(V_R, E_R)$: card(V_R) = 18894 and card(E_R) = 23226
- Pedestrian graph $G_p(V_p, E_p)$: card(V_p) = 22301 and card(E_p) = 28853
- Bicycle graph $G_B(V_B, E_B)$: card(V_B) = 22113 and card(E_B) = 28711
- Subway graph $G_S(V_S, E_S)$: card(V_S) = 41 and card(E_S) = 51
- Car-Rental graph $G_{CR}(V_{CR}, E_{CR})$: only two car rental locations (airport and main station) are considered in this graph, so card(V_{CR}) = 2 and card(E_{CR}) = 0
- Car Pooling graph $G_{CP}(V_{CP}, E_{CP})$: this graph is initialized as an empty graph (card(V_{CP}) = 0 and card(E_{CP}) = 0) but as described before, the graph is dynamically changed when the users add new availability to share rides.
- Logical graph $G_L(V_L, E_L)$: card(V_L) = 0 and card(E_L) = 40790

After the definition of the urban network and the identification of the Dijkstra algorithm as the solver for the urban soloist, it is possible to process some queries provided by the orchestrator.

For example, we assume now that a planning from the source address "Lutxana asua errepidea, Bilbao" to the destination address "Basauri, Bilbao" is sent by the orchestrator to the urban soloist. It is possible to notice in the following figures as the optimal solution changes according to the set of transport means that the user is available to use.

In Figure 27, a set of itineraries from the source address (indicated on the map with the red marker having the label 'S') to the destination address (marker with label 'D') are presented.

Each itinerary represents the optimal solution for a specific set of allowed transport means. In particular, the itinerary in red in image A is the solution returned for a query where only the usage of the private car is allowed. Image B depicts in sky blue the solution for a query where it is possible only to move by bike. In the case the query considers also the possibility to take the subway, the urban soloist returns to the orchestrator the solution shown in C where it is suggested to go by bike (sky blue path) to a near subway station, to continue by subway for 9 stops (orange path) and then walk to the destination (dark-blue path again). Finally, image D shows the solution in the case the query includes the possibility to rent a car. In fact, the urban soloist will suggest in this case to walk to the near car-rental office (highlighted with a green marker on the map) and then to drive toward the destination using the rented car.

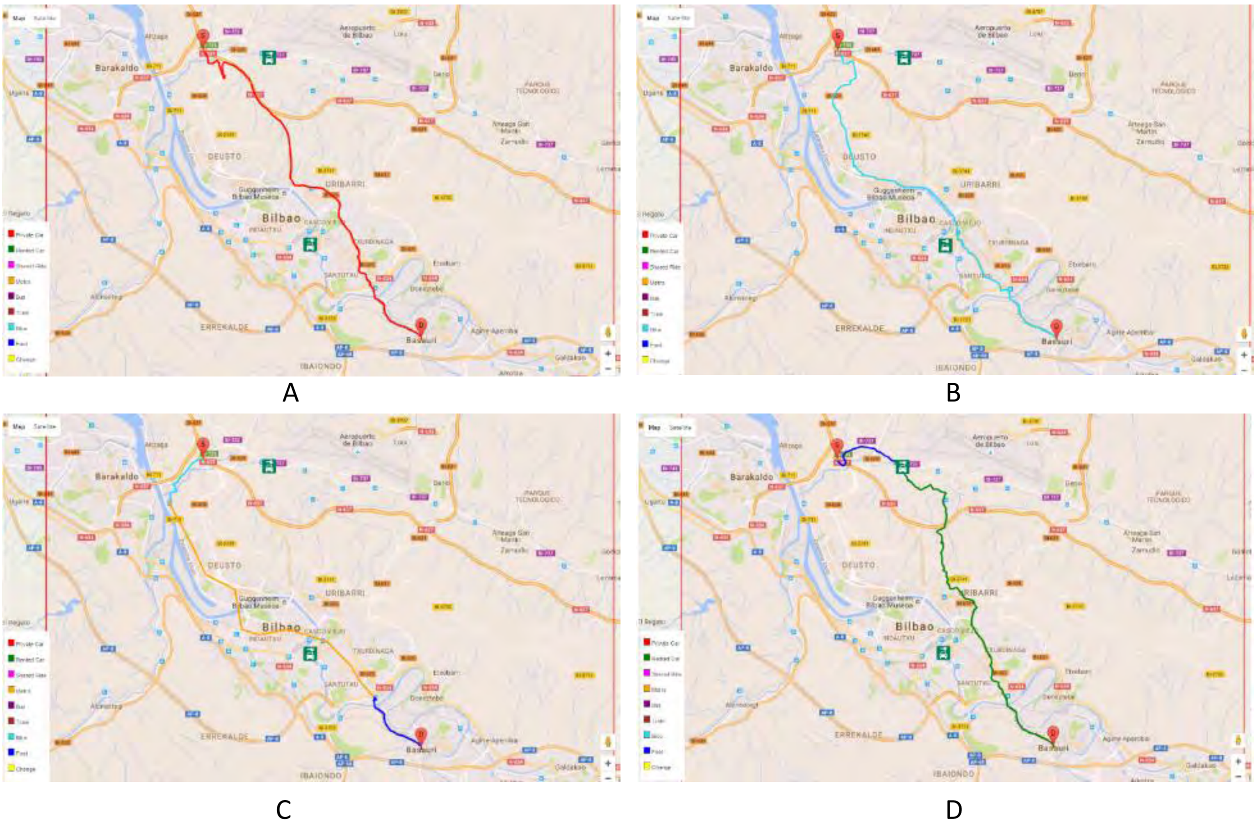

Figure 27 - solutions returned by the urban soloist

As described before, each solution strictly depends on the user's profile and in particular on the tendency that the user has to select, for example, the shortest path, rather than the fastest or the cheapest. In fact, two queries having the same user's preferences in terms of transport means and executed in the same context (e.g., same traffic conditions, car pooling availabilities, etc.) could return different solutions in the case they concern users with different profiles.

In fact, in the case the orchestrator asks to the urban soloist for a solution including all the available transport modalities, the planning algorithm will return solutions A or B reported in Figure 28, depending on whether the user is more sensitive to the time or the price of the travel.

We refer here to the research activities carried out within Task 4.1 User Profiler Tool and reported in this deliverable (see Section 4.1.3).

A B

Figure 28 - Urban soloist solutions depending on user's profile

Finally, 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 29 shows in red the itinerary that the user will follow with his/her car.

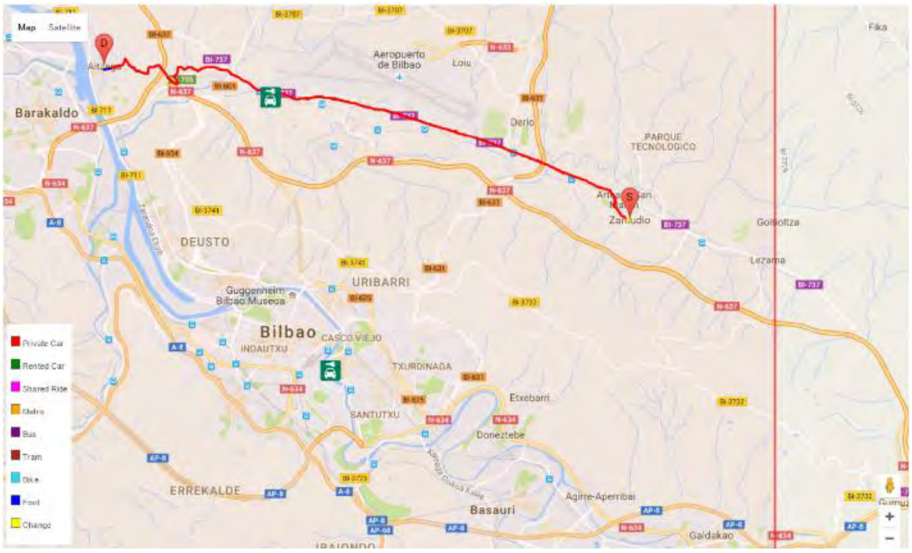

Figure 29 - Car pooling service: the driver shares a ride

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 30, 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).

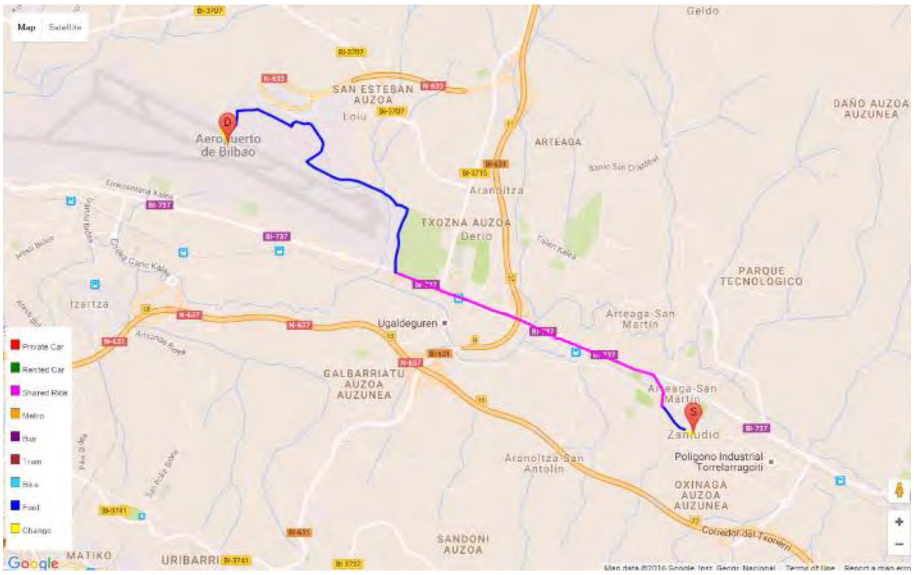

Figure 30 - Car pooling service: single source-multi destination solution example

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 31, where Gamma reaches by bike Alpha (sky-blue path) in an intermediate node and then they will go to Altzaga sharing the ride.

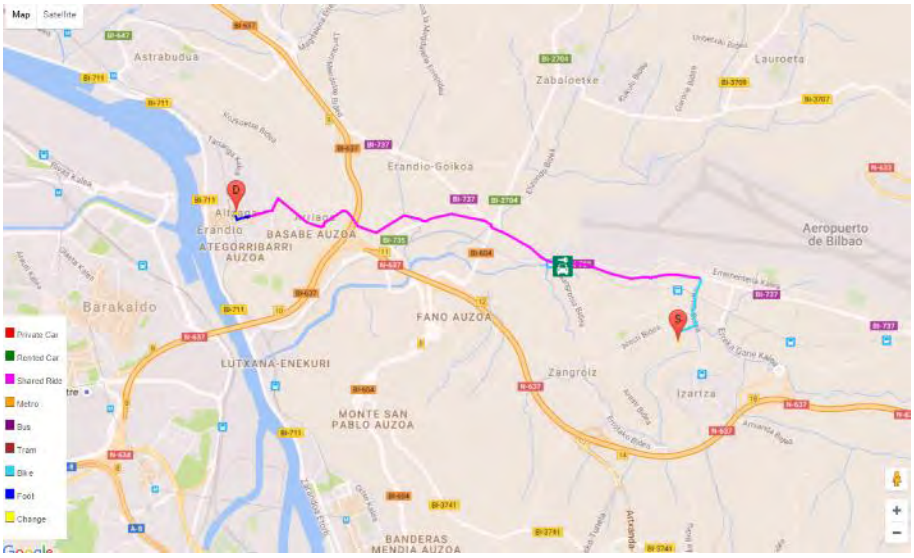

Figure 31 - Car pooling service: multi source-single destination solution example

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 32, 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 together 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.

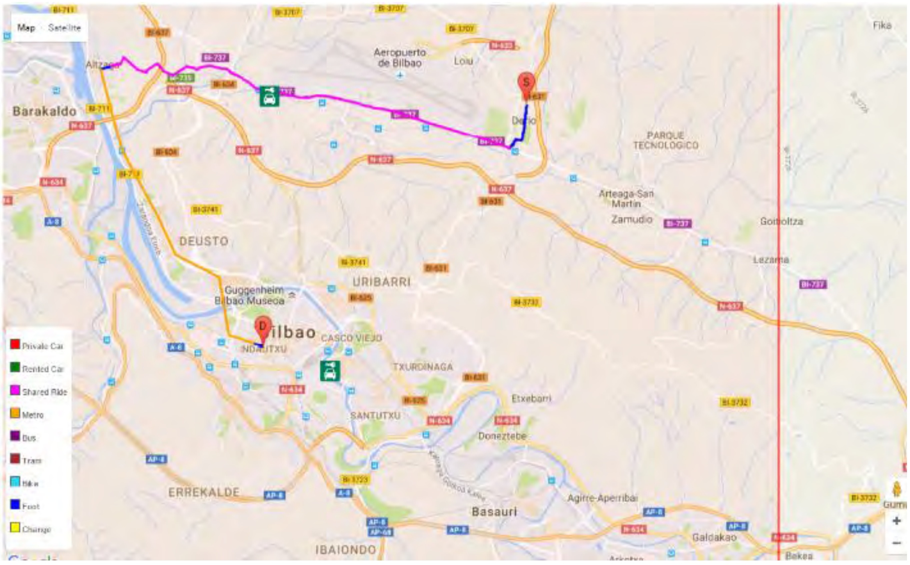

Figure 32 - Car pooling service: multi source-multi destination solution example

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) compatible 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., handicap, 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.

5.4 Scenario representation and list of relevant use cases

As discussed in the previous section, any Urban Soloist allows to perform trip planning within any urban area. The Orchestrator will then integrate such an urban travel solution with the optimal trip calculated at extra-urban level, thus providing the user with a complete set of Candidate Travel Solutions that exhibits the highest resolution made available by the underlying multi-layer graph. With specific reference to the situation when a generic Urban Soloist has to perform multi-passenger trip planning, the current section details the car pooling scenarios that have been taken into account and the next section describes a suitable trip planning algorithm that has been developed to tackle the problem of aggregating, into the same car pool, passengers exhibiting similar travel preferences.

Realistically, urban trip planning scenarios may be characterized by passengers planning a multi-modal trip, also including car sharing/car pooling options, to be shared with other BONVOYAGE users. The corresponding use case, outlining such a situation, is represented by UC_02_42, which is extensively described in D2.2.

In particular, the related workflow begins with a passenger, who is willing to travel from a source node to some destination node in the urban multi-modal transportation network, interacting with the BONVOYAGE platform and expressing either (i) his/her availability to share his/her own car with other BONVOYAGE users, or (ii) his/her interest in availing him/herself of a car sharing service together with other BONVOYAGE users who intend to follow the same itinerary (at least partially). Three relevant Alternative Flows have been identified as stemming from such a situation (within UC_02_42) and are going to be taken care of by the Urban Soloist.

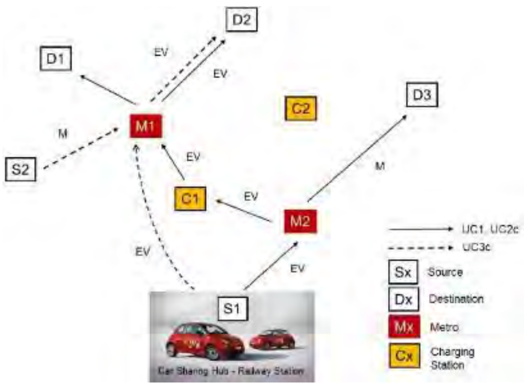

Figure 33 - Urban trip planning scenario

Alternative Flow 1: Standard Car Pooling A group of passengers who already know each other intend to travel together by sharing the same (possibly electric) car sharing vehicle, starting from the same source node and getting off the car at different optimal intermediate points in order to reach their own specific destinations. BONVOYAGE is expected to find the optimal multi-passenger trip plan which makes use of car sharing.

An example is given to better explain Alternative Flow 1. Three colleagues need to get home from the train station and decide to share an electric vehicle offered by the local car sharing operator. They share the same source node but they need to get to three different destinations (namely, D1, D2 and D3 in Figure 33). By interacting with the BONVOYAGE platform they form a car pool and as a result the Urban Soloist solves a multi-modal multi-passenger trip planning problem involving a car pooling phase. With reference to Figure 33, the car pool starts moving from S1, the third passenger is left in M2, that is, the optimal intermediate point from which such a passenger will reach destination D3 by using a different transport modality and following one of the routes prescribed by the Urban Soloist itself. Then, the car pool is scheduled for a recharge in charging station C1 (in case the shared vehicle is a FEV) and, subsequently, leaves the first passenger in M1, that is, the optimal intermediate point from which the passenger will reach destination D1 on his/her own. Eventually, the second passenger will proceed towards destination D2, where he/she will park the car. The planned path can be read in Figure 33 by following the solid line (labelled as UC1).

Alternative Flow 2: Car Pooling with aggregation of passengers This alternative flow is the same as the previous one, except for the fact that the group of passengers sharing the car is assembled by BONVOYAGE on purpose, starting from car reservations for the same node and time period, user profiles and digital reputations.

The hypothesis (assumed in Alternative Flow 1) that the passengers in the car pool already know each other is a really strong one. Hence, in order to consider a more general scenario, also the situation when the BONVOYAGE platform has to board people who do not know each other onto the same vehicle is taken into account. So, in this case, before invoking the trip planning algorithm for the car pool, according to the vehicle capacity (normally, three or four passengers) it is necessary to aggregate passengers into suitable groups (for instance, belonging to the same profile, moving towards destinations that are located in a specific area, etc.). In such a case, the trip planning algorithm cannot be immediately run as before, but it has to be properly invoked, previously taking into account the necessity of the optimal aggregation among passengers as well as profiling, service personalization and digital reputation. This is all taken care of by the Passenger Aggregator submodule in the Urban Soloist (see Figure 34 and the related description). The planned path for Alternative Flow 2 can be read in Figure 33 by following the solid line once again (labelled as UC2c), as the only difference with respect to Alternative Flow 1 lies in the preliminary aggregation phase envisaged in this case.

Alternative Flow 3: Passenger Pick-Up Passengers having the same destination, but not the same source, make use of car sharing. BONVOYAGE is expected to find the optimal multi-passenger trip allowing passenger pick-up along the road.

An example is given to better explain Alternative Flow 3. It seems reasonable that the BONVOYAGE platform can plan for two passengers, who move from different starting points but need to get to the same destination, to meet at an optimal intermediate point and from that point onwards to proceed as a car pool towards their common destination. In the previous cases, the tree of the optimal path was swept from its root node towards its leaves; in this case, the problem is set the other way around. Moreover, in the previous cases, there was no temporal constraint; instead, in this case, there is a relevant temporal constraint that must be taken into account. For instance, the first passenger may need to collect the other one ensuring that the rendez-vous occurs within a certain time window, otherwise he risks missing a scheduled deadline/appointment (e.g., a departing flight or train). The planned path for Alternative Flow 3 can be read in Figure 33 by following the dashed line (labelled as UC3c). Namely, the first passenger moves from S1 driving an electric vehicle available for car sharing. At the optimal intermediate point M2 he/she collects the second passenger who has arrived from S2 on his/her own. Then, the car pool moves towards the common destination D2, where the two passengers park and get out of the car.

5.4.1 *Internal architecture of the Urban Soloist and brief description of the architectural blocks*

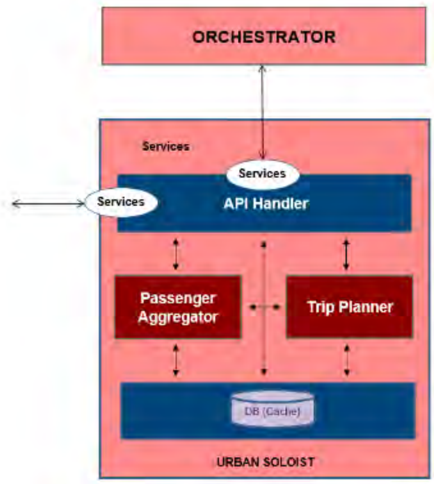

Figure 34 - Architecture of the generic Urban Soloist

In order to enable the above mentioned urban use cases and support the execution of use cases defined at global level, the Urban Soloist is preliminarily designed as depicted in Figure 34. The main components are:

- *The API Handler*, responsible for exposing local trip planning services to other components of the BONVOYAGE architecture and managing the calls to internal components and databases;
- *The Trip Planner*, implementing the algorithm for calculation of the optimal intra-urban, multi-modal, multi-passenger trip, thus behaving as the fundamental enabler of single passenger trip planning and car pooling use cases;

- *The Passenger Aggregator*, implementing the algorithm for composing pools of users which are suggested to share the same car, based on user profiles, digital reputation and on the overlap of travel preferences.

5.5 State of the art and Passenger Aggregator design

Most car pooling studies in the literature are focused on the *to-work* problem (from different origins to a common destination) and on the *return-from-work* problem (from the same origin to different destinations) and it is exactly these two problems that the Urban Soloist is aimed at tackling – namely, Alternative Flows 1 and 2 address the to-work problem, whereas Alternative Flow 3 addresses the return-from-work one, as described in use case UC_02_42 in D2.2. Namely, Alternative Flows 2 and 3 require the intervention of the Passenger Aggregator for arranging proper car pools.

It has turned out to be quite complicated to simultaneously and optimally determine participant roles (driver or passenger), previous/new car pool member schedules, previous/new passenger delivery options, as well as to match the participants in the same car pool, given the available context data. All of this involves the complicated movement of previous/new car pool members in the dimensions of time and space. In particular, *pre-matching* information, i.e., the information related to the potential car pool partners as well as to the route/schedule for each participating user, is quite relevant for performing passenger aggregation and, yet, it has been considered only very recently in the literature (the most significant related studies are cited below). In this respect, the Passenger Aggregator behaves as a service that uses network-based temporal and spatial information (i) to select the users who will drive and those who will be carried, (ii) to consequently match passengers with drivers, thus developing the car pooling team, and eventually (iii) to establish the order in which the driver will pick up and drop off all team members, thus providing suitable car pool routes [34]. This is done with the aim of achieving the usual goals of car pooling (e.g., reducing traffic congestion and CO_2 emissions, as well as allowing to share driving costs and parking fees), but explicitly taking into account the specific car pool time window, the passenger/driver type and preferences as well as the vehicle capacity constraints. This is known in the recent literature as the *car pooling problem with pre-matching information* (CPPPMI).

In [35] a time-space network technique is applied to deal with such a problem. Given the time-space networks related to the vehicle flow before car pooling, the drivers' flow and the passengers' flow, as well as the relational constraints, the problem is formulated as an integer multiple commodity network flow model, where the objective is to minimize the overall system cost, including the travelling cost for both drivers and passengers. Changes are made between previous and new (i.e., car pooling) plans, ensuring flow conservation at all nodes.

In [36], passenger aggregation is performed only if the passenger's path falls within a suitable detour range specified by the user who is driving the potential car pool. The problem is tackled by also considering the need for minimizing the passenger's waiting time at the departure point as well as the delay time which corresponds to the difference between his/her desired arrival time and the actual arrival time at the final destination. In [37], too, the proposed algorithm looks for car pooling candidates whose starting point belongs to the detour area swept by the driver along his/her path. If a candidate is found, the driver's path is recomputed to pick the passenger up; by the way, if this makes the detour bigger than the maximum detour allowed, the candidate is discarded and no car pool is formed.

However, since real problem sizes are expected to be huge, it is actually difficult to optimally solve the CPPPMI within a reasonable time. Thus, to efficiently solve the problem in practical-sized scenarios, heuristic algorithms are generally designed, returning suboptimal travel solutions in reasonable time. This is exactly the case of the Passenger Aggregator: as described in detail in the following subsections, a heuristic procedure, relying on pre-matching information, designed on the basis of [35], [36] and [37], and adapting Dijkstra's shortest path algorithm, is run with the aim of bending driver trajectories for suitably picking up and dropping off passengers, hence promoting the creation of car pools [38], [39]. Note that the bending action concerns both *passenger* and *driver* trajectories and thus all the Alternative Flows described in Section 5.4 can be addressed. Nonetheless, the Passenger Aggregator allows to solve, not only the to-work and return-from-work problems, but also the more general case of *many-to-many* car pooling problems with multiple vehicle and person types, based on pre-matching information, as shown in the simulation results reported in Section 5.5.4.

In particular, the aggregation process is structured into the three steps below:

1) *Pre-processing phase*. In the User Query, each user is identified as either a *passenger* user, or a *driver* user or a *both* user (which means that he/she is available to play both roles). First of all, this stage reduces the problem dimension by excluding the (driver, passenger) couples who cannot be aggregated (and will be dealt with in the next steps). Then, on the basis of a suitable metric defined over user profiles and queries, a similarity matrix is here arranged with the aim of assessing the similarity degree (with respect to the expressed preferences) between drivers, on the one hand, and passengers, on the other hand.
2) *Main processing stage*. For each *driver* or *both* user, a car pool is created based on the outcome of the pre-processing phase. This step is in charge of performing the actual aggregation of users. The process is based on the previously defined similarity matrix and considers, in an iterative manner, each aggregable (driver, passenger) couple, thus trying to create car pools composed of a driver and as many passengers as the number of free seats specified by the driver him/herself in the query. Moreover, at this stage (i.e., before running the post-processing phase), *both* users are assumed to behave as if they were *driver* users.

3) *Post-processing phase*. The final step of the algorithmic procedure addresses the problem of further reducing the number of vehicles circulating on the roads. This result is achieved by exploiting the double nature of *both* users who gave their availability of being managed either as a passenger or a driver. More in detail, if it occurs that a *both* user after the main processing stage is still alone in the car, the Passenger Aggregator tries to add him/her to an already existing car pool, if deemed convenient on the basis of the same similarity criterion as above. Eventually, all travel queries are divided into aggregated and non-aggregated ones, so that the Urban Soloist can easily sort them out and deal with them properly. In particular, the created car pools and their planned routes are returned to the Orchestrator.

So far, we have given just a brief overview of the Passenger Aggregator design: an in-depth analysis of the different steps of the algorithmic procedure run by the Passenger Aggregator is reported below.

5.5.1 Pre-processing phase

Step 1 (or similarity assessment step)

As anticipated above, the proposed algorithm is based on the pre-matching information encoded in a similarity matrix. The *similarity matrix S* is arranged with as many rows as the querying drivers and as many columns as the querying passengers. Each entry of such a similarity matrix represents the similarity degree between each driver, identified by the row index, and each passenger, identified by the column index. The similarity degree of each (driver, passenger) couple is computed according to a properly designed criterion for similarity assessment which takes into account two kinds of user constraints, namely *hard constraints* and *soft constraints*[13]. Indeed, there occur to be a set of hard constraints and a set of soft constraints accompanying each User Query.

Hard constraints, explicitly indicated by users, express mandatory travel conditions which have to be satisfied. For instance, a hard constraint can specify that the user does not want to be in a car with smokers or needs a vehicle that is eligible for the transportation of handicapped passengers. Hard constraints are used to preliminarily detect groups of users who may be aggregated. Then, soft constraints are used to assess the similarity degree of each (driver, passenger) couple. In other words, they are not mandatory conditions but express user preferences that are taken into account to quantify the similarity among drivers and passengers on a *behavioural basis*. For instance, a soft constraint may be the fact that a user is a teenager, or listens to a specific music genre only, etc.: this means that such a user will be preferably aggregated with a driver or other passengers who are young people, or share similar interests, etc.

[13]It is also possible for some of these constraints to be activated as a hard one for a given user, and instead as a soft one for another user.

It is worth stressing out the fact that soft constraints are defined by means of two contributions. On the one hand, each user may explicitly express some preferences, for instance, relative to the age or sex of the users with whom he/she would like to be aggregated. On the other hand, this class of constraints is enhanced with information coming from the User Profiling module (see Section 5.1) which is implicitly associated with each user.

Given this framework, the algorithmic procedure in the pre-processing phase is organized according to the two bullets below.

- First of all, it is checked whether the hard constraints of a driver match the hard constraints of a passenger, for each (driver, passenger) couple. If so, the similarity assessment described in the next bullet follows; otherwise, the corresponding element of the similarity matrix is zeroed out, signifying that the considered passenger cannot be aggregated in the same car pool as the chosen driver.
- After going through the hard constraints of all (driver, passenger) couples, soft constraints are taken into account. Based on the difference between the soft constraints expressed by the driver and the soft constraints expressed by the passenger, the similarity degree between the two is properly evaluated. Namely, this similarity measurement is designed so as to reasonably favour those (driver, passenger) couples such that the passenger's source and destination are found to be closer to the driver's source and destination, thus making sure that the similarity assessment is performed also on a spatial basis. More precisely, the similarity is given by the difference between the soft constraints of the (driver, passenger) couple plus a measure of how close their sources and destinations are. In other words, a *spatial bias* is introduced in order to foster the aggregation of users whose trajectories are similar. By properly weighing these two contributions, the aggregation process can be suitably biased, taking into account the behavioural similarity between users more than the spatial affinity, or vice versa.

Note that if a driver and a passenger prove to be aggregable as a result of the first bullet, but they are very dissimilar (i.e., their soft constraints do not match at all), the corresponding value in the similarity matrix is not zero due to the spatial bias.

Step 2 (or reduction step)

Before proceeding with the very aggregation task, a preliminary reduction step is taken: the similarity matrix is further reduced in order to *limit the computational cost* of running the Passenger Aggregator itself. In this respect, we must look for the three specific cases described below, which represent some critical or trivial situations that may arise when attempting to match users into the same car pool.

- Case 1) If, as a result of the generation of the similarity matrix, there happen to be *both* users who cannot be aggregated with any passenger (i.e., the corresponding rows are all zero), their aggregation is put off until the post-processing phase.

- Case 2) If there are *passenger* users who cannot be aggregated with any driver (i.e., if the corresponding columns contain only zeros), their queries are directly considered as solved in a classical single-passenger trip planning fashion.
- Case 3) If there are *driver* users who cannot be aggregated, their queries are not considered as solved for now, since in the post-processing phase they may still be aggregated with the remaining *both* users.

So, only the queries of those *users* who appear to be fit for aggregation will move on to the main processing stage. Hence, the reduction of the similarity matrix is carried out as follows.

- The rows associated with the *both* users who cannot be aggregated (refer to Case 1 above) are removed from the similarity matrix and the related queries will be dealt with directly in the post-processing phase.
- The columns associated with the *passenger* users who cannot be aggregated (refer to Case 2 above) are removed from the similarity matrix. Their queries are then directly sent to the trip planner, signifying that such passengers are not in a position to benefit from the car pooling service.
- The rows identifying the *driver* users who cannot be aggregated (refer to Case 3 above) are removed from the similarity matrix and the related queries will be dealt with directly in the post-processing phase.

Therefore, the rows of the reduced similarity matrix are associated with only those drivers who have turned out to be aggregable with at least one of the passengers and, conversely, the columns of the reduced similarity matrix are associated with only those passengers who have proved to be aggregable with at least one driver. This means that, as a result of the reduction step, there are no rows or columns whose elements are all zero. Moreover, the maximum number of car pools that can be created is given by the number of rows of the reduced similarity matrix.

5.5.2 Main processing stage

The main aggregation phase is an iterative procedure, based on the reduced similarity matrix, aimed at creating car pools. At each iteration, the (driver, passenger) couple with the highest similarity degree (identified by the entry of the matrix with the highest value) is considered and an attempt to aggregate them is made: if this attempt is successful, a car pool is created (or updated) and the corresponding element of the similarity matrix is set to zero as well as all the elements of the column associated with the current *passenger* user. That is, each couple of users is considered at most once because either the aggregation is successful, and thus the *passenger's* query is solved, or the current couple is not eligible for aggregation. The iterative procedure just described is repeated until the reduced similarity matrix contains only zero entries.

More in detail, until there is at least a non-zero entry in the reduced similarity matrix the following steps are performed: once the entry of the reduced similarity matrix with the highest value has been identified, the corresponding (driver, passenger) couple is the one with the highest similarity degree and is therefore considered for aggregation by following the steps below.

1. At first it is checked if the number of seats requested by the passenger is less than or equal to the number of seats made available by driver. If this condition is not verified, the entry of the matrix associated with the current couple is zeroed out and the matrix is searched for a new candidate couple of users with the largest value of the similarity degree.
2. If instead the previous condition is satisfied, by means of an adapted version of Dijkstra's shortest path algorithm, the shortest path for the current passenger is computed considering not just the pedestrian network and the public transport network (as it occurs in standard single-passenger trip planning), but *also the private transport network*, including all and only the nodes that are *reachable* from the *driver* according to the *detour range* specified by the driver him/herself in his/her User Query (thus embedding a *further spatial criterion* for route selection). In other words, the minimal source-destination path for the considered passenger is returned, including in this case the possibility of being picked up and left at some reachable nodes by the considered driver.
3. If, as a result of this routing procedure, the passenger is not planned to enter the driver's car, a suitable flag is set to 0, thus signifying that there will be no aggregation and the passenger's path will be computed in a single-passenger trip planning fashion. Also, the corresponding entry of the reduced similarity matrix is set to 0, so that the matrix is updated for the next iterations.
4. If, instead, the passenger is planned to enter the driver's car and the related flag is set to 1, this means that there is a potential common path and a car pool could be arranged. It is therefore checked whether the time it takes the passenger to follow this new travel solution (in car pooling) is less than the time it takes if he/she goes on his own (according to single-passenger trip planning over the pedestrian and public transport network only).
5. Then, if the new path turns out to be convenient for the passenger as a result of point 4, it is also checked if the car pool is empty (i.e., if the current driver has not been aggregated with any passenger yet), if the number of transit nodes for the driver is within the maximum allowable one (specified by the driver him/herself) and if the absolute value of the difference between the time it takes the driver to reach the rendez-vous node and the time instant when the passenger is expected to visit the rendez-vous (accordingly to the path computed at point 2) is less than a certain pre-defined – possibly specified in the query – tolerance value. This allows us to state that passenger

aggregation is performed also *on a temporal basis*, as it envisages these feasibility constraints expressed in terms of time.

6. If all these conditions hold, then the current passenger and driver are aggregated. The passenger's query is updated with the routing results achieved at point 2. The driver's query is also updated with the detour he/she has to make in order to share some part of the path with the passenger. Then, the previously initialized car pool is updated with the common path between the driver and the passenger, and the number of seats available in the car pool is decreased according to the number of seats requested by the passenger (who in general can be more than one). The similarity matrix is updated as well: the column associated with the current passenger is zeroed out and, if either the maximum number of seats or the maximum number of stops specified by the driver is reached, then the row associated with the driver is zeroed out, too.
7. If the conditions at point 5 are all satisfied except for the emptiness of the car pool (i.e., the current driver has already been aggregated with some passenger), then the processing phase is more complex. First of all, it is checked if the nodes where the passenger is expected to be picked up and dropped off by the driver are already in the path of the car pool: if so, the problem is simpler since the path of the car pool does not change as the paths of the passengers are already aggregated with the current driver. Hence, in such a case the passenger's query is updated with the routing results obtained at point 2 and the driver's query is not modified. The car pool and the similarity matrix are updated as described at point 6.

With reference to point 7 – that is, a situation when the Passenger Aggregator is attempting to aggregate a new passenger with a driver whom other passengers have already been aggregated to – six possible scenarios can occur in a classical car pooling scenario (with three seats per car) and have to be properly dealt with. Let us refer to the current passenger as *user2* and assume, for the sake of simplicity, that only one passenger – *user1* – has been already aggregated with the current driver. Recall that at this point of the iterative procedure, *user2* has proved to be aggregable with the driver both from a spatial and a temporal point of view. Let *source1*, *destination1* and *source2*, *destination2* be the points where *user1* and *user2* are expected to be picked up and left by the driver according to the computed path. Then the Passenger Aggregator may assign to the driver one of the following six travel solutions: start at the driver's source and then

(i) reach *source1* and pick up *user1*, reach *destination1* and leave *user1*, reach *source2* and pick up *user2*, reach *destination2* and leave *user2*, reach the driver's destination;
(ii) reach *source1* and pick up *user1*, reach *source2* and pick up *user2*, reach *destination1* and leave *user1*, reach *destination2* and leave *user2*, reach the driver's destination;
(iii) reach *source1* and pick up *user1*, reach *source2* and pick up *user2*, reach *destination2* and leave *user2*, reach *destination1* and leave *user1*, reach the driver's destination;

(iv) reach *source2* and pick up *user2*, reach *destination2* and leave *user2*, reach *source1* and pick up *user1*, reach *destination1* and leave *user1*, reach the driver's destination;

(v) reach *source2* and pick up *user2*, reach *source1* and pick up *user1*, reach *destination1* and leave *user1*, reach *destination2* and leave *user2*, reach the driver's destination;

(vi) reach *source2* and pick up *user2*, reach *source1* and pick up *user1*, reach *destination2* and leave *user2*, reach *destination1* and leave *user1*, reach the driver's destination.

Hence the problem here is to choose the best sequence of actions among the following four: {reaching *source1* and picking up *user1*, reaching *destination1* and leaving *user1*, reaching *source2* and picking up *user2*, reaching *destination2* and leaving *user2*}. Such a choice is made on a temporal basis and, more precisely, all six scenarios are computed and, among them, the most convenient solution for the driver in terms of time is chosen. In this respect, the Candidate Travel Solution, which has to be acceptable for *user1*, is chosen as follows.

- First of all, it is determined if is more convenient for the driver to pick up *user1* before *user2* or vice versa. Such convenience is assessed on a temporal basis: the passenger who is going to be picked up first is the one who is reached by the driver in less time.
- Assuming that it turns out that picking up *user1* before *user2* is more convenient (i.e. cases (i), (ii) and (iii)), it must now be determined if it takes the driver less time to reach *source2* and pick *user2* up than it does to reach *destination1* and drop *user1* off or vice versa.
- If, at this point, it is more convenient to drop *user1* off first and then pick *user2* up, then the final car pool path is ready to be arranged according to the sequence represented by case (i). Note that in this case the path previously computed by the Passenger Aggregator for *user1* does not need to be modified and so it is not necessary to check that the new car pool path is feasible. However, it is necessary to check that the arrival time for the driver at *source2* and the waiting time of *user2* are compatible. If they are, then the aggregation is finally performed following the order specified in case (i).

In all the other cases (i.e., cases from (ii) to (vi)), instead, the time instant when the driver drops *user1* off at *destination1* is modified: so, in such cases, it is necessary to check that the arrival time for *user1* with the new car pool path is actually less than the time it takes him/her to reach *destination1* by public transport only. If not, the candidate travel solution is rejected and *user2* cannot be aggregated with the pool that includes *user1*. If, instead, using the car pool is still convenient for *user1*, it must be checked that the time it takes the driver to reach *source2* is compatible with the time it takes *user2* to reach *source2*. If this condition too is fulfilled, then the aggregation is performed, the car pool path is updated, and the queries of the driver, of *user1* and of *user2* are updated with the adjusted path.

Again with reference to point 7, in the more general situation when, instead, the number of passengers already associated with the car pool is more than one, then, among the above-mentioned six possible scenarios, only scenarios (i) and (iv) are taken into account, assuming this time *user2* as the current passenger to be aggregated with the car pool and *user1* as the collection of the passengers who already belong to the car pool.

Note that the procedure just described is consistent with the choice of assigning a higher priority in the aggregation process to those couples of users with a higher similarity degree. Following this observation and with reference to point 7, it can be observed that, if more than one passenger have already been aggregated with the current driver, the Passenger Aggregator as far as possible considers these passengers as a single user so that the variations among their paths are minimized.

Moreover, with reference to point 2, it is not guaranteed at all that there always exists a path from a reachable node to another. This happens if and only if the graph is strongly connected. As, in general, it is not so, a suitable search algorithm (such as the breadth-first search one) can be adopted for efficiently detecting the reachable nodes that belong only to strongly connected graph components and consequently avoiding as far as possible the risk of falling into any disconnected graph components.

It is also worth noticing that, if the most convenient solution for the driver is not feasible, the aggregation process is not stopped but the algorithm continues searching through the other feasible travel solutions, looking for the most convenient one.

5.5.3 Post-processing phase

The final step of the algorithmic procedure addresses the problem of further reducing the number of vehicles circulating on the roads. This result is achieved by exploiting the double nature of *both* users who gave their availability of being managed either as a passenger or a driver. More in detail, if it occurs that a *both* user after the main processing stage is still alone in the car, the Passenger Aggregator tries to add him/her to an already existing car pool, if deemed convenient on the basis of the same similarity criterion as above. Eventually, all travel queries are divided into aggregated and non-aggregated ones, so that the Urban Soloist can easily sort them out and deal with them properly. In particular, the created car pools and their planned routes are returned to the Orchestrator.

5.5.4 Simulation results

The following simulations have been carried out in the MATLAB® environment, considering a multi-graph with 4981 nodes and 9790 edges, as made available on OpenStreetMap, representing the multi-modal traffic network in the Bilbao city centre, as shown in the figure below.

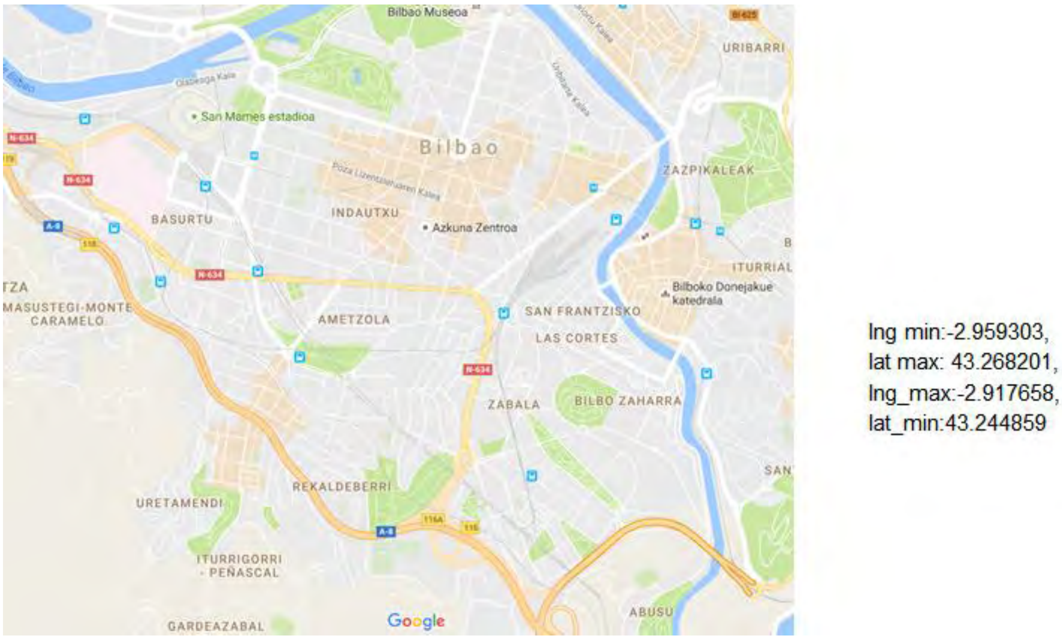

Figure 35 - The section of the Bilbao city centre, with the corresponding min/max longitude and latitude values, considered in the presented simulations.

5.5.4.1 Simulation of a simple many-to-many car pooling scenario with two drivers and five passengers

The simulation setup presented below consists in two drivers and five passengers. Namely, let us assume that the following User Queries are made:

USER	QUERY ID	SOURCE NODE	DESTINATION NODE	DETOUR RANGE	FREE SEATS	# OF PEOPLE	MAX # OF TRANSIT NODES
Driver 1	1	Nodes(687)	Nodes(4731)	0.0011	3	-	180
Driver 2	2	Nodes(3652)	Nodes(968)	0.002	3	-	140
Passenger 1	3	Nodes(2202)	Nodes(286)	-	-	1	-
Passenger 2	4	Nodes(2357)	Nodes(2892)	-	-	1	-
Passenger 3	5	Nodes(3000)	Nodes(1078)	-	-	1	-
Passenger 4	6	Nodes(1100)	Nodes(4750)	-	-	1	-
Passenger 5	7	Nodes(771)	Nodes(972)	-	-	1	-

The table above shows the data of each User Query that are relevant for the algorithmic procedure carried out in the Passenger Aggregator. In particular, the entries associated with the Source Node and Destination Node columns specify the node index within the node array Nodes for the source and destination of each user, respectively.

In this simulation (and also in the next ones), for the sake of simplicity, we have assumed not to consider the presence of hard constraints. Passenger Aggregation is here performed only on a temporal and spatial basis. This is due to the fact that the computational complexity of the algorithm mainly falls in embedding a spatial criterion for route selection, especially since an expensive preliminary analysis has to be carried out, for the drivers, on the reachable nodes that belong to strongly connected graph components.

The detour range specifies the radius of the circle within which a driver at a generic point $P(latitude, longitude)$ is willing to take a detour for picking up/dropping off passengers. Such a detour range, as specified in the User Query, is used by the algorithmic procedure discussed above as stated in point 2 of Section 5.5.2.

The simulation outcome consists in the Passenger Aggregator returning two car pools: namely, one including *Driver 1*, *Passenger 4* and *Passenger 5*, and the other including *Driver 2*, *Passenger 2* and *Passenger 3*. Only one passenger is not aggregated at all, i.e., *Passenger 1*. In Figure 36 – Figure 42, the user paths before running Passenger Aggregation, i.e., as the output of the urban soloist in charge of trip planning in Bilbao, are depicted. Instead, in Figure 43 – Figure 48, the modified paths, obtained as a result of Passenger Aggregation, are depicted. More in detail,

- Figure 36 represents the path of *Driver 1*, before Passenger Aggregation is run, in black;
- Figure 37 represents the path of *Driver 2*, before Passenger Aggregation is run, is red;
- In Figure 38 – Figure 42, the paths of *Passenger 1*, *Passenger 2*, *Passenger 3*, *Passenger 4* and *Passenger 5* are represented, respectively, before Passenger Aggregation is run, in yellow;
- In Figure 43 and Figure 44, the paths of both drivers are represented, after Passenger Aggregation is performed, as composed of three line-strings (or polygonal paths), eventually collapsing into a single destination node: namely, two black line-strings in Figure 43 and two red line-strings in Figure 44 standing for the solo part of each driver's ride, plus a green line-strings representing the car pool path;
- In Figure 45 - Figure 48, the paths of the passengers are represented, after Passenger Aggregation is performed, as composed of three line-strings (or polygonal paths), eventually collapsing into a single destination node: two yellow line-strings which are the solo paths before being picked up and after being dropped off by the driver, and one black/red line-string which represents the car pool path.

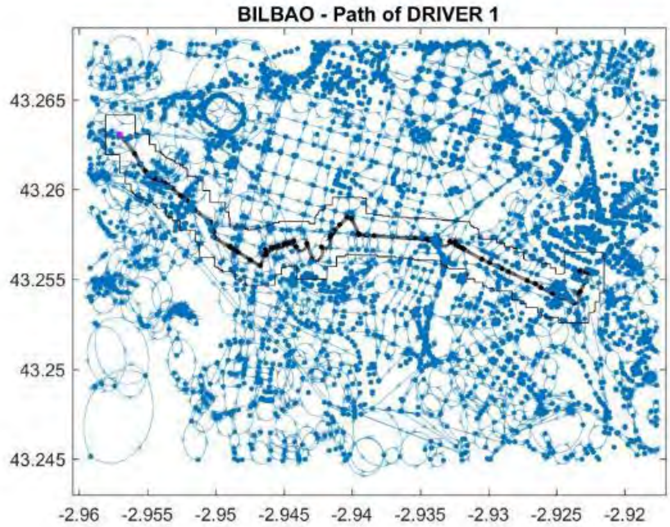

Figure 36 - Planned path for Driver 1, before Passenger Aggregation is run, depicted in black.

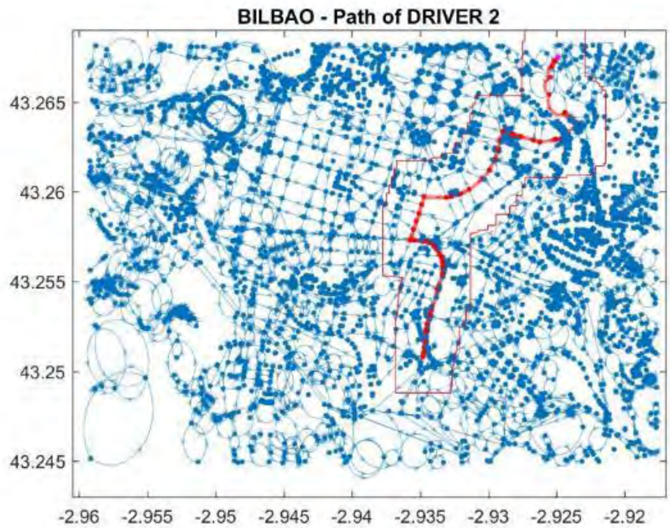

Figure 37 - Planned path for Driver 2, before Passenger Aggregation is run, depicted in red.

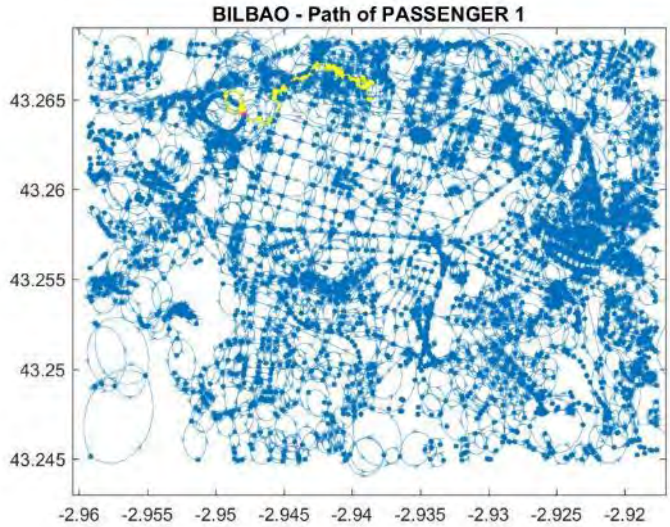

Figure 38 - Planned path for Passenger 1, before Passenger Aggregation is run, depicted in yellow.

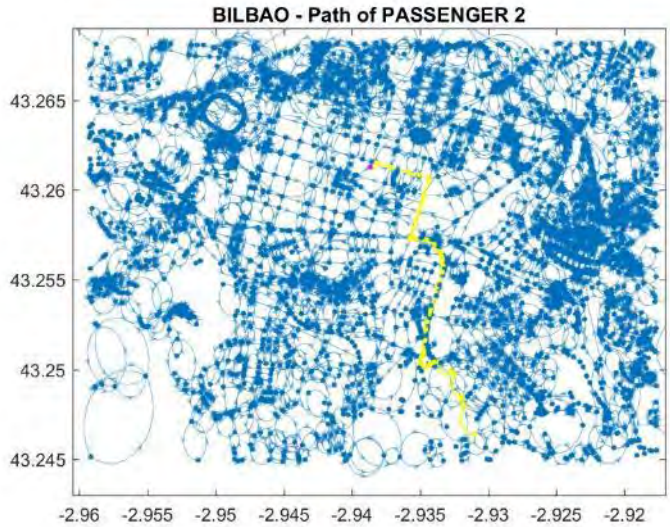

Figure 39 - Planned path for Passenger 2, before Passenger Aggregation is run, depicted in yellow.

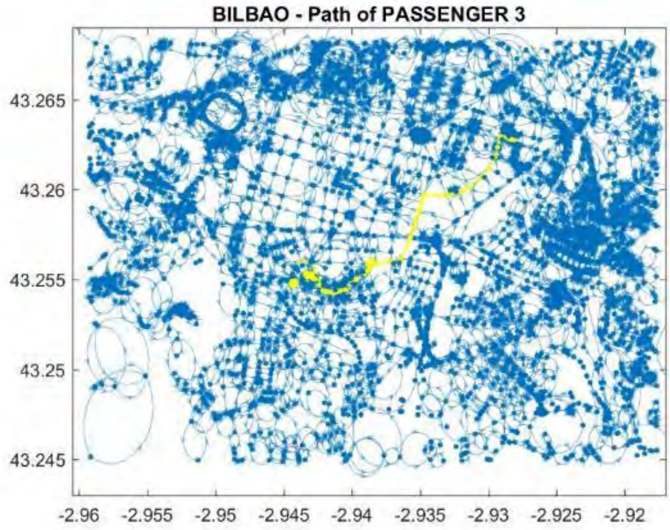

Figure 40 - Planned path for Passenger 3, before Passenger Aggregation is run, depicted in yellow.

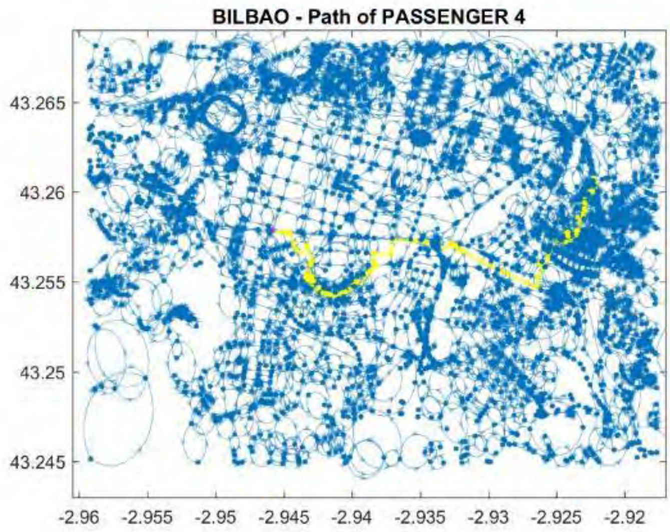

Figure 41 - Planned path for Passenger 4, before Passenger Aggregation is run, depicted in yellow.

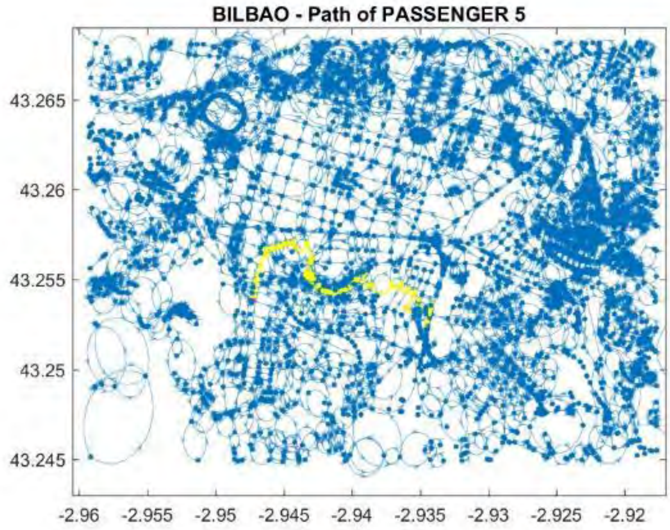

Figure 42 - Planned path for Passenger 5, before Passenger Aggregation is run, depicted in yellow.

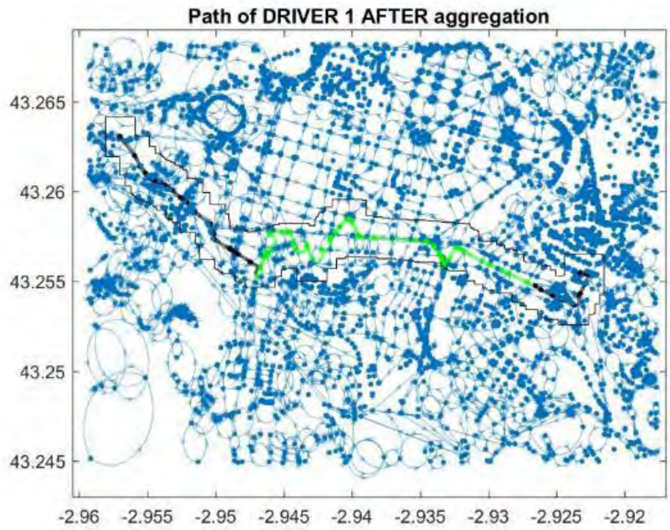

Figure 43 - Planned path for Driver 1, after aggregation with Passenger 4 and Passenger 5, as composed of three line-strings (or polygonal paths), namely two black line-strings standing for the solo part of Driver 1's ride, plus a green line-string representing the car pool path.

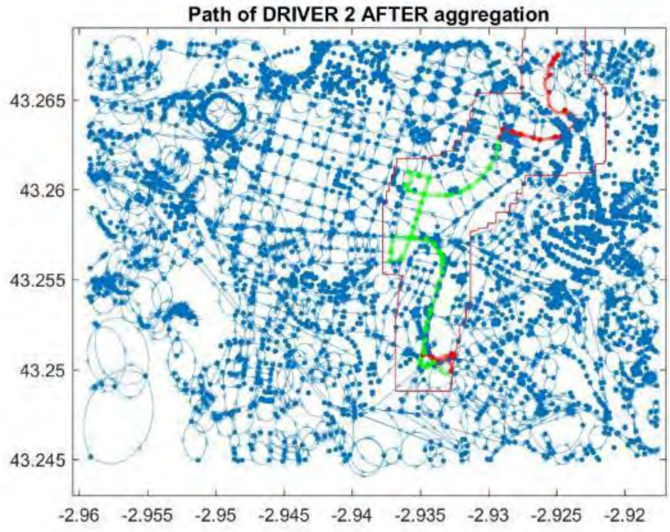

Figure 44 - Planned path for Driver 2, after aggregation with Passenger 2 and Passenger 3, as composed of three line-strings, namely two red line-strings standing for the solo part of Driver 2's ride, plus a green line-string representing the car pool path.

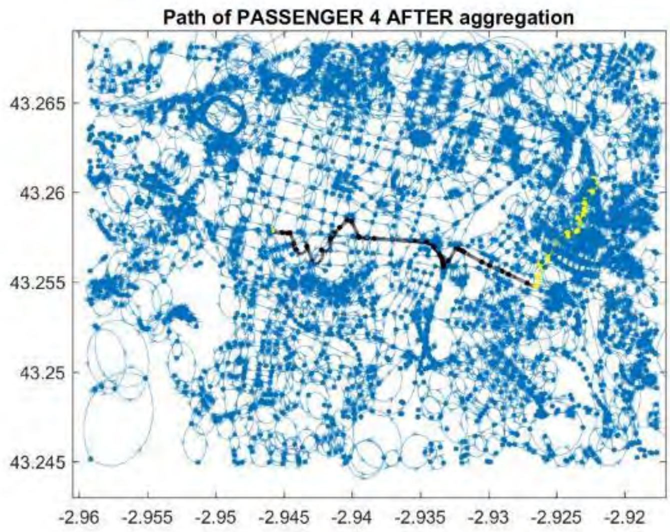

Figure 45 - Planned path for Passenger 4, after Passenger Aggregation is performed, as composed of three line-strings, namely two yellow line-strings which are the solo paths before being picked up and after being dropped off by the driver, plus a black line-string which represents the car pool path.

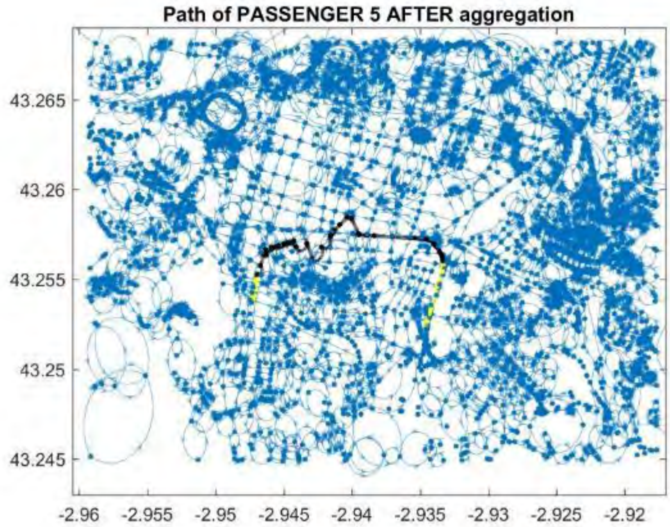

Figure 46 - Planned path for Passenger 5, after Passenger Aggregation is performed, as composed of three line-strings, namely two yellow line-strings which are the solo paths before being picked up and after being dropped off by the driver, plus a black line-string which represents the car pool path.

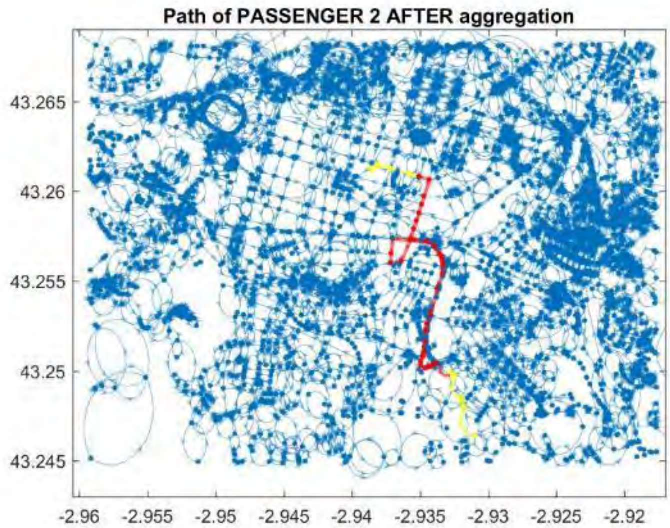

Figure 47 - Planned path for Passenger 2, after Passenger Aggregation is performed, as composed of three line-strings, namely two yellow line-strings which are the solo paths before being picked up and after being dropped off by the driver, plus a red line-string which represents the car pool path.

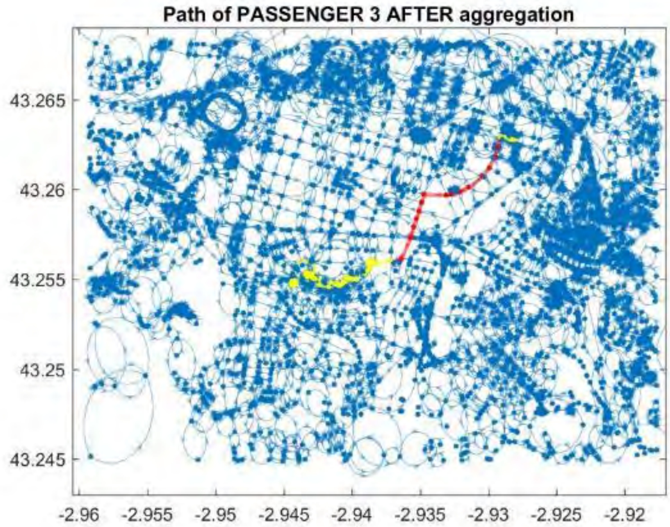

Figure 48 - Planned path for Passenger 3, after Passenger Aggregation is performed, as composed of three line-strings, namely two yellow line-strings which are the solo paths before being picked up and after being dropped off by the driver, plus a red line-string which represents the car pool path.

Hence, the simulation results depicted in Figure 36 – Figure 48 show the successful aggregation, on the one hand, of *Passenger 4* and *Passenger 5* with *Driver 1*, and, on the other hand, of *Passenger 2* and *Passenger 3* with *Driver 2*. This result is achieved in $12.5\ seconds$, of which 6 seconds are devoted to Path Generation and $6.5\ seconds$ are devoted to Passenger Aggregation. Only one passenger remains non-aggregated and needs to go on his/her own. In this respect, for the sake of the simulations, CRAT has arranged a Path Generator which is invoked in order to determine the shortest path for all passengers over the mixed transport network (i.e., public plus pedestrian along with the private network defined by the current driver). Further integration throughout the project will allow the replacement of the Path Generator with the corresponding urban soloist that is in charge of trip planning, as foreseen in Section 5.2.

5.5.4.2 Simulation of a more complicated many-to-many car pooling scenario with fifteen drivers and thirty-five passengers

Let us now consider a more complicated many-to-many car pooling scenario, featuring fifteen drivers and thirty-five passengers requesting for car pooling; hence, the similarity matrix is a 15×35 matrix (i.e., it is characterized by 525 entries). In particular, the $max(\,)$ operator is applied exactly 525 times, and for each element of the similarity matrix the Passenger Aggregator computes:

- the shortest path for the current passenger over the mixed transport network, i.e., public plus pedestrian along with the private network defined by the current driver, as in point 2 of Section 5.5.2 (this is the heaviest operation from a computational point of view);

- the path for the driver to pick up the passenger and the path for the driver to reach his/her own destination after dropping the passenger off (the so-called line-strings or polygonal paths);
- in addition, if the car pool is not empty, the path for the driver for all possible combinations (which have been identified in Section 5.5.2 as six scenarios if there is already one passenger in the car pool).

Moreover, it is worth noting that the Passenger Aggregator performance strongly depends on:

- conditions specified both from the drivers and passengers, which determine how quickly (driver, passenger) couples can be successfully aggregated[14];
- specified drivers' detour range and the outcome of the computation of the reachable nodes[15].

The results of the simulations that have been carried out are listed below, along with the corresponding choice of the various User Query parameters. In particular, different values are foreseen for the maximum number of transit nodes allowed by the drivers, thus yielding different results in terms of aggregation of passengers.

Furthermore, in these simulations, three aggregation points have been selected and it has been assumed that 70% of both driver and passenger users have as destination one of such aggregation points. This choice reflects a real scenario in which it is likely, in an urban context, to have some nodes which are more attractive, such as railway stations, schools, public offices, shopping centers, etc.

Sim. 1. detour range = 0.005; maximum number of transit nodes = 200

- Simulation (scenario creation + Path Generator + Passenger Aggregator): $102\ seconds$
- Path Generator[16] (computation of the reachable nodes + shortest path, as in point 2 of Section 5.5.2): $42\ seconds$
  - Computation of the reachable nodes: $18\ seconds$
  - Computation of the shortest path: $24\ seconds$

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[14]In particular, the values of the maximum number of transit nodes for the drivers have a considerable effect on the results achieved by the Passenger Aggregator, thus implying that the highest such values, the more likely the successfulness of the aggregation process in the considered problem.

[15] Taking into account that the higher the detour range, the higher the aggregation probability, so there is a trade-off between computational costs and the probability of aggregation between users.

[16]The time requested by the Path Generator can be drastically reduced by replacing the Path Generator with the intervention of the orchestrator plus urban soloist, as described in Section 5.2.

- Passenger Aggregator: 51 *seconds*
- Number of aggregated passengers: 21

Sim. 2. detour range = 0.005; max number of transit nodes = 150

- Simulation (scenario creation + Path Generator + Passenger Aggregator): 157 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 45 *seconds*
  - Computation of the reachable nodes: 18 *seconds*
  - Computation of the shortest path: 27 *seconds*
- Passenger Aggregator: 104 *seconds*
- Number of aggregated passengers: 24

Sim. 3. detour range = 0.002; max number of transit nodes = 200

- Simulation (scenario creation + Path Generator + Passenger Aggregator): 94 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 38 *seconds*
  - Computation of the reachable nodes: 11 *seconds*
  - Computation of the shortest path: 27 *seconds*
- Passenger Aggregator: 34 *seconds*
- Number of aggregated passengers: 19

Sim. 4. detour range = 0.002; max number of transit nodes = 300

- Simulation (scenario creation + Path Generator + Passenger Aggregator): 102 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 41 *seconds*
  - Computation of the reachable nodes: 13 *seconds*
  - Computation of the shortest path: 28 *seconds*
- Passenger Aggregator: 53 *seconds*
- Number of aggregated passengers: 23

Sim. 5. detour range = 0.002; max number of transit nodes = 200

- Simulation (scenario creation + Path Generator + Passenger Aggregator): 89 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 28 *seconds*

- Computation of the reachable nodes: 9 *seconds*
- Computation of the shortest path: 19 *seconds*
  - Passenger Aggregator: 53 *seconds*
  - Number of aggregated passengers: 20

Sim. 6. detour range = 0.002; max number of transit nodes = 150
- Simulation (scenario creation + Path Generator + Passenger Aggregator): 74 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 25 *seconds*
  - Computation of the reachable nodes: 8 *seconds*
  - Computation of the shortest path: 16 *seconds*
- Passenger Aggregator: 40 *seconds*
- Number of aggregated passengers: 23

Sim. 7. detour range = 0.0015; max number of transit nodes = 300
- Simulation (scenario creation + Path Generator + Passenger Aggregator): 75 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 32 *seconds*
  - Computation of the reachable nodes: 9 *seconds*
  - Computation of the shortest path: 22 *seconds*
- Passenger Aggregator: 34 *seconds*
- Number of aggregated passengers: 20

Sim. 8. detour range = 0.0015; max number of transit nodes = 200
- Simulation (scenario creation + Path Generator + Passenger Aggregator): 96 *seconds*
- Path Generator (computation of the reachable nodes + shortest path): 33 *seconds*
  - Computation of the reachable nodes: 8 *seconds*
  - Computation of the shortest path: 25 *seconds*
- Passenger Aggregator: 55 *seconds*
- Number of aggregated passengers: 23

As a result of the simulations that have been carried out, we can state that Passenger Aggregation requires less than 2 *minutes* in a general-case scenario, assuming the presence of fifteen drivers and thirty-five passengers requesting for car pooling.

The uncertainty in the execution time of the Passenger Aggregator algorithm mainly depends on two factors: (1) the fact that a high similarity degree translates into a high aggregation probability, and (2) the availability of other feasible travel solutions featuring car pooling, should the currently proposed one turn out to be infeasible for the driver.

Instead, the search for the set of nodes that are reachable from the drivers within strongly connected graph components has been embedded in the Path Generator.

In the next deliverable (D4.2), the computational complexity of the Passenger Aggregation algorithm will be evaluated as the multi-graph dimensions grow and as the number of drivers and passengers is further increased. Such analysis will allow testing the scalability of the proposed approach and suggesting meaningful corrections to the algorithmic procedure.

6 Membership management

This section summarizes the research work performed in the field of personalized membership management in intelligent transportation systems.

6.1 Overview of the Membership Management Functionality

The BONVOYAGE Membership Management is composed of:

- A “green” Score Policy.
- A Loyalty Programme.

They both aim to reward users that use BONVOYAGE platform to plan and purchase travel solutions but with different ultimate goal:

- 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, through the application of a set of scoring rules as well as a system personalised incentives and penalties;
- The Loyalty programmes is intended to reward users showing a high level of “fidelity” to BONVOYAGE, by purchasing a conspicuous number of tickets from the BONVOYAGE transport operators associated to a significant user expenditure and income for transport operators.

The following paragraphs describe how both the BONVOYAGE “green” score policy (that is strictly related with the Set Score Policy Functionality) and the Loyalty Programme were defined and how they were progressed and innovated compared to the current state-of-art.

Specifically, the Set Score Policy functionality was developed from a methodological and technical perspective either, whereas, for the time being, the Loyalty Programme was only methodologically defined.

6.2 Score Policy

6.2.1 Methodology and score policies state-of-the-art

The present paragraph provides an overview of the working methodology, of the activities and analysis carried out to develop the BONVOYAGE “Set Score Policy” functionality.

Particularly, the following activities were carried out:

- **Benchmark study of existing tariff models, initiatives and policies and trends** aimed to highlight possible evolutions to strengthen the Set Score Policy Functionality innovative features;

- **Analysis of factors pushing the user towards socially desirable mobility solutions**.

Both the benchmark analysis and the analysis of "push factors" were conducted focusing on comprehensive **tariff models, initiatives and policies**, since most of times score policies are a part of them.

Regarding the **Benchmark study**, the specific objective was to carry out a mapping exercise and an analysis of existing **tariff models, initiatives and policies** implemented or under discussion by passenger transport operators and/or municipalities, across both EU and non EU countries. This exercise was aimed at identifying the main innovative trends and at highlighting which tariffs, tax policies, scoring rules and awards that can "push" passengers to prefer specific means of transport and solutions.

The main output of the benchmark analysis was the identification of **cause-effect relations** between existing **tariff models, initiatives and policies** on one side and **users mobility demands and choices** on the other side, in order to understand how specific **tariff models, initiatives and policies** can influence or push passengers to prefer and choose specific means of transport.

In details, the benchmark analysis:

- was aimed **to identify which elements of the tariff models, initiatives and policies can "push" passengers to choose and use eco-friendly means of transport and select eco-friendly transports mix** (e.g., bikes and subway; walking and train), on the basis of dedicated scoring and awarding systems intended to foster eco-friendly mobility choices. In the particular case of two or more public transports running on the same path, the aim was to identify which tariff models, initiatives and policies can "push" users to prefer one of the available transports. Furthermore, the benchmark analysis was focused on the identification of tariff models, initiatives and policies applied to different time frames to achieve an equal passengers load on a means of transport during the day (thus avoiding excessive loads in peak time).
- focused on the **identification of how policies aiming to the implementation of multi-modal hubs** (platforms/nodes where user can access to different means of transport, e.g., subway, train, buses, car sharing) can influence passengers mobility choices and can contribute to increase the use of public transports. In this case, the objective was to identify urban mobility policies and/or measures able to contribute to discourage the usage of private transports (e.g., car and motorbike) and to increase the usage of public transports.
- took into account also **existing tariff models for freight transports** implemented by different freight transport operators (in Spain and/or other EU and non EU countries).
- focused on **current tariff models implemented at local level** (e.g., Barcelona, Amsterdam, etc.) by transport operators and/or by municipalities across EU and in other non EU countries.

For each tariff model, initiative and/or policy analysed several core aspects and specific elements were investigated (where applicable), as listed below:

- Main information on the tariff model, initiative and policy: name, responsible transport operator/municipality, city/location where the tariff model, initiative and/or policy is in place, starting date of implementation;
- Tariff model, initiative and/or policy core elements: scoring rules; consumer preferences addressed, in terms of preferred means of transport and related to the "push factors" that can influence users choices on the basis of their attitudes and preferences; transport operators/municipalities partnerships);
- Reasons, objectives and needs why the tariff model, initiative and/or policy has been introduced;
- Context, demographic, societal and environmental situation from which the need to introduce the tariff model, initiative and/or policy has arisen;
- Expected impacts and results that the tariff model, initiative and/or policy was intended to produce;
- Target users: number of users targeted by the tariff model, initiative and/or policy (in terms of users involved, tickets sold, etc.) and users current behaviour in terms of mobility choices;
- Results achieved since the introduction of the tariff model, initiative and/or policy;
- Results achieved compared to envisaged expected impacts and results, highlighting if the results are in line or not with the expected impact;
- Changes identified with respect to the ex-ante situation and the results of this change;
- Hypothesis on a cause-effect relation between existing tariff models, initiatives and policies and users mobility demands and choices.

In relation to the **analysis of factors pushing the user towards socially desirable mobility solutions**, the specific objective was to validate the hypothesis arisen from the benchmark analysis in order to verify and confirm the identified relations between specific tariff models, initiatives and/or policies and users mobility choices and to identify additional factors and variables that should be included in the Set Score Policy Functionality. The validation was carried out through a survey questionnaire. As shown in Appendix B, to this aim a dedicated section (Section 5) was included in the questionnaire, specifically aimed to the identification of factors that can influence user's selection of eco-friendly travel solutions. The list of questions included in this Section is provided in the following table:

QUESTIONS SECTION TARIFF MODELS
Which factor would you consider more effective in fostering you to choose to travel through public transports for urban travels?

Questions Section Tariff models
Which factor would you consider more effective in fostering you to choose to travel through collective public transports for long - distance travels?
Which of the following options would be more effective in fostering you to consider the CO2 reduction as first parameter when planning your urban and long - distance travels?
In the case of a urban travel that takes the same time by private and public transports (e.g., half an hour), which of the following factors would you consider more effective in fostering you to choose to travel through public transports for a ticket price of 2 €?
In the case of a long-distance travel that takes approximately the same time by private and public transports (e.g., from 3 to 4:30 hours), which of the following factors would you consider more effective in fostering you choose to travel through public transports? Please, consider a ticket price of 30 - 50 €
In the case of a long-distance travel that takes approximately the same time by private and public transports (e.g., from 3 to 4:30 hours), which of the following factors would you consider more effective in fostering you choose to travel through public transports? Please, consider a ticket price of 50 € - 100 €
If after paying a certain amount of money in a single day you would get unlimited number of urban travels through public transports for that same day, which is the maximum amount of money would you pay? Please, consider a 2 € ticket cost for a single travel and a minimum number of 8 travels to be performed
Would the measure in question 5.7 be enough to foster you to not use private transports at all for that day?
If you got a discount on urban public transports tickets to travel only during off-peak times (e.g., 10 - 12 am; 2 - 4 pm; 8 - 12 pm), would you choose to travel by public transports? Please, consider a 2 € ticket cost for a single travel
If you got a discount on long - distance public transports tickets to travel only during off-peak times (e.g., 10 - 12 am; 2 - 4 pm; 8 - 12 pm), would you choose to travel by public transports? Please, consider a ticket cost of 20 € - 50 € for a single travel
If you got a discount on long - distance public transports tickets to travel only during off-peak times (e.g., 10 - 12 am; 2 - 4 pm; 8 - 12 pm), would you choose to travel by public transports? Please, consider a ticket cost of 50 € - 150 € for a single travel
If you could buy a daily or weekly "open ticket" for urban/inter-urban travels, which of the following options would you rather getting?
If you received awards (in terms of discounts/money bonus to be spent for transport services, free tickets for events) for the number of daily km covered by public transport for both urban and long - distance travels, would you choose to travel by public instead of private transports?
If answer to question 5.13 is "Yes" or "It depends on the award entity": which of the following awards would you consider more effective in fostering you to travel by public transports?
Would you be available to buy a package of urban public transport services (e.g., buses, subways, trains, taxis, car sharing, bike sharing services) at a lower price than the total actual price (that is the sum of all single ticket price)?
If the answer to question 5.15 is: Yes, but only if I get a considerable money saving: how much would you expect to save to be available to buy the services package?
Would you choose to go to an event by public transports if you had the possibility to buy simultaneously the event and the public transport ticket?
If the answer to question 5.17 is: Yes, but only if I can save money or get another type of award: how much would you expect to save to be available to buy the ticket package?
If the answer to question 5.17 is: Yes, but only if I get a considerable money saving or another type of award: which type of award would you expect to get to be available to buy the ticket package?
If you owned a public transport fidelity programme that enables you to collect scores to get different types of prizes, in how long or upon achievement of what "target" would you expect to get envisaged prizes?

Table 13 - Survey Section 5 - questions

As explained in Appendix B, results gathered through the survey cannot be considered as a representative sample of the entire and wide BONVOYAGE target users group, as users participating to the survey were significantly polarised. Therefore, the Set Score Policy Functionality was finally defined on the basis of the evidence arisen from the benchmark study, that proved to be a valuable instrument to pursue the pre-set objective, that is to introduce innovative elements or ways able to "push" users to choose travel solutions with lower environmental impact, thus improving user level of eco-friendliness.

For the benchmark analysis, several **tariff models, initiatives and policies** were identified and analysed. Below it follows the comprehensive list of the **tariff models, initiatives and policies** investigated.

Tariff models, initiatives and policies intended to "push" users to make specific mobility choices:

  - Apps: WeCity; GoEco; TraffiCO2; Tripzoom.
  - Tariff Models: Capping; Zapping.
  - Subscriptions: AltoAdige Pass; UbiGo.
  - Studies: "Congestion pricing, transit subsidies and dedicated bus lanes: Efficient and practical solutions to congestion"; "Congestion tolls and parking fees: A comparison of the potential effect on travel behavior".
- Azkar Tariff Model (for freight transport operators).
- Policies aiming to the implementation of multi-modal hubs:
  - PersonalBus; Uber's U-line; RideshareOnline.com; Edinburgh's Park-and-ride initiative; Park and bike terminal in Aarhus; Warsaw's Park-and-ride system; AIRail; Rail&Fly; TGVair; Night&Flight; HSR station at London Heathrow.
- **Tariff models, initiatives and policies** implemented in municipalities across EU and non EU countries:
  - Barik (province of Bizcay, Basque Country);
  - Mugi (Province of Gipuzkoa, Spain);
  - SwissPass (Switzerland);
  - OV-Chipkaart (Netherlands);
  - T-Mobilitat (Barcelona, Spain).

A brief description of the tariff models, initiatives and policies showing the most pertinent elements for the purposes of the Set Score Policy Functionality is provided below. The selection was based on the presence in these tariff models, initiatives and policies of the "push factors" that can influence users mobility choices in terms of lower environmental impact. The whole description of all the tariff models, initiatives and policies included in the benchmark analysis will be reported in Appendix.

WECITY

<u>Core elements</u>: WeCity is an app (digital platform) founded in Modena (Italy) in 2013. The app was officially launched in February 2014. It is currently in place in all the main cities in Italy and it is going to be launched also in Spain and England within 2016.

Wecity is a digital platform that allows citizens to interact with Kyoto protocol mechanisms[17], thanks to the ISO 14064 on CO2 emissions reduction. Wecity provides a tool to each citizen to contribute to the CO2 emissions reduction, ensuring an active participation and a scientific and accurate measurement of the citizen commitment.

Thus, in order to promote sustainable mobility and have a positive impact on the environment, Wecity technically gives credits to the user for every Kg of avoided CO2, to be spent on the Wecity store to obtain sustainable prizes. It promotes the use of means of transport with low level of CO2 emissions and assigns score for each selected means of transport (e.g., more points are assigned for bicycle, car pooling). In details, it promotes the use of public transports rather than the car in order to reduce the CO2 emissions. The amount of CO2 the user avoids depends on both the type of public transport (train, bus) and the type of fuel (gasoline, natural gas, electricity).

Once the user has collected enough credits, he/she can go on the store Wecity and can choose his prizes among an intelligent mobility product offer (e.g., free-rides with Enjoy, bicycles, travels etc). For each prize the user is required to add a certain amount of money. To offer prizes, Wecity has established several partnerships with companies (e.g., Car2go and Enjoy, Little Italy, etc).

<u>Target users:</u> the app aimed to reach as many users as possible, focusing on users who are environment oriented, interested to sustainable mobility and CO2 reduction themes and open to new and innovative mobility systems.

<u>Achieved Results:</u> 10.000 downloads within the first 6 months after the app was launched. The number of users that will use the app is estimated to increase in the future.

GOECO

<u>Core elements</u>: GoEco project has been proposed by SUPSI (Professional University of Italian Switzerland) and ETH (Federal Institute of Technology) Zurich; the app development started in January 2015 and it will be tested during 2016/2017. The main objective of the project is to investigate if and how information feedback and social interactions (social comparison and peer pressure) can be effective in fostering changes in personal mobility behaviour, facilitating the long-term challenge to reduce private motorized transport usage and bringing about a transition to different mobility options, such as vehicle-sharing, intermodal use of means of transport, public transportation and slow mobility. Within GoEco the users test a smart-device application developed on purpose, that challenges them to reduce personal vehicle use by:

[17] Kyoto protocol is an international agreement linked to the United Nations Framework Convention on Climate Change which commits its Parties by setting internationally binding emission reduction targets.

- tracking their trips, providing them with feedback on their mobility behaviour and suggesting alternative, low-impact modal options, and letting users define personal reduction objectives and targets;

- creating a virtual community among them, setting up a social comparison rewarding scheme which acts as a further trigger to stimulate behaviour change.

GoEco uses the data provided by another app, Moves, which measures the GPS coordinates of people movements, in order to identify which transport the person is using. GoEco also asks each user the reason of the movement. At the end of every day, GoEco asks to the person to validate the data measured with respect to transports used and reasons for the movement. Thus, after one month that the person uses the app, GoEco automatically learns how and how much the person moves and it is able to provide a report which shows the mobility habits/behaviours of the person and shows/suggests potential changes in his mobility habits/behaviours aimed to reduce CO2 emissions, or the use of the car, and increase the use of bike. Thus, GoEco encourages the user to set a goal for his behavioural change. Once the user sets the goal, the App proposes him a weekly-challenges in order to achieve the selected goal. The complexity of the challenges proposed by GoEco increases every time the user pass the previous challenge. At the end of every week, GoEco informs the user about the status of the overall goal achievement: if the user achieves the goal, the app let him set a more ambitious goal, otherwise, if the user does not achieve the goal, the app suggests him a more affordable goal. Furthermore, the app fosters the social and gaming features by including the "Hall of Fame", which is a section that shows users with the best performance related to their goal in order to push/incentives other users to do better.

Target users: the testing phase was expected to involve around 800 users.

Achieved Results: achieved results are not yet available since the app is in testing phase.

TraffiCO2

Core elements: TraffiCO2 project consists in the development of a social network for sustainable mobility available via web and mobile apps. TrafficO2 application offers a concrete tool for smart and dynamic management and regulation of urban flows. It is designed to be offered primarily to associations, institutions and companies who decide to support the project.

Basically, users who subscribe to TrafficO2 will move within the city, will earn points (called O2 points) based on the sustainability level of the means of transport chosen and will win prizes from local businesses and sponsors (service providers including: restaurants, bar, bike shopping etc).

TrafficO2 works through 3 main features of the project:

- Move: selecting on the map the starting point and destination, users can plan and visualise their travel itinerary. Each travel itinerary is enriched through the following information: distance, avoided CO_2 emissions and burnt calories. The more sustainable the selected transport is, the more points the user will get;

- Play: users can share routes on social networks, invite their friends to save CO_2 and challenge them with games tailored to each business participating in the local network. The entire system is based on the concept of "CO_2" as the measurement unit and the virtual currency trading within the platform. The platform is controlled by a virtual marketplace based on the exchange of volumes of CO_2;

- Win: once the user reaches the destination, users will gain CO_2 points which can be used to obtain prizes and discounts at the local businesses and sponsors. Based on the number of check-in, the user will unlock new contents, find out new offers and take part to lotteries.

Target users: The project targets three different urban actors: communities needing new traffic management solutions; local businesses willing to invest in innovative local advertising; big companies willing to engage customers with positive values. During the testing phase, 60.000 students of the University of Palermo were involved.

Achieved Results: The project involved 1.877 active users, 187 local businesses have adhered to the initiative giving prizes and discounts. The mobile app has tracked 13228 routes, recording a total amount of 55.160g of spared CO_2. The results showed interesting features allowing to detect specific behaviours connected to urban mobility and improve the solution that may be included in planning processes and result in new solutions for policy-makers in EU.

TRIPZOOM

Core elements: Tripzoom is a mobile app that records personal-level mobility patterns while people are on the move. It gives personalised incentives for mobility improvements and includes social community features to make people move better.

Tripzoom aimed to:

- Optimise personal mobility through the careful use of personal, mobile ICT services via the smartphone, enhanced by providing mechanisms to distribute personalised incentives to adopt new ways of travel;

- Optimise social-induced mobility, in which travellers inform and help each other using ICT-enabled social networks, such as Twitter, Facebook and mobile applications on the Smartphone.

Tripzoom supports different incentive schemes that have been designed with the purpose to make the mobility system of urban environments more efficient and sustainable. The basic assumption of the initiative is that an incentive is effective if individual travellers adopt different behavior, resulting in positive impacts on the policy goals.

Tripzoom took into account personalised incentives that can be created in three ways:

1) incentives provided by road authorities and city governments;

2) via third party service providers like public transport companies or employers;

3) by other travellers who share experiences, create group-based challenges and provide meaningful information to other travellers.

Challenges, incentives and rewards were defined:

- an incentive consists of a challenge that describes the task that a user needs to do, and a reward that will be given to users who manage to succeed with the given challenge;
- rewards: as soon as a challenge has been accomplished, the user is given a reward.

Tripzoom incentives can be clustered into four different groups: real-time travel information (e.g., delays information, planned or emergency road works etc), feedback and self-monitoring (in order to provide travellers with tangible evidence in a comprehensive manner, so as to raise their awareness on impact caused by the way they travel), rewards and points (rewards can be in many forms, ranging from simple recognition of achievement within the community or tangible ones with a monetary value) and social networks (in order to provide users with a means to communicate, share their experience and information with each other).

Target users: the app is focused on urban mobility with a fine grained maze of roads (as opposed to long-distance highways) and on commuters with good static knowledge of the environment but with limited overview over the dynamic situation. The testing phase in the Living Lab involved around 200 people in Enschede and 140 people in Gothenburg.

Achieved Results: It was found that individual behavioural change can be achieved in terms of change in travel times (time shifting out of rush hour) and change in modality (e.g., shift towards sustainable bike alternatives). The analysis found out that influential incentives should be based on the following areas:

- Time: efficient use, control, saving, and planning;
- Money: save (e.g., discounts on transportation tickets) or even generate (e.g., coupons);
- Information: receive (real-time, personalized) information about progress, travel alternatives;
- (Social) recognition: for being green and healthy/fit; giving feedback to and receive feedback from others.

Incentives have proven to influence personal mobility choices at different extents. Self-monitoring provides a means to see and understand one's travel habit, but it has been suggested self-monitoring should be combined with other types of information, such as environmental or financial feedback or social influence so as to achieve the system's goals.

Additionally, the choice of metrics should be selected with care, for instance, people who are only interested in cutting their carbon footprints should be presented with measurements related to the environment such as CO2 emission.

Some of the main results highlighted during the Living Labs testing phase are described below:

- Congestion: 23% of the participants changed departure times. The car use of the users in the challenge dropped from 63% to 57%-47% depending on the time the challenge was in place and the level of the rewards. Simultaneously the share of public transport increased from 9% to 10%-16%. The users report however to have changed only incidentally as a result of the challenges. Finally, it seems that the challenge in itself or in terms of raising awareness on travel timing rather than the size or nature of the reward is the more important factor.

- Environment: not clear environmental effects have been demonstrated. However the experiments did observe relative increase of bicycle use and an increase in the use of public transport to the expense of the car.

UBIGO

Core elements: The UbiGo is a subscription to a mobility service, oriented to offer a combination of means of transport that can meet individuals' transport needs, bridging the gap between private and public transports by creating a "broker for daily travel" that can procure (on the market) and offer (to end-users) tailored mobility services adapted to the individual traveller's needs and wishes. The mission is to make everyday life easier for urban households and foster sustainable cities by offering a simple, flexible, reliable and priceworthy service as an alternative to car ownership.

By uniting different means of transport (public transport, taxi, car- and bike-sharing, and car rental), UbiGo offers a simple, flexible, and priceworthy monthly subscription that the entire household can access via a mobile App. This works like a flexible mobile phone subscription but with units for public transport, car, taxi etc instead of minutes of talk, number of SMS or Gbyte of surf, accessible to all members of a household through digital punch-cards in the cloud.

The UbiGo households subscribe to their prepaid monthly need of public transport (as days to use in one or more zones) and car (as hours that can be translated on to days or longer). Credit could be topped up or rolled over, and the subscription could be modified on a monthly basis. If the cards run empty, extra days or hours will be registered and billed afterwards, as will taxi-trips, waivers etc. Un-used days or hours will be saved for later use.

To access their travel services, the UbiGo traveller logges into the app via a Google or Facebook login, where he/she could activate tickets/trips, make/check bookings, and access already activated tickets (e.g., for validation purposes). The app also allows them to check their balance, bonus, and trip history, and get support (in terms of FAQ/customer service). Each participant receives a smartcard, used for instance to check out a bicycle from the bike-sharing service or unlock a booked car, but also charged with extra credit for the public transport system in case there was any problem using the UbiGo service.

To provide added value, UbiGo also includes a customer service phone line open 24 hours per day and an "improved" travel guarantee.

UbiGo subscription also offers bonus for sustainable choices: for every kilo CO_2 saved (compared to if the trip would have been made by private car), users get bonus points that can be used to buy services or products from UbiGo partner organisations (bike services, home delivery, concerts etc).

Target users: households with a high propensity in car ownership.

The implementation of UbiGo has been carried out as a pilot trial in the city of Gothenburg for half a year and has involved 83 households, that have subscribed to the fully integrated mobility service.

Among the 83 participating households, 20 of them agreed to hand-over their private cars for half a year (they got a compensation for the fixed cost of ownership). Other households did not own a car at all, but saw advantages of getting a full and integrated service. Few households were already members of car or bike sharing schemes.

Achieved Results: over 12.000 transactions (day tickets, car or taxi-reservations etc) where made. The results of the pilots showed that an innovative approach to mobility, in this case a personalized and diverse package of services, can offer “something to everyone”. In the case of UbiGo, even people who were already using services as car-sharing, found added value in the integration of services. None of the households stopped using the service and a clear majority wants to stay as customers. Based on the positive results achieved, Ubigo partners are preparing for relaunching the service in a 2.0 version.

The analysis of the current tariff models, initiatives and policies showed that **attention to CO2 emissions is considered as a core element** for the collection of scores and achievement of awards by the users, in order to promote sustainable mobility and reduce the impact on the environment.

The **main common and relevant features** of the currently available tariff models, initiatives and policies, related to their innovation level and their close relation with the purposes of the Set Score Policy Functionality are:

- Provision of information about the level of CO2 emissions for each travel itinerary (e.g., TraffiCO2).
- Provision of credits/points on the basis of the users means of transport choices, promoting the use of means of transport with low level of CO2 emissions. These points can be used by the users to obtain prizes, awards and discounts (e.g., WeCity; TraffiCO2; UbiGo).
- Monitoring functionality, in order to gather information about users’ mobility behaviour and provide them feedback, alternatives, low-impact travel solutions reducing private motorized transport usage and increasing the use of public transportation and vehicle-sharing (e.g., GoEco; Tripzoom).
- Provision of personal incentives on the basis of the users behaviour (e.g., Tripzoom).

On the basis of the achieved results of the tariff models, initiatives and policies analysed, **cause – effect relations** have been derived. Below it follows an overview of most relevant relations for the Set Score Policy functionality:

- **Prizes, awards and discounts** for sustainable/low-environment impact mobility choices increase people propensity to choose sustainable means of transport with a lower environmental impact.
- **The possibility to purchase and obtain a package of travels with different means of transport** (e.g., through a monthly pre-paid subscription) at a lower price than purchasing a single means of transport, combined to rewarding schemes for sustainable mobility choices, increases people propensity to choose sustainable means of transport.
- **The creation of an "amusing environment"** (e.g., offering the possibility to invite friends to save CO2, to create games and to share achieved results and information with other users) that leverages on **people motivation and ambition** to achieve their personal goals is able to push them towards more sustainable mobility choices.

Cause-effect relations represent the "lessons learned" and lay the basis for the definition of the core elements of the Set Score Policy Functionality of BONVOYAGE, that can be summarized as follows and will be described in details in the next paragraph:

- the provision of **information about the environmental impact of the mobility choices** can make users more informed and can influence their behaviour. Information about environmental impact have to be provided to the users before, during and after the travel. Monitoring systems able to follow users during the trip and feedback provision functions have to be taken into account.
- **Awards and discounts seem to be the main "push factors" that can influence people mobility choices**. More awards and discounts have to be provided for travel solutions that involved means of transport with low CO2 emissions and low environmental impact.

People ambition seems to be an important lever to influence their behaviour. The definition of personal challenges, individual objectives and **personalized incentives** in terms of reduced environmental impact must be provided in a score policy.

6.2.2 BONVOYAGE green score policy

The BONVOYAGE Set Score Policy Functionality is 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 select travel solutions composed of means of transport with a low level of CO2 consumption. This objective is achieved through the assignment of scores on the basis of the means of transport selected by the users and offering 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).

Score is assigned to the users also in case of travel solutions that involve just one means of transport (mono-modal travel solutions that are not door-to-door).

The main innovative element is that the **Set Score Policy functionality evaluates users behaviour during time**, leading to the definition of different "**User Eco-friendliness Profile**". The functionality improves people awareness of their mobility behaviour and allows to define personalized incentives and penalties in order to "push" the users to choose travel solutions with low environmental impact.

For the definition of the "User Eco-friendliness Profile", user 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.

Based on the assumption above, the BONVOYAGE users profile categories (identified in Deliverable 2.1 Use cases and reference architecture) were distinguished into the three groups defined above, taking into account their most likely travel behaviors, in terms of frequency usually characterizing each user profile category[18]:

Occasional Travellers	Periodic Travellers	Frequent Travellers
After 20 travel solutions	*After 30 travel solutions*	*After 60 travel solutions*
Families; Groups; Religious groups; Romantic; Adventure (adventure travels); Food; Art and culture; Music; Elderly	Bike lovers; Luxury; Backpacker; Low cost; Eco-friendly; Single; Pregnant; Disabled travellers; Special needs	Heavy Vehicles drivers; Schools (students groups); Business; Day tripper

The group “**Occasional Travellers**” encompasses the following user profile categories:

- Families, Groups and Religious groups based on the assumption that they travel occasionally for several reasons, like summer/Christmas holidays, religious events, outdoor trips in groups;
- Romantic, Adventure travellers, Food, Art and culture and Music, which are supposed to travel in case of special events like wedding anniversary, concerts, festivals etc;
- Elderly, based on the hypothesis that older people usually do not travel a lot, for example because of their physical conditions.

The group “**Periodic Travellers**” includes the following user profile categories:

- Bike lovers, Luxury, Backpacker, Low cost, Eco-friendly, Single, Pregnant, Disabled travellers, Special needs, which are supposed to like to or to have to travel fairly for several pleasure or family-related reasons.

Finally, the group “**Frequent Travellers**” encompasses the following user profile categories:

[18] Classification of BONVOYAGE user profile categories in the defined groups was based also on the survey “Mobility Survey Basque Country 2015”

- Heavy Vehicles drivers, Schools (students groups), Business and Day tripper, because it was hypothesized that they must often travel, e.g., to go to work every day, to school based on the assumption that their job requires them to travel several times per week.

Once the users reaches the travel solutions threshold, he/she "moves" from Time 0 to Time 1, and his/her User Eco-friendliness Profile is defined. To alert the user, BONVOYAGE Platform sends him/her a push notification indicating that, from that moment, scores gained for each selected travel solution will be assigned on the basis of his Eco-friendliness profile defined (Eco-friendly User; Quite Eco-friendly User; Low Eco-friendly User; Not Eco-friendly User).

A message prototype that will be received by the user, assuming that the user is a woman named Christele, is:

- For Not-Eco-friendly Users, Low Eco-friendly Users and Quite Eco-friendly Users: *"Dear Christele, to encourage you make more eco-friendly choices, BONVOYAGE will provide you with incentives and penalties: from today, the scores you gain for each travel solution will be higher if you choose eco-friendly transport modes and lower if you choose not eco-friendly transport modes. BONVOYAGE kindly suggests to take care of your mobility choices!"*
- For Eco-friendly User: *"Dear Christele, to reward and to encourage you to keep on making eco-friendly choices, BONVOYAGE will provide you with incentives and, only if needed, penalties: from today, the scores you gain for each travel solution will be higher if you choose eco-friendly transport modes and lower if you choose not eco-friendly transport modes. BONVOYAGE kindly suggests to keep on paying attention to your mobility choices!".*

The definition of the User Eco-friendliness Profile entails the application of **different incentives and penalties** (in terms of percentage of increased or decreased scores assigned for each kilometre), in order to **reward the users that selected eco-friendly travel solutions** and **encourage less eco-friendly users to choose travel solutions with low consumption of CO2**.

On the basis of the user profile category, User Eco-friendliness Profile is revised periodically – every 20 times for Occasional Travellers, every 30 times for Periodic Travellers and every 60 times for Frequent Travellers – in order to confirm or modify and update the previously defined User Eco-friendliness Profile.

Furthermore, in case of modification of the user profile category (e.g., from student to low-cost travellers), the number of pre-set travel solutions after which the User Eco-friendliness Profile is revised changes accordingly to the new user profile category in which the user has been classified.

Another key element of the BONVOYAGE Set Score Policy Functionality is that scores are assigned taking into account the distance (in number of kilometres) of each uni-modal leg included in the multi-modal travel solution bringing the user from the point of departure to the point of arrival. In this regards, three different areas have been considered:

- **Urban Area** (area that defines city borders): up to 70 kms;
- **Extra-urban Area** (area outside the city borders) from 70 kms up to 160 kms;
- **Long Haul**: over 160 kms.

The scoring methodology of the Set Score Policy Functionality is based on the insertion of several "**Input Information**", in an "ad hoc calculation methodology". Input information constitutes the "basic element" of the calculation methodology that determines the score to be assigned to users. This input information is:

- **CO2 consumption per kilometre** of the means of transport included in the travel solution selected by the users (e.g., plane, car, train, bus, etc.).
- **Scores assigned for each kilometre covered**. The score assigned is lower for more polluting means of transports and increases for means of transport that have low environmental impact. It is noteworthy to explain the specific criteria applied to define scores related to some specific transport modes:
    - score assigned to **bicycle** and **"by foot"** is the highest because in both cases there is no CO2 consumption;
    - score assigned to scooter was defined based on an average of CO2 consumption between mopeds and motorcycles;
    - no score was assigned to car, taxi and plane because of their high level of CO2 consumption. In details, car CO2 consumption was calculated as an average of CO2 consumption among small, medium and large sized cars; CO2 consumption of taxi was considered higher than car because it was assumed that taxis are usually medium-sized or large-sized vehicles; finally, plane CO2 consumption was defined considering that the plane overall CO2 consumption is "shared" between the on-board passengers (therefore, the value of the CO2 consumption selected is related to the single passenger).
    - Car pooling was assigned with a higher score than the car (that does not receive any score), because, although car is used as transport mode, users share the consumption of CO2 of a single car (instead of producing CO2 associated to different cars), achieving CO2 savings.

The following table shows the CO_2 consumption and scores assigned per each kilometre covered by each means of transport at T0:

Means of Transport	CO2 consumption per Km[19]	Score per each Kilometer
By foot	0 Kg	3,4
Bicycle	0 Kg	3,4
Tram/filobus	0,042	2,6
Electric car	0,043	2,5
Minibus	0,055	2,3
Train	0,06	2,2
Subway	0,065	2,1
Bus	0,069	2,0
Scooter	0,084	1,7
Ferry	0,115	1,1
Car	0,142	0,0
Car pooling	0,142	0,6
Plane	0,14	0,0
Taxi	0,17	0,0

- **Minimum number of kilometres** to be covered in order to get the scores. For all the means of transports the minimum number of kilometres to be covered is 1 kilometre, while for people who decide to walk to reach the destination (or decide to walk for a part of the entire trip) the minimum number of kilometres to be covered is equal to 0,1.
- **Number of the kilometres covered** by the users through the different means of transport included in each travel solution selected by the user.

The ***output*** is the calculation of the score that envisages two steps:

- **"Baseline Score" calculation**: it is calculated multiplying the score assigned for each kilometre with the number of kilometres covered:

Score assigned for each kilometre *(on the basis of the selected means of transport)*	**X**	**Number of kilometres covered** *(covered through the selected means of transport)*

[19] Source: http://www.co2nnect.org/help_sheets/?op_id=602&opt_id=98&nmlpreflang=it

- **"Master Score" calculation**: it is the score effectively assigned to users and it is obtained dividing the Baseline Score for a conversion factor.
  The conversion factor varies depending on the type of area in which the trip is done (urban area, extra-urban area, long-haul route) and allows to compare scores obtained in different areas (making scores with the same "order of size"). The following table shows the calculation methodology of the Master Score:

Master Score calculation	Urban Area	Extra-urban Area	Long Haul
Conversion Factor	10	100	1000
Master Score	Baseline Score/10	Baseline Score/100	Baseline Score/1000

For each travel solution, "**Total Baseline Score**" and "**Total Master Score**" have to be calculated, through the sum of the single Baseline Score and Master Score obtained for each means of transport (e.g., baseline score means of transport x, y, z).

Total Baseline Score		Total Master Score	
$\sum$	Baseline Score means of transport *x* Baseline Score means of transport *y* Baseline Score means of transport *z*	$\sum$	Master Score means of transport *x* Master Score means of transport *y* Master Score means of transport *z*

At T1, on the basis of the user mobility choices made during T0, *User Eco-friendliness Profile* is defined and a set of **incentives and penalties is applied for each cluster of users**. To Eco-friendly users only incentives are applied, in order to encourage them to continue to select means of transport with low consumption of CO2. Instead, for the other clusters of users a mix of incentives and penalties is applied, in order to stimulate them to select means of transport with lower consumption of CO2 (incentives) and discourage them to select means of transport characterized by a higher environmental impact (penalties). Penalties and incentives are different on the basis of the user cluster: they increase from the "Quite Eco-friendly" user cluster to the "Not Eco-friendly" user cluster, because the latter needs more "pressing" incentives and penalties. Therefore, score assigned per kilometre for each means of transport in T1 is higher or lower than score assigned in T0.

For the next selected travel solutions, and specifically every 20 selected travel solutions for Random Travellers, every 30 selected travel solutions for Regular Travellers and every 60 selected travel solutions for Frequent Travellers, **incentives decrease progressively**, whereas **penalties increase progressively** for 3 time periods: Time 1 (T1), Time 2 (T2) and Time 3 (T3), as shown in Figure ***49***.

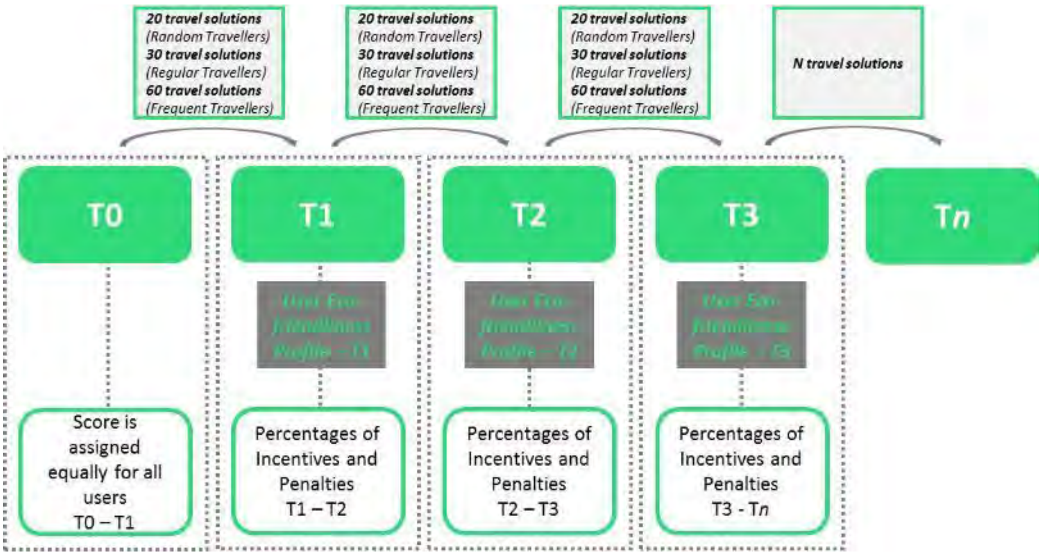


Figure 49 - Incentives and Penalties application scheme

The objective is to stimulate users, in an increasing "sharp" way, to select multi-modal travel solutions composed of means of transport showing low CO2 consumption over time.

In case of modification of the User Eco-friendliness Profile, the calculation of the score re-starts from T1.

In the following tables, percentages of incentives (in green) and penalties (in red) as well as scores to be assigned per kilometre, for each means of transport and for each of the four user clusters, are reported separately for T1, T2 and T3:

Means of Transport	Eco-friendly User		Quite eco-friendly User		Low eco-friendly User		Not eco-friendly User	
	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer
By foot	+30%	4,4	+30%	4,4	+40%	4,8	+40%	4,8
Bicycle	+30%	4,4	+30%	4,4	+40%	4,8	+40%	4,8
Tram/filobus	+30%	3,3	+30%	3,3	+40%	3,6	+40%	3,6
Electric car	+30%	3,3	+30%	3,3	+40%	3,6	+40%	3,6
Minibus	+30%	3	+30%	3	+40%	3,2	+40%	3,2
Train	+30%	2,9	+30%	2,9	+40%	3,1	+40%	3,1
Subway	+30%	2,7	+30%	2,7	+40%	2,9	+40%	2,9
Bus	+30%	2,6	+30%	2,6	+40%	2,8	+40%	2,8
Scooter	-	1,7	-10%	1,6	-20%	1,4	-30%	1,2

Ferry	-	1	N.A.	1	N.A.	1	N.A.	1
Car	-	0	-10%	0	-20%	0	-30%	0
Car pooling	-	0,6	-10%	0,5	-20%	0,4	-30%	0,4
Plane	-	0	-10%	0	-20%	0	-30%	0
Taxi	-	0	-10%	0	-20%	0	-30%	0

Table 14 - User Eco-friendliness Profile: incentives and penalties at T1

Means of Transport	Eco-friendly User		Quite eco-friendly User		Low eco-friendly User		Not eco-friendly User	
	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer
By foot	+25%	4,2	+20%	4	+30%	4,4	+30%	4,4
Bicycle	+25%	4,2	+20%	4	+30%	4,4	+30%	4,4
Tram/filobus	+25%	3,2	+20%	3,1	+30%	3,3	+30%	3,3
Electric car	+25%	3,2	+20%	3	+30%	3,3	+30%	3,3
Minibus	+25%	2,9	+20%	2,8	+30%	3	+30%	3
Train	+25%	2,8	+20%	2,6	+30%	2,9	+30%	2,9
Subway	+25%	2,6	+20%	2,5	+30%	2,7	+30%	2,7
Bus	+25%	2,5	+20%	2,4	+30%	2,6	+30%	2,6
Scooter	-10%	1,6	-20%	1,4	-30%	1,2	-40%	1
Ferry	N.A.	1	N.A.	1	N.A.	1	N.A.	1
Car	-10%	0	-20%	0	-30%	0	-40%	0
Car pooling	-10%	0,5	-20%	0,5	-30%	0,4	-40%	0,3
Plane	-10%	0	-20%	0	-30%	0	-40%	0
Taxi	-10%	0	-20%	0	-30%	0	-40%	0

Table 15 - User Eco-friendliness Profile: incentives and penalties at T2

Means of Transport	Eco-friendly User		Quite eco-friendly User		Low eco-friendly User		Not eco-friendly User	
	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer	% of Incentives/ Penalties	Score for each kilometer
By foot	+20%	4,1	+10%	3,7	+25%	4,3	+25%	4,3
Bicycle	+20%	4,1	+10%	3,7	+25%	4,3	+25%	4,3
Tram/filobus	+20%	3,1	+10%	2,8	+25%	3,2	+25%	3,2
Electric car	+20%	3	+10%	2,8	+25%	3,2	+25%	3,2
Minibus	+20%	2,8	+10%	2,5	+25%	2,9	+25%	2,9
Train	+20%	2,6	+10%	2,4	+25%	2,8	+25%	2,8
Subway	+20%	2,5	+10%	2,3	+25%	2,6	+25%	2,6
Bus	+20%	2,4	+10%	2,2	+25%	2,5	+25%	2,5

Scooter	-20%	1,4	-25%	1,3	-40%	1	-50%	0,9
Ferry	N.A.	1	N.A.	1	N.A.	1	N.A.	1
Car	-20%	0	-25%	0	-40%	0	-50%	0
Car pooling	-20%	0,4	-25%	0,4	-40%	0,3	-50%	0,3
Plane	-20%	0	-25%	0	-40%	0	-50%	0
Taxi	-20%	0	-25%	0	-40%	0	-50%	0

Table 16 - User Eco-friendliness Profile: incentives and penalties at T3

Score calculation example

The objective of the following example is to show how 2 users, categorized as Business Travellers, that choose different travel solutions to cover the same travel itinerary, obtain different score:

Time 0

Input:

- Travel itinerary: from Grenoble (France) to Bilbao (Spain);
- Number of selected travel solutions: 60[20];
- Selected travel solution and related means of transport covering single legs:
  - *User 1*: Car pooling; Plane; Taxi;
  - *User 2*: By Foot; Train; Subway.

For the calculation of the Master Score, the Baseline Score is divided for the related conversion factor taking into account the reference area of each leg. Therefore, for each travel solution several conversion factors are applied.

[20] For simplification reasons, it is assumed that both the users in T0 select the same travel solution for 60 times.

User 1

	LEG	TRANSPORT MODE	No. KMs		SCORE per KM		BASELINE SCORE		CONVERSION FACTOR	MASTER SCORE
1	User address in Grenoble – Lyon Airport	Car pooling	89,3	×	0,6	=	53,6	÷	100	0,5
2	Lyon Airport– Bilbao Airport	Plane	676	×	0,0	=	0	÷	1000	0
3	Bilbao Airport– User hotel in Bilbao	Taxi	13	×	0,0	=	0	÷	10	0
									TOTAL USER SCORE	0,5

Total Baseline Score: 53,6 x 60 = **3.216**;

Total Master Score: 0,5 x 60 = **30**.

User 2

	LEG	TRANSPORT MODE	No. KMs		SCORE per KM		BASELINE SCORE		CONVERSION FACTOR	MASTER SCORE
1	User address in Grenoble – Grenoble railway station	By Foot	0,5	×	3,4	=	1,7	÷	10	0,2
2	Grenoble railway station – Bilbao railway station	Train	1243	×	2,2	=	2734,6	÷	1000	2,7
3	Bilbao railway station – User hotel in Bilbao	Subway	1	×	2,1	=	2,1	÷	10	0,2
									TOTAL USER SCORE	3,1

Total Baseline Score: (1,7 + 2.734,6 + 2,1) x 60 = **164.304**;

Total Master Score: 3,1 x 60 = **186**.

T1

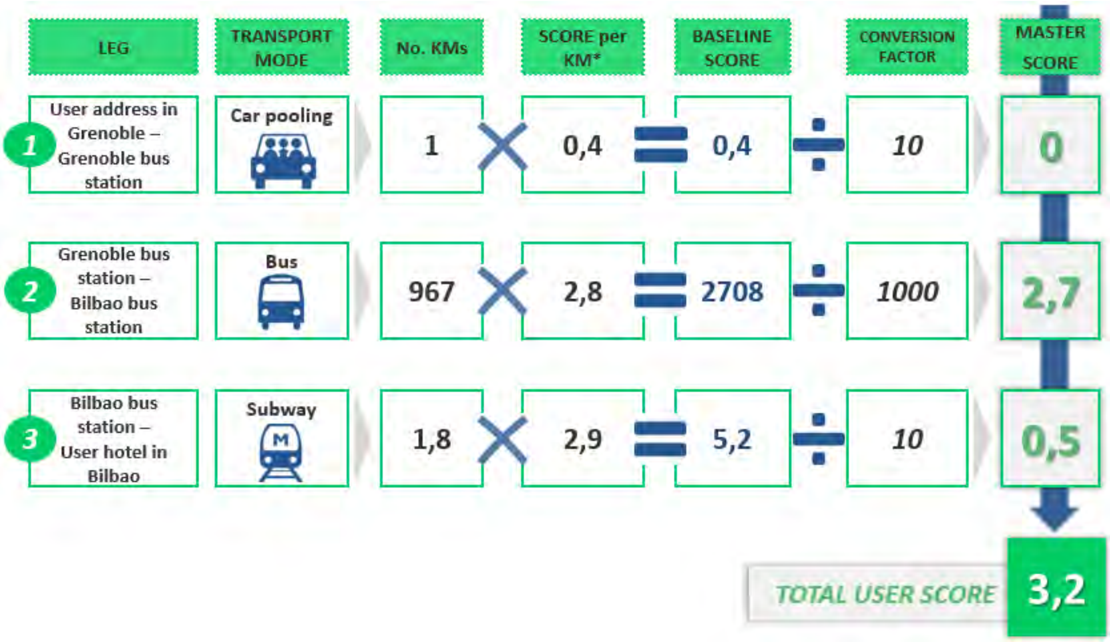
- Travel itinerary: from Grenoble (France) to Bilbao (Spain), therefore it is a long haul trip;
- Number selected travel solutions: 60[21];
- Users:
    - 1 Not Eco-Friendly User (User 1);
    - 1 Eco-Friendly User (User 2).
- Selected travel solution and included means of transport:
    - User 1 & User 2: Car pooling; Bus; Subway.

For the calculation of the Master Score, also in this case, the Baseline Score is divided for the related conversion factor taking into account the reference area of each leg.

In T1, the assigned score per km is different from the "basic" score per km assigned in T0 because of: the incentives granted to the users for choosing low CO2 impact means of transport; the penalties applied for choosing high CO2 impact means of transport***.***

User 1

User 1 is classified as "***Not Eco-friendly User***", because in T0 he/she selected the most polluting travel solution for 60 times.



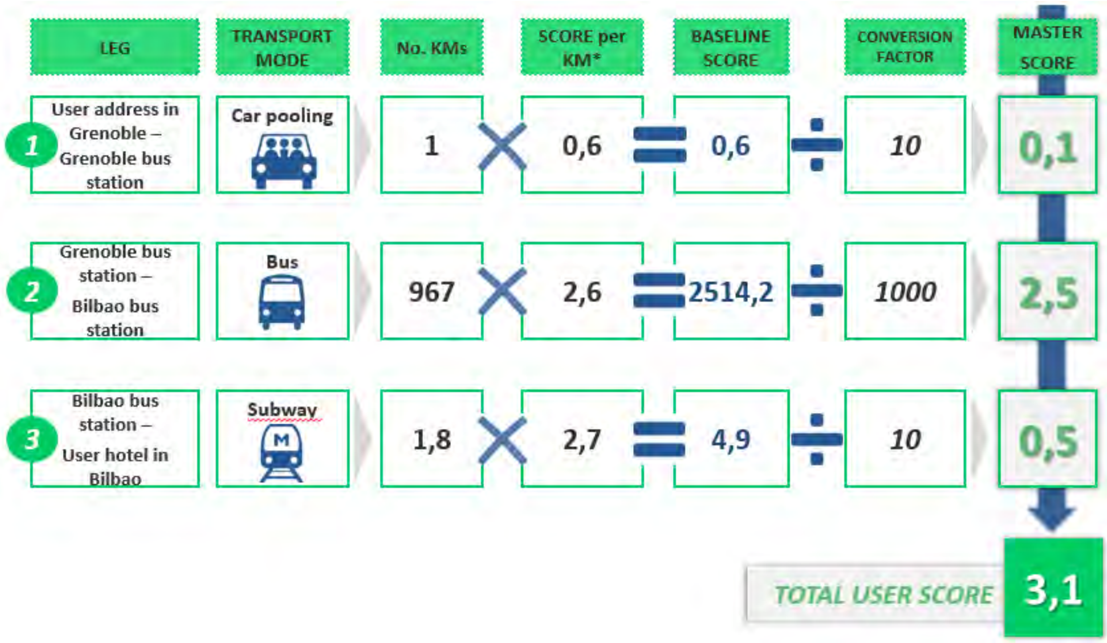
Total Baseline Score: **3.216** (score gathered in T0) + [(0,4 + 2.708 + 5,2)*60 **= 162.816**] = **166.032**

[21] Also in this case, for simplification reasons, it is assumed that in T1 users cover the same route for 60 times.

Total Master Score: **30** (score gathered in T0) + (**3,2***60) = **222**.

User 2

User 2 is classified as “***Eco-friendly User***”, because in T0 he/she selected the less polluting travel solution for 60 times.



Total Baseline Score: **164.304** (score gathered in T0) + [(0,6 + 2.514,2 + 4,9)*60 = **151.182**] = **315.486**

Total Master Score: **186** (score gathered in T0) + (**3,1***60) = **372**

Set Score Policy Functionality of BONVOYAGE: awards, prizes and promotions

The scores accumulated over time, based on the User Eco-friendliness Profile, allow users to receive “green” awards, prizes and promotions.

On the basis of the scores accumulated, “green” awards, prizes and promotions can be gained by the users. They are grouped in three clusters:

- Transport services;
- Eco-friendly accessories;
- Cultural services.

Furthermore, every six months, BONVOYAGE Platform evaluates all users mobility choices made during this period of time and defines a “General User Eco-friendliness Profile”.

On the basis of the “General User Eco-friendliness Profile” and of the total score accumulated, free “green” awards, prizes and discounts are offered to the following users:

- Eco-friendly Users: free awards and prizes;
- Quite Eco-friendly Users: discount of 75% for awards and prizes.

In this case, “green” awards and prizes to offer to the users are selected by the BONVOYAGE Platform among the awards, prizes and promotions provided for the three clusters defined above.

“Green” awards, prizes and promotions provided by the Score Policy are reported in the table below:

Award/Prize/Promotion Cluster	Awards/Prizes/Promotions description	Required Score
Transport services awards	▪ **Free transport tickets** for local public transportation and trains. ▪ **One free monthly subscription** for local public transport and trains**;** ▪ **A carnet of 10 tickets** to travel with trains (for a total expenditure under 150 €) ▪ **Free bike transportation** in train for 6 months	▪ **One free transport ticket** after the achievement of the following scores: - urban routes: at least 50 points; - extra-urban: at least 200 points; - national long-haul: at least 400 points; - international long-haul: at least 500 points; ▪ **One free monthly subscription for local public transport and trains** after the achievement of 100 points; ▪ **A carnet of 10 tickets** to travel with trains after the achievement of 500 points; ▪ **Free bike transportation** in train for 6 months after the achievement of 100 points.
Eco-friendly Supplies	▪ **T-shirt** of BONVOYAGE; ▪ **One Backpack**; ▪ **One Thermos**; ▪ **Pillow to sleep in train**; ▪ **Voucher of 50 €** to be spent to Decathlon and similar retailers; ▪ **Free bike;** ▪ **One GoPro;** ▪ **One Fit Bit chargeHR**; ▪ **Photovoltaic system** for residential buildings**.**	▪ **T-shirt** of BONVOYAGE after the achievement of 50 points; ▪ **One Backpack** after the achievement of 100 points; ▪ **One Thermos** after the achievement of 100 points; ▪ **Pillow to sleep in train** after the achievement of 100 points; ▪ **Voucher of 50 €** to be spent to Decathlon and similar retailers after the achievement of 150 points; ▪ **Free bike** after the achievement of 500 points; ▪ **One GoPro** after the achievement of 1000 points; ▪ **One Fit Bit chargeHR** after the achievement of 500 points; ▪ **Photovoltaic system for residential buildings** after the achievement of 3000

		points.
Cultural services awards	▪ **Annual subscription** to the magazine National Geographic and similar magazines; ▪ **A kit of Organic cosmetics**; ▪ **Walking tour** of one day "out of the city"; ▪ **Dinner for 2 people in a country farmhouse**.	▪ **Annual subscription** to the magazine National Geographic and similar magazines after the achievement of 100 points; ▪ **A kit of Organic cosmetics** after the achievement of 100 points; ▪ **Walking tour** of one day "out of the city" after the achievement of 500 points; ▪ **Dinner for 2 people in a country farmhouse** after the achievement of 500 points.

Table 17 - Score Policy "green" awards, prizes and promotions

The scores to be achieved by the users to receive "green" awards, prizes and promotions listed in the table above was defined taking into account:

- The medium price of the products and services proposed as awards, prizes and promotions (awards, prizes and promotions that include products and services with lower prices can be gained by the users with a lower number of points compared to products and services characterized by higher prices);
- The medium number of travel solutions that the user has to purchase in order to receive the awards, prizes and promotions.

6.2.3 Technical implementation of the Set Score Policy Functionality

This section describes the technical implementation of the Set Score Policy Functionality within the BONVOYAGE platform. The master score, described above, is presented to the user of the platform as "green points".

Score Policy Module

The Set Score Policy Functionality is implemented as an encapsulated service of the BONVOYAGE platform. It will be deployed with the Smart Middleware of the mobile application. The Smart Middleware takes care of the communication between the BONVOYAGE Platform and the mobile application. It orchestrates services that are needed to process requests from the mobile application.

The Score Policy Module implements the methodology described in section above. The module uses the Multi-Modal Mobility Database (MMM-DB) to store User Eco-Friendliness Profile for each user and it is triggered by requests by the Smart Middleware. The service is implemented using JAVA and offers the service as REST API.

The module implements four services:

- **Float tripScore (user, trip)**: it calculates the green points of a travel solution for a specific user;
- **SaveScore (user, trips, selectedTrip)**: it updates the user profile based on travel solutions that the user has selected;
- **Float totalScore (user)**: it returns the score of a user;
- **EcoProfile currentUserEcoProfile (user)**: it returns the user User Eco-Friendliness Profile.

Workflow of the Score Policy Module

The main workflows of the Score Policy Module are described below. They focus on the interactions with other components of the BONVOYAGE platform.

Calculation of score for the travel solutions

The travel solutions provided by the BONVOYAGE platform include Set Score Policy Functionality scores. Figure 50 shows the workflow for enriching the travel solutions provided by the Trip Planner module with personalized scoring.

1. The user requests a travel solution via the mobile application. User ID and query is sent to the Smart Middleware.
2. The query is sent to the Trip Planner component.
3. The Trip Planner returns personalized travel solutions for the user to the Smart Middleware.
4. The travel solutions are sent to the Score Policy Module using the **TripScore** method.
5. The current profile of the specific user is requested from the MMM-DB.
6. The MMM-DB returns the current user profile that is used for the score calculation of the travel solutions.
7. The travel solutions are enriched by green points and the CO2 consumption. The data are returned to the middleware.
8. The travel solutions are forward to the mobile application and presented to the user.

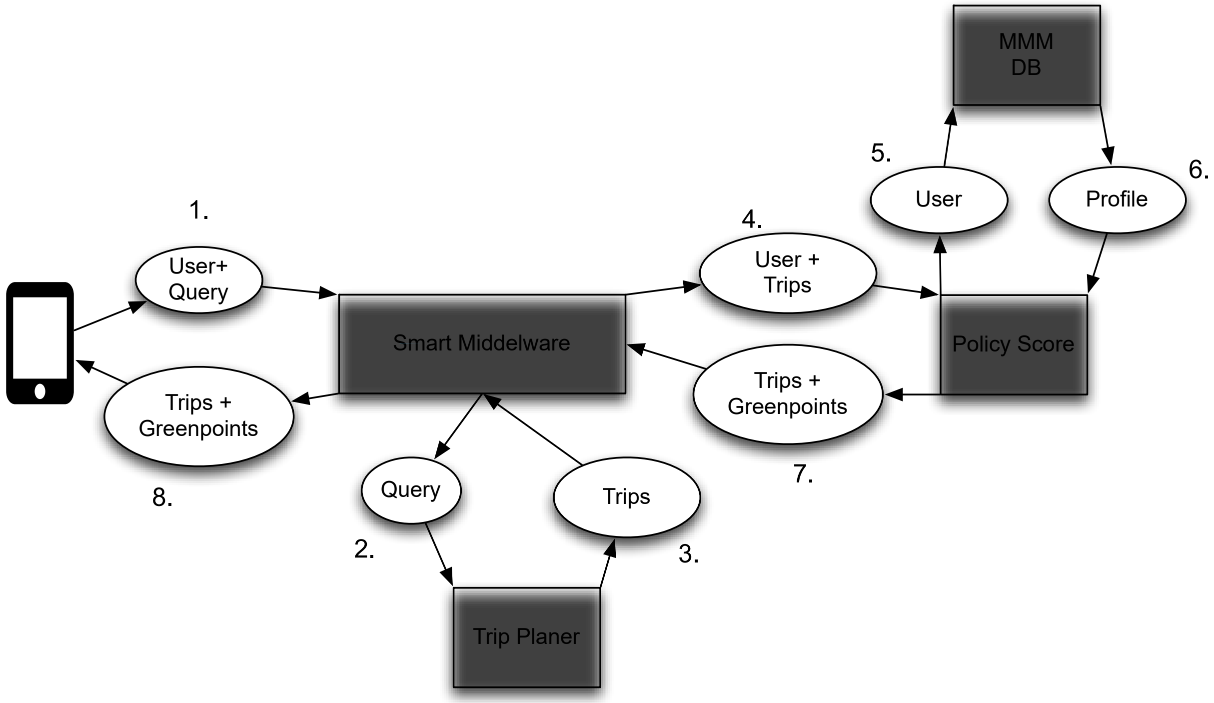


Figure 50 - Workflow calculation of score

Update User Eco-Friendliness Profile

The User Eco-friendliness Profile for the Set Score Policy Functionality is determined based on the selected travel solutions and the travel frequency by the user. Each selected trip is submitted to the Policy Score model that determines the update of the User Eco-friendliness Profile depending on the following factors: the user profile category, the related travel frequency (e.g., occasional, periodic, frequent travellers) as well as the "history track" of the travel solutions selected by the user over time. . The User Eco-friendliness Profile rewards the selection of eco-friendly travel solutions. The selected travel solution is compared against the alternative travel solutions with respect to the CO2 consumption of each of them. The workflow for the update of the User Eco-Friendliness Profile is shown in Figure 51.

1. The user selects the preferred travel solution from the list of alternative travel solutions. The mobile application commits the user selection to the Smart Middleware.
2. The data are forwarded to the Score Policy Module using the service **SaveScore.**
3. The Score Policy Module evaluates the user decision according to the scoring policy described above. The User Eco-Friendliness Profile is updated accordingly. The update of the User Eco-Friendliness Profile is stored in the MMM-DB.

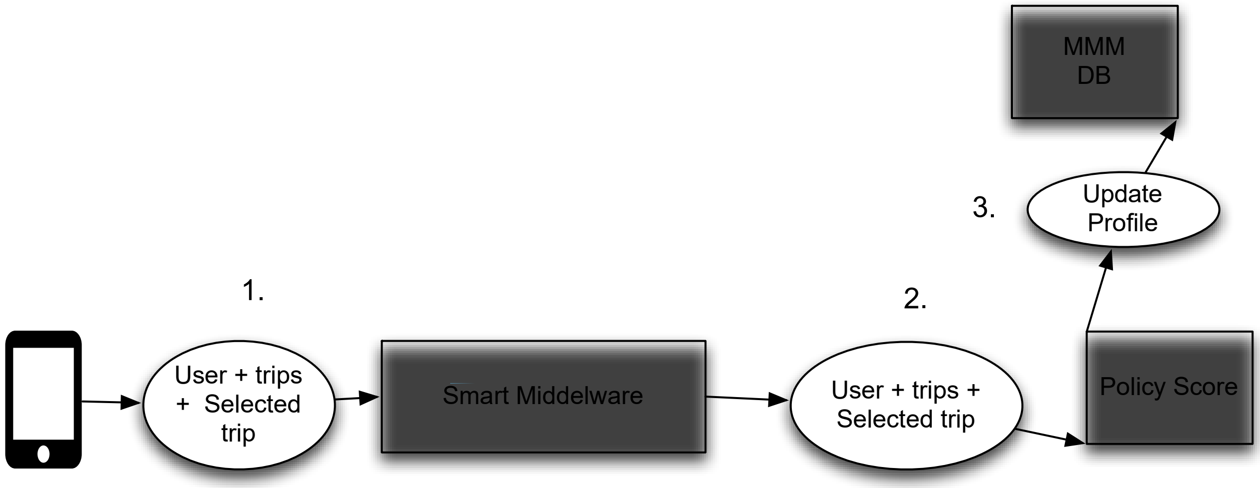


Figure 51 - Update User Profile

Show User Profile

The User Eco-Friendliness Profile consists of the collected green points and current User Eco-Friendliness Profile. All green points are collected for the travel solutions of each user. The mobile application shows the current green point score and the current User Eco-Friendliness Profile as part of his/her account. The workflow for querying the User Eco-Friendliness Profile data is shown in Figure 52.

1.-2. The user data are requested from the mobile application after login via the Smart Middleware from the Score Policy Module. The services **TotalScore** and **CurrentUserEcoProfile** of the Score Policy Module are used to request the data.

3.-6. The data are requested for the MMM-DB by the Score Policy Module and forwarded to the mobile application via the Smart Middleware.

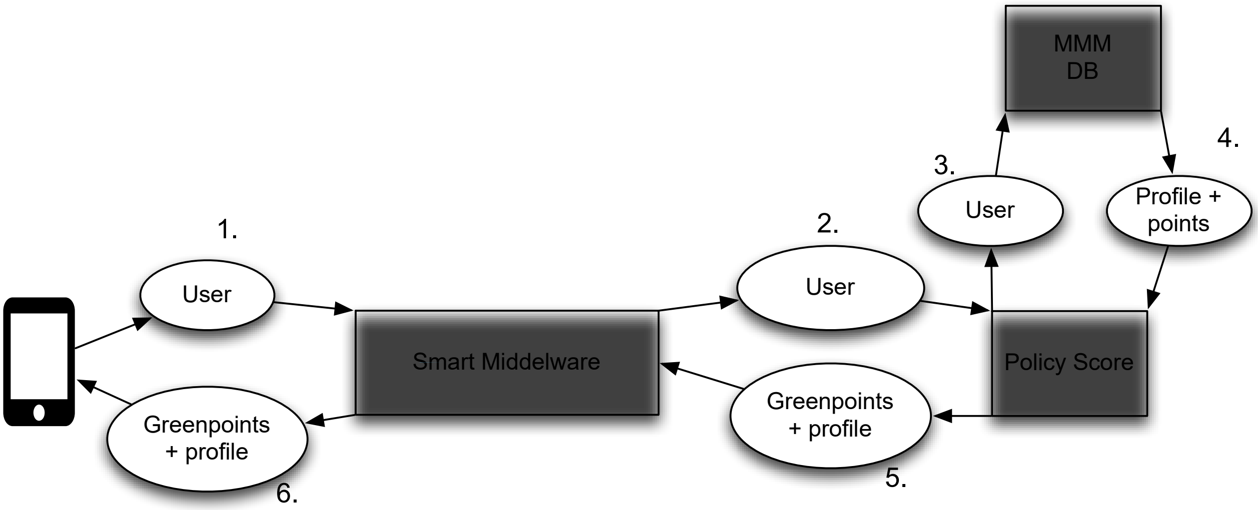


Figure 52 - Show User Profile

Mobile Application

The green points are presented to the user in the mobile application in two major use cases. For each request made by the user, different travel solutions alternatives are presented to the user. For each travel solution, the green points and the CO2 consumption are calculated, as defined in the workflow *Calculation of score for routes* Figure 53 shows a design of the travel solutions alternatives screen of the mobile application. The CO2 consumption and the green points are shown for each travel solution.

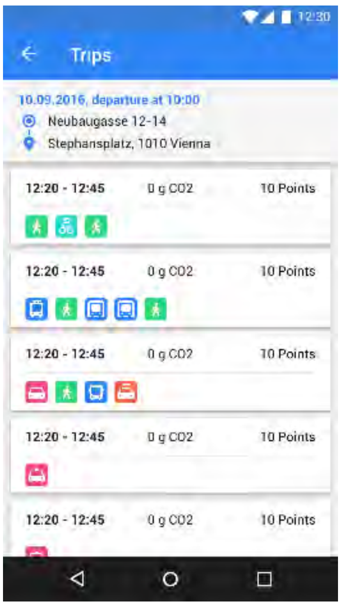


Figure 53 - Design Travel Solutions Alternatives

The Eco-Friendliness Profile of each user is shown in the mobile application. The profile should encourage the user to select eco-friendlier travel solutions. Figure 54 shows a design example for the User Eco-Friendliness Profile. The screen shows the CO2 consumption and the collected green points of the user. The background image indicates the User Eco-Friendliness Profile. The landscape is dark for not eco-friendly user and becomes more green (by leaf trees that grow) for eco-friendlier profiles (low-, quite- and eco-friendly user).

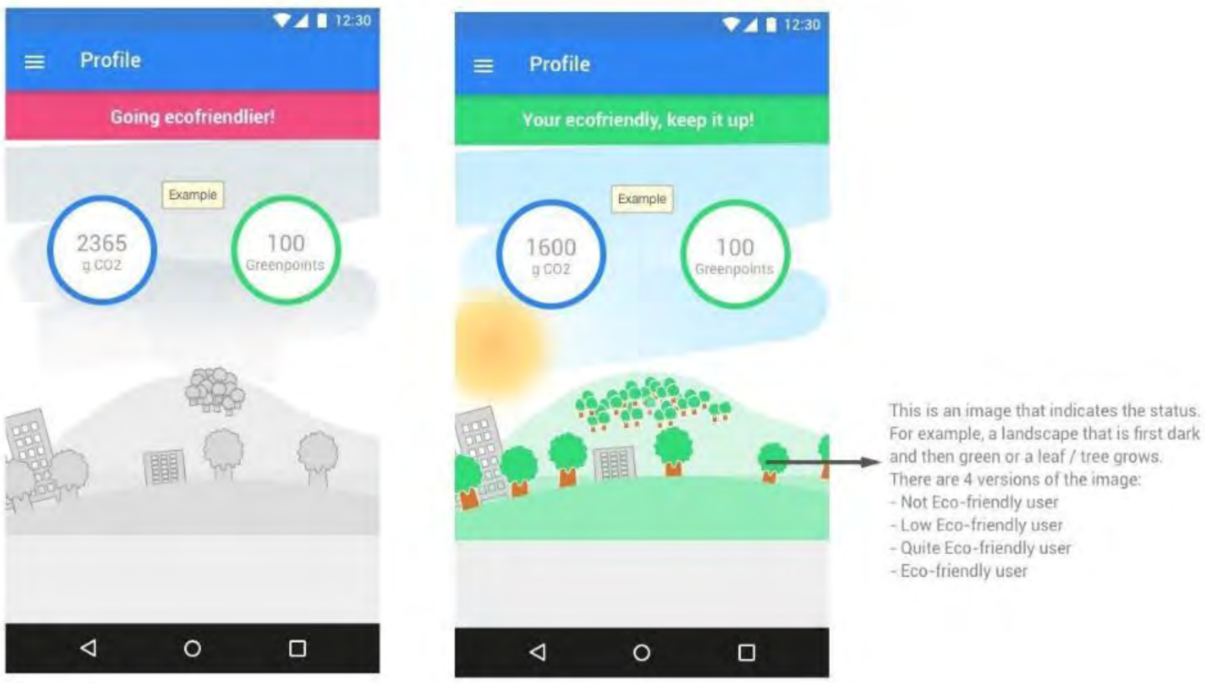


Figure 54 - Design Profile

6.3 Loyalty Programme

The BONVOYAGE Loyalty Programme is aimed to **reward users that showed a high level of "fidelity" to BONVOYAGE**, by purchasing a high number of tickets from the BONVOYAGE transport operators associated to a significant user expenditure and income for transport operators. Therefore, the objective of the Loyalty Programme is to encourage users to continue to purchase transport operators tickets through the BONVOYAGE Platform, by means of a plurality of customized awards, prizes and promotions based on user profile categories (as identified in Deliverable 2.1 Use Cases and Reference Architecture[22]). In this way, the

[22] BONVOYAGE users profile categories include: Bike lovers; Heavy Vehicles drivers (including both truck drivers as well as bus drivers); Luxury (5 star tourists looking for luxury travel conditions); Backpacker (hostel tourists); Low cost; Families; Business; Schools (students groups); Eco-friendly (CO2 saving and naturalistic itineraries); Groups

BONVOYAGE Loyalty Programme contributes to increase the user perceived quality of BONVOYAGE services and aims to increase users "fidelity", thus bringing higher incomes to BONVOYAGE and related transport operators.
Because of its awarding rules, the Loyalty Programme is able to "privileged" users purchasing expensive transport services tickets (e.g., long-haul train tickets, airline tickets). In the particular case of users frequently travelling by air plane, that are disadvantaged by the green Score Policy, the Loyalty Programme represents an alternative compensation, as it rewards users fidelity in terms of money spent through BONVOYAGE, regardless of the level of eco-friendliness of the means of transport included in the selected travel solutions.

6.3.1 Methodology and loyalty programme state-of-the-art

In order to define the BONVOYAGE Loyalty Programme, a benchmark analysis of existing Loyalty Programmes of several transport operators was carried out, with the aim to identify:

- Their common features and the most relevant elements fitting the purposes identified for the BONVOYAGE Loyalty Programme;
- The potential innovative elements to be included and re-shaped in the BONVOYAGE Loyalty Programme.

For the benchmark analysis six existing Loyalty Programmes of different rail and air transport operators were investigated (namely, CartaFRECCIA; Italo Più; MilleMiglia; AAdvantage program; Star Alliance Loyalty Programme; Miles and More) and the following information were identified and investigated (if available):

- Name of the Loyalty Programme;
- Transport operator holder;
- Area in which the Loyalty Programme is valid (e.g., national area, international area);
- Core features of the Loyalty Programme;
- Awards provided by the Transport Operator(s) within the Programme;
- Target of users;
- Additional promotions related to the Loyalty Programme (e.g., promotion valid for the holders of the card provided for the Loyalty Programme).

A brief description of the six selected Loyalty Programmes is reported below.

CartaFRECCIA

CartaFRECCIA is the Loyalty Programme **provided by Trenitalia** S.p.a. (an Italian rail transport operator) and it is applied in a national area.

- **Validity period**: it is valid from 1 January 2015 until 31 December 2016.
- **Scoring rules**:

(tourists groups); Religious groups (religious tourism); Romantic (romantic travels for couples, scenic tours); Single; Adventure (adventure travels); Disabled travellers (with disabilities - also specifying the kind of disability); Food (wine and food travels); Art and culture (artistic itineraries); Music (itineraries for music events); Sport (itineraries for sporting events); Pregnant; Elderly; Day tripper (one day round trip); Special needs.

- 1 point for each euro spent for the purchasing of tickets and subscriptions (also in this case, each euro spent counts one point) for national roots, with the following train categories: Frecciarossa, Frecciargento, Frecciabianca;
- 0,5 points for each euro spent for the purchasing of tickets and subscriptions (each euro spent counts 0,5 points) for national roots, with the following train categories: Intercity, Intercity night, Euronight, Eurocity;
- points gained through the purchase of goods and services provided by the Partner companies of Trenitalia (e.g., points gained for each night booked in a partner hotel of Trenitalia). There is also the possibility to exchange points between the Loyalty Programme of Trenitalia and the other partners.

- **General conditions**: rail tickets that allow users to gain "points" can be purchased from all authorized sales channels. In case of full or partial reimbursement of the purchased ticket that allowed users to gain points, these points will be deleted. In the case in which the accumulated points are not sufficient to request awards, they could not be used, and they could not be converted into money. However, there is the possibility to transfer and receive points from other holders of CartaFRECCIA for a maximum of 1500 points during the entire period of validity of the Loyalty Programme.
- **Type of cards and/or status**: four different type of cards are provided: "CartaFRECCIA", "CartaFRECCIA prepagata", "CartaFRECCIA Oro" and "CartaFRECCIA Platino". All of these cards provide the possibility to gain and transfer points, to purchase a carnet of 10 travels, to receive promotions from Trenitalia Partners. “CartaFRECCIA prepagata” is a prepaid card that can be charged and allows the users to make purchases. "CartaFRECCIA Oro" and "CartaFRECCIA Platino" offer also the access to the "FrecciaClub" and the possibility to gain additional points. Finally, "CartaFRECCIA Platino" offers free access to little lounge areas inside the train, free call center services and access to the "Area meeting" (a meeting room inside the train with 5 seats).
- **Target of Users**: CartaFRECCIA Loyalty Programme is directed to the holders of the “CARTAFRECCIA”, “CARTAFRECCIA Oro”, “CARTAFRECCIA Platino”, “CARTAFRECCIA PREPAGATA” or “TRENITALIA PASS”.

  The following users categories are not allowed to participate:
  - employees of Trenitalia S.p.a. or of companies belonging to the “Ferrovie dello Stato” Group;
  - holders of Free Movement Card (which offers unlimited travel tickets for the employees of Trenitalia);
  - people who do not fall within the definition of holders (e.g.: Travel Agencies, Tour Operators etc).
- **Awards, Prizes and Promotions**: points accumulated can be used (in whole or in part) to request different kinds of awards offered by Trenitalia:

- *Train awards*: Trenitalia train tickets or other services, listed in the catalog published on the website, in force at the time of the request of the prizes. The availability of award tickets may be subject to limitations, e.g., for a few days and for certain routes; restrictions on the availability of award tickets will be notified in advance on the website;
- *Awards catalog*: other goods and services indicated in the catalog, available in the website.

  In case of unavailability of the required awards, Trenitalia will propose to the user comparable awards. In case of rejection of the awards, the user could not receive money and must choose one of the available awards.

- **Other related promotions**:

  - "CartaFRECCIA Special": this promotion gives the possibility for the user to have a discount of 50% purchasing train tickets in certain days and times of the week.

  - "Passaparola CartaFRECCIA": this promotion is addressed to all holders of CartaFRECCIA who have invited new subjects to join the CartaFRECCIA and gives the possibility to receive a Trenitalia voucher of 10 €.

  - "CartaFRECCIA prepagata" that provides reserved prizes for the holders of this card.

  - CartaFRECCIA Young and Senior: it gives the possibility to young people (< 26 years) and old people (> 60 years), holders of the CartaFRECCIA to travel receiving 20% of discount.

  - "Carnet 10 trips": the promotion gives the possibility to purchase 10 train tickets at the price of 8 for the holders of CartaFRECCIA.

Italo Più

Italo Più is the Loyalty Programme **provided by Italo (an Italian rail transport operator)** and it is applied in a national area.

- **Validity period**: it is valid from 1 January 2015 until 31 December 2016.
- **Scoring rules**:
  - 250 points at the moment of the registration;
  - points for each euro spent to purchase train tickets, subscriptions and carnet;
  - points gained purchasing goods/services from Italo Partners.
- **General conditions**: if accumulated points are not sufficient to request awards, they could not be used, and they could not be converted into money.
- **Type of cards and/or status**: there are 2 different type of cards:
  - *Italo Più*: 5 points for each euro spent, award tickets starting from 2.500 points, customized promotions on the basis of the purchased travels, possibility to purchase in a faster and easier manner, registering user credit card in total safety, personal profile, wi-fi, conversion of points into miles to access to the prizes of the “MilleMiglia Program”;

- *Italo Più Privilege*: this program is dedicated to users that have passed the threshold of 10.000 points. In addition to the benefits provided to the Italo Più customers, it provides: 6 points for each euro spent, free updates on board, access to "Lounge Italo Club" areas, possibility to transfer points to other customers, preferential access to the Contact center.

- **Target of Users**: all individuals resident and/or domiciled in Italy over 18 years, enrolled to the "Italo Più" Loyalty Programme.
- **Awards, Prizes and Promotions**: points accumulated can be used to receive:
  - *Free tickets:*
    - short routes: after 2.500 points (smart), 3.000 (extra large), 4.500 (first class), 5.500 (club executive);
    - medium routes: after 3.000 points (smart), 3.500 (extra large), 6.000 (first class), 8.000 (club executive);
    - long routes: after 4.500 points (smart), 5.000 (extra large), 7.000 (first class), 10.000 (club executive).
  - *Traveling in the cabin of guide*: a voucher that allows the customers to visit cabin and to watch Italo trains guide.
  - *MilleMiglia Program*
- **Other related promotions**:
  - "*Carta Italo American Express*": it gives the possibility to gain points purchasing goods and services, and the possibility to receive 250 bonus points for each first class ticket purchased by this card;
  - "*Italo Più Gold Corporate*": it is reserved to employees of partner companies of Italo. It gives the possibility to receive 250 points at the moment of the registration, discounts, 10 points for each euro spent and other privileges.

MilleMiglia

MilleMiglia is the Loyalty Programme **provided by Alitalia S.p.a. (the Italian national airways company)** and it is applied in an international area.

- **Validity period**: it is valid from 1 January 2013 until 31 December 2017.
- **Scoring rules**: miles are the basic unit of calculation. The member earns miles purchasing Alitalia and airlines companies partners tickets, as well as purchasing goods/services from promoters and commercial partners.
  The amount of miles earned for flights is calculated based on: the distance; the type of class booked; the type of tariff chosen. For multi-leg flights miles are assigned for each single route.
- **General conditions**: tickets purchased and not used are not eligible for the assignment of miles. Miles earned for the use of air transport services are assigned to the member's account only after flights. It is not possible to gain miles in case of tickets purchased by

the member but used by others. After 24 months, if the member did not accumulate any mile, miles gained in the past are cancelled and after 5 years of inactivity, the account of the member is cancelled from the system. If accumulated miles are not sufficient to request awards, it is possible to receive and transfer miles among members.

- **Type of cards and/or status**:
  - *Corporate Premium Card*: it is addressed to the employees of companies that made a commercial agreement with Alitalia. It adds additional benefits and services dedicated to companies and improve the efficiency of the business trip.
  - *MilleMiglia Young*: it gives the possibility for the user to gain 50% of miles more than the basic program and to get back some miles when the user choose an award ticket.
  - *MilleMiglia Kids*: it is addressed to kids from 2 and 14 years. It gives the possibility to assign to the parent the miles of the child.
- **Target of Users**: all individuals over 14 years, that travel with Alitalia, and/or Alitalia partners, and/or who have purchased goods/services of promoters and partners of Alitalia.
- **Awards, Prizes and Promotions**: miles accumulated can be used to receive:
  - *Award tickets*: on the basis of the number of miles accumulated, it is possible to receive free tickets for several destinations. There are several type of award tickets that can be chosen: economy and premium economy class, business class for medium/long haul, multiclass;
  - *Awards*: several types of goods and services that can be choose;
  - *MilleMiglia Cash & Miles*: it give the possibility to receive a discount from a minimum of 25€ to a maximum of 25% of the total cost;
  - *Upgrade of the class* (e.g., from economy to business class for long haul international flights);
  - *Charity*: possibility to use the miles accumulated to make a charitable contribution to no profit and charitable associations.
- **Other related promotions**:
  - "Carta Alitalia Platino", "Carta Alitalia Oro"; "Carta Alitalia Verde"; "Carta Alitalia Business Oro"; "Carta Alitalia Business Verde" they give the possibility to gain miles faster, assigning miles for daily expenses etc.
  - "Presenta un amico": it gives the possibility to receive a bonus for each friend presented.

AAdvantage program

AAdvantage program is the Loyalty Programme **provided by American Airlines** (air transport operator of USA) and it is applied in an international area.

- **Scoring rules**: the program gives the possibility to earn miles purchasing airline tickets of American Airline and its partners (other airline companies, hotels, car rental).

- **General conditions**: AAdvantage Loyalty Programme gives the possibility to: buy miles to reach award travel faster, share miles, transferring miles from one account to another etc.
- **Type of cards and/or status**:
  - *Citi®/AAdvantage Executive Card*: it gives the possibility to earn 60.000 bonus miles; Admirals Club® membership; possibility to earn Elite Qualifying Miles and other benefits;
  - *Citi®/AAdvantage Platinum Select Card*: it offers the possibility to earn 30.000 bonus miles, first checked bag free, group 1 Boarding and more and other benefits;
  - *CitiBusiness/AAdvantage Platinum Select Card*: it offers the possibility to earn 30.000 bonus miles, first checked bag free; to save 25% on eligible inflight purchases on American Airlines flights, to get online Account Summaries to track expenses, quarterly and annually and other travel and business benefits.
- **Awards, Prizes and Promotions**: miles accumulated can be used to receive:
  - *Flight awards*: it gives the possibility to book American Airlines and/or other airline partner companies flights with miles accumulated;
  - *Upgrades*: it gives the possibility to move into the next cabin on the flight;
  - *Hotels, cars and more*: possibility to use miles receiving free hotel stays, rental cars, vacation packages and other retail products.
- **Other related promotions**: the Elite Status:
  - *AAdvantage Executive Platinum*: 4 one-way system wide upgrades (with the ability to earn up to 4 more for a total of 8 per year); Complimentary auto-requested upgrades; 100-hour upgrade window; 120% elite mileage bonus; Complimentary Main Cabin Extra and Preferred Seats; 3 free checked bags.
  - *AAdvantage Platinum*: Complimentary auto-requested upgrades on flights 500 miles or less; 72-hour upgrade window 60% elite mileage bonus; Complimentary Main Cabin Extra and Preferred Seats; 2 free checked bags.
  - *AAdvantage Gold*: Complimentary auto-requested upgrades on flights 500 miles or less; 24-hour upgrade window 40% elite mileage bonus; 50% off Main Cabin Extra Seats (complimentary at check-in); Complimentary Preferred Seats; 1 free checked bag.

Star Alliance Loyalty Programme

Star Alliance Loyalty Programme includes **several Airline Companies** (e.g., Lufthansa; Adria; Swiss; Air Canada, etc.) and it is applied in an international area.

- **Scoring rules**: Membership in any of the Star Alliance network programs gives the possibility to the users to earn miles or points on qualifying fares.
- **Type of cards and/or status**:

- *Silver Status*: priority reservation waitlist; priority stand-by.
- *Gold Status*: this status includes several benefits: priority airport check-in; priority baggage handling; airport lounge access; priority reservation waitlist; priority boarding; priority stand-by; extra baggage allowance; priority security clearance (gold track security) check-in.

- **Awards, Prizes and Promotions**:
  - *Flight Awards*: accumulated miles and points to "pay for" a flight; users can redeem them to fly on any member airlines, irrespective of where they have been gained.

Miles and More

Miles and More is the Loyalty Programme of **several Airline Companies** (Lufthansa; Egyptair; Eurowings, etc.) and it is applied in an international area.

- **Scoring rules**: the Loyalty Program gives the possibility to earn miles purchasing:
  - *airline tickets*, from several airline companies partner of Miles and More. For each airline company there are several rules to accumulate miles;
  - *other services/products*: car sharing, finance and insurance, books, telecommunications and electronics, shopping and lifestyle etc.

  Several promotions are available for a certain period of time.
- **Type of cards and/or status**:
  - *Members*: it gives the possibility to gain miles through more than 300 partners in the world, receive miles at the moment of the registration and so on;
  - *Frequent traveller* (after 35.000 miles): preferential treatment during the check-in for business class, access to business lounge, baggage allowance and other benefits;
  - *Senator* (after 100.000 miles): faster check-in, access to senator lounge or star alliance gold lounge, priority baggage delivery on arrival, benefits for the family and so on;
  - *HON Circle Member* (after 600.000 miles): preferential treatment with absolute priority on the waiting list, access to the first class lounge, the partner could take the senator status, personal assistant and other benefits.
- **Awards, Prizes and Promotions**:
  - *Flight Awards*: accumulated miles to receive airline tickets;
  - *Upgrades*: possibility to fly in a higher class;
  - *Special awards*: fly smart (possibility to book ticket in advance and receive 50% of discount); star alliance round the world (possibility to travel around the world) and other promotions for certain period of time.

The benchmark analysis highlights that the main common features and the most relevant elements for the purposes of the BONVOYAGE Loyalty Programme) of the selected Programmes are:

- the possibility for the users to earn points (or miles) purchasing transport operators tickets as well as goods and services offered by several partners of the transport operators;
- The possibility to use points and miles accumulated to receive awards, mainly transport operators free tickets and goods and services offered by their partners;
- The possibility to receive an upgrade of the seat class or to travel in the cabin of guide;
- The provision of several type of special cards and/or status that can be obtained after the achievement of a certain amount of points or miles. These cards and/or status offer the possibility to receive special services and benefits.

Importantly, the main evidence of the benchmark analysis is that **the provision of customized awards, prizes and promotions, based on the specific user profile and preferences, is currently poorly developed and it is, therefore, a potential innovative element**, for the BONVOYAGE Loyalty Programme.

Hence, as described in the next paragraph, the definition of the BONVOYAGE Loyalty Programme started from the inclusion of main common features and most relevant elements of the selected Loyalty Programmes, that were re-shaped and customised taking into account BONVOYAGE project objectives, and was focused on the inclusion of potential innovative elements related to the provision of personalized awards, prizes and promotions for different users profile categories.

6.3.2 BONVOYAGE loyalty programme

As explained before, the main objective of the BONVOYAGE Loyalty Programme is to encourage users to continue to purchase transport operators tickets through BONVOYAGE Platform by means of a plurality of "profiled" awards, prizes and promotions based on user profile categories (reported in paragraph 7.3). In this way, the BONVOYAGE Loyalty Programme contributes to increase the perceived quality of BONVOYAGE services and aims to increase users "fidelity", with specific reference to those travelling a lot and that purchase the most expensive transport operators tickets, bringing higher incomes to BONVOYAGE and related transport operators.

The creation of the BONVOYAGE Loyalty Programme relied upon the definition of the following aspects:

- *Scoring Rule*;
- *Score Management* (several conditions to be respected);
- *Special Status and/or Cards* assigned to users;

- *Customizes Awards/prizes/promotions* provided by the BONVOYAGE Loyalty Programme;
- *Additional Awards/promotions/cards* (provided in special situations and/or period of time).

As starting point, the following **scoring rules** are at the basis the of BONVOYAGE Loyalty Programme::

- At the moment of the registration to the BONVOYAGE Platform the user receives an initial and pre-set number of points (15 points).
- Afterwards, points are gained for each euro spent for the purchase of:
    - tickets from transport operators of BONVOYAGE;
    - goods/services provided by BONVOYAGE partners.

  In brief, 1 point is assigned to the user for each euro spent.

The rules above are combined with the following conditions related to the **score management**:

- In case of reimbursement of the purchased ticket on the initiative of the user, points related to the ticket purchased will be deleted.
- Awards can only be received once the pre-set and necessary score has been achieved.
- Scores cannot be converted into money.
- Users have the possibility to transfer among them until a maximum of 1.000 points in one year.

BONVOYAGE Loyalty Programme provides **special status** that can be obtained by the users after the achievement of a certain amount of points and that give users the possibility to receive special promotions and benefits. Three different special status are included in the Programme:

- **Green status**: after 1.000 points accumulated;
- **Silver status**: after 2.500 points accumulated;
- **Gold status**: after 4.500 points accumulated.

For each special status a different **electronic card** is assigned to the user:

- **Green electronic card** for Green status;
- **Silver electronic card** for Silver status;
- **Gold electronic card** for Gold status.

In case of upgrade to the next, higher status, benefits provided for the previous status are maintained and new additional benefits are offered to the user.

The Table 18 below contains the list of the special promotions and benefits provided to the users for each special status and related electronic card:

GREEN STATUS (green electronic card)	SILVER STATUS (silver electronic card)	GOLD STATUS (gold electronic card)
➢ possibility to purchase a carnet of 10 travels that can be composed by the user, selecting tickets for at least two different means of transport; ➢ priority reservation waitlist.	➢ possibility to purchase a carnet of 10 travels that can be composed by the user, selecting tickets for at least two different means of transport; ➢ priority reservation waitlist; ➢ priority during the check-in and/or possible control lines (e.g., in airports, train stations, etc.); ➢ possibility to give the "green status" as a gift to another BONVOYAGE user (e.g., family member, friend, partner, etc.); ➢ possibility to receive special promotions and "Birthday gift card".	➢ possibility to purchase a carnet of 10 travels that can be composed by the user, selecting tickets for at least two different means of transport; ➢ priority reservation waitlist; ➢ priority during the check-in and/or possible control lines (e.g., in airports, train stations, etc.); ➢ possibility to give the "silver status" as a gift to another BONVOYAGE user (e.g., family member, friend, partner, etc.); ➢ possibility to receive special promotions and "Birthday gift card"; ➢ 1,5 points for each euro spent instead of 1 point; ➢ priority boarding; ➢ priority baggage handling; ➢ extra baggage allowance; ➢ access to lounge areas (e.g., in train or in plane); ➢ baggage tracking through beacon (to be customized on the basis of the travel conditions).

Table 18 - Special status promotions and benefits

Regarding the **awards, prizes and promotions** provided by the BONVOYAGE Loyalty Programme, the main innovative feature is the ability to offer customized awards, prizes and promotions on the basis of the **User Profile Categories**, targeted by BONVOYAGE. They are:

- Bike lovers;
- Heavy Vehicles drivers (including both truck drivers as well as bus drivers);
- Luxury (5 star tourists looking for luxury travel conditions);
- Backpacker (hostel tourists);
- Low cost; Families;
- Business;
- Schools (students groups);
- Eco-friendly (CO2 saving and naturalistic itineraries);
- Groups (tourists groups);
- Religious groups (religious tourism);
- Romantic (romantic travels for couples, scenic tours);
- Single; Adventure (adventure travels);

- Disabled travellers (with disabilities - also specifying the kind of disability);
- Food (wine and food travels);
- Art and culture (artistic itineraries);
- Music (itineraries for music events); Sport (itineraries for sporting events);
- Pregnant;
- Elderly;
- Day tripper (one day round trip);
- Special needs.

On the basis of the User Profile Categories, BONVOYAGE grants users awards, prizes and promotions suitable for their travel profile and preferences, with the ultimate goal to enrich their customers experience and improve their fidelity. They are shown in Table 19 below and include:

- **Awards, prizes and promotions grouped in four clusters** (transport services awards, holiday prizes, cultural services awards, music awards)**.**
- **Specific awards, prizes and promotions provided addressed to identified user profile categories and "matching" different user interests; category**: each category includes several specific awards, prizes and promotions.

The Table also **provides examples of user profile categories to which the c**ustomized awards, prizes and promotions are addressed and points out the **required score to be achieved** in order to obtain awards, prizes and promotions.

Award/Prize/Promotion clusters	Awards/Prizes/Promotions description	Users interests	Users Profile Categories	Required Score
Transport services awards: - free tickets - tickets discounts	▪ **Free transport tickets** offered by transport operators of BONVOYAGE. Users can decide to use free tickets for: - profiled travel solutions automatically proposed by BONVOYAGE (e.g., once the user achieves a pre-set number of scores, BONVOYAGE sends a list of possible profiled travel solutions he/she can get for free); - a travel solution the user intends to buy. ▪ **Transport tickets discount**, offered by transport operators of the BONVOYAGE. Users can decide to use transport tickets discount for: - profiled travel solutions automatically proposed by BONVOYAGE (e.g., once the user achieves a pre-set number of scores, BONVOYAGE sends a list of possible profiled travel solutions he/she can get for free); - a travel solution the user intends to buy.	Users that: ▪ prefer to receive awards that enable them to achieve savings in economic terms; ▪ do not want to receive other type of awards because they are not interested in holidays, cultural events etc; ▪ cannot enjoy other type of awards (e.g., due to mobility issues).	Free transport tickets and transport tickets discounts are addressed to all the user profile categories.	▪ **One free transport ticket** can be received by the user after the achievement of the following scores: - urban routes: at least 50 points; - extra-urban: at least 500 points; - national long-haul: at least 1000 points; - international long-haul: at least 2000 points. ▪ **One transport tickets discount** can be used by the user after the achievement of the following scores: - 10%: at least 200 points; - 25%: at least 1000 points; - 50%: at least 2000 points.
Holidays prizes	**Holiday prizes** provide: - profiled "holiday prizes" automatically proposed by BONVOYAGE (e.g., once the user achieves a pre-set number of scores, BONVOYAGE sends a list of possible profiled "holiday prizes" he/she can get for free); - holiday prizes selected by the user.	Users who like to travel.	▪ **Free night in hotel**: - business travellers who travel for job and often make short journeys; - low cost travellers who prefer to save money. ▪ "**Weekend out of town**": - bike lovers, or adventure	Free night in hotel, weekend out of town and holiday package can be used by the user after the achievement of the following scores: ▪ **Free night in hotel**: - for overnights that cost between

	Holiday prizes include: - **Free night in hotel**: one free night in an hotel; - "**Weekend out of town**": 2 transport tickets for 2 people (both for the outward and the return) and one free night in hotel with breakfast; - **Holiday package**: free transport tickets and free nights in hotel, available in several formulas, for example 2 nights for 4 people, or 4 nights for 2 people.		travellers who want to receive holiday prizes for short stays; - romantic travellers who organize the short-holiday quickly. ▪ **Holiday package**: - families who want to receive the entire travel package, including the journey and the stay for the whole family; - romantic travellers who want to receive a complete package of services; - disabled travellers and groups who need to receive the entire travel package for convenience and special needs.	20 € - 40 €: 500 points; - for overnights that cost between 41 € - 60 €: 1000 points; - for overnights that cost between 61 € - 80 €: 1500 points. - for overnights that cost between 81 € - 100 €: 2000 points. ▪ "**Weekend out of town**": - for expenses until 150 €: at least 2000 points; - for expenses until 350 €: at least 4000 points. ▪ **Holiday package**: - for expenses until 500 €: at least 6000 points; - for expenses until 1000 €: at least 10000 points.
Cultural services awards	**Cultural services awards**, offered by BONVOYAGE Partners, provide free tickets for: - profiled cultural services automatically proposed by BONVOYAGE (e.g., once the user achieves a pre-set number of scores, BONVOYAGE sends a list of possible profiled cultural services he/she can get for free); - a cultural service the user intends to buy. Cultural services awards include: - **Guided tour**; - **Entrance to museums**: free tickets for several type	Users that: - prefer to receive awards related to cultural events; - show interest in adventurous experiences.	▪ **Guided tour**: - adventure travellers; - students groups who want to visit new places; ▪ **Entrance to museums**: - families; - groups; - religious groups; - single travellers; - "art and culture" travellers; - day tripper;	**One cultural service free ticket** can be used by the user after the achievement of the following scores: - for tickets of cultural events that cost between 5 € - 20 €: 500 points; - for tickets of cultural events that cost between 21 € - 50 €: 1000 points; - for tickets of cultural events that cost between 51 € - 100 €: 2000 points.

	of museums; - **Entertainment**: shows, cultural events, theatres.		- people with special needs. ▪ **Entertainment**: - luxury travellers; - families; - groups; - disabled travellers and travellers with special needs; - "art and culture" travellers; - day tripper; - sport travellers.	
Music awards	Music awards, offered by BONVOYAGE Partners, provide: - music awards automatically proposed by BONVOYAGE (e.g., once the user achieves a pre-set number of scores, BONVOYAGE sends a list of possible profiled music awards he/she can get for free); - a music award the user intends to buy. Music awards include: - **Spotify subscription** for one year; - **Free tickets for concerts**.	Users that: - for their age prefer to use points accumulated receiving musical events and services awards (e.g., young people); - are in groups and prefer to use points accumulated sharing the available awards (e.g., participating in a musical or entertainment event).	▪ **Spotify subscription:** - students groups; - romantic travellers; - music travellers. ▪ **Free tickets for concerts**: - families; - groups; - romantic travellers; - "art and culture" travellers; - music travellers; - elderly travellers.	▪ **Spotify subscription** for one year after the achievement of 1000 points. ▪ **One free ticket for concerts** can be used by the user after the achievement of the following scores: - for tickets of concerts that cost between 15 € - 30 €: 500 points; - for tickets of concerts that cost between 31 € - 50 €: 1000 points; - for tickets of concerts that cost between 51 € - 70 €: 2000 points; - for tickets of concerts that cost between 71 € - 100 €: 3000 points.

Table 19 - Customized Awards, Prizes and Promotions

Finally, **additional awards, promotions and cards**, can be offered to the users in special situation and/or period of time are:

- "**Special card**": the user receives this (electronic) card after the achievement of 750 points. It gives the possibility to receive a 25% discount for travelling in specific days and times of the week. This special card can be associated to green, silver and gold electronic cards.
- "**Bring a friend promotion**": the user receives a bonus (50 points) for each friend that he/she brings in BONVOYAGE (the user invites the friend and, following the invitation, his/her friend subscribes to BONVOYAGE).
- **Special promotions**: special promotions that give the possibility to receive profiled promotions (in terms of free tickets or discounts for travel solutions and/or cultural services) every time the user achieves the threshold of 1000 points. BONVOYAGE proposes the user a profiled promotions that remain available for a limited period of time.
- "**Birthday gift electronic card**": it offers the user the possibility to receive a special discount to purchase travel solution tickets for him/her-self and for other people (e.g., the family or for a group of friends) on his/her birthday (e.g., a 10% discount for at least two tickets purchased, until a maximum of five tickets).

The last two are provided just for users who own silver and gold card.

In conclusion, the BONVOYAGE Loyalty Programme builds upon a set of features already provided by existing Loyalty Programmes, shaping and integrating them in a suitable way for BONVOYAGE project purposes. Importantly, the Loyalty Programme overcomes the state-of-the-art and can be considered innovative because of the provision of profiled, customised awards, prizes and promotions, feature that is relevant to the general objective of the BONVOYAGE Project to provide a journey planner that always takes into account users personal profile.

7 Multi-part tariff scheme design

This section is aimed at designing tariff schemes that create new business opportunities for transport operators (through partnerships) and encourage the use of bundles of transportation services with low environmental impact. In particular, we consider the case of multi-modal long-distance trips operated by air transport and high-speed rail (hereafter, HSR).

This is relevant because the HSR can complement air transport offering connections between airports and nearby cities (on legs where the rail service is comparable to flights in terms of total journey time and costs) and the European Commission is encouraging cooperation between the two modes of transport. In 2001, it stated that ‘‘network planning should, therefore, seek to take advantage of the ability of HSR to replace air transport and encourage rail companies, airlines and airport managers not just to compete, but also to cooperate’’[40]. In fact, there is increasing evidence of air transport-HSR partnerships: in Germany, the cooperation between Deutsche Bahn and Lufthansa gave life to AIRail, a service that offers integrated air-rail tickets and full-integrated baggage handling; in France, the partnership between Air France and *Train à Grande Vitesse* (TGV) brought the TGVAIR service to the market, which integrates air and rail tickets.

Since the tariff scheme hinges on a (stylized) model of passenger utility, prior to the design of the scheme we investigate passengers’ preferences in long-distance trip chains and their willingness to pay for the different dimensions of quality of the travel.

The structure of the section is as follows: sections 7.1 and 7.2 describe the preliminary studies on passengers’ preferences and section 7.3 develops tariff schemes for multi-modal long-distance trips.

7.1 Preliminary study on the quality of service at multi-modal hubs

7.1.1 Objective

This study is a prior assessment of the dimensions of quality of travel for passengers at multi-modal hubs, in the case of long distance trip chains.

In line with BONVOYAGE’s objective of identifying personalized travel solutions, we study the impact of the socio-demographic attributes of passengers (e.g., age and income) and of the attributes of the trip (e.g., leisure or business trips) on the relevance of the dimensions of the quality of service identified.

This is preparatory to the survey on passengers’ preferences.

7.1.2 Methodology

This preliminary analysis of the quality of service at multi-modal hubs has relied on the review of the literature. The review used two databases: Scopus and Web of Science. In particular, we selected the studies that adopt an empirical basis and we focus mainly on airports and train stations. Indeed, though local public transport is frequently involved in long-distance trip chains, our purpose is to understand passengers' preferences at the air-rail infrastructure interchange.

The studies considered for the review were published between 2000 and 2015, they mainly focus on European case studies and they rely on stated or revealed preferences surveys. In other words, the respondents are either asked to *state* their preferences (by ranking or scaling) or to choose among (fictional or actual) travel alternatives (therefore *revealing* their preferences) [41].

The following section summarizes the findings of the literature review that are most relevant to our tariff schemes.

7.1.3 Results

The main dimensions of quality of passengers' transfer at a multi-modal hub are: time for transfer, baggage handling and check in facilities, reliability of connections, availability of information, quality of services at the hub.

<u>Time for transfer</u>

The time of transfer can be broken into time for movement between vehicles and time spent waiting for the next vehicle [41]. The values that passengers attach to the two dimensions of the connecting time are different and their level is highly affected by the quality of information available and the quality of services supplied in the multi-modal area.

Passengers usually perceive waiting time to be higher than the actual values [42]. Furthermore, the value of perceived transfer waiting time is higher than the value of perceived transfer (walking) time ([43] and [42]).

[44] finds that passengers are willing to pay less for a reduction of the connecting time than for increased availability of information and quality of services in the multi-modal area. Furthermore, [45] argues that there is a trade-off for passengers when it comes to waiting times in long distance trip chains: on the one hand, passengers want to reduce the time spent connecting because their time has a value and, on the other hand, the prefer long waiting times to reduce the fear of losing the connection.

[46] estimates that the willingness to pay for the (reduction) of the connecting time for passengers travelling from the Canary Island to continental Spain is 11.96 €/hour - 24.46 €/hour.

Baggage handling and Check in facilities

The effort of transferring the pieces of luggage is a source of disutility for passengers. In fact, it has been recognized in the literature that integrated baggage handling among transport operators is necessary to make long-distance multi-modal trips attractive [47], [48], [49] [50]).

The literature suggests that there are two alternative approaches for integrated handling of the baggage between two consecutive lags of the trip: (a) the passenger checks the luggage before boarding on the vehicle of the first lag of the trip; (b) passenger checks the luggage upon her arrival at the interchange node, before moving to the vehicle of the second lag of the trip.

[46] finds that passengers travelling from the Canary Island to continental Spain are willing to pay € 3.33 - € 8.65 for the integrated handling (check in at the origin at withdrawal at the destination).

[45] finds that international passengers travelling from Lille railway station and connecting at Paris Charles de Gaulle airport are willing to pay €35 for the integrated handling of their luggage (check in at Lille and withdrawal at the destination) while they reject the luggage check-in at Charles de Gaulle train station. In this case, the advantage arising from not having to carry the luggage from the train station to the check-in desk of the airlines seems to be offset by the additional risk in terms of losing the luggage.

[47] suggests that the difference between the estimation for integrated handling of the luggage between [46] and [45] is driven by the fact that baggage handling matters more in the case of international travels than in the case of national trips.

Reliability of connection

Missed connections and delays cause anxiety to the user [51]. Reducing the uncertainty of waiting times has been shown to improve passengers' satisfaction and thus to increase ridership [52]. Some travellers may start their journeys early to reduce the risk of missing a connection [53], thereby incurring an increased journey time penalty.

The fear of missing the connection is more relevant as the trip chain involves modes of transport with low frequency of service supplied. Providing guarantees over the next link of the trip is positively valued by passengers and it is often used by transport operators to justify the extra-cost of combined tickets compared to tickets sold separately [45].

[46] finds that passengers travelling from the Canary Island to continental Spain are willing to pay € 19 - € 26 for guarantees in case of delay.

[45] finds that passengers travelling from Lille railway station to Paris Charles de Gaulle airport to catch an international flight are willing to pay €11.26 for guarantees in case of delay.

These results might be driven by the fact that, in the case of national travels, arriving in advance at the airport to avoid the risk of missing the connection would weight more on the total trip time than in the case of international travels. Alternatively, [47] suggests that the difference lies in the way in which the service is marketed to passengers.

Availability of information

Availability of information about the next link of the journey in a multi-modal hub is regarded as the most valued attribute at the connecting experience by [44]. Indeed, pre-trip integrated information on schedule and ticketing and real time information at the facility are able to reduce perceived and actual connecting time of passengers, because they allow better planning of the trip and they reduce the stress at the multi-modal hub ([54], [55]).

Nevertheless there are several barriers to the provisions of integrated information, including differences in the standards of data and difficulties in operators coordination [56].

Quality of services at the hub

The quality of the services supplied at the multi-modal hub is regarded as the second most relevant dimension of quality of the connecting experience by [44]. Examples of services that passengers value at the interchange node are: toilets, shops and food and beverage [47].

Regarding the impact of passengers' profile on her preferences, the literature found that passengers' willingness to pay is affected by their socio-demographic attributes - mainly sex, age, gender and income - as well as by the purpose of their trip and travel habits ([45], [44] and [57]).

Age

Older passengers show very strong preference for integrated baggage handling and passengers over 50 years old are willing to pay almost double of those under 50 for guarantees in case of delay [45].

The willingness to pay for lower transfer time is increasing among the ranges of age <34, 35-54, 55-64, but it decreases for people older than 65. A similar trend is followed by the willingness to pay for the availability of information and the quality of services at the interchange area [44]. Nevertheless, the dynamics of the differences in willingness to pay among the age groups is different depending on the attribute of the journey under exam. In fact, for people older than 65 years old the quality of services available in the interchange area is much more relevant than the availability of information and the transfer time. For people aged from 55 to 64 years old the availability of information and the quality of services are very important and the time of connection has low relevance in comparison. People younger than 54 years old values much more the availability of information than the service quality and the transfer [44].

Gender

Females value improvements in the quality of the available information 2.5 times more than males, while the two groups attribute similar – though slighter greater for males – values to the quality of services in the multi-modal area and availability of information [44].

Purpose of the trip

Leisure passengers (€ 35) are willing to pay more than business passengers (€ 22) for integrated baggage handling. The reason might be that business passengers usually carry lighter suitcases [45]. Business passengers prefer lower connecting time [45] as their value of time is higher than that of leisure [58] passengers

Frequent travelers

Frequent flyers are willing to pay less (€27) than occasional travellers (41€) for baggage handling, but they are willing to pay significantly more (€20 vs 8€) for guarantees in case of delay [45]. Again, this can be explained by their higher value of time.

Income

High earners value the quality of the information available in the multi-modal area much more than low/medium earner, while the willingness to pay for improved quality of services at the point of interchange and the willingness to reduce transfer times is lower for high than for low/medium earners [44].

7.2 A Survey on passengers' preferences

7.2.1 Objective

The survey focuses on long distance trip-chains and considers two multi-modal solutions: (LPT[23]/car) – HSR – flight, (LPT/car) – flight – flight. The aim of the study is to (i) identify the dimensions of quality that shape passengers preferences; (ii) rank the dimensions of quality by relevance; (iii) understand how passengers' profiles (e.g., socio-demographic attributes, travel habits, life habits) affect preferences.

[23] Local Public Transport.

7.2.2 Methodology

Our study of passengers' behaviour relies on a stated preferences survey.

Precisely, we develop two surveys:

- *Pilot survey*: it builds on the results of Section 7.1 and on the benchmarking study and proposes a list of dimensions of quality that might be relevant in long distance trip chains. The respondents are asked to select the dimensions of quality that fit their preferences and (eventually) to suggest others.
- *Main survey (BONVOYAGE Questionnaire 2*, see Appendix C*)*: the main survey updates the list of dimensions of quality from the results of the pilot survey and asks the respondents to assess the relevance of each dimension on a five-point Likert scale.

See the Appendix C for further information about the surveys.

In both surveys the respondents are asked to give information about her socio-demographic status and her habits.

The survey is available on the Internet[24] and it can be filled in anonymously. This strategy is aimed at reaching a large number of respondents, but it is prone to the risk of getting a sample that is not representative of the population.

7.2.3 Preliminary results

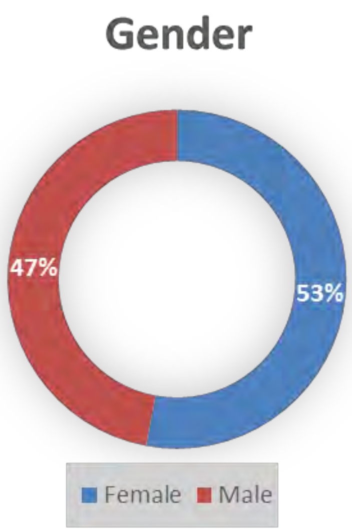
Figure 55 shows some information about the respondents of the survey. Currently the survey has reached 1.127 people and 531 of them already responded. Among these 531, 95% are Italian, 53% are male and 47% are female. Furthermore, 49% of the respondents were born between 1988 and 1997, 21% were born between 1978 and 1987 and 29% were born before 1978. The highest educational qualification is the upper secondary school or a technician diploma for 52% of the respondents, 32% of them awarded a University degree and 3% of them a Ph.D. The remaining owns a lower secondary school diploma and 32% of the respondents are still students. Most of the respondents – precisely 58% - live in cities with more than 50.000 inhabitants. Furthermore, they are used to travel by car - as drivers (50%) or passengers (84%)-, airplane (54%), conventional train and high speed rail (41%) and they mostly travel long distance for leisure (72%).

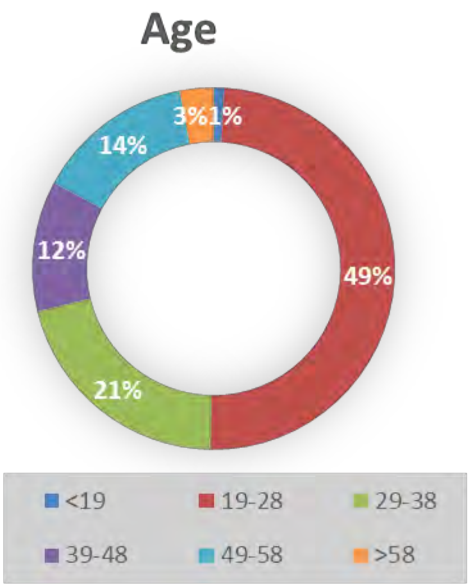
Overall, this descriptive statistics suggest that the survey turned out to be an Italian case study[25]. However, in order to have a sample representative of Italian travellers, the basis of respondents shall be balanced across ages and municipalities, taking into account the age and the

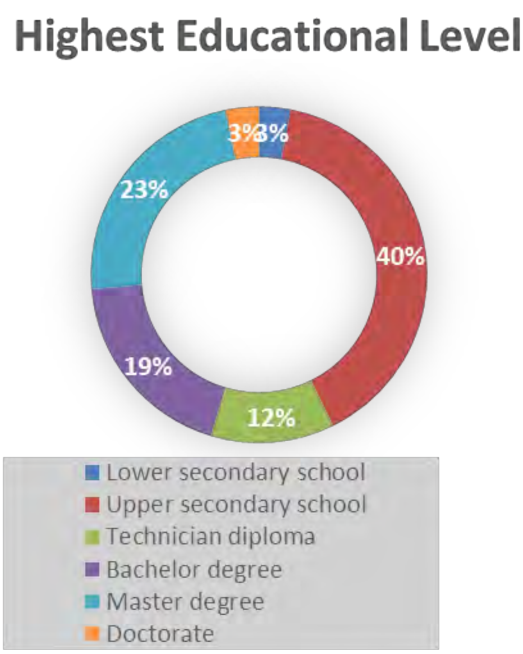
[24] http://BONVOYAGE2020.eu/take-action/long-distance-travels-preferences/

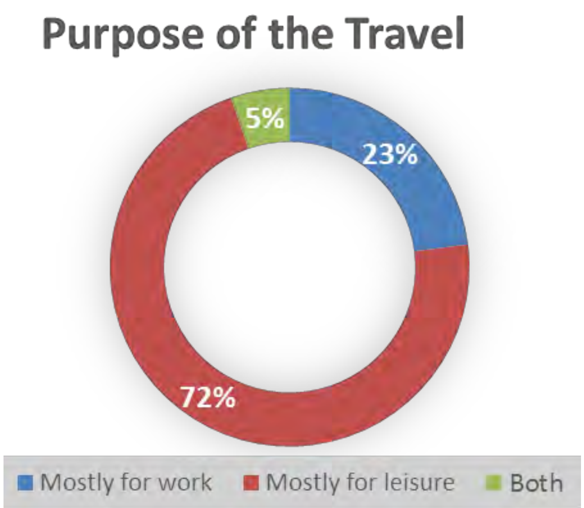
[25] However, the questionnaire is available both in English and in Italian.

geographical distribution of the Italian population. Future effort in data collections will go in this direction.









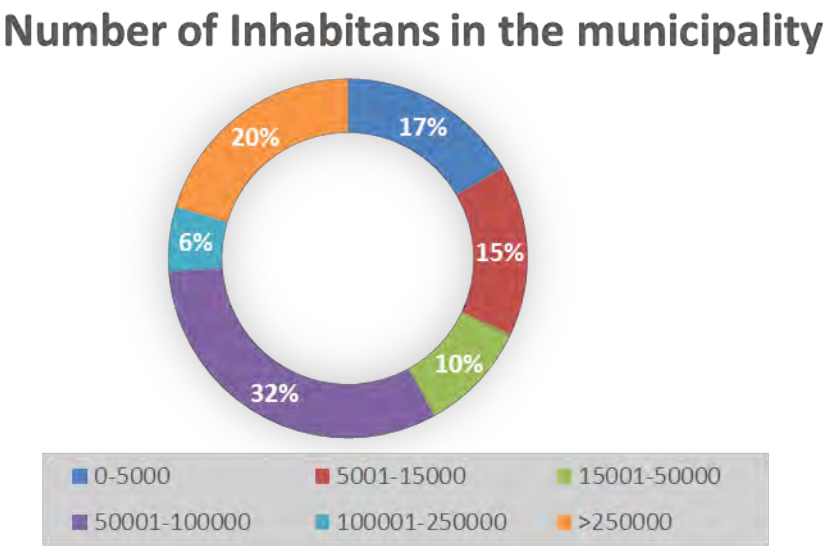


Figure 55 - Preliminary sample of respondents of the survey.

7.3 Tariff Scheme Design

7.3.1 Objective

The algorithm designs pricing rules when two transport operators, an airline and a high-speed rail (HSR) operator, can build a partnership. The aim of study is to identify pricing rules that (i) allow to the transport operators that build the partnership to increase their profits; (ii) benefit passengers and (iii) reduce (some) externalities (congestion and pollution).

The algorithm will be developed theoretically (parametrizing the preferences' of passengers and the costs of the transport operators) and it will be simulated on representative case of studies.

7.3.2 The network

We consider the network of three cities illustrated in Figure 56. An airline (i.e., operator *a*) operates the domestic route between city A and city H as well as an oversea route between city H and city B and a HSR (i.e., operator *r*) transport operator serves the domestic route AH.

Figure 56 - Reference network structure

City H can serve as a multi-modal HUB because there is a HSR station at the airport. We take the runway capacity k at airport H as exogenously given. Thus, depending on traffic, airport H may be congested. On the other hand, we abstract away from capacity constraints at the other transport infrastructures, so that congestion is not an issue either for airports A and B or for HSR platforms.

Markets

- A-H (**domestic market**): it links a hub city H with the city A. The market is served by air transport and HSR;
- H-B (**international market**): it is served by the air transport and the HSR;
- A-B (**multi-modal market**): this market is served by the airline with a one-stop flight, in principle, passengers travelling from city A to city B could transfer from A to H by HSR and then fly from H to B. However, since the market AB is covered by a single-carrier service, which involves integrated baggage handling, ticketing and schedules, we assume that multi-modal trips do not occur unless the airline and the HSR operator build a partnership.

7.3.3 Passenger preferences

In our model, passengers' preferences are described by the following strictly concave quadratic utility function[26]:

$$U(\boldsymbol{q}) = \sum_m \sum_t \alpha_m^t q_m^t - \frac{1}{2} \sum_m \left(\sum_t \beta_m^t {q_m^t}^2 + 2\gamma_m \prod_t q_m^t \right) \tag{1}$$

where $m = AH, HB, AB$ denotes the market and t indicates the transport mode(s) involved in the transportation product. Precisely, $t = A$ $(t = R)$ when the product consists of a direct fight (HSR ride), $t = AA$ when the product consists of a one-stop air travel, and $t = AR$ in the case of a multi-modal trip. Given the transport network in Figure 56, we have: (i) if $m = AH$ then $t = A, R$;

[26] $\beta_m^t \beta_m^{-t} - \gamma_m^t > 0$ and $\alpha_m^t \beta_m^{-t} - \alpha_m^{-t} > 0$, where $-t$ is the competitor (if any) of transport operator t on the market m.

(ii) if $m = HB$ then $t = A$; (iii) if $m = AB$ then $t = AA$ when the airline and the HSR do not cooperate, and $t = AA, AR$ when they sign an agreement.

The parameter γ_m $(0 \leq \gamma_m \leq \beta_m^t \beta_m^t)$ captures the degree of substitutability between the transport modes and larger values of γ_m indicate more substitutable services. For instance, consider $m = AB$, when $\gamma_{AB} = \beta_{AB}^{AA} \beta_{AB}^{AR}$, the one-stop flight and the air-rail product supplied to market AB are perceived as perfect substitutes by travellers. On the other hand, when $\gamma_{AB} = 0$ the two modes are seen as independent products. Practically, air travellers do not care about the price of the air-rail product, they would never buy it because its feature of the product does not match their taste and vice versa for air-rail travellers.

The parameter α_m^t represents the maximum willingness to pay (wtp) of passengers for the transportation service operated by t on the market m[27]. In other words, if the transport operator t sets $p_m^t = \alpha_m^t$ he is not going to sell any ticket to the market (i.e., $q_m^t = 0$) because the price is too high.

The parameter β_m^t represents the sensitivity of prices to quantities. For instance, when $\gamma_{AH} = 0$, a 1% increase in the air traffic on market AH produces a reduction of the price of the flight of β_{AH}^A%. On the other way round a 1% reduction of the price of the ticket increases the number of air tickets supplied to AH passengers by $(1/\beta_{AH}^A)$ %.

The parameters α_m^t and γ_m model passenger taste for the alternative travel solutions and depend on the dimensions of quality identified in Sections 7.1 and 7.2.

We assume that passengers maximize their utility function subject to their budget constraints.

$$\begin{gathered} max_{\boldsymbol{q}} U(\boldsymbol{q}) \\ s.t. \sum_m \sum_t p_m^t q_m^t \leq s \\ q_m^t \geq 0, \forall m, t \end{gathered} \qquad (2)$$

Where s stands for the total budget available to the passengers.

From the first order conditions of problem (2) we find individual (inverse) demand functions:

$$\begin{gathered} \boldsymbol{p_{AH}^A(q) = \alpha_{AH}^A - \beta_{AH}^A q_{AH}^A - \gamma_{AH}\, q_{AH}^R} \\ \boldsymbol{p_{AH}^R(q) = \alpha_{AH}^R - \beta_{AH}^R q_{AH}^R - \gamma_{AH}\, q_{AH}^A} \\ \boldsymbol{p_{HB}^A(q) = \alpha_{HB}^A - \beta_{HB}^A q_{HB}^A} \end{gathered} \qquad (3)$$

[27] We remark that by allowing $\alpha_m^{\bar{t}} \neq \alpha_m^{\tilde{t}}$ when $\bar{t} \neq \tilde{t}$, we aknowledge that the services might be vertically differentiated.

$$\boldsymbol{p_{AB}^{AA}(q) = \alpha_{AB}^{AA} - \beta_{AB}^{A} q_{AB}^{AA} - \gamma_{AB}\ q_{AB}^{AR}}$$
$$p_{AB}^{AR}(q) = \alpha_{AB}^{AR} - \beta_{AB}^{R} q_{AB}^{AR} - \gamma_{AB} q_{AB}^{AA}$$

7.3.4 Transport operators

We assume that the size of the vehicles (airplanes/trains) of the transport operators is fixed. As a result, the transport operators bear a cost c_m^t to supply one seat on the market m (which depends on the distance travelled, the size and the type of the vehicle used[28]). Consequently, the cost functions of the transport operators are as follows: $C_m^t(q_m^t) = c_m^t q_m^t$.[29] Furthermore we assume that $c_{AB}^{AA} = c_{AH}^{A} + c_{HB}^{A}$ and $c_{AB}^{AR} = c_{AH}^{R} + c_{HB}^{A}$.

The objective of the transport operators is to maximize their profits subject to the (runway) capacity constraints at the airport and the non-negativity constraint on quantities.

7.3.5 Methodology

We investigate two scenarios:

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 competition)*.

$$max_{q_{AH}^{R}} \pi_r^b(\boldsymbol{q}) = (p_{AH}^{R}(\boldsymbol{q}) - c_{AH}^{R}) q_{AH}^{R}$$

$$\begin{aligned} max_{q_{AH}^{A}, q_{HB}^{A}, q_{AB}^{AA}}\ & \pi_a^b(\boldsymbol{q}) \\ &= (p_{AH}^{A}(\boldsymbol{q}) - c_{AH}^{A}) q_{AH}^{A} + (p_{AB}^{AA}(\boldsymbol{q}) - c_{AB}^{AA}) q_{AB}^{AA} + (p_{HB}^{A}(\boldsymbol{q}) - c_{HB}^{A}) q_{HB}^{A} \end{aligned} \quad (4)$$
$$s.t.\ q_{AH}^{A} + q_{HB}^{A} + 2q_{AB}^{AA} \le k$$
$$q_m^t \ge 0, \forall m, t$$

Where superscript *b* stands for *benchmark* and the cost function and the inverse demand functions are defined in Section 7.3.3.

We denote the optimal solutions of the game by $q^{b,*}$.

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

[28] In principle, it would also depend on the type of passengers (e.g., business or leisure). However, our (representative) passengers are homogeneous.
[29] See section 8.3.7 for further details on costs.

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).

This relationship can be modelled as a two-stage Nash equilibrium problem.

In the first stage the HSR, taking into account the effect that the tariff w would have on the quantities decided in the second stage of the game (i.e., $\boldsymbol{q^p}(w)$), decides the wholesale price as to maximize its own profits.

$$max_w\ \pi_r^w(\boldsymbol{q^p}(w)) = (p_{AH}^R - c_{AH}^R)q_{AH}^{R,p}(w) + (w - c_{AH}^R)q_{AB}^{AR,p}(w) \tag{5}$$

In the second stage, observed the level of the infrastructure charge w, the airline and the HSR simultaneously decide how many seats to supply on the markets as to maximize their own profits.

$$\begin{aligned} max_{q_{AH}^A,q_{HB}^A,q_{AB}^{AA},q_{AB}^{AR}}\pi_a^p(\boldsymbol{q}) & \\ &= (p_{AH}^A(\boldsymbol{q}) - c_{AH}^A)q_{AH}^A + (p_{AB}^{AA}(\boldsymbol{q}) - c_{AB}^{AA})q_{AB}^{AA} \\ &+ (p_{HB}^A(\boldsymbol{q}) - c_{HB}^A)q_{HB}^A + (p_{AB}^{AR}(\boldsymbol{q}) - c_{AH}^A - w)q_{AB}^{AR} \\ & s.t.\ q_{AH}^A + q_{HB}^A + 2q_{AB}^{AA} + q_{AB}^{AR} \leq k \\ & q_m^t \geq 0, \forall m, t \\ max_{q_{AH}^R}\pi_r^w(\boldsymbol{q^p}(w)) &= (p_{AH}^R - c_{AH}^R)q_{AH}^{R,p}(w) + (w - c_{AH}^R)q_{AB}^{AR,p}(w) \end{aligned} \tag{6}$$

The problem is solved by backward induction: we solve problem (6) to derive $q^p(w)$ and then we solve (5) to derive the optimal tariff $w^{p,*}$ (which determines $q^{p,*} = q^p(w^{p,*})$).

We evaluate:

<u>The profitability of the partnership:</u> the transport operators will decide to build the partnership if and only if $\pi_a^p(q^{p,*}) - F_a^p > \pi_a^b(q^{b,*})$ and $\pi_r^p(q^{p,*}) - F_r^p > \pi_r^b(q^{b,*})$, where

F_a^p and F_r^p are the (fixed) costs that would arise if they build the partnership, for the airline and the HSR respectively.[30]

The effect on consumers: to evaluate consumers' well being we refer to *consumer surplus (CS)* that is defined in (7) and represents the aggregate utility that passengers derive travelling net of the total amount of money that they pay for the tickets.

$$CS(\boldsymbol{q}) = U(\boldsymbol{q}) - p_{AH}^{A} q_{AH}^{A} - p_{AH}^{R} q_{AH}^{R} - p_{AB}^{AA} q_{AB}^{AA} - p_{HB}^{A} q_{HB}^{A} - p_{AB}^{AR} q_{AB}^{AR} \quad (7)$$

In particular we measure the benefits of the partnership for passengers as $CS(q^{p,*}) - CS(q^{b,*})$.

Externalities: we measure the degree of congestion of the airport as $Cong(q) = q_{AH}^{A} + q_{HB}^{A} + 2q_{AB}^{AA} + q_{AB}^{AR} - k$. The benefits of the partnership on congestion are given by $Cong(q^{p,*}) - Cong(q^{b,*})$. Furthermore, we evaluate the impact of the air-rail partnership on CO_2 emissions (see [2] for the description of a methodology to measure the effect of inter-modality on environmental externalities in OD markets).

7.3.6 *Preliminary results*

In this section we summarize the main results obtained from the model theoretically (or parametrically), i.e., not assigning numerical values to the exogenous parameters $(\alpha_m^t, \beta_m^t, \gamma_m, k, c_m^t, F_a^p, F_r^p)$.. We do not provide the analytical expression of the optimal solution of the decision problems of the game but they are available in [3].

The advantage of this approach is that it allows to understand which is the level of the partnership's tariffs and which are their implications for consumers and society in each region of feasible parameters. In other words, we are able to understand in which cases (e.g., market where passengers have high willingness to pay for the travels, the product are close substitutes and the capacity available at the airport is low) the partnership is profitable, increases (or decreases consumers' well being) and/or increases (or decreases) externalities.

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[30] 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).

However, we have to introduce some simplifying assumptions for analytical tractability: we assume that: $\alpha_{AH}^t = \alpha_{HB}^t = \alpha$ and $\alpha_{AB}^t = 2\alpha$ (passengers have a higher maximum willingness to pay (wtp) for the long-distance travel AB than for the direct trips from A to H or from H to B); $\beta_{AH}^A = 1$ and $c_m^t = 0$, $\forall m, t$; $\gamma_m = \gamma$, with $0 < \gamma < 1$. These assumptions will be relaxed in the case study (see Section 7.3.7).

We find that, compared to the benchmark scenario in which there is not an agreement between the airline and the HSR, if the partnership is formed:

(i) the number of people travelling (by air or rail) in the market AB increases;

(ii) the number of people travelling in the market AH and HB might decrease if the capacity of the airport is fully utilized and air and rail are sufficiently similar ($\gamma > 0.5$);

(iii) the total number of people travelling in all the markets increases;

Furthermore, we find that when (and only when) air and rail are sufficiently similar and the capacity available at the hub airport is sufficiently high ($\gamma > 0.5$ and $\mathrm{k} \geq \tilde{\mathrm{k}}(\alpha, \gamma, k)$), the partnership reduces congestion.

The rationale for the result is that, on the one hand, the introduction of the air-rail product incentivizes more people to travel while, on the other hand, thanks to the partnership, the airline substitutes some feeding flights by feeding HSR rides on the market AB and thereby reduces congestion.

Turning to consumers' well being (i.e., $CS(q)$) our analysis suggests that if there is spare capacity at the airport the partnership benefits consumers, however, when the capacity constraint is binding at the equilibrium, if air and rail are sufficiently differentiated (i.e., $\gamma < \tilde{\gamma}_3 (\cong 0.33)$), it may reduce consumers' surplus.

In fact, on the one hand, the partnership after the partnership more people travel, i.e., there are more people that enjoys the transport services, and $CS(q)$ increases. On the other hand, with the partnership, the transport operators compete less aggressively on the market AH, compared to the benchmark scenario in which there is no partnership, and this might lead to higher prices on that market (and decrease $CS(q)$).

Finally, turning to the transport operators' side, we find that the agreement always allows to the transport operators to increase profits. Furthermore, our analysis suggests that if the air-rail product and the one stop flight are sufficiently differentiated (i.e., $\gamma < 1/2(\sqrt{5} - 1)(\cong 0.62)$), the HSR earns more revenues for every seat supplied to the airline than for the rail tickets supplied to the market AH.

Finally, the impact of the partnership on the environmental externalities will be evaluated on representative case studies building on [2].

7.3.7 Case study

The network

We consider an example of three cities connected by air transport and HSR as in Figure 56.

Cities: $A \equiv Nantes$; $H \equiv Paris$; $B \equiv$ Philipsburg (Saint Martin);

Transport operators: $R \equiv SNCF$, $A \equiv Air\ France$.

More precisely, in this case study we define the network represented in Figure 56 as a (oriented) graph, $G = (V, E)$, where

- $V = \{\mathrm{N}, \mathrm{P}, \mathrm{PB}\}$ is the set of nodes, where:

$$\mathrm{N} = \begin{cases} \text{Nantes Atlantique Airport (NTE), Nantes, France} & if\ (t = A \vee t = AA) \\ \text{Gare de Nantes (QJZ), Nantes, France} & otherwise \end{cases}$$

$$\mathrm{P} = \begin{cases} \text{Paris Charles De Gaulle Airport (CDG), Paris, France} & if\ (t = A \vee t = AA) \\ \text{Gare de Paris Montparnasse, Paris, France} & otherwise \end{cases}$$

$$\mathrm{PB} = \text{Princess Juliana International Airport (SXM), Philipsburg (Saint Martin)}$$

- $E = \{\mathrm{NP}, \mathrm{PPB}, \mathrm{NPB}\}$ is the set of edges, where:

$$\mathrm{NP} = \begin{cases} \mathrm{NTE - CDG} & if\ t = A \\ \mathrm{QJZ - PMP} & if\ t = R \end{cases}$$

$$\mathrm{PPB} = \mathrm{CDG - SXM}$$

$$\mathrm{NPB} = \begin{cases} \mathrm{NTE - SXM} & if\ t = AA \\ \mathrm{QJZ - SXM} & if\ t = AR \end{cases}$$

Baseline story

Maria has to go from Nantes (rue Adolphe Moitiè,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 and takes a flight towards Paris Charles De Gaulle Airport. Here she connects to a flight towards Princess Juliana International Airport.

2) TGVAir product offered by SNCF-Air France. This is a combined air-rail ticket. Maria leaves from Gare de Nantes and takes a high-speed ride towards Paris Charles De Gaulle

Airport. The ride is offered by SNCF (Societè Nationale des Chemines Francaises); once in Paris Charles De Gaulle Airport, she takes the flight towards Princess Juliana International Airport.

When making a flight booking online from Air France's website, Maria simply selects her departure from Gare de Nantes (QJZ) – as she would if she was booking a normal flight. Once she has finalised her reservation on Air France's website, she receives an Air France ticket which will include her train journey from QJZ to CDG. If the train or flight is delayed, SNCF and Air France are committed to rebooking Maria on the first available train or flight. As far as loyalty programmes are concerned, if Maria is a member of both Air France Flying Blue and SNCF's loyalty programmes, as her ticket is considered an airline ticket, only Flying Blue Miles will apply.

The following procedure must be accomplished by Maria:

- At the TGV AIR counter of the departure station (QJZ)

  Between 24 hours and 20 minutes before the train's departure, Maria has to proceed to the TGV AIR counter with her trip summary and ID. The TGV AIR team completes her check-in for her flight and provides the customer train ticket, which she must validate.

- At Paris-Charles de Gaulle airport

  To check in the baggage upon arrival at the airport, the customer has to proceed to the check-in counter for her flight or to the baggage drop-off counter.

Only 15 minutes are needed between the airport terminals and the TGV station at Paris-Charles de Gaulle.

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 takes a flight towards Paris Charles De Gaulle Airport.

2) High-speed rail ride. People leave from Gare de Nantes and takes 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.

Relevance of the case study for the calibration of the model

There are three reasons why we choose this case study.

First, the case study may be representative of the market described in our model:

1) In the leg Nantes-Paris, Air France is a monopolist in the air transport market. Direct flights are offered from Nantes Atlantique Airport to Paris Charles De Gaulle Airport. In other words, taking off in NTE and landing in CDG by means of an Air France flight is the only option that available for travellers who want to a direct air journey. We note that flights from NTE to Paris Orly International Airport (ORY) are offered by HOP, which is the brand name of the regional flights operated by subsidiaries of Air France. HOP flights are operated by Airlinair, Brit Air and Régional under the HOP! brand. The new airline brand was created in 2013 to better compete with the low-cost airlines, which have taken a significant market share of Air France's regional routes. In our model, we abstract away from this product (i.e., the flight offered by HOP! From NTE to ORY). However, this does not change qualitatively our results, since the profit maximize decision maker is, in both cases, Air France.

2) In the leg Nantes-Paris, SNCF is a monopolist in the High-Speed Rail transport market. Direct rides are offered from Gare de Nantes to Gare de Paris Montparnasse.

3) In the leg Paris-Philipsburg, Air France is a monopolist in the air transport market. Direct flights are offered by Air France or KLM from CDG to Princess Juliana International Airport (SXM). We note that Air France–KLM is the result of the merger in 2004 between Air France and KLM. Both Air France and KLM are members of the SkyTeam airline alliance.

4) In the market Nantes-Philipsburg, customers might book only two products. First, there is TGVAir product from QJZ to SXM via CDG. Second, there is a connecting flight offered by Air France/KLM offered from NTE to SXM via CDG or Amsterdam Schiphol Airport (AMS). Again, this does not change qualitatively our results, since the profit maximizing decision maker is, in both cases, Air France-KLM, no matter what the connecting airport.

Second, the HSR network of SNCF is one of the most developed in Europe. Nowadays, SNCF operates nearly 5500 TGV services per week serving around 230 stations. In 2013, SNCF carried about 125 million passengers per year and acknowledged that at least 2 billion passengers (equivalent to one third of the Earth's population) had already travelled by TGV. According to SNCF's President Guillaume Pepy, the third billion is expected by 2021, but it is possible that this figure may be reached before then [59]. In fact, the TGV Atlantique connecting NTE and CDG is a prominent example of a strong complementarity between the HSR system and the operation of the major air hubs (OECD/ITF, 2014). On the Paris-Nantes route, the introduction of the TGV network decreased the air traffic by 30% [60]. Travellers from Nantes are increasingly fed into the Air France hub by TGV (OECD/ITF, 2014). In particular, two High speed services connect Nantes to Paris: Nantes - Angers - Le Mans – Paris; Le Croisic - Saint-Nazaire - Nantes – Paris. Direct services are guaranteed toward both city Paris city centre and CDG (25 km from Paris city centre).

Third, tourism can be considered more important to the Caribbean than to any other region in the world [61]. In 2010, the World Travel and Tourism Council (WTTC) ranks the region first in terms of the sector's contribution to national economies: total long-stay arrivals to the region were estimated at just over 20.1 million, compared to approximately 4 million in 1970. The total contribution of Travel & Tourism to GDP (including wider effects from investment, the supply chain and induced income impacts) was USD51.9 billion in 2014 (14.6% of GDP). It is forecasted to rise by 3.3% per annum (pa) to USD73.6 billion by 2025 (15.4% of GDP). Leisure travel spending (inbound and domestic) generated 90.6% of direct Travel & Tourism GDP in 2014 (USD35.7 billion) compared with 9.4% for business travel spending (USD3.7 billion). Leisure travel spending is expected to rise by 3.3% pa to USD50.7 billion in 2025. Business travel spending is expected to rise by 3.2% pa to USD5.3 billion in 2025.

According to the database Eurostat (Air Transport Section), in 2015, 145,276 air travellers have been recorded flying from CDG to SXM, 428,570 from NTE to CDG, 85,936 from NTE to ORY.

Calibration of parameters

The following Table collects estimation for parameters for Maria's trip (leisure purpose)

Demand			
	WTP	α_{NP}^{R}	258€
		α_{NP}^{A}	258€
		α_{PPB}^{A}	1,635€
		α_{NPB}^{AA}	1,828€
		α_{NPB}^{AR}	1,828€

	Price sensitiveness of demand	$\boldsymbol{\beta}_{NP}^{A}$	0.5
		$\boldsymbol{\beta}_{NP}^{R}$	0.65
		$\boldsymbol{\beta}_{PPB}^{A}$	0.7
		$\boldsymbol{\beta}_{NPB}^{AA}$	0.75
		$\boldsymbol{\beta}_{NPB}^{AR}$	1
	Degree of substitutability	γ_{NP}	0.71
		γ_{NPB}	0.71
Supply			
	Cost for the provision of air services in the international leg	c_{PPB}^{A}	217.34€
	Cost for the provision of air services in the international leg	c_{NP}^{A}	40.61€
	Cost for the provision of rail services in the domestic leg	c_{NP}^{R}	36.10€
Fixed cost for the partnership			
	Fixed costs that would arise for the airline if they build the partnership	F_{a}^{p}	0€
	Fixed costs that would arise for the HSR if they build the partnership	F_{r}^{p}	0€

In particular, F_a^p and F_r^p are set equal to 0. We note that the value of F_a^p and F_r^p does not affect the equilibrium prices, but only the profitability of the partnership [62] .Different simulations can be run to see how profitability of the partnership changes with a marginal increase of F_a^p and F_r^p.

- The willingness to pay for the travel

α_{NP}^{R} [€] : maximum willingness to pay for the travel QJZ – PMP by HSR ride

α_{NP}^{A}[€]: average maximum willingness to pay for the travel NTE – CDG by flight

α_{PPB}^{A}[€]: maximum willingness to pay for the travel CDG – SXM by flight

α_{NPB}^{AA}[€]: maximum willingness to pay for one-stop travel NTE – SXM via CDG, where NTE-CDG and CDG-SXM are both made by flight.

α_{NPB}^{AR}[€]: maximum willingness to pay for one-stop travel QJZ – SXM via CDG where NTE-CDG is made by HSR and CDG-SXM is made by flight.

In order to approximate such parameters, we have recorded daily prices (one way) for each product offered by Air France on websites every day in the week 18/08/2016-25/08/2016 for each travel class. Data have been observed in the slot 10.00am-11.00am. Everyday x we set departure at day $x+1$. Indeed, hub-and-spoke carriers make use of dynamic pricing for revenue maximization and load-factor optimization [63]. It has been demonstrated that fares behaviour, under dynamic pricing rules, can be approximated by a strictly increasing hyperbole until the day before departure, when the maximum fare is registered[31]. At this price, some evidence shows that 2 or 3 reservations are registered [64]. Thus, we expect that the maximum of the fares for flights rides departing the day after the observation is a good approximation of the maximum WTP of customers for such products, i.e., the reservation price at which demand tends to 0.

We easily derive α_{NP}^{A}, α_{PPB}^{A}, α_{NPB}^{AA}. Maximum wtp for rail travel can be derived from such parameters by sensitivity analysis, i.e., $\alpha_{NP}^{R}=\theta_S\alpha_{NP}^{A}$ $\alpha_{NPB}^{AR}=\theta_L\alpha_{NPB}^{AA}$, where $-0.1\leq\theta_S\leq 0.1$, $-0.1\leq\theta_L\leq 0.1$ (S stands for short-haul; L stands for long-haul). Upper and lower bounds have been set according to two three reasons: (i) usually, the willingness to pay for HSR travel can be, in principle, higher or lower than air travel, i.e., θ_i can be greater or lower than 0, $i=S,L$; (ii) if different, the difference between the willingness to pay for HSR and air travel is not huge. Within an air-rail agreement, products are differentiated (i.e., the short-haul rail ride and the long-haul flight) and the air-rail service is perceived as a feasible alternative to the connecting flight if and only if it is provided at comparable "quality" [65]. In this baseline example, we set $\theta_S=\theta_L=0$.

On the short haul, we set the WTP of leisure passengers for air travel being equal to the maximum price charged among Air France Economy classes. On the long haul, we set the WTP of leisure passengers for air travel being equal to the maximum price charged among Air France Economy and Economy Flex classes. We report such observation on Appendix B. For the sake of generality, we also report observations related to the TGVAir product during the same week.

- The degree of substitutability between travel products

γ_{NP}: degree of substitutability between the travel QJZ – PMP by HSR ride and travel NTE – CDG by flight;

γ_{NPB}: degree of substitutability between the one-stop travel NTE – SXM via CDG, where NTE-CDG and CDG-SXM are both made by flight and the one-stop travel QJZ – SXM via CDG where NTE-CDG is made by HSR and CDG-SXM is made by flight.

Following [66], [67] and [2], based on [68] on the London-Paris route, we set $\gamma_{NP}=0.71$. In general, literature suggests that, while γ_m may cover a wide range of values due to the diversity of market characteristics, it is more likely to be relatively large ([69] and [70]). Depending on the

[31] ICCSAI Factbook, 2015. La competitività del trasporto aereo in Europa.

quality of the connection at the multi-modal hub, travellers might perceive the air-air and air-rail products being more substitutable, i.e., $\gamma_{NPB} \lessgtr 0.71$). In this baseline example, we set $\gamma_{NPB} = 0.71$.

- Price sensitiveness to own demand

$\boldsymbol{\beta}_{NP}^{A}$: own price sensitiveness of demand for the travel NTE-CDG by flight;

$\boldsymbol{\beta}_{NP}^{R}$: own price sensitiveness of demand for the travel QJZ-PMP by HSR ride;

$\boldsymbol{\beta}_{PPB}^{A}$: own price sensitiveness of demand for the travel CDG-SXM by flight;

$\boldsymbol{\beta}_{NPB}^{AA}$: own price sensitiveness of demand for the travel NTE-SXM by connecting flight via CDG;

$\boldsymbol{\beta}_{NPB}^{AR}$: own price sensitiveness of demand for the travel QJZ-SXM by air-rail product via CDG;

[69], [70], [68] find that own elasticity of demand is lower for HSR than for airlines. For instance, according to [68] based on a case study on the London-Paris route in 2009, if the fare of the Eurostar alternative (Air France, taking off from London Heathrow) decreases by 1%, market share would increase of 0.07% (0.33%) and 0.15% (0.54%) in the business and leisure market, respectively. Moreover, price elasticities in the connecting market is usually lower than in the long-haul market. The latter is usually lower than in the short-haul market. In this baseline example, we set $\boldsymbol{\beta}_{NP}^{A} = 0.55$ and we adjust $\boldsymbol{\beta}_{m}^{t}$, with $t = R$ if $m = NP$, $t = A$ if $m = PPB$ and $t = AA, AR$ if $m = NPB$, consequently to maintain the identified ordering.

- Operators costs

Airline

[71] found that great circle distance, D, and the number of seats on an aircraft, S, are the two main factors affecting aircraft trip costs (as estimated with 2001 data). Two market based equations were developed based on average length of haul, which incorporate aircraft size. Equation:

$$C = \$0.0115(D + 2200)(S + 211)$$

provides the cost function per flight for long haul markets (more than 5,000 kilometres), which can be used to model the cost function on the international market served by Air France and from Paris to Philipsburg. Dollar values in such equations have been multiplied by 1.2 in order to translate the dollar values into euros given 2001 prices. The reference great circle distance is $D = 6711.99\text{km}$ between CDG and SXM. The reference number of seats on an aircraft is $S = 275$ on the Airbus A340-300 used by Air France on this route. We derive the level of airline operating costs per-flight, $59{,}770.93€/flight$, that is, on average, $217.34€/seat$.

Equation:

$$C = \$0.019(D + 722)(S + 104)$$

provides the cost function per flight for short haul markets (less than 5,000 kilometres), which can be used to model the cost function on the domestic market served by Air France from NTE to CDG. The reference great circle distance is $D = 380{,}65km$. The reference number of seats on an aircraft is $S = 150$, calculated as the average between $S = 178$ on the Airbus A320, $S = 212$ on the Airbus A321, $S = 118$ on the Airbus A318 used by Air France on this route. We derive the level of airline variable costs per-flight, $6{,}863.34€/flight$, that is, on average, $40.61€/seat$.

HSR

We estimate the operating costs per-seat. [72] provides an estimation of HSR total operating costs for available seat kilometres (ASK), that is $0.094€/ASK$. The length of the route from is 384 km, therefore the total operating costs are $36.10€/seat$ (*vs* $40.61€/seat$ for the provision of the the air service on the same short-haul leg). We confirm some evidence suggested by literature and airlines' consultation[32]: the reduction of operating costs (substitution of feeder flights with cheaper rail services) in order to increase profitability is one of the main driver of inter-modality development for airlines.

- Prices

At the equilibrium, the model specifies the following prices

Price of the flight NTE-CDG	p_{NP}^{A}	$119.74€$
Price of HSR ride QJZ-PMP	p_{NP}^{A}	$91.26€$
Price of the flight CDG-SXM	$p_{PPB}^{A,p,*}$	$926.17€$
Price of the connecting flight NTE-SXM	$p_{NPB}^{AA,p,*}$	$1042.98€$
Price of the intermodal solution QJZ-SXM	$p_{NPB}^{AR,p,*}$	$1053.76€$

[32] Eurocontrol, 2005. Potential airport intermodality development, M3S/ATM/MODAIR/EEC/WP2/1.1

8 Conclusion and future work

In this document we presented the work carried out within WP 4 during period M6-M18. The complexity and heterogeneity of different scientific results, achieved by different research groups with different skills and expertise, may have made difficult the overall presentation of the main contributions given by all partners within WP4. Reporting and harmonizing so different visions of the intelligent functionalities has not been an easy task. Nonetheless, starting from a common background provided by all design activities carried out within WP2 (and summarized in Section 2) and one common BONVOYAGE Glossary (reported in Appendix E), a joint effort has been made in order to figure out how the intelligent functionalities developed within WP4 will cooperate each other. A preliminary agreement concerning User Profiler Tool and Multi-Objective Optimization Tool is reported in Section 3 (further details can be found in Section 4.1.2).

On the other side, individual efforts allowed each partner to contribute to this deliverable by reporting high quality scientific contribution and valuable research results in terms of methodologies and algorithms in three fundamental tasks according to the rationale illustrated in Section 1.1. Accordingly, methods and models adopted and developed to realize the intelligent functionalities of the BONVOYAGE platform are reported in this document (see Sections 4-7).

In Task 4.1, two main components have been developed: (*i*) User Profiling Tool back-end component (UPT-BE) including important personalization functionalities like the On line User Profiler (see Section 4.1.3) and the Rank Tool (see Section 4.1.4) and (*ii*) User Profiling Tool front-end component (UPT-FE), including the user stress level (see Section 4.2.1) and transportation mode (see Section 4.2.2) assessment functionalities. Methods (*i*) will be used for developing pre-trip functionalities driving the trip planning functionalities and methods (*ii*) for developing on-trip functionalities driving the trip control functionalities.

Both trip planning and trop control functionalities are offered by the Multi-Objective Optimization Tool developed in Task 4.2 and here reported in the most characterizing features: (*iii*) the Orchestrator (see Section 5.2), (*iv*) the Urban Soloist (see Section 5.3) and (*v*) the Passenger Aggregator (see Section 5.5). All methods (*iii*)-(*v*) receives in input the driving parameters provided by methods (*i*) and (*ii*) in the pre-trip and on-trip phase, respectively.

The membership functionalities developed in Task 4.3 are here reported in terms of (*vi*) Score Policy functionality (see Section 6.2); (*vii*) Loyalty programme (see Section 6.3) and (*viii*) Multi-part Tariff Scheme Design (see Section 7).

The most mature scientific results have already been subject to dissemination (see [1]–[4] in Section 9). Others are about to be disseminated according to the dissemination plan reported in deliverable D8.1.

In consideration of the fact that some of the activities within WP4 are still ongoing at M18 (please see Section 1.3.2, with particular attentions to Table 3, Table 4 and Table 5), important connections between (i)-(ii) and (iii)-(v) and between (i)-(ii) and (vi)-(vii) are outlined in this deliverable but still subject to modifications until the end of WP4.

The next deliverable D4.2 (due by M26) will summarize experimental and simulation results obtained by implementing and integrating basic functionalities described in this deliverable D4.1.

9 Reference

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Appendix A User Data Model

The User Data Model has been developed in order to design a customize system for the user's specific needs. The model takes into account all data needed input and output of intelligent functionalities developed within BONVOYAGE.

User Data Model is a logical representation of entities and relationships between two (or more) entities, describing the user from the personalization, the trip planning and the membership point of view. Basically, we considered five main entities:

- *User*: this entity represents the user in BONVOYAGE.
- *Travel*: this entity represents the travels characteristics.
- *Membership*: this entity represents which are the group or groups of which the user is member.
- *Feedback*: this entity contains the explicit feedback left by each user about the services provided by BONVOYAGE.
- *Sensors*: available sensors useful to acquire implicit feedbacks.

The entities previously introduced might contain several different sub-entities, in terms of difference occurrences of the same entities in different contexts. In particular, the main entity *User* contains three different sub-entities:

A) *Pre_trip* is the sub-entity that represents the user before a travel;

B) *On_trip* is the sub-entity that represents the user during a travel;

C) *Post_Trip* is the sub-entity that represents the user after a travel.

The main entity *Travel* contains three sub-entities:

A) *Travel Solution* is the sub-entity representing all the travel solutions, ranked for a user, when he requests a travel;

B) *Uni-Modal Travel link* is the sub-entity that represents each single path into the overall travel;

C) *Actual Trip* is the sub-entity that represents the overall travel composed by at least one uni-modal travel link.

The main entity *Feedback* contains four sub-entities:

A) BONVOYAGE *Service*: A feedback referred to the overall BONVOYAGE service.

B) *Selected Travel Solutions*: A feedback for the travel solutions proposed by the system to each user.

C) *Implicit Feedback*: A feedback directly acquired by sensors

D) *Actual Trip*: A feedback for the overall travel experience, the travel evaluation.

The main entity *Membership* contains three sub-entities:

A) *Fidelity program*: specification about fidelity programs (for example a fidelity card, etc.)

B) *Cluster(s)*: one or more cluster/s of which each user belongs to.

C) *Social Member*: specification about which social account each user used (e.g., from Google+ or Facebook) from which we are in charge to take information

The main entity *Sensors* contains three sub-entities:

A) *Single sensor*: sensors consist of several "single sensor"

B) *Features* are relevant information computed from the different sensors

C) *Models* are functions that estimate User Stress Level and User Transportation Mode from features, using machine learning algorithms and techniques.

Once designed the data model, it has been translated in a ER logic model in order to formalize the data objects to develop the database, where the data provided by user and algorithms will be stored.

Figure 57 shows the ER logic schema where data objects with their relative attributes are described. It can be divided into six macro data objects:

A) *User* includes the entities that characterize the BONVOYAGE user (*Registered User*, *User query*, *User Class*, *User Profile*);

B) *Travel* describes the travel features (*Travel Solutions*, *Travel Link*, *Travel Nodes*, *Tariff Scheme*);

C) *Car Pooling* includes the entities that rely on the car pooling services (*Transfer*, *Pool*, *Shared Car*, *Car*);

D) *Operator* includes the entities that describe the Transport Operator (*Transport Operators*, *Transport Service*, *Ancillary Services*);

E) *Feedback* includes the entities characterized users' feedbacks (*Feedback Actual Trip*, *Feedback App*);

F) *Sensor* describes the entities involved in the sensors activities (*Model Sensor*, *Features Sensors*).

In Figure 57, the entities in yellow are recalled in section 4.1.3, the entities in orange in section 4.1.4, the entities in light blue in section 4.2, the entities in red in section 5.3-5.3, the entities in purple in section 6.2, and the entities in green in section 7.

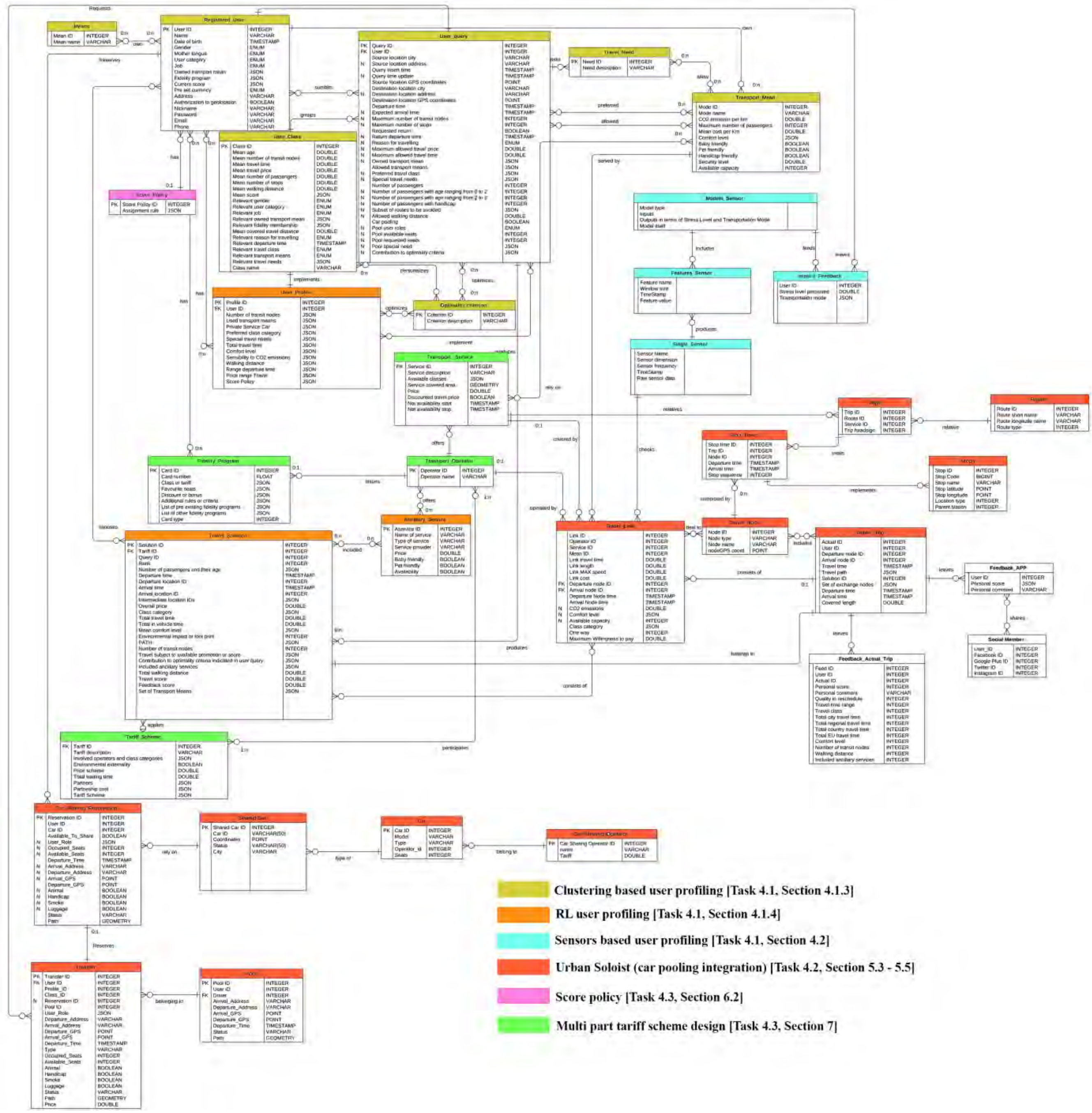

Figure 57 - ER logic Schema

Appendix B BONVOYAGE Questionnaire 1

With the aim of investigate the main users' preferences and constraints for mobility services, have been created a public survey (actually available in two different languages Italian and English, link: http://BONVOYAGE2020.eu/take-action/travel-preferences/), in order to collect real data, thus creating a Knowledge Base useful to intelligent algorithms to classify users, as described in section 5.1. The survey contains a questionnaire divided into six main categories: 1) Personal Information: the users can leave some personal information (in terms of e.g., age and nationality, income level, owned transport means, preferred transport means, reason for travelling, etc.) as well as the users can specify some information concerning their main objectives (e.g., environmental impact, burn calories, etc.) when he/her chooses a trip. 2) Travel preferences and habits: In this category the questions are aimed to figure out the behavioural profile of the travellers (e.g., price range for European travel, special needs during travel, range departure hour, etc.)

3) Imagine to travel from Rome to London: in this category the users can choose among four different travel solutions, having the same journey, indicating the optimality criteria for the given travels.

4) Hypothetic multimodal long-haul travel: the users can specify the personal relevant attributes that make a quality journey.

5) Tariff models: In this category, the users can specify which inducement, in terms of promotions and price, are available to choose, in order to change their travel preferences. 6) Multi-Modal travel: in this category, the users can express their tendency to perform multimodal travels with the relative travel's preferences.

Actually, the users that have fill in the questionnaire are about 352, with several different nationalities (i.e., Afghan, Austrian, British, Dutch, French, German, Greek, Iranian, Italian, Moldovan, Norwegian, Portuguese, Romanian, Russian, Spanish, Swiss, Syrian, Taiwanese), and ages.

In order to show how the survey has been fundamental to study the user preference for the travels, and with the data acquired modelling the learning algorithms, Figure 58 shows a 2D histogram graph comparing the preference criteria chosen by the users with respect to their professional status.

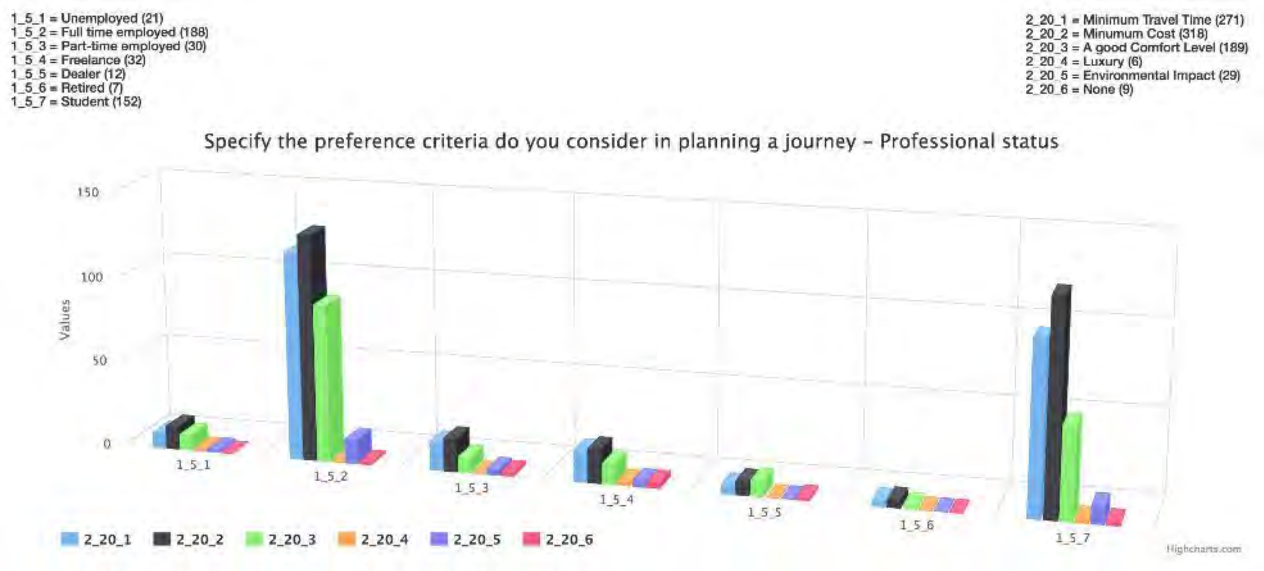

Figure 58 - 2D histogram graph, comparing preference criteria and professional status

Appendix C BONVOYAGE Questionnaire 2

BONVOYAGE questionnaire #2 investigates passengers' preferences in long-distance trip chains. In particular, the questionnaire considers the scenario of a hypothetical international travel and, within this scenario, considers two alternative travel solutions: a one-stop flight and multi-modal rail-air trip. The data collected by means of this questionnaire supported basic research on multi-part tariff scheme design reported in Section 7. In this appendix, the questionnaire is described in each part.

The questionnaire is made up by 6 sections.

Section 1 collects personal information about the respondents. This section of the questionnaire mirrors the section *personal information* of BONVOYAGE questionnaire #1 and it collects (i) socio-demographic information; (ii) information about respondents' travel habits (e.g., means of transport owned or regularly used or purpose of the trips); (iii) information about the use of the Internet and/or Apps. The relevance of (i) and (ii) to passengers' preferences has been widely recognized in the literature (see Section 7.1.3) and including these questions in the survey allows us to understand to which of the profiles identified by BONVOYAGE the respondent belongs. Furthermore information (iii) are aimed at understanding whether being familiar with the Internet and web-based Apps affects passengers' preferences, especially when it comes to travel reservations and availability of real-time information during the travel.

Section 2 and 3 of the questionnaire investigate passengers' preferences as they travel from home to the airport, in the case of a one-stop flight (section 2), and from home to the rail station, in the case of the rail-air trip (section 3). We investigate the access to the airport and the access to the rail station separately, because we expect passengers' preferences to differ across the two travel solutions. Indeed, rail stations are usually close to the city center while airports are usually located at the outskirts of the cities, furthermore, travelling by air requires the passengers to undergo lengthy security screenings and boarding procedures, which might induce them to place higher attention to the reliability of the mode of transport used to access the infrastructure.

Sections 4 and 5 focus on quality at interchange (hub) airport. They investigate which are the information and the services that passengers value at the infrastructure, as well as how they prefer the information about the hub to be delivered, e.g., via maps and signs at the airport or via Apps. This section has been designed on the basis of the literature on quality of service at multimodal hubs surveyed in Section 7.1.

Finally, section 6 focuses on the reservation of multi-modal travel solutions and aims at understanding which services deliver higher value to passengers that are booking air-rail products. The information collected in this section is useful to understand how the airlines and high-speed rail operators can design multimodal products that are appealing to passengers (within a partnership).

Table 20 **-** BONVOYAGE Questionnaire 2

1) Personal Information

1.1) Year born

1.2) Gender

□ M	□ F

1.3) Nationality

1.4) Number of inhabitants of the municipality in which you live

0-5000	5001-15000	15001-50000	50001-100000	100001-250000	more than 250000

1.5) What is your highest educational qualification?

□ No qualification	□ Primary education qualification	□ Lower secondary school qualification (middle school/junior secondary school/junior high school)	□ Upper secondary school diploma (senior high school)	□ Technician diploma/primary professional education	□ Bachelor degree
Master degree	Doctorate				

1.6) Current principal professional status

□ Unemployed	□ Full-time employed	□ Part-time employed	□ Self employed or Freelance	□ Looking after home/family	□ Retired from employment
□ Student					

1.7) Main source of income

□ from employment	□ from self-employment/freelanc	□ Pension	□ Allowances or various	□ Patrimonial	□ Support from the family/the

	e activities		benefits		partner or others

1.8) How would you describe the level of the income referred to in the previous question?

□ Very low	□ Low	□ Medium	□ High	□ Very high

1.9) Which of the following means of transport do you own?

□ Car	□ MotorBike	□ Bicycle	□ Own airplane	□ Sailboat or cabin cruiser	□ None

1.10) How do you usually travel to work, school or college?

□ Conventional train	□ High-speed rail	□ Airplane	□ Tram	□ Subway	□ Bus
□ Coaches, Courier	□ School or company coach	□ Private car (as driver)	□ Private car (as passenger)	□ Motorcycle or moped	□ Bicycle
□ Others					

1.11) Which means of transport do you usually use for medium-long distance travel? Do not consider only local trip

□ Conventional train	□ High-speed rail	□ Airplane	□ Tram	□ Subway	□ Coaches, Courier
□ School or company coach	□ Private car (as driver)	□ Private car (as passenger)	□ Motorcycle or moped	□ Bicycle	□ Others

1.12) Why do you usually travel long distance?

□ Mostly for work	□ Mostly for leisure	□ Both for work and leisure

1.13) How often do you travel for business (on average per year)?

□ 0	□ 1 or 2	□ From 3 to 6	□ From 7 to 12	□ 13 or more

1.14) Number of flights in the last 12 months (count round trip as two flights)

□ 0	□ 1 or 2	□ From 3 to 6	□ From 7 to 12	□ 13 or more

1.15) Number of High Speed Rail rides in the last 12 months (count round trip as two rides)

□ 0	□ 1 or 2	□ From 3 to 6	□ From 7 to 12	□ 13 or more

1.16) Do you usually book direct or connecting flights?

Direct flights	Connecting flights	Both	I do not travel by air

1.17) How often have you used Internet over the last 12 months?

□ Every day	□ Sometimes a week	□ Few times a month (less than four times)	□ Less than once per month

1.18) Over the past 12 months have you connected to the Internet in places other than home or work using a portable device (E.g., bars, on the street, at the station, house of friends)?

□ No	□ Yes, with smartphones or tablets	□ Yes, using a laptop

1.19) Over the last 12 months did you use Internet applications (APPs) on portable devices?

□ Every day	□ Sometimes a week	□ Few times a month (less than four times)	□ Less than once per month

1.20) When you book a travel, you do it through the internet?

□ Never	□ Rarely	□ Sometimes	□ Often	□ Very often	□ Always

2) You are going to the airport since you need to take a one stop long distance flight. How much relevant the following attributes are to the quality of your trip?

	Very important	Important	Fairly important	Slightly important	Not important
Total access time from your starting point to the airport	□	□	□	□	□
Total expenditure to access the airport	□	□	□	□	□
Total distance from your starting point to the airport	□	□	□	□	□
Being able to arrive at the airport by your own car and to park the car (eventually not for free)	□	□	□	□	□
Being able to arrive at the airport by public	□	□	□	□	□

transport					
Number of interchanges from your starting point to the airport	□	□	□	□	□
Reliability of public transport schedules (both departure and arrival time)	□	□	□	□	□
Comfort on the public transport vehicle	□	□	□	□	□
Availability of a dedicated space for luggage on the public transport vehicle	□	□	□	□	□
Availability of private transport services towards the airport with fixed schedules and stops (e.g., Terravision, Alitalia shuttle) although at a higher cost than public transport	□	□	□	□	□
Availability of information about the schedules/stops location of transport services (public/private), vanpooling/car pooling and car sharing) towards the airport	□	□	□	□	□
Availability of real-time updates of this information	□	□	□	□	□
Availability of this information on the websites of operators	□	□	□	□	□
Availability of this information on a unique website	□	□	□	□	□

Availability of this information on a unique smartphone/tablet's app	☐	☐	☐	☐	☐
Availability of a trip planning tool to reach the departure transport infrastructure from your starting point	☐	☐	☐	☐	☐

3) You are going from your home to the train station. A high speed rail ride would take you in an airport where you will take a one stop-long distance flight. How much relevant the following attributes are to the quality of your trip from home to the train station?

	Very important	Important	Fairly important	Slightly important	Not important
Total access time from your starting point to the train station	☐	☐	☐	☐	☐
Total expenditure to access the train station (e.g., sum of the tickets for links covered by public transport, taxi charge) from your starting point	☐	☐	☐	☐	☐
Total distance from your starting point to the train station	☐	☐	☐	☐	☐
Being able to arrive at the train station by your own car (there is a dedicated parking spot, although not for free)	☐	☐	☐	☐	☐
Being able to arrive at the train station by public transport	☐	☐	☐	☐	☐
Number of interchanges from your starting point to	☐	☐	☐	☐	☐

the train station					
Reliability of public transport schedules (both departure and arrival time) from your starting point to the train station	☐	☐	☐	☐	☐
Comfort on the public transport vehicle from your starting point to the train station	☐	☐	☐	☐	☐
Availability of a dedicated space for luggages on the public transport vehicle chosen to reach the train station	☐	☐	☐	☐	☐
Availability of information about the schedules/stops location of transport services (public/private), vanpooling/carpoolin g and car sharing) towards the airport	☐	☐	☐	☐	☐
Availability of real-time updates of this information	☐	☐	☐	☐	☐
Availability of this information on the websites of operators	☐	☐	☐	☐	☐
Availability of this information on a unique website	☐	☐	☐	☐	☐
Availability of this information on a unique smartphone/tablet's app	☐	☐	☐	☐	☐
Availability of a trip planning tool to reach the departure transport	☐	☐	☐	☐	☐

infrastructure from your starting point					
4) You have accessed the interchange airport (arriving by high speed rail or flight) in order to take a long distance flight to your final destination. How much relevant the following attributes are to the interchange airport?					
	Very important	Important	Fairly important	Slightly important	Not important
Availability of a map of the interchange airport	□	□	□	□	□
Availability of an information kiosk within the interchange airport	□	□	□	□	□
Availability of personnel at the information kiosks	□	□	□	□	□
Availability of information about the schedules of the departing flights	□	□	□	□	□
Availability and clarity of internal navigation signage	□	□	□	□	□
Availability of a dedicated smartphone/tablet app to assist the interchange	□	□	□	□	□
Availability of services	□	□	□	□	□
Availability of shops (e.g., tobacco, duty free, restaurants)	□	□	□	□	□
Comfort	□	□	□	□	□
Walking time from your arrival point to reach the point where you have to take the flight	□	□	□	□	□
Walking distance from your arrival	□	□	□	□	□

point to the point where you have to take the flight					
Presence of speed walk	☐	☐	☐	☐	☐
Presence of trolleys	☐	☐	☐	☐	☐
Ticket sale points that supplies the tickets of the transport operators that serve the airport	☐	☐	☐	☐	☐
5) There is an app available for your smartphone or tablet which provides you information on the exchange airport and/or assists you in moving within it. How much relevant the following attributes are to the quality of the app?					
Turn-by-turn voice-guided instructions on how to arrive at a given point of the interchange infrastructure	☐	☐	☐	☐	☐
Instructions on how to arrive at a given point of the interchange infrastructure	☐	☐	☐	☐	☐
Information about shops available within the interchange infrastructure	☐	☐	☐	☐	☐
Information about services available within the interchange infrastructure	☐	☐	☐	☐	☐
Information about the schedules of the flights departing from the interchange infrastructure	☐	☐	☐	☐	☐
Real time tool to re-schedule the rest of the trip to reach your final destination	☐	☐	☐	☐	☐

Information about baggage handling	☐	☐	☐	☐	☐
6) You are buying a multi-modal travel solution: you will take a high-speed train to the airport and then you will take a long distance flight to your final destination. How relevant are the following factors?					
Possibility to buy an integrated ticket rather than two separate tickets	☐	☐	☐	☐	☐
Possibility to buy the integrated ticket on the Internet	☐	☐	☐	☐	☐
Possibility to check in the luggage at the train station and to collect the luggage at the destination airport	☐	☐	☐	☐	☐
Guarantee of a seat on the next flight in the case of delay of the high-speed rail	☐	☐	☐	☐	☐

Appendix D Market studies

WeCity app

Tariff model/initiative/policy analysed

WeCity

It is an app (digital platform) founded in Modena (Italy) in 2013. The app was officially launched on February 2014. WeCity is currently in place in all the main cities in Italy. The App is going to be launched also in Spain and England within 2016.

Description of the Tariff model/initiative/policy

Wecity is the first app that rewards the users for each CO2 emission avoided with prizes.

As matter of fact, Wecity is the first digital platform that allows citizens to interact with Kyoto protocol mechanisms, thanks to the ISO 14064-II certification on CO2 emissions reduction. For the first time at global level, Wecity provides a tool to each citizen to contribute on the CO2 emissions reduction, ensuring an active participation and a scientific and accurate measurement of the citizen commitment.

Thus, in order to promote sustainable mobility and have a positive impact on the environment, Wecity technically gives credits to the user for every Kg of avoided CO2, to be spent on the Wecity store to obtain sustainable prizes.

Below it follows a detailed description of scores assigned to each transport mode selected by the user:

- Wecity promotes the use of bikes that eliminates CO2 emissions altogether, thus it assigns the user 16 scores per each km. It is necessary to cover at least 1 km to receive scores;

- Wecity strives for the reduction of the use of the (individual) cars by promoting car pooling: through Wecity users can offer/find a ride to share with other people in order to reduce the number of cars used and CO2 emissions. When choosing car pooling, as many more passengers the user "brings on board", the more credits he obtains. This is applied to both the person who offers the ride and the person who "accepts" the ride. Scores are assigned as follows: 4 credits each for 2 passengers; 5 credits each for 3 passengers; 6 credits each for 4 passengers. To gain credits using car pooling, the trip should be at least 3 km long;

- Wecity promotes the use of public transports rather than the car in order to reduce the CO2 emissions. The amount of CO2 the user avoids depends on the type of public transport (train, bus) and the fuel (gasoline, natural gas, electricity). This is the reason why the credits the user earns are based on an average which is 4 scores per Km. To earn credits, the trip needs to be at least 3 km long or more.

Wecity limits the daily amount of collectable credits to the first 100 km, in order to ensure impartiality among the users.

Once the user has collected enough credits, he can go on the store Wecity and choose his prizes among an intelligent mobility product offer. Prices include: t-shirts, free-rides with Enjoy, bicycles, termos, back-packs, travels and many other. For each prize the user is required to add a certain amount of money.

To offer prizes, Wecity has established several partnerships with:

- Seaty Lock, a company that produces bike seats which can be turned into a tough lock in order to keep the bike safe;
- Siva Cycle which produces a device that thanks to the kinetic energy generated by riding the bike, it can be used as power for electronics such as iPhone, GoPro and more;
- 24 Bottles, which offers sustainable products such as bottle for bike riding with less steel or sustainable packs for travelling;
- Little Italy, an Italian company that produces electric bike;
- Hawkers, which produces sustainable;
- Car2go and Enjoy that offer car sharing services;
- Italo, an Italian rail transport provider.

Wecity is also technical partners of the following national events:

- CycloPride;
- BikeFest;
- Sunrisebike;
- Comune di Modena, which uses Wecity to track soft mobility.

Targeted users

The App aims to reach as many users as possible.

The App targets user who are environment-oriented and open to new and innovative mobility systems.

The target user is interested to sustainable mobility themes, environment aspects, CO2 reductions and it is also active on social networks.

To provide an idea of the number of users reached up-to-now, the following figures could be taken into account:

- 10.000 downloads within the first 6 months after the app was launched (in 2014);
- 400.000 km covered and 20.000 travels shared by Wecity users.

Ex-ante/current situation

Wecity initiative has not changed nor replaced any tariff model/policy in place.

Where it has been introduced, it "collaborates" with local policies/tariff implemented by municipalities or local transport operators and strives to promote the use of public transports or to foster users towards more sustainable mobility decisions.

Results achieved/forecasted

Based on the number of users involved up-to-now, it has been estimated that more than 30.000 users will use the App by the end of 2015.

Cause-effect relation hypothesis

If a user is rewarded for sustainable/low-environment impact mobility choices, his propensity to choose sustainable modes of transports (or ways of transports with a lower environment impact) will increase.

Capping

Tariff model/initiative/policy analysed

Capping (2015) is a tariff model implemented by Transport for London in the London city area.

Description of the Tariff model/initiative/policy

Capping is a feature of pay as you go included in the Oyster card service provided to London citizens by the local transport operator Transport of London.

The Capping system allows a passenger to travel as much as he likes in a single day or a week (from Monday to Sunday) and limits the amount to be paid for all the travels.

Each time the passenger makes a journey, he is charged a fare (depending on zones he travels across). Once the total cost of all his fares reaches a certain amount, he will not have to pay for any additional journey in the daytime.

"For example if a passenger makes many rail journeys or a mixture of rail, bus and tram journeys in one day within Zones 1-9 of London, pay as you go with daily capping is better value than buying a Day Travelcard. If the passenger makes many bus and tram journeys, pay as you go with daily capping is better value than buying a One Day Bus & Tram Pass.

To benefit from capping, the passenger must touch in and out on every journey using the same Oyster card (touch in only on buses)"[33].

Technically the capping system works as follows: "daily caps are calculated over a 24-hour period, covering all the journeys started between 04:30 and 04:29 the next day. There are different caps for different types of transport and times of day" (e.g. off-peak times). For instance, different caps are applied to:

- "All services (bus, Tube, tram, DLR, London Overground, TfL Rail and most* National Rail journeys in London);
- Bus & Tram (bus and tram journeys only)".

Thanks to the capping system, it is possible to calculate when a passenger has reached a cap because every journey he makes is logged/registered into the system that automatically updates a total of:

- "all the zones the passenger travels through;
- what time the passenger touches in on each journey (this determines both the fare and the cap);
- all fares paid in a single day"[34].

[33] https://tfl.gov.uk/fares-and-payments/oyster/using-oyster/price-capping

When the total cost of all the passenger journeys reaches a certain amount, a cap is applied (the amount to be reached is determined based on all parameters listed above). Any journey he makes for the rest of the day in the same zones will not be charged.

In the Note section of this file, it is provided the link to all the caps fairs listed.

The rank of the refund amount is 0.70£ - 2.4£ for the adult rate and 0.35£-1.20£ for half the adult rate (applied to young people aged more than 16 years).

Targeted users

The number of users targeted by this tariff model corresponds to all people residing in the Alto Adige region as well as all tourists that visit the Alto Adige.

Ex-ante/current situation

The Zapping system is part of the current public transport service offer in the city of Lisbon.

Cause-effect relation hypothesis

The Capping system pushes people to use public transports rather than private transports (as cars).

The cause-effect relation may be the following: if a user is sure that he will not pay more than a certain amount of money for all journeys made through public transports, he will be more disposed to choose public transports rather than private transport means.

Notes and references

https://tfl.gov.uk/fares-and-payments/oyster/using-oyster/price-capping

AltoAdige Pass

Tariff model/initiative/policy analysed

AltoAdige Pass is an innovative public transport subscription launched in the Alto Adige region in 2012 and it is in place in all the Alto Adige areas.

Description of the Tariff model/initiative/policy

AltoAdigePass is a personal/family rechargeable subscription that allows the passenger to obtain decreasing fares when his frequency of the public transport use increases. It has a subscription cost of 20 euros and it has an annual validity. The renewal is automatic after one year and within one year from the

[34] Ibid.

expiration date it is possible to request the refund of the amount not used and return the travel document if the passenger has no intention to renew the subscription.

To provide a clear idea of how the Alto Adige pass works a list of the different fares according to km covered by public transports is provided below:

- from 1 to 1.000 km, AltoAdige fare is 12 cent/km and AltoAdige Pass Family 10 cent/km;
- from 1.001 to 2.000 km, AltoAdige fare is 8 cent/km and AltoAdige Pass Family 7 cent/km;
- from 2.001 to 10.000 km, AltoAdige fare is 3 cent/km and AltoAdige Pass Family 2 cent/km;
- from 10.001 to 20.000 km, AltoAdige fare is 2 cent/km and AltoAdige Pass Family 2 cent/km;
- more than 20.000 km, 0 cent/km for both the subscription types.

AltoAdige Pass includes different subscription modalities with different prices:

- AltoAdige for Family, reserved for family with at least one son. In this case, a personal subscription for each member of the family can be requested;
- AltoAdige Pass 65+, a preferential tariff for people over 65 years old or free for people over 70 years old;
- AltoAdige Pass Abo+, special subscription for students that is offered for free to high-school students, whereas it has to be purchased by university students;
- AltoAdige Pass free, offered for free to people with a minimum of 74% invalidity level.

Furthemore, there are different mobility cards offered with AltoAdige Pass, especially to tourists:

- Mobilcard;
- Museummobilcard;
- Bikemobilcard.

As the mobility offer in AltoAdige is integrated, both from ticket side and tariffs side, the AltoAdige Pass can be used on different public transports.

Furthermore, it has been established a daily maximum amount (15 euro) that a user can pay (it corresponds to the price per day of the Mobilcard (initial subscription type provided in Alto Adige)). Therefore, even if the amount that the passenger should pay for public transports in a single day exceeds 15 euros, the effective amount charged on the AltoAdige Pass will not be higher than 15 euros.

Targeted users

The number of users targeted by this tariff model corresponds to all people residing in the Alto Adige region as well as all tourists that visit the Alto Adige.

Ex-ante/current situation

AltoAdige Pass is part of the current public transport service offer in the Alto Adige region.

Results achieved/forecasted

AltoAdige Pass has gained a great success. In 2013, 130.000 people have purchased the AltoAdige Pass, with a 95% increasing number compared to 2011, while 160.000 have received AltoAdige Pass for free or with a preferential tariff.

Furthermore, following the success of the tariff models, more services have been included in the AltoAdigePass:

- special prices for bikes transport on public transports;
- possibility to charge the pass also using automatic ticket booth;
- Nightliner service.

AltoAdige Pass is considered a "360 degrees ticket", that guarantees the mobility of the person and not only the transport.

Cause-effect relation hypothesis

AltoAdige Pass has been introduced to increase the satisfaction of the passengers (local and tourist) while using the public transport. AltoAdige Pass does so offering a new tariff model that rewards the passengers that use more the public transport by offering a reduction of the tariffs when the usage of public transports increases.

Thus, it may be assumed that:

a) if the amount that the user pays for public transports decreases when the user covers longer distances by public transports, the user will be more disposed to choose to travel by public transports;

b) if the user can purchase a combination of mobility and tourist cards for a fixed amount of money, he will prefer to move by public transports;

c) if a user is sure that he will not pay more than a certain amount of money for all journeys made through public transports, he will be more disposed to choose public transports rather than private transport means.

Notes and references

Report: "*Analisi della soddisfazione del trasporto su gomma*", carried out by "*Agenzia provinciale per la mobilità*" in collaboration with "EURAC". (2013). https://www.sii.bz.it/it/titoli-di-viaggio/altoadige-pass-un-pass-per-tutti.

Zapping

Tariff model/initiative/policy analysed

Zapping is a tariff model implemented by Transportes de Lisboa in the Lisbon city area.

Description of the Tariff model/initiative/policy

« Zapping consists in charging money onto a 7 Colinas, Viva Viagem or Lisboa Viva card" (that are different types of cards provided by different transport operators in the city area), "which is deducted as the customer validates the card on different transports, according to the prices established by each Operator.

This solution was designed for customers who are not regular users but often use one or more Public Transport Operator »[35].

Zapping chargeable credit system works as follows:

-The first charging is €2 minimum and €15 maximum.

- The following charges can be €0,01 minimum and €15 maximum.

- The total stored on the card must be €20 as most.

ZAPPING VALIDATION and FARES CHARGING:

- One zone trips: Validation is made on any electronic validator. The device debts only one unit on the first validation and no other on following trips during one hour. Validation is obligatory on every trip.

- Two zones trips: zones selection is made in the first trip on the validator through different keys. The user must press key 2 to indicate that he will make a 2 zones trip and then pass cards covering involved zones (e.g. 7 Colinas and Viva Viagem) at the same device. This systems debts immediately two units of the one zone ticket which will expire 2 hours later. On the following trips during this period, validation is still obligatory and can be made on any validator, without having to press keys or being debited other units until the validity period expires.

If the customer wants to take a two zone trip but has validated a ticket/card just for one zone, he can select at any moment key 2 and validate this option, passing the card at the device again. The device debits one more unit and the customer may use the ticket for 2 hours, counting from the initial validation (1st trip). Validation is obligatory on every trip.

A zapping solution would be more convenient than purchasing a single bus/tram or subway ticket because those ones are only valid for a single journey (there is no a fixed amount of time during which the ticket is valid).

Targeted users

« The number of users targeted by this tariff models correspond to the total amount of people (residents or tourists) that use the public transport system in the city of Lisbon ».[36]

Ex-ante/current situation

The Zapping system is part of the current public transport service offer in the city of Lisbon.

Cause-effect relation hypothesis

The Zapping solution allows user to use public transports for a longer time paying the same amount of money they would have to pay for a single journey ticket.

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[35] **carris.transporteslisboa.pt**/.../en/pre-buy-ticket

[36] Ibid.

The cause-effect relation may be the following: if, for the same price, a user can use public transports for a longer time range (e.g. one or two hours), he will be more disposed to choose public transports rather than private transport means.

Notes and references

http://carris.transporteslisboa.pt/en/pre-buy-ticket/

Ubigo (City of Gothenburg)

Tariff model/initiative/policy analysed

"UbiGo was developed and tested as part of a two-years project Go:smart, headed by Lindholmen Science Park and involving a dozen partners from the industry, academia and public sector, co-funded by Vinnova"[37]. It was launched in 2013/2014.

Description of the Tariff model/initiative/policy

The idea with UbiGo is to offer a combination of transport modes that can meet individuals' transport needs, bridging the gap between private and public transports by creating a "broker for daily travel" that can procure (on the market) and offer (to end-users) tailored mobility services adapted to the individual traveller's needs and wishes. The mission is to make everyday life easier for urban households and foster sustainable cities by offering an "easy, flexible, reliable and priceworthy service as an alternative to car ownership"[38]. The basic assumption is that if Ubigo can offer a "reliable and easy-to-use service that households feel confident enough to let go of their own car, they will drive much less"[39].

By uniting different transport modes (public transport, taxi, car- and bike-sharing, and car rental), Ubigo offers a simple, flexible, and priceworthy monthly subscription that the entire household can access via a mobile App. This works like a flexible mobile phone subscription but with units for public transport, car, taxi etc. instead of minutes of talk, number of SMS or Gbyte of surf, accessible to all members of a household through digital punch cards in the cloud.

"The UbiGo households subscribe to their prepaid monthly need of public transport (as days to use in one or more zones) and car (as hours that can be translated on to days or longer). Credit could be topped up or rolled over, and the subscription could be modified on a monthly basis. If the cards run empty, extra days or hours will be registered and billed afterwards, as will taxi-trips, waivers etc. Un-used days or hours will be saved for later use".[40]

To access their travel services, the UbiGo traveller logs into the app via a Google or Facebook login, where he could activate tickets/trips, make/check bookings, and access already activated tickets (e.g. for

[37] http://www.ubigo.se/las-mer/about-english/
[38] Ibid.
[39] Ibid.
[40] Ibid.

validation purposes). The app also allows them to check their balance, bonus, and trip history, and get support (in terms of FAQ/customer service). Each participant receives a smartcard, used for instance to check out a bicycle from the bike-sharing service or unlock a booked car, but also charged with extra credit for the public transport system in case there was any problem using the UbiGo service.

To provide added value, UbiGo also includes:

- a customer service phone line open 24 hours per day;

- an "improved" travel guarantee, where UbiGo would cover the cost and deal with the paperwork to reclaim the extra expenditure from e.g. the public transport provider.

Ubigo subscription also offers bonus for sustainable choices: "for every kilo CO2 saved (compared to if the trip would have been made by private car), users get bonus points that can be used to buy services or products from UbiGo partner organisations (bike services, home delivery, concerts etc.)"[41].

Unbigo pilot has aimed to test not only the service from a technology and market perspective, but also the underlying business model, in order to find out "a viable business model that is tested by real customers, paying real money for real services"[42].

Project partners:

Lindholmen Science Park, AB Volvo, Commute Greener, Chalmers Technical University, City of Gothenburg, Västra Götaland Region, Västtrafik (regional PT-company), Swedish ICT Viktoria Institute, Tyréns, Swedish Transport Authority, Arby Kommunikation, Mistra Urban Future, Move About and PayEx.

Targeted users

The identified targeted users are households with a high tendency to car ownership.

The implementation of Ubigo has been carried out as a pilot trial in the city of Gothenburg for half a year and has involved 83 households that have subscribed to the fully integrated mobility service, used and tested the service in reality.

They acted as early adopters, i.e. people who are curious, want to be first with something they think might become big, but who also have high expectations.

Among the 83 participating households, 20 of them agreed to hand-over their private cars for half a year (they got a compensation for the fixed cost of ownership). Other households did not own a car at all, but saw advantages of getting a full and integrated service. Few households were already members of car or bike sharing schemes.

Ex-ante/current situation

Currently, public transport in Gothenburg is provided by Västtrafik, a company that operates in the whole Västra Götaland region. The public transport offer includes: bus, tram, train and ferry.

[4141] Ibid.

[42] Ibid.

The fare system offered by Västtrafik includes:

- Single ticket;
- Pay as you go ticket;
- Period cards (e.g. 30days, 90 days, 365days);
- Touristic cards (e.g. 1-day ticket; 3-day ticket; 7-day ticket).
- Particularly, period cards that can be used only during off-peak times (e.g. from 6 am to 3 pm) are available.
- Several discounts are offered for youth and elderly people.
- Three main assumptions shaped the project and the subsequent service:
- “Collective transport”: the desired changes towards a more sustainable mobility cannot be brought about by the development of a single transport mode or by focusing solely on a shift from fossil-fuelled, private cars to public transport, but by the integration of different transport services including both public and private solutions, i.e. “collective transport”;
- Current societal trends: current shifts in individuals' attitudes and values in a more environmentally conscious direction, and the trends towards joint/shared ownership or no ownership at all – including car- and bike-sharing – open up new possibilities for new types of travel offers or services;
- Advances in and dissemination of mobile ICT: The technological developments in the field of Information and Communication Technology (ICT) as well as the dissemination of mobile ICT as made it increasingly possible to create and test new types of offers.

Results achieved/forecasted

To provide an idea of the effective usage of Ubigo service by the 70 households involved in the pilot, it is sufficient to take into account that during the pilot, over 12 000 transactions (day tickets, car or taxi-reservations etc.) where made.

The results of the pilots have shown that an innovative approach to mobility, in this case a personalized and diverse package of services, can offer “something to everyone”. In the case of UbiGo, even people who were already using services as car sharing, found benefit in the integration of services.

The results of the pilots have been evaluated by Chalmers University of Technology through surveys, interviews, travel diaries, focus groups and have proved to be very positive: “none of the households stopped using the service and a clear majority wants to stay as customers”[43].

The evaluation is still going on.

Based on the positive results achieved, Ubigo partners are preparing for relaunching the service in a 2.0 version for households and companies in Gothenburg and one or two other Nordic cities.

Cause-effect relation hypothesis

Ubigo initiative combines a series of measures to push users towards more sustainable mobility choices.

[43] Ibid.

It may be assumed that: if users can purchase and obtain a package of travels with different transport modes (through a monthly pre-paid subscription) at a lower price than purchasing a single transport mode, and if this possibility is also combined to rewarding schemes for sustainable mobility choices, their propensity to choose sustainable mobility ways of transports will increase.

Notes and references

"An innovative mobility service to facilitate changes in travel behaviour and mode choice", study published by Chalmers University of Technology (2015). http://www.ubigo.se/las-mer/about-english/

GoEco

Tariff model/initiative/policy analysed

Project proposed by SUPSI (Professional University of Italian Switzerland) and ETH (Federal Institute of Technology) Zurich. The App development started in January 2015. The App will be tested in 2016 and 2017 in the Ticino Region and the city of Zurich.

Description of the Tariff model/initiative/policy

"The main objective of the project is to investigate if and how information feedback and social interactions (social comparison and peer pressure) can be effective in fostering changes in personal mobility behaviour, facilitating the long-term challenge to reduce private motorized transport usage and bringing about a transition to different mobility options, such as vehicle-sharing, intermodal use of means of transport, public transportation and slow mobility. Within GoEco users test a smart-device application developed on purpose, that challenges them to reduce personal vehicle use:

- by tracking their trips, providing them with feedback on their mobility behaviour and suggesting alternative, low-impact modal options, and letting users define personal reduction objectives and targets;
- by creating a virtual community among them, setting up a social comparison rewarding scheme which acts as a further trigger to stimulate behaviour change"[44] (to defined once the App test phase will be launched).

As matter of fact, GoEco uses the data provided by another app, Moves, which measures the GPS coordinates of people movements, in order to identify which transport the person is using. GoEco also asks each user the reason of the movement. At the end of every day, GoEco asks to the person to validate the data measured with respect to transports used and reasons for the movement. Thus, after one month that the person uses the app, GoEco automatically learns how and how much the person moves and it is able to provide a report which shows the mobility habits/behaviours of the person so that to

[44] http://www.goeco-project.ch/wp-content/uploads/downloads/NRP_71_GoEco.pdf

show/suggest potential changes in his mobility habits/behaviours aimed to reduce CO2 emissions, or the use of the car, and increase the use of bike. Thus, GoEco encourages the user to set a goal for his behavioural change: e.g. "I want to reduce energy consumption of 25%". Here starts the gaming and innovative feature of the App: once the user sets the goal, the App proposes him a weekly-challenges in order to achieve the selected goal (e.g. " This week I will go to grocery by foot" or " This week I will go to work by bike"). The complexity of the challenges proposed by GoEco increases every time the user pass the previous challenge: for instance, once the user pass an easy challenge, the week after he will receive another challenge with the same aim of the previous one but more complex (e.g. " This week I will go to work by bike independently from the weather conditions"). At the end of every week, GoEco informs the user about the status of the overall goal achievement: if the user achieves the goal, the app let him set a more ambitious goal; otherwise, if the user does not achieve the goal, the app suggests him a more affordable goal. Furthermore, the app fosters the social and gaming features by including the " Hall of Fame", which is a section that shows users with the best performance related to their goal in order to push/incentives other users to do better.

Targeted users

The App testing phase is expected to involve around 800 users.

Ex-ante/current situation

Once it will be introduced, GoEco initiative will not change nor replace any tariff model/policy in place.

Where it is introduced, it "collaborates" with local policies/tariff implemented by municipalities or local transport operators and strives to promote the use of public transports or to foster users towards more sustainable mobility decisions.

Cause-effect relation hypothesis

The assumption behind GoEco project is that traditional approaches to sensitize people towards more sustainable mobility behaviours have failed. Thus, the initiative intends to experiment an innovative way to encourage people to a more sustainable mobility: the solution proposed by GoEco is the creation of an amusing environment that leverages on people motivation and ambition to achieve their personal goals in order to push them towards more sustainable mobility choices.

Notes and references

Information collected from an article published on the "Giornale del Popolo" in Lugano (2014) and from the official website of the project: http://goeco-project.ch/index.php/en/

TraffiCO2

Tariff model/initiative/policy analysed

Launched as a Pilot project in Palermo in 2013 by PUSH, a non-for-profit research laboratory that studies urban dynamics and develops concrete actions to trigger a systemic change.

Description of the Tariff model/initiative/policy

The TraffiCO2 project consists in the development of a social network for sustainable mobility available via web and mobile applications. TrafficO2 application offers a concrete tool for smart and dynamic management and regulation of urban flows. It is designed to be offered primarily to associations, institutions and companies who decide to support the project.

Basically, users who subscribe to TrafficO2 will move within the city, will earn points (called O2 points) based on the sustainability level of the means of transport chosen and will win prizes from local businesses and sponsors (service providers including: restaurants, bar, bike shopping, optician, music shop, clothes shop, gyms, and travel shops). The latter become TrafficO2 stations: points of departure and arrival from where the user plans his movements.

TrafficO2 works through three main features of the project:

- Move: selecting on the map the starting point and destination, users can plan and visualise their travel itinerary.

Each travel itinerary is enriched through the following information: distance, avoided CO2 emissions and burnt calories. The more sustainable the selected transport is, the more points the user will get;

- Play: users can share routes on social networks, invite their friends to save CO2 and challenge them with games tailored to each business participating in the local network. The entire system is based on the concept of "CO2" as the measurement unit and the virtual currency trading within the platform. The platform is controlled by a virtual marketplace based on the exchange of volumes of CO2;

- Win: once the user reaches the destination, users will gain CO2 points which can be used to obtain prizes and discounts at the local businesses and sponsors. Based on the number of check-in, the user will unlock new contents, find out new offers and take part to lotteries.

A list of all the service providers supporting the TraffiCO2 pilot in Palermo is provided at the following link: http://www.trafficо2.com/en#partners

Targeted users

The project targets three different urban actors: communities needing new traffic management solutions; local businesses willing to invest in innovative local advertising; big companies willing to engage customers with positive values. During the testing phase, 60.000 students of the University of Palermo were involved.

Ex-ante/current situation

TraffiCO2 project has not changed nor replaced any tariff model/policy in place.

The project has been launched in Palermo where the current situation shows that traffic situation is the worst in Italy and among the five worst in Europe (Tom Tom traffic observatory).

Results achieved/forecasted

The project has been tested in three different periods involving students of the University of Palermo: the users who have actively used the mobile app are 1877, while 187 local businesses have adhered to the initiative giving prizes and discounts. The mobile app has tracked 13228 routes, recording a total amount of 55.160g of spared CO2. The results, compared with data on mobility habits collected thanks to a survey filled out by the users during the subscription phase, show interesting features allowing to detect specific behaviours connected to urban mobility and improve the solution that may be included in planning processes and result in new solutions for policy-makers in EU.

Cause-effect relation hypothesis

The cause that pushed the founders to implement TraffiCO2 can be identified in the need to reduce traffic in the city of Palermo.

Thus, TraffiCO2 aims to alleviate the problem by promoting an innovative way to encourage people to a more sustainable mobility. This innovative way is characterized by the engagement of people through the creation of a social network for sustainable mobility and a challenging system that rewards people for each of their sustainable mobility choices.

It may be assumed that: if a user is rewarded for sustainable/low-environment impact mobility choices, his propensity to choose sustainable modes of transports (or ways of transports with a lower environment impact) will increase.

Notes and references

http://www.trafficO2.com/

Tripzoom

Tariff model/initiative/policy analysed

Tripzoom is a Mobile App developed within the European FP7 project "Sustainable Social Network Services for Transport" (SUNSET).

Project partners:

- STICHTING NOVAY;
- DOCOMO COMMUNICATIONS LABORATORIES EUROPE GMBH;
- UNIVERSITEIT TWENTE;
- LOCATIENET BV;
- GEMEENTE ENSCHEDE;
- VIKTORIA SWEDISH ICT AB;
- Eco2Win AB;
- UNIVERSITY OF LEEDS;
- QUEEN MARY UNIVERSITY OF LONDON.

Description of the Tariff model/initiative/policy

Tripzoom is a mobile App that records personal-level mobility patterns while people are on the move. It gives personalised incentives for mobility improvements and includes social community features to make people move better.

It has been developed in the context of the SUNSET project, focused on defining the relationships between individual objectives and system objectives using behaviour modelling and network modelling methodologies. Within the overall context of sunset project, Tripzoom aimed to:

- "Optimise personal mobility through the careful use of personal, mobile ICT services via the Smartphone, enhanced by providing mechanisms to distribute personalised incentives to adopt new ways of travel;
- Optimise social-induced mobility, in which travellers inform and help each other using ICT-enabled social networks, such as Twitter, Facebook and mobile applications on the Smartphone. Exchange and sharing of information on the individual level will take place and in that process individuals have the chance to respond to common challenges and collect rewards that encourage them to change their travel towards more sustainable choices"[45].

For the purposes above, "Tripzoom supports different incentive schemes that have been designed with the purpose to make the mobility system of urban environments more efficient and sustainable. The basic assumption of the initiative is that an incentive is effective if individual travellers adopt different behaviour resulting in positive impacts on the policy goals"[46].

Tripzoom has taken into account that personalised meaningful incentives can be created in three ways:

1) incentives provided by road authorities and city governments;
2) via third party service providers like public transport companies or employers;
3) by other travellers who share experiences, create group-based challenges and provide meaningful information to other travellers.

The following information on Tripzoom functionalities are helpful to have a good understanding of how the incentive schemes concretely works. Once the user has registered and logged-in to Tripzoom, the App:

- "Records, automatically and 24x7, personal trips of the end-user in the background irrespective of modality used and without any needed user trigger (like start-stop);
- provides a subsequent overview of end-user mobility in terms of trips, frequent trips, places visited and a mobility footprint;
- it provides incentives and rewards earned from their factual travel behaviour;
- it provides a means to invite friends and to get information about the travel behaviour of friends (in terms of last trip, total costs, total CO2 emission, and time and distance travelled);

[45] www.sunset-project.eu/.../pdf/SUNSET_Project_Final_Report.pdf
[46] Ibid.

- it notifies the user when someone invites them to become a friend, if a new incentive ('challenge') has been made available to them, if they earned a reward based on their travel behaviour or there is a new experience sampling question available for them to answer"[47].

With specific reference to challenges, incentives and rewards:

- incentives represent a central tool for city controllers to initiate changes in mobility behaviour of individuals or groups of users; an incentive consists of a challenge that describes the task that a user needs to do, and a reward that will be given to users who manage to succeed with the given challenge; for the user, the dynamic set of challenges is characterized and represented by: a title and a description providing details about how to achieve the task set by the challenge; a time period in which the challenge is open; 0-5 stars showing the average rating that this challenge was given by the community; each user who received the challenge can rate it;
- rewards: as soon as a challenge has been accomplished, the user is given a reward; for the user, a reward is characterized and represented by: the date/time it has been received; an explanation as to why it has been received;

« A value representing the number of points the user has been awarded with this reward.

Tripzoom incentives can be clustered into four different groups: real-time travel information, feedback and self-monitoring, rewards and points and social networks.

Real-time travel information: to provide users with real-time information on the conditions of the transport network such as delays information, planned or emergency road works, park availability and traffic alerts and hazards (e.g. a road accident or a train cancellation). Information on these conditions can be coupled with personal habitual travel patterns to deliver information that are personalised to individual users. In addition, real-time road conditions can be applied to generate intelligent travel suggestions, such as an alternative route and/or modality, in case someone's usual way to work is found to be currently congested.

Feedback and self-monitoring: providing personalised feedback on individual travel behaviours aims to provide travellers with tangible evidence in a comprehensive manner, so as to raise their awareness on impact caused by the way they travel. Metrics used are often relatively simple, such as cost, time, calories, distance and carbon footprint, and this aims to help users to identify an area (or areas) for improvement. This functionality, in other words, provide a way for users to monitoring their own behaviour. Recommendations can also be suggested to users based on their performance and by identifying suitable alternatives.

Rewards and points: rewards can be in many forms, ranging from simple recognition of achievement within the community or tangible ones with a monetary value. The notion of points provides a common currency which may help motivate user participation. It can also mimic the operation of a reward scheme in which users can "spend" their points. Combinational and accumulative incentives can be coupled with target or challenge settings in the design of a scheme or game framework.

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[47] Ibid.

Social networks: the key incentive of social networks to users is to provide them with a means to communicate, share their experience and information with each other. There is strong evidence that allowing users to share their performance is a way to: boost their achievement and trigger competition; help promote group behaviour; increase trust among users and reduce social ambiguity. Providing such an incentives-based platform allows users to interact with each other to help promote peer influence as well as loyalty to the system, which in turn helps attract more users.

To be able to evaluate the effect of different (combinations of) incentives, TRIPZOOM offers dynamic and controllable incentive management. It allows for generating and placing incentives in real-time during the entire runtime of the system. This means that weak or unintended side effects of incentive offers can be detected early and that incentive operators such as city representatives can alter incentives accordingly.

NB: challenges are defined by City Governments and/or Road Authorities through a City Dashboard, that allows to define, register, retrieve, and modify incentives in the form of challenges in a database. Tripzoom then maps actual user travel behaviour on these conditions and automatically manages rewarding when challenges are met »[48].

Targeted users

« The focus of the project is on urban mobility with a fine grained maze of roads (as opposed to long-distance highways) and on commuters with good static knowledge of the environment but with limited overview over the dynamic situation.

In Enschede about 200 people agreed to participate in the Living Lab. In Gothenburg the number was around 140 people. The users in Enschede are primarily male (69%), whilst the users in Gothenburg are female in majority (60%). In both Living Labs the age distribution is similar and the majority of users are between 25 and 45 years of age.

The Leeds Living Lab adopted a different format. This involved trialling automatic data collection via tripzoom, followed by a series of qualitative and quantitative data collection using focus groups and questionnaires »[49].

Ex-ante/current situation

TRIPZOOM project has not changed nor replaced any tariff model/policy in place.

Results achieved/forecasted

« Tripzoom has been tested in three Living Labs in Enschede, Gothenburg and Leeds, that have been designed, organised and maintained for nearly a year.

In the Living Labs, Tripzoom and the incentive schemes delivered have been evaluated on the basis of a comprehensive evaluation methodology. This evaluation methodology has been developed in two stages,

[48] Ibid.

[49] Ibid.

the first stage covering a) key indicators for the evaluation of operational success and b) an analysis approach for the effectiveness of incentives.

The analysis has found out that individual behavioural change can be achieved in terms of change in travel times (time shifting out of rush hour) and change in modality (shift towards sustainable bike alternatives). The analysis has found out that influential incentives should be based on the following areas:

- Time: efficient use, control, saving, and planning;
- Money: save (e.g., discounts on transportation tickets) or even generate (e.g., coupons);
- Information: receive (real-time, personalized) information about progress, travel alternatives, etc;
- (Social) recognition: for being green and healthy/fit; giving feedback to and receive feedback from others.

Incentives have proven to influence personal mobility choices at different extents. For instance, while self-monitoring provides a means to see and understand one's travel habit, such a function on its own may not be adequate in changing people's behaviour in anyway. It is perhaps effective for the most motivated individuals who are keen to change their behaviour in the first place. Thus, it has been suggested self-monitoring should be combined with other types of information, such as environmental or financial feedback or social influence so as to achieve the system's goals.

Additionally, the choice of metrics should be selected with care, for instance, people who are only interested in cutting their carbon footprints should be presented with measurements related to the environment such as CO2 emission; presenting them with a cost breakdown may not be useful and effective.

Although the project did not reach broad product up-take, it has been able to demonstrate that the concept creates positive effects within the scale of the Living Labs towards sustainable travel behaviour of individuals. For example, Tripzoom has created effects in its user base like travel at different times, using different routes and travel using alternative modalities. Also, insight in individual's own 24x7 travel behaviour is considered a valuable source of information for people supporting them in travel decision making and is considered as a new way for stakeholders to tailor incentives such as social challenges or individual rewards on the actual personal travel behaviour, history, context and personal interests.

Some of the main results highlighted during the Living Labs testing phase are described below:

- Congestion: Although the majority of the tripzoom participants reported not to have changed their travel behaviour as a result of the tripzoom challenges, 23% of the participants changed departure times. Although the change was rather small (share of departures in the peak hour dropped about 3% in both Enschede and Gothenburg) a trend was perceived that the morning peak was alleviated. In Gothenburg the peak was shifted in time and occurred 30 minutes earlier. In Enschede the peak appeared to be broadened during the challenge. Specifically in Gothenburg some users indicated that they have switched from car to public transport. The car use of the users in the challenge dropped from 63% to 57%-47% depending on the time the challenge was in place and the level of the rewards. Simultaneously the share of public transport increased from 9% to 10%-16%. The users report however to have changed only incidentally as a result of the challenges. Finally, it seems that the challenge in itself or in terms of raising awareness on travel timing rather than the size or nature of the reward is the more important factor.

Moreover to relieve traffic congestion a minor behavioural change from some travellers in the system may be sufficient to reduce congestion dramatically.

Environment: It proved difficult to demonstrate clear environmental effects as a result of our experiments and challenges focussed on modality-changes towards sustainable modes of travel. However, the experiments did observe relative changes in favour of more bicycle use, but in absolute sense the amount of bicycle trips decreased. On the other hand, the experiment to reduce congestion and improve the environment in Gothenburg did show an increase the use of public transport to the expense of the car, as previously mentioned. This can also be considered as an environmental improvement »[50].

Cause-effect relation hypothesis

The central concept of the SUNSET project has been to balance system goals by influencing personal behaviour using positive incentives.

The assumption is that sharing personal mobility patterns via social networks and the use of incentives can encourage citizens to utilize sustainable forms of transportation and to generate a win-win situation for all involved stakeholders.

Notes and references

http://www.sunset-project.eu/pdf/SUNSET_Project_Final_Report.pdf

Congestion pricing, transit subsidies and dedicated bus lanes: Efficient and practical solutions to congestion

Tariff model/initiative/policy analysed

The authors of this study are Leonardo J.Basso, Cristiàn Angelo Guevara, Antonio Gschwender, Marcelo Fuster. The study has been published on the Transport Policy Journal on 2011.

Description of the Tariff model/initiative/policy

« The basic assumption of this study is that people have a choice between using a car or public transportation, and these two modes share road capacity and thus interact with each other. This happens directly on the road, when vehicles are in motion, or when passengers are boarding in bus stops. In other words, buses delay cars and cars delay buses. Yet, as important as this may seem in practice, it has been very uncommon in the literature to consider congestion pricing and optimization of scheduled public transportation in a unique/joint model. Most of the congestion pricing literature deals with cases where only cars are considered, while the public transportation literature does not consider interactions either, nor the fact that buses may impose congestion on other buses if there are too many. The study faces this issues proposing a simple model that: (i) allows users to choose between car, public transportation or an

[50] Ibid.

outside option (biking) through a discrete choice model; (ii) considers congestion interactions between cars and buses; (iii) allows for optimization of frequency, vehicle size, spacing between stops and the number of lanes to be dedicated to buses if applicable.

The model mentioned above considers a road of infinite length with a capacity of Q vehicles/hour, where Y commuters per kilometre and hour travel l km in the same direction. In order to avoid dealing with border conditions, the authors modelled a representative kilometre of the road; in this sense, a circular road model would be equivalent. All travel commuters choose one of three modes –car, bus or bicycle – in a utility maximization framework. For the two motorized modes, the study considers congestion externalities caused both by their interaction while in motion, as well as congestion caused by the existence of bus stops. The variables that the planner can (potentially) adjust in order to maximize social welfare are:

- bus frequency and bus capacity;

- bus fare;

- number of equidistant bus stops per kilometre;

- congestion toll for cars;

- percentage of road capacity dedicated exclusively to bus services.

Obviously, as these variables change, utility levels are affected and, consequently, so will be the modal split. The possible policies that the authors consider are:

- congestion pricing;

- transit subsidies;

- dedicated bus lanes.

Then, the scenarios analysed are made of combinations of these policies and, therefore, some of the variables may not be available to the planner in some of the scenarios (for example, in some of the scenarios the study does not allow the planner to use dedicated bus lanes). An optimum point, then, for a given scenario is reached when the welfare is maximized and each user has chosen the mode that maximizes his utility. Different scenario proposed in the study are:

- Scenario 1: Self-financing transit, no congestion pricing, mixed- traffic (base case). It features a self-financing bus system (through fares only), absence of congestion pricing and road capacity shared by buses and cars.

- Scenario 2: Transit subsidies, no congestion pricing, mixed-traffic. In this second case, the study considers a transit subsidization policy, which here takes the form of no longer asking the transit fare to cover transit costs. In this sense, subsides in this scenario are optimal given the rest of the system environment; an (worse) alternative would be to fix an a priori amount for the subsidy.

- Scenario 3: Transit subsidies, congestion pricing, mixed-traffic. The third scenario, in addition to transit subsidies, considers congestion pricing which, according to the model above, consists of a per-kilometre charge.

- Scenario 4: Transit subsidies paid for by congestion pricing revenues, mixed-traffic. In the final scenario with mixed-traffic conditions, the intent is to explore by comparison with Scenario 3 whether optimal transit subsidies can be covered by optimal congestion pricing plus optimal bus fare; in other words, whether imposing an urban transport sector self-financing constraint leads to welfare losses or not.

Analyses of numerical results of the model allowed the authors to better see the full implications of different measures targeted at dealing with congestion in cities, such as congestion pricing, transit subsidies or dedicated bus lanes, as well as to explore the level of public support for each of these policies »[51].

Results achieved/forecasted

« The results show that:

- dedicated bus lanes is the best stand-alone policy possible, as it achieves – and by far – larger social welfare than transit subsidization or congestion pricing. Congestion pricing is marginally better than subsidization in terms of social welfare but has a negative impact in consumer surplus (at least before revenue recycling);

- without congestion pricing in place, efficient transit subsidies are quite large since in many cases the efficient transit price is negative;

- establishing dedicated bus lanes or implementing congestion pricing render subsidies unnecessary for high demand levels, while decreasing substantially the amount of subsidy required importantly for smaller demands;

- in terms of the support that each policy may raise, both subsidization and dedicated bus lanes should count with public support; although, probably, it is easier, from a political standpoint, to implement dedicated bus lanes than raise political support for subsidies. Congestion pricing on the other hand, is a policy that will probably encounter strong public opposition. To reverse this, an important level of tax recycling would need to be promised:

- in mixed traffic conditions, bus size, frequency, circulation speeds and spacing between bus stops do not change much when moving from the base case to subsidies or congestion pricing. It is only dedicated bus lanes that actually induce sizeable changes in these variables;

- in all the cases and settings analysed in this study, revenues from congestion pricing are enough to cover transit subsidies when required;

- for the cases analysed in this study, the optimal percentage of capacity that should be devoted for bus traffic is around one third »[52].

Congestion tolls and parking fees: A comparison of the potential effect on travel behaviour.

Tariff model/initiative/policy analysed

[51] www.researchgate.net/.../links/54c9012c0cf25087c4ec2c35.pdf

[52] Ibid.

The authors of this study are Gila Alberta and David Mahalelb. The study has been published on the Transport Policy Journal on 2006.

Description of the Tariff model/initiative/policy

« This paper presents a study aimed at evaluating the differences in attitudes towards congestion tolls and parking fees and forecasting the impact of each of these policies on demand for trips and on travel behaviour. The study shows the results of a stated preference survey that was designed to compare and contrast the potential effects of congestion tolls and parking fees. The interviewees consisted of a sample of people linked to the Technion—Israel Institute of Technology. The sample population was divided into two groups, based on actual travel patterns:

1. Group A: employees who usually arrive at the campus during the morning rush hour (7:15–8:30 a.m.);
2. Group B: employees who usually arrive at the campus during other times of the day.

Group A was introduced to Scenario A—the congestion toll: A congestion toll would be imposed on every vehicle that arrived during the morning peak time, between 7:15 and 8:30 a.m. The objective of the toll and the need to alleviate congestion on entering the Technion campus throughout the morning peak hours were explained to the survey respondents during the face-to-face interviews.

Group B was faced with Scenario B—the parking fee: A flat daily parking fee would be imposed on every vehicle throughout the day. The purpose of the fee and the necessity of coping with the lack of sufficient parking spaces on campus were explained to the survey respondents during the face-to-face interviews.

The purpose of this distribution into two groups was to reduce somewhat the extent of the main issue related to stated preferences technique for survey: people do not consistently behave as they stated »[53].

Results achieved/forecasted

« The results of the study show that following the imposition of new tolls that would require drivers to incur ‘‘out-of-pocket expenses’’, drivers will tend to change their travel behaviour. Following the introduction of a parking fee, 54% of the drivers of the sample would prefer to use other options in order to avoid this charge. Following the introduction of a congestion toll, 72% of the drivers of the sample would prefer alternatives that avoid this charge. This strong influence of tolls on social behaviour is also reflected in the relatively high values of demand elasticity (1.8 for the congestion toll and 1.2 for the parking fee). This effect indicates a strong tendency to avoid new tolls (especially the congestion toll) and to choose an alternative. It should be mentioned that the high level of toll fees caused a significant increase in the total auto travel cost in both scenarios, which might therefore account for the high values of demand elasticity that were found.

The large difference in attitudes towards congestion tolls and parking fees can be explained, firstly, by the general acceptance of parking fees and, secondly, by the appealing alternative of choosing another time for the journey. Respondents’ reactions reflect their strong reluctance at paying a new toll; they are

[53] Ibid.

apprehensive at the unfamiliar and the unknown. It seems that drivers are already used to paying for parking (although not on the university campus), and therefore parking fees may be more acceptable. In addition, when paying an out-of-pocket cost for a parking permit drivers receive something concrete in return: a parking space; on the other hand, the compensation that they may obtain for paying a congestion toll is more fuzzy. The willingness to pay a parking fee is higher, and the general tendency is to pay this charge and to continue driving a passenger car to work »[54].

PersonalBus

Tariff model/initiative/policy analysed

PersonalBus is a Dial-a-Ride Transite Service or Demand-Response Transit Service (DRTs) operated by the local public transport operator ATAF in the area of Campi (municipality of Florence).

It has validated under the EU 4th RTD Framework Programme. The service is in response to calls from passengers to the transit operator, who then dispatches a vehicle to pick up the passengers and transport them to their destinations.

Description of the Tariff model/initiative/policy

« The characteristics are:

(a) The vehicles do not operate over a fixed route or on a fixed schedule except, eventually, on a temporary basis to satisfy a special need or event;

(b) The vehicle may be dispatched to pick up several passengers at different pick-up points before taking them to their respective destinations and may even be interrupted *en route* to these destinations to pick up other passengers.

Circulating Shuttles carry passengers for short trips along busy corridors, including business districts, employment and education campuses, and parks or recreation areas. They may connect major activity centres, such as a transit station and a commercial centre. DRT systems may also provide a public transport service for areas of low passenger demand, such as rural areas, where a regular bus service would not be viable. DRT services may also be provided especially for disabled passengers.

The service is available from 6.30am to 7.30 pm.

The reservation is made by phone (only week-days) and a 30 minutes advance is needed. The user indicates its preferred departure and arrival stop (among nearly 200 stops within the area available), as well as her preferred schedule. The operator communicates the exact departure and arrival time, the one that approximates at most the preferred schedules communicated by the users.

The operational constraints are:

1) resources (available vehicles, vehicle type and capacity)

2) network characteristics (bus stops location, bus parking area locations, physical and functional features

[54] Ibid.

of road network)

3) service standards such as: the Direct Ride Time (the passenger ride time from origin to destination with no stop in between and via the shortest route), the Maximum Ride Time (the maximum allowed passenger
ride time), the Widest Shift at Pickup Time, (the maximum delay at pickup time allowed during planning) and the Widest Shift at Delivery Time (the maximum early arrival at destination stop allowed during planning) »[55].

Targeted users

« Main observed users' age:

15-30 (47,8%)

31-45 (26,5%)

Main users' characteristics:

women (56%)

workers (55,4%)

students (29,1%)

non car-owners (42,2%)

Main users' motivations:

work (51,8%);

shopping (31,2%);

school (15,2%).

Main observed frequency of use:

5 times per week (50,9%)

once per week (25,9%)

from 2 to 4 times per week (15,2%) »[56]

Ex-ante/current situation

The previous transit service was structured on three fixed route lines serving only a small part of the built-up area.

Results achieved/forecasted

"1. expansion of the transit service throughout the built up area of Campi;

[55] http://www.energy-cities.eu/db/firenze_569_en.pdf

[56] Ibid.

2. increase of the amount of potential users;

3. positive effect on the overall perception of the transit effectiveness, thus improving the relation between the Company and its customers;

4. benefit-cost analysis [taking into account the costs for the realisation of the new services (such as: acquisition of new hardware instruments and of the related software licenses, training of personnel, etc.), the yearly operating and maintenance expenses incurred before and after (1999) situations and the changes in revenues resulting from the increase in the amount of transported passengers] shows that the introduction of PERSONALBUS™ has brought to ATAF an yearly saving of about 51.600 Eur;

5. the total energy savings resulting from the DRT services is approximately 5,84 million megajoules per year (estimated through a model for calculating the amount of energy consumption and the emission in a particular time period, applied to the scenarios before and after the implementation of the service)”[57].

Cause-effect relation hypothesis

Suitable solution in situations such as low-density population areas, or low travel demand periods. It is a more efficient and user-oriented public transport system to cope with the changing mobility needs.

DRTs can also help to achieve social objectives, such as increasing travel choices, reduce emissions and reduce traffic congestion (especially when the target users are daily one such as workers and students).

Notes and references

http://www.energy-cities.eu/db/firenze_569_en.pdf

http://www.ataf.net/it/azienda/progetti-innovativi/servizi-flessibili/personalbus--cos-e/personalbus--i-risultati-ottenuti.aspx?idC=398&LN=it-IT

Uber's U-line

Tariff model/initiative/policy analysed

Uber's U-line is an experiment set up by UBER.

Description of the Tariff model/initiative/policy

« The experiment involved a circular route consisting of nine stops. Such stops have been manned by a constant supply of black cars and minibuses, which helped to transport people in the capital between December 10th and 24th (8am-8pm) (launched just two days after the 2016 Holy Jubilee of Mercy.

[57] Ibid.

The 9 stops are Piazza Euclide, Piazza Fiume, Roma Termini, San Giovanni, Piramide, Stazione Trastevere, Sant'Andrea della Valle, Castel Sant'Angelo e Piazza Mazzini. Roma Termini is hub to the local public transport lines (underground, train, bus). The stops have been chosen through an online survey (by 50000 users).

The user signs in the app. By moving inside the map and adding the name of the stop where she is, she will identify the areas covered by the service. If she is within an area covered by the UBER U-line, she will be invited to move near the stop. Once there, she will be able to see the waiting time. After request, any user can go from that stop to one of the other 8 stops, directly and without intermediate stops. The cost is 5 euros (e-ticket).

each ride can be shared with other people through the function "Divisione Corsa", after inserting the name of the person with whom the user desires to travel.

Once in the car, the user can change itinerary but the tariff will become the standard Uber Black »[58].

Targeted users

Commuters and (public/private) event goers.

Results achieved/forecasted

« +63% of users for the Transport on Demand service within the first week;

+ 170% of APP subscribers in the first day; + 60% in the first week;

30% of UBER users has chosen the U-line within the first week at least twice;

More than 80% of U-line users is Italian »[59].

Cause-effect relation hypothesis

It is effective in increasing travellers' mobility choice; help to achieve social objectives, such as increasing travel choices, reduce emissions, reduce traffic congestion

Notes and references

http://www.romatoday.it/politica/linea-u-roma-uber-fermate.html

http://www.ilpost.it/2015/12/09/uber-roma-linea-u/

[58] http://www.romatoday.it/politica/linea-u-roma-uber-feIbrmate.html;
http://www.ilpost.it/2015/12/09/uber-roma-linea-u/

[59] Ibid.

RideshareOnline.com

Tariff model/initiative/policy analysed

RideshareOnline.com is a regional project managed by Washington State Department of Transportation and is currently available in Washington and Idaho (US) to incentivize commuters to ridesharing. It provides services for commuters and employers.

Description of the Tariff model/initiative/policy

« COMMUTERS

It provides to ability to use the following services:

1. Car pooling with friends, neighbours or co-workers;

2.Vanpooling for short- and long-distance commutes.

The platform provides a Ridematch tool, through which you'll be put in touch with other smart carpoolers like you who are looking to save money, time, and the environment. They are friends and neighbours who share the same commute schedule and work location. The user signs up for an account. Next, enter her trip's starting and ending points. Then, select the ridematch preferences that best fits your schedule. Ridematch securely match her with other registered co-workers or commuters in her neighbourhood. The user choose how much personal information is shared during the ridematch process.

The user can match without using her home address – simply choose a local corner or Park and Ride lot as her starting point. Users are encouraged to use their work email address so they can match easily with co-workers.

Vanpools, in particular, are for groups of five to 15 commuters to share their ride to work. Washington and Idaho rideshare agencies provide the modern vans, gas cards, insurance and maintenance. The user can search for existing groups to join or start her own vanpool. Each vanpool agency is unique, but most fares cover gas, insurance, maintenance, roadside assistance, and an emergency ride home. Some programs even offer to waive the fare and allow personal use of the van for participants willing to drive. Some vanpool providers offer short distance vanpooling called vanshare. Vanshare bridges the gap between the bus, rail or ferry and home or work for groups of five or more commuters. These vans are placed at transportation hubs, such as bus or rail stations, to carry groups of employees to and from their workplace. The user sings in a choose vanshare provider from a list.

The use of option 1 and 2 is incentivized through a Commute Cost Calculator Tool. The user fills out a form to figure out her annual drive-alone commute cost. Compare it to the cost of car pooling and vanpooling. If the employer subsidizes commute options such as transit, carpooling or vanpooling, or if the user receives free HOV parking, the costs of other modes may be even lower. The user must indicate: 1. How many days per month do you work? 2. What is your round-trip commute (in miles)? 3. What is your cost per mile for fuel, maintenance, insurance, tires, license, registration, and taxes? 4. How much do you pay for monthly parking? The tool gives back the estimated cost of drive-alone commuting (Monthly $; Yearly

$); compares the yearly cost of other commute options such as: Carpool with one other person or Vanpool five days/week with six other people.

3. Biking to Work

RideshareOnline.com provides the information to get the user bike commute moving: Find a biking partner with Ridematch; Get guidelines for bike safety; Find out how to take your bike on the bus; Get more information from biking resources.

4. Walk/Wheel/Run

It incentivizes choosing an active way to get to work, which can bring the user better health and a super green commute. This is done by logging trips in Trip Calendar: the user can quickly see both her financial and environmental savings for choosing an active commute. Simply record commute trips on a daily or weekly basis. Trip Calendar is engaging and enlightening because the user can watch the numbers—and user's contribution—add up. When the user use Trip Calendar on a routine basis, she may be eligible to win valuable prizes through incentive programs such as monthly drawings when available.

5. SchoolPool Programs

SchoolPool is a way to help you share rides with other parents at your child's school. Any public or private elementary, middle or high school can set up a SchoolPool program for free. Each parent decides whether to participate and what kind of schedule works best for them. Parents can choose to find a bike or walk buddy or your child can be a passenger in a carpool.

EMPLOYERS

It assists employers in managing their employee transportation program. The tool described (Ridematch; Trip Calendar; Emergency Ride Home; Commute Cost Calculator Tool) are integrated into:

Management of commute benefits programs. Includes tools to promote transportation alternatives through prize drawings and incentives.

Customization program – A customization feature allows creating your own company web page using your logo and information about your commute benefits program.

The platform has special features for PRIVATE EVENTS or PUBLIC EVENTS

To start, sign up for an account. For public events, there is an Events menu. Select the event you plan to attend and enter your trip's starting point. Then, select the ridematch preferences that best fits your schedule. Ridematch securely matches the user with other registered commuters in your neighbourhood. In private events, event ridematching allows the user to decide who receives an email invitation to carpool to her event and who can participate

THE AWARDS PROGRAM associated to RideshareOnline.com are:

Communities in Motion - where every trip counts (http://www.kingcounty.gov/transportation/kcdot/MetroTransit/InMotion/GetInMotion.aspx);

Curb the Congestion reward (http://www.commtrans.org/curbit/);

Wheel Options Prize (http://www.wheeloptions.org/faqs/) »[60].

Targeted users

Employers, commuters, event-goers and parents of school-aged children.

Results achieved/forecasted

« COMMUTERS BENEFITS

Save money;

Reduce greenhouse gas emissions (A solo driver who changes their 20-mile round trip commute to the bus or rail can reduce their CO2 emissions by 4,800 lbs. per year.)

Save time (Carpools and vanpools can get you to work and back home faster by using high occupancy vehicle (HOV) lanes and HOV bypass on-ramp meters when available);

Stay healthy (Biking or walking to work can help you stay fit and reduce stress.

Under the Transportation Equity Act, employers are allowed to offer payroll tax savings for transportation assistance up to $125 a month per employee for bus/rail passes or vanpool vouchers.

The 2008 Energy Act added, "qualified bicycle commuting reimbursement" to the list of qualified transportation fringe benefits. As of 2009, any employer may reimburse an employee up to $20 per month tax free for reasonable expenses incurred by the employee for the purchase of a bicycle and bicycle improvements, as well as repair and storage if the bicycle is regularly used for travel between the employee's residence and place of employment »[61].

Cause-effect relation hypothesis

Rideshare programs and platforms are convenient and easy to use tool for the traveling public to help reduce traffic congestion, improve air quality and sustain the quality of living in our region. Employers, commuters, event-goers and parents of school-aged children may benefit.

Such programs are effective:

1- in providing free information on travel options and incentive programs for commute and non-commute trips. They offers tools for employers to implement effective commute reduction programs.

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[60] http://www.rideshareonline.com/

[61] Ibid.

2 - combined with a Park and Ride lots offer. Whether the user bicycle, carpool, vanpool, ride the bus, train or the ferry, using a park and ride lot can help commuting and reducing congestion.

Notes and references

Saranow, J. (2006). Carpooling for Grown-Ups---High Gas Prices, New Services Give Ride-Sharing a Boost; Rating Your Fellow Rider. Wall Street Journal.

Wiedenkeller, P. (2008). Suddenly, sharing a ride looks good. The New York Times.

http://www.rideshareonline.com/

Edinburgh's Park-and-ride initiative

Tariff model/initiative/policy analysed

The Ingliston project was managed by TIE on behalf of Edinburgh council.

Description of the Tariff model/initiative/policy

« Construction of the facility, off the A8/Airport junction on Eastfield Road began in September 2004. The 550-space site cost £ 2.6m (€ 3.5m) to build and is served by two bus services operated by Lothian Buses. The branded express service X48 runs at least every 10 minutes in peak times with a direct link into the city centre, and service 35 which travels to Edinburgh Park, Sighthill, Chesser, via the old town and on to Ocean terminal.

Hermiston was project-managed by the council itself. Situated on the A71 west of the A720 city by-pass junction, this site has 450 parking spaces and cost £ 3.4m (€ 4.6m) to construct. The slightly higher costs than Ingliston were due to improvements in the nearby road network, allowing better bus access to the site, while also creating a new bus priority lane from the proposed Hermiston junction connecting to the Calder junction. The facility is served daily by bus services 25 and 34 and on Mondays through to Fridays during peak times the 45 and express service X25 Hermiston offer a service to the city centre every five minutes. There is also a night service served by N25.

Parking at each site is free and bus fares to the city centre cost £ 1.30 (€ 1.80) each way (or less with monthly and annual passes). By 2011 Edinburgh had three more successful P&R facilities operating in Wallyford, Straiton and Sheriffhall »[62].

Targeted users

Commuters, car-owners.

Ex-ante/current situation

[62] http://www.eltis.org/discover/case-studies/edinburghs-successful-park-and-ride-initiative-uk

Edinburgh (and Scotland generally) has been slow to embrace the clear benefits of such schemes. Since 2004 a number of Scottish cities have adopted the P&R concept. In Edinburgh, the council, its partners, Lothian Region Buses and TIE - a private project-management company owned by council - set about constructing of a number of P&R facilities in Edinburgh.

Results achieved/forecasted

« In 2008, both sites were operating at 80 per cent capacity and 500 new spaces were set to be created in Ingliston in summer 2008. Results of a 2008 survey by Edinburgh council showed that:

92% of drivers thought parking conditions were good;

85% were impressed with the service;

90% thought it was good value for money;

84% said the security was excellent or good.

In total, Edinburgh council estimates that over 100000 road trips into Edinburgh have been averted. With plans to expand both Hermiston and Ingliston and adding two new P&R facilities, this reduction in inner-city car trips will increase these figures further »[63].

Cause-effect relation hypothesis

Park-and-ride (P&R) schemes reduce car usage and promote more sustainable transport alternatives

Notes and references

http://www.eltis.org/discover/case-studies/edinburghs-successful-park-and-ride-initiative-uk

Park and bike terminal in Aarhus

Tariff model/initiative/policy analysed

Park and Bike Terminal is located by Egå Engsø in Lystrup.

Description of the Tariff model/initiative/policy

« The total cost for the project was € 250 000 and it was funded and implemented in December 2011 by the Municipality of Aarhus.

The starting point for the project was that the city wanted to give people that commute to Aarhus the opportunity to park outside the city centre. Instead of wasting time on congested roads they could cycle the last part of their trip and at the same time get some fresh air and exercise. It was decided to build the first facility in Egå Engsø as it has space for about 100 bikes and 60 parked cars. Commuters who want to leave their bike at the terminal at night have a possibility to rent an individual and locked parking booth for around DKK 400 (€ 50) per year.

[63] Ibid.

Aside from the parking facilities, the project also included an outdoor fitness area and a bicycle playing area for children. Thus the terminal area is intended to be a recreational area that can be used for various activities during the whole day and not just when commuters use it in the mornings and afternoons.

The Park and Bike Terminal in Lystrup was established in connection with a whole new cycle route to Aarhus, where planners have focused on creating a fast and comfortable route that also offers a recreational experience on the bike ride, far from cars and noise »[64].

Targeted users

Commuters, bike-owners, fitness-oriented people .

Ex-ante/current situation

Aarhus is the second-largest city in Denmark with over 300 000 inhabitants. Many commuters that work in Aarhus live in the surrounding municipalities and thus have a long drive before they reach their workplace.

Results achieved/forecasted

« Increase the number of multimodal trips and encourage commuters to cycle for part of their work journey.

The terminal has received good feedback from users and the individual parking booths have also proved to be popular . The biggest challenge has been to share information about the new facility to citizens. In order to find users for the individual parking booths several announcements in local newspapers were published. However, the most successful way to find interested people was to directly contact companies located in the area.

Indeed, the terminal has also been promoted to larger companies that employ people from the surrounding areas, such as Randers and Djursland, that do not have parking spaces for all their employees. The companies can keep company bikes at the terminal and thereby offer their employees a healthy transport alternative.

Overall the project has been a great success and it has received a lot of national media coverage. In the upcoming years the City of Aarhus plans to build more Park and Bike Terminals within a 5 to 10km radius of the city centre »[65].

Cause-effect relation hypothesis

[64] Ibid.

[65] Ibid.

The main idea is to increase the number of multimodal trips by establishing a parking facility close to radial roads and cycle tracks. This goal is in line with the Cycling Action Plan for Aarhus that has targeted an increase of the number of multimodal trips as one of the means to solve congestion problems in Aarhus.

Notes and references

http://www.eltis.org/discover/case-studies/denmarks-first-park-and-bike-terminal-aarhus

Warsaw's Park-and-ride system

Tariff model/initiative/policy analysed

The first P&R car park in Warsaw was constructed in 2006.

Description of the Tariff model/initiative/policy

« It was assumed that, after leaving their cars in a P&R car park, drivers who had tickets for public transport (one-day, weekend, 30-day, 90-day or senior tickets) would transfer to public transport, which was destined for the centre of Warsaw.

Potential locations of such car parks needed to be identified and selected. One of the main selection criteria was the availability of a transport hub. The locations picked were all close to transport hubs, in particular rail transport. The Warsaw authorities entrusted this task to the Board of Transport Authority (the ZTM). In early 2006 the authorities started the construction of the first car park, which was officially up and running in the first half of 2007. Not only was it the first parking of that type in Warsaw, but it was also the very first in Poland. Further car parks were being completed by the ZTM in subsequent years.

Eight out of the thirteen car parks that are currently fully operational were co-funded by the EU from the European Regional Development Fund (link is external) under the Regional Operational Programme for Mazowieckie Voivodeship 2007-2013. They have a joint capacity of almost 1 000 parking spaces, including 85 for disabled drivers. In addition, there are nearly 640 bicycle parking stations available at the car parks. Warsaw is planning the construction of further P&R car parks with public transport connections. The decision was made to start the construction of at least five new car parks in neighbourhoods with heavily used train stops all within the city borders of Warsaw »[66].

Targeted users

Commuters, car-owner, bike-owners.

Ex-ante/current situation

[66] http://www.eltis.org/discover/case-studies/reducing-congestion-warsaws-park-and-ride-system-poland

Warsaw faces the problem of heavily congested roads. The car owner ratio is steadily growing; currently, there are over 600 cars for every 1 000 residents of the city. One of the negative impacts of more cars is that urban space is becoming degraded. Cars cause heavy road congestion, noise and air pollution. In addition, Warsaw is facing serious parking challenges. Drivers park their cars freely, even in public spaces that are not designated parking locations.

Results achieved/forecasted

« According to ZTM Warsaw, 740 000 cars used P&R car parks in Warsaw in 2014. Krajnow believes that one of the reasons P&R car parks in Poland's capital are popular is because of the low cost. Parking at the P&R is free when the user buys at least one one-day travel card. 'As such it is definitely less expensive than a daily onward journey by car,' he adds. The price of a one-day travel card is also significantly lower than the cost of leaving the car for eight hours in a paid parking zone in Warsaw. 'If a driver uses the long-term tickets, which are the most cost-effective form of transport fares, the scales get tipped even more in favour of the P&R car parks'.

Be able to save time is another crucial factor. Commuting every day to the centre through congested streets is very time consuming. The P&R car parks are located in close proximity to rail transport hubs, where drivers can change trams, trains or take the metro »[67].

Cause-effect relation hypothesis

It is important for P&R car parks to be built in locations where it is possible to have the most convenient transfer to public transport, especially to the most efficient and ecological rail transport. Clearly marking the access roads to the cars parks by using big and clear sign posts is equally crucial.

Informational activities directed at the users and concerning the basic rules of the P&R operations, and promotional activities encouraging using the P&R parks system, directed at those drivers who have not used them yet, are also important. The best way to reach potential users is to show them the most significant benefits they can get by leaving their cars at a car park.

Notes and references

http://www.eltis.org/discover/case-studies/reducing-congestion-warsaws-park-and-ride-system-poland

AIRail

Tariff model/initiative/policy analysed

AIRail is a service that offers integrated tickets and baggage handling between rail and air transport.

Description of the Tariff model/initiative/policy

[67] Ibid.

« The service was born from the cooperation among Deutsche Bahn, Lufthansa and Fraport on March 2001 on the route between Frankfurt Airport and Stuttgar. In 2002 it was launched on the route between Frankfurt Airport and Cologne. Through the years, many other airlines signed agreements with Lufthansa to use the AIRail service to feed passengers to Frankfurt.

The program offer a full-integrated baggage handling service: the baggage is checked in Cologne or Stuttgard and is carried directly to the final destination. The check in desk is operated by Lufthansa employees, while Deutsche Bahn's employees load and unload the pieces of luggage.

AIRail offer precise coordination of the trains with Lufthansa flights in order to guarantee optimal transfer times. Some compartments of the train are for Lufthansa exclusive use and baggage containers are located in a separate compartment. Travelling with AIRail awards miles to passengers.

Required significant of investment expenditures (e.g. the costs for the extension of the baggage handling system at the airport). Nevertheless operating costs are regarded as a manageable expense with limited risk for Lufthansa The program entails a criticality: it deviates from standard security procedures found in international aviation. A significant marketing effort was undertaken »[68].

Targeted users

Business and leisure passengers travelling internationally from/to Stuttgard and Cologne

Ex-ante/current situation

Since 1999 a train station was built at terminal 1 of Fraport (in the course of the construction of the high speed line connecting Cologne and Frankfurt).

Results achieved/forecasted

« Frankfurt Airport increased its catchment area (people living less than 2h far from the airport) by 10 million people.

AIRail service from Cologne and Stuttgart to Frankfurt significantly harmed the competitiveness of Cologne–Bonn Airport for international passengers travelling from Germany.

Passengers travelling with AIRail face low waiting time for connecting flights compared to passengers travelling to Fraport by air.

AIRail travel time between Cologne and Fraport was approximately 60 min, while the Lufthansa flight took 40 to 50 min, plus access and check in time.

The target ridership was 60%, but in the first year of operation, the actual ridership was 30%.

It took several years for the AIRail product to gain market share, particularly for the Frankfurt–Stuttgart market. Lufthansa managed to shift 10000 short haul flights per year to rail services and to allocate more slot to long haul flights.

[68] http://www.lufthansa.com/us/en/AIRail-just-like-flying

Frankfurt–Stuttgart was less successful than the Frankfurt - Cologne line. On the Frankfurt–Stuttgart route, AIRail led to: 39% reduction in passengers; 46% reduction in available seats, and 17% reduction in frequency. Passengers' satisfaction rate was 95% in the first year of operation »[69].

Cause-effect relation hypothesis

The program targets four key dimensions of quality for intermodal passengers: integrated ticketing and information, guarantees in case of missed connections and integrated baggage handling.

However, it was not successful since the early years of operation because It was not possible to book AIRail tickets on Lufthansa website, due to technical problems, until 2007. This provided competitive advantage to substitute feeding flights.

When AIRail was first launched, the timetables of rail rides and flights were not coordinated and this lengthened connecting times. It took time for passenger to learn to know and appreciate the product.

Notes and references

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Molina Cecchetti, M. A. (2004). Evaluating airline-transit cooperation in airport rail and remote check-in services: a strategic approach for increased ridership (Doctoral dissertation, Massachusetts Institute of Technology).

Smith, S. et al. (2006): Air and Rail Competition and Complementarity Final Report, Study Commissioned by the European Commission, DG TREN, 2006.

http://www.lufthansa.com/us/en/AIRail-just-like-flying

Rail&Fly

Tariff model/initiative/policy analysed

The Rail&Fly is a ticketing program launched in 1992. It is offered by airlines and tour operator in combination.

Description of the Tariff model/initiative/policy

[69] Ibid.

« The Rail&Fly ticket is a discounted rail ticket that is valid for any station in Germany to the airport and viceversa (sometimes the ticket is included in the airfare).

Rail&Fly required low investments and featured low operational complexity.

The cooperation agreement with Deutsche Bahn limits the availability of the Rail&Fly option to international flights only »[70].

Targeted users

« Travellers that depart from Germany to travel internationally (only few services are available for bookings from abroad and search costs are high for individuals that do not know well the transport market in Germany and the German travel agents) »[71].

Ex-ante/current situation

Passengers purchased separate tickets for the rail trip and the flight

Results achieved/forecasted

« The program was immediately successful.

In 2005 At Frankfurt Airport 1.6 million passengers used a Rail&Fly tickets (6.5% of departing passengers).

Some airlines include Rail&Fly in the airfare to incentivize passengers to use the train to access the airport rather than domestic feeder flights. In this sense, Rail&Flight is seen as a competitive lever against Lufthansa.

On December 2005, TUIfly.com started offering one-way rail tickets from any point in Germany to the respective airport of departure for € 19. Germanwings followed suit. However, the cooperation agreement with Deutsche Bahn limits the availability of the Rail&Fly option to international flights only »[72].

Cause-effect relation hypothesis

The program targets two key dimensions of quality for intermodal passengers: integrated ticketing information and discounts on the integrated ticket with respect to the two separate tickets.

Notes and references

Clewlow, R., Sussman, J., & Balakrishnan, H. (2012). Interaction of high-speed rail and aviation: exploring air-rail connectivity. Transportation Research Record: Journal of the Transportation Research Board, (2266), 1-10.

[70] http://www.bahn.com/i/view/GBR/en/prices/germany/rail_and_fly.shtml
[71] Ibid.
[72] Ibid.

Grimme, W. (2007). Experiences with advanced air–rail passenger intermodality—The case of Germany. In 11th ATRS World Conference, Berkeley, June.

http://www.bahn.com/i/view/GBR/en/prices/germany/rail_and_fly.shtml

TGVair

Tariff model/initative/policy analysed

TGVAIR is a partnership between the French rail operator SNCF (Société nationale des chemins de fer français) and various airlines.

Description of the Tariff model/initiative/policy

« The program was launched in in 1996. At the beginning the program was essentially a code-sharing agreement between SNCF and Air France.

TGVAIR offers integrated tickets at discounted rates compared to the single fares that make up the trip.

In case of missed connection TGVAIR guarantees a seat on board the next available flight or train at no extra charge.

TGV AIR connects the Paris-Charles de Gaulle TGV station to: Angers - St-Laud, Avignon TGV, Champagne-Ardenne TGV, Le Mans, Lille Europe, Lorraine TGV, Lyon Part-Dieu, Nantes, Poitiers, St-Pierre-des-Corps, Toulon, Valence TGV. The check-in for the flight can be made at the rail station, but the program does not offer integrated baggage handling: the baggage must be checked at the check-in counter in the airport.

Passengers travelling with TGVair collect miles »[73].

Targeted users

Business and leisure passengers travelling from/to the France cities served.

Ex-ante/current situation

A TGV station was available at Paris Charles de Gaulle.

Results achieved/forecasted

« TGVair is acknowledged by a successful experience of integration between air transport and high-speed rail. The success of the program is apparent in the growth rate of the number of agreement between SNCF and the airlines willing to join the program »[74].

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[73] https://www.airfrance.nl/NL/en/common/resainfovol/avion_train/reservation_avion_train_tgvair_airfrance.htm

[74] Ibid.

Cause-effect relation hypothesis

The program targets two key dimensions of quality for intermodal passengers: integrated ticketing information and guarantees in case of missed connections.

Notes and references

Arduin, J. P., & Ni, J. (2005). French TGV network development. Japan Railway & Transport Review, 40(3), 22-28.

https://www.airfrance.nl/NL/en/common/resainfovol/avion_train/reservation_avion_train_tgvair_airfrance.htm

Night&Flight

Tariff model/initiative/policy analysed

Night and Flight is a program that allows travellers to purchase a combined transport service.

Description of the Tariff model/initiative/policy

The combined transport service consists of an overnight railway journey to a destination and a daytime flight back (or vice versa) as a complete package. The program was launched in 2005 and the product is supplied by a European night train operator CityNightLine, and Swiss International Air Lines (SWISS).

Targeted users

The program was designed to attract business travellers.

Ex-ante/current situation

Passengers travels with the same mode of transport for the whole round trip

Results achieved/forecasted

Night&Flight program is found to be not able to be appealing for people that usually travel by train but it shows low ability to shift passengers from other modes of transport.

Cause-effect relation hypothesis

Eliminating the mid-journey physical transfer present in other air-rail trips was meant to make the product appealing.

Nevertheless, a key criticality for the low success of the program was the inability to buy tickets online. Indeed, SWISS argued that the potential demand was insufficient for developing and maintaining an Internet-based self-booking system.

Notes and references

Sauter-Servaes, T., & Nash, A. (2009). Increasing Rail Demand by Improving Multimodal Information and Ticketing: Results of the Night&Flight Case Study.Transportation Research Record: Journal of the Transportation Research Board, (2117), 7-13.

HSR station at London Heathrow

Description of the Tariff model/initiative/policy

London Heathrow directly connected to the high speed network

Targeted users

Leisure and business passengers travelling to/from London Heathrow

Ex-ante/current situation

The airport is not served by the HSR and it is experiencing severe congestion delays, in fact As can be seen, arrival flight demand exceeds the airport capacity 17 h of the day.

Results achieved/forecasted

Difference on in-vehicle time between the two transport modes.

Substitution of less that 2% of short-haul flights with HSR rides is able to:

(i) save about 20% in airline air passenger delays;

(ii) save ten to three hundred tons of CO2e (these savings linearly increase with the number of substituted flights);

(iii) reduce the cost of noise (these savings increase linearly in the number of substituted flights).

Cause-effect relation hypothesis

The environmental impact per-passenger of HSR operations is lower than the environmental footprint per-passengers of airlines

Notes and references

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transportation Research Part D: Transport and Environment, 16(2), 137-149.

Azkar

Description of the Tariff model/initiative/policy

« In general, basic tariff is calculated depending on the weight (and dimensions or equivalent volume) of the parcel to be delivery as well as the origin and destination.

The logistic operators also commonly offer express services and the cost depends on the customer needs, if the parcel should be delivered at a specific day or time of the day, weekends, etc.

In the case of Azkar/Dasher a % over the basic express tariff (domestic deliveries within 24/48 hours) is charged depending on the service required by the client:

- Azkar Fix – Delivery at a fixed day
- Azkar night – Delivery before the opening of the commerce.
- Azkar 10 and Azkar 13 – Delivery before 10:00 or 13:00 respectively

Other added value services are also in general offered with additional costs such as:

- delivery to private residences
- picking-up service
- warehousing
- handling
- original dispatch note return

Special freight has associated exceptional tariff conditions:

- Special dimensions, weight exceeding
- Special material
- Air delivery
- Others

Other international services and tariffs are offered ».

Barik

Tariff model/initiative/policy analysed

- responsible transport operator/municipality: Biscay Transport Consortium (CTB) in Biscay, Basque Country;
- city/location where the tariff model/initiative/policy is in place; province of Biscay (Basque Country);
- starting date of implementation: 11/10/2012 in coexistence with the previous model until 01/01/2014.

Description of the Tariff model/initiative/policy

« Barik is a contactless smart card which can be used in different transport modes operating in the province of Bizcay (Basque Country): Metro (MetroBilbao), tram and train (Euskotren, FEVE, RENFE), urban and interurban buses (Bilbobus, Bizkaibus, Kbus, Erandio bus, Etxebarri bus). This card can be also used in other services such as bicycle system (Bizimeta), funicular (Artxanda and Larreineta), Suspension Bridge, Ereaga Lift even some parking areas (BEC, Etxebarri, Leioa).

Barik is an e-wallet system that allows usual public transport passengers to travel around the province by using a unique payment system besides getting special tariffs and/or discounts as well as pay for other services related to mobility. Also there are different Barik models to customize the tariff scheme and get special benefits depending on users' profile: young people, large family, elderly, disabled or special social groups.

Each transport operator has its own tariff policy being most of them based on a zone system, which means that the prize of the trip depends on the zones you are moving around.

All transport operators apply a single fare (one way or round trip) for occasional users (not Barik users) and some of them also offer one day pass which allow unlimited trips during the day.

In general terms, for Barik users there are two main models to be applied in almost all transport operators:

Creditrans title for anonymous card, which applies a special price over the single trip fare and can be used by different users allowing multiple people trips cancellation at the same time (e.g. a group of people till 10).

Customized cards (that are not transferrable) with special fares depending on the user profile, in general:

Gizatrans title for elderly people: discount over the single trip price;

Hirukotrans title for large family (two different groups: general and special): discount over the single trip price;

Gazte title (for young people) or monthly pass with unlimited trips for 30 days.

Apart from that, depending on the transport operator, additional tariff rules are applied. Some examples below:

Bilbobus

Transfers between lines are free within 45 minutes

Bilbotrans title is a special social fare

Gazte Bio title applies an additional discount to the monthly price if the user belongs to a large family »[75].

Metro Bilbao

Super50 bonus to make 50 trips within 30 days

Anual26, annual bonus for young people (<26 years old)

And so on

This initiative was launched with the aim of promoting the use of the public transport over the private transport.

[75] http://www.ctb.eus/en/public-transport

Targeted users

« The number of users targeted by the tariff

The travels made by using the common title "creditrans" (the previous one) in 2012 were 114.532.089 while the travels made with the common title "Barik" in 2014 were 118.311.765. This means an increment of a 3.3% of travels made by using this system.

Identified users current behaviour in terms of mobility choices.

In the city of Bilbao %44 uses public transport, %33 private transport, %17 on foot, %3 by bicycle.

From those travelling in the public transport in 2014, CTB has these percentages:

Metro Bilbao: %52,7

Bizkaibus: %16,5

Bilbobus: %15,7%

Renfe: %5,4

Other: %3,3

Euskotren: %3,2

Euskotran: %1,8

Other buses: %0,8

Feve: %0,7 »[76].

Ex-ante/current situation

CREDITRANS

It began in September 2000 as a consequence of the development of the Marco Agreement, and in the last years it has become a referent for the users of the public transport.

Creditrnas was a multimodal transport title, valid to travel with the transport operators included in the system: Metro Bilbao, Bilbobus, Bizkaibus, Funicular de Artxanda, Puente Colgante, Erandio Bus, Autobuses Lujua, Tranvía de Bilbao, Bilbao-Lezama Euskotren, Etxebarri bus, Ascensor de Ereaga and Feve.

This transport title could be of 5€, 10€, 15€. The credit was deducted in the way "pay as you go". Every time a trip was made, a new balance was printed in the side of the ticket, with other necessary information such as date, line of operator.

Each operator established the tariffs. Discounts were applied when transfers (within 45 minutes for urban trips and 90 for interurban) within the same or between different transport operators. A discount of 20% was applied over the total fare, it means 20% over the sum of both trips (except when the operator had its own transfer rules).

[76] Ibid.

Results achieved/forecasted

« Description of results achieved since the introduction of the tariff model

Increase in travels by using the common title "Barik" of a 3,3% since the introduction of the system.

Description of results achieved compared to envisaged expected impacts and results

It was expected a universal card for all the public transports in Bizcay, but the result is only the first step to a standardized tariff model for all the operators.

In 2013 the great amount of Barik cards that was operating was bigger than expected, so there were implemented more recharge points in the transport systems and also the possibility to recharge in ATM.

As the impact was higher than expected, the Institutions are managing to expand the system further than Biscay, preparing to allow the use of Barik in the culminant provinces, where they have a similar system.

Description of changes identified with respect to the ex-ante situation.

The implementation of the Barik model was on October 2012. This year, there is a descent in passengers, but, from 2013 to 2014 there is a rise in the public transport passengers and an increase on the people using the barik system.

Description of the extent, scope of the change, emphasising if the change has been positive or negative.

At first, there was a luck of information that made the user learn by mistakes.

One of the biggest changes is the validation of the card also at the exit of the transport. This was habitual for some operators, but not for the bus operators; so in the first balance of the system, a month after the implementation, most of the incidences were not validating the card at the exit.

It is easier to use the card than the previous models. As the Creditrans was paper made, the new balance was printed in the card when validating the ticket. The printing was sometimes illegible.

The creditrans could be as maximum of 15€, which made the user to buy new ones every week/two weeks. The Barik can have 90€ charge.

It is also easier to recharge them, and new technological advances are implemented; in the next months, a new recharging system with the mobile phone will be introduced.

Description of any change or effect identified in the environmental situation.

Reduction of waste, as the Creditrans titles were paper made and throwaway »[77].

Cause-effect relation hypothesis

Description of the hypothesis on a cause-effect relation between existing tariff models/initiatives/policies and users mobility choices and demands, in order to understand how specific tariff models can influence or push passengers to prefer and choose specific transport modes.

Notes and references

[77] Ibid.

http://www.ctb.eus/en/public-transport
http://www.ctb.eus/sites/default/files/18148-009_f01_ctb_tarjeta_barik_2013-09-23.pdf
http://www.ctb.eus/sites/default/files/ctb_informe14_web_0.pdf
http://www.ctb.eus/sites/default/files/memoria14_c.pdf
http://www.ctb.eus/sites/default/files/memoria12_c_web_1.pdf
http://www.ctb.eus/sites/default/files/memoria_11c_web_0.pdf

Mugi

Tariff model/initiative/policy analysed

- responsible transport operator/municipality: Territorial Transport Authority of Gipuzkoa
- city/location where the tariff model/initiative/policy is in place; Province of Gipuzkoa (Spain)
- starting date of implementation: 04/03/2013

Description of the Tariff model/initiative/policy

« Description of the tariff model

Common tariffs: The common pricing allows the same trip in different transport operators to cost the same. For example, traveling for A to B in train or in bus costs exactly the same.

Common zonification: the tariff system is based on zones. There are 15 zones. The tariff depends on the origin and destination zones.

Scoring rules:

Discounts per use: the objective of the Mugi system is to prize the people that use the public transport more than the average; that is the reason to have discounts in their trips.

There are three sections of use and its correspondent discounts:

- 1 – 20 trips: Discounts of %45 to the one-trip ticket.
- 21 – 50 trips: Discount of the %56 to the one-trip ticket.
- 51 or more: Discount of%90 to the one-trip ticket.

The discounts are applicable with the trips made in the natural month.

The number of trips is 0 at the beginning of every natural month.

Transfers: There are two types of transfers:

- Transfers in the same operator: The transfers inside the same operator are free of charge.
- Transfers between different operators: In transfers between different operators, the cost is the price of the most expensive trip and the %25 of the cheapest.

Collectives: The Mugi system is a pre-paid system. The collectives recharging Mugi card will receive a bonus in the recharge.

- Young (from 5 to 25): %14 of bonus
- Elder (older than 65): %108 bonus
- Dissabled (from %65 or more): %108 bonus
- Social: %108 bonus
- Numerous family: general (%25 bonus), Special (%100 bonus)

The discount for numerous families are applicable with other collectibles.

Transport operators' municipalities partnerships:

BUS: Lurraldebus, Dbus, IrunBus, Buses in the following municipalities: Hernani, Irun, Donostia, Arrasate, Errenteria, Eibar and Zarautz.

TRAIN: Euskotren

OTHER: Tram of Vitoria-Gasteiz, Tram of Bilbao, Funicular of Larreineta-Trapagarán, Rent of electrical cars Elgoibar Emugi, Rento of bicycle »[78].

Targeted users

« Identified users current behaviour in terms of mobility choices.

By foot: %40,9

Bicycle: % 1,,3

Private vehicle: % 39,7

Discretionary bus: % 4,5

Bus public Transport: % 7,7

Train public Transport: % 3,8

Other: % 2,1

(the data is from the last questionnaire in a province level, 2007) »[79].

Ex-ante/current situation

LURRALDEBUS card

This card was implemented in 2007. The scoring rules of Mugi are based on the scoring rules of Lurraldebus. The rules are discounts per trip and based on zone jumps.

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78 http://mugi.eus/index.php/es/mugi/q-ventajas-mugi

79 Ibid.

For the same zone:

- 0 - 10 trips: normal tariff
- 11 - 25 trips: %15 discount
- 26 - 50 trips: %35 discount
- 51 - 75 trips: %70 discount
- more than 75: %90 discount

For 1 zone jump:

- 0 - 10 trips: normal tariff
- 11 - 20 trips: %15 discount
- 21 - 35 trips: %35 discount
- 36 - 50 trips: %70 discount
- more than 50: %90 discount

For 2 or more zone jumps:

- 0 - 10 trips: normal tariff
- 11 - 20 trips: %15 discount
- 21 - 35 trips: %35 discount
- 36 - 40 trips: %70 discount
- more than 40 %90 discount

It is a personalized card, only for the Lurraldebus Operators at the beginning and more operators added themselves with the time.

At the moment Mugi and Lurraldebus are in coexistence.

There were also some other cards for the bus in Donostia, chip cards provided by the bank operators, and rechardable in ATM.

Results achieved/forecasted

« Description of results achieved since the introduction of the tariff model

The system is a reference tariff model. The results of this model is the implementation of the same model on all the province of Gipuzkoa.

Description of results achieved compared to envisaged expected impacts and results.

There is a high use of Mugi/Lurraldebus in Gipuzkoa; as the previous models were also very used, it is difficult to compare to the situation before the other cards. The use of public transport in Gipozkoa has increased since the Mugi system was added.

Description of the extent, scope of the change, emphasising if the change has been positive or negative.

Everybody uses the Mugi/Lurraldebus system, as there was a previous chip card system similar to the Mugi, the use was easily understood by the people.

It also makes faster the flow of passengers, as it is a fast system with a contactless card »[80].

Cause-effect relation hypothesis

Description of the hypothesis on a cause-effect relation between existing tariff models/initiatives/policies and users mobility choices and demands, in order to understand how specific tariff models can influence or push passengers to prefer and choose specific transport modes.

Notes and references

http://mugi.eus/index.php/es/mugi/q-ventajas-mugi

http://www.euskalyvasca.com/pdf/estudios/2007/12_diciembre/Estudio_movilidad_CAV_07.pdf

http://www.gipuzkoa.eus/noticias/archivos/lurraldebus-billeteunico.pdf

http://www.dbus.eus/wp-content/uploads/2014/04/4-optimizacion-del-diseno-de-lineas-de-autobus-aplicacion-a-donostia-san-sebastian.pdf

http://www.garraioak.ejgv.euskadi.eus/contenidos/informe_estudio/em2011/es_def/adjuntos/Movilidad%20Encuesta%202011.pdf

SWISSPASS

Tariff model/initiative/policy analysed

- responsible transport operator: Swiss Federal Railway - SBB, born in 1902.
- location where the initiative is in place: All Switzerland, in SBB railways, other railways and also on boats, buses and trams.
- starting date of implementation: 1 August 2015

Description of the Tariff model/initiative/policy

« SBB tickets options is very wide: There are 7 season tickets for Swiss and other 9 single tickets for Swiss or other travellers. The new SWISSPASS initiative is related to season tickets, especially to 2 travel card:

1. General Abonnement Travelcard (GA travelcard): unlimited travel on SBB trains and most other railways in Switzerland. In addition, you can travel on boats, buses and trams and you will also receive discounts on many mountain railways. Different options:

- AG General: From 25 years to 64 (woman)/65 (man)

-AG Child: up to 16 years

[80] Ibid.

-AG Junio: From 16 to 25 years

-AG Young: students from 25 to 30 years

-AG Senior:

-AG Family:

-AG Disabled:

2. Half-Fare travelCard: It brings the possibility to use the offered journeys a half fare price.

The season tickets are paid annually or monthly, according to the tariff established by the Service Direct Suisse - SB institution.

Reasons why the initiative was introduced:

-More than half of SBB customers renew their travelcards seamlessly. Thanks to the SwissPass, traveller no longer has to think about renewing his travelcard and so he/she always stay mobile.

-SwissPass Card is valid for several years and the owner travel card (AG or Half Fire) is renewed on the same card, helping to protect the environment, as the number of cards produced and distributed decreased, all in the name of sustainability.

-It is a red plastic card with RFID technology, where the most usual travelcards used in Switzerland Rail Network have been inserted, but adding new services from Mobility Carsharing, PubliBike, SwissMobile and the ski areas.

There is a Federal Institution called "Service Direct Suisse - SD" , which more important task is the acceptation of fares, based on the Federal Transport Law (LTV, RS 745.1). Transport Operators who became partners, agree with all the Service Direct fare system, or just with one or someone. Actually, 248 transport operators are SD members, and the SBBB belongs to it.

Apart from the SBB tariff model, in Switzerland exist other 20 Fare Networks that belongs to each canton, which are focused in regional and urban public transport. In those regional areas, there is a single ticket for city or country journeys, as different transport operators works together. Examples: ZVV, TNV, Libero, Passepartout, Mobilis, Unireso, Arcobaleno »[81].

81

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiUtYSTvMzKAhUKthoKHVAtCsAQFggiMAA&url=http%3A%2F%2Fwww.are.admin.ch%2Fdokumentation%2Fpublikationen%2F00016%2F00433%2Findex.html%3Flang%3Dfr%26download%3DNHzLpZeg7t%2

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj2sIKzvMzKAhWKiRoKHWTlDqoQFggiMAA&url=http%3A%2F%2Fwww.bfs.admin.ch%2Fbfs%2Fportal%2Ffr%2Findex%2Fnews%2Fpublikationen.Document.171396.pdf&usg=AFQjCNEYOCEFelpa47JHqYe

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj_zvq-vMzKAhXJPBoKHbwDDZIQFgggMAA&url=http%3A%2F%2Fwww.voev.ch%2FT600_f&usg=AFQjCNEutYeTLbMvsnk9IPq7IuTIFGSCag&sig2=A3-WrW43NhgpTAoWHCoMeQ

Targeted users

« There is not data available for the SWISSPASS Card, but the data concerning the use of the rail in Switzerland shows the following behaviours in term of mobility choice:

In Switzerland, the daily distance per person is around 37Km, 4km more than the year 2005.

The model split is:

74% private car

6% walking or bicycle

3% Land Public Transport

16% Rail

The public transport use has been increased from 16% in the year 1998 to close to 20% the year 2011 »[82].

Ex-ante/current situation

Before the progressive implementation of the SwissPAss Card in August 2015, more than half SBB customers renew their travelcards seamlessly, being the renewing process an annoying process.

Thanks to the SwissPass, traveller no longer has to think about renewing his travelcard and so he/she always stay mobile. SwissPass Card is valid for several years and the owner travel card (AG or Half Fire) is renewed on the same card, helping to protect the environment, as the number of cards produced and distributed decreased, all in the name of sustainability.

Cause-effect relation hypothesis

The fare integration has permitted a more comfortable use of the public transport, as with one single ticket you can cover all your travels on public transport. However, there are other inputs that affect to the public transport use percentage. Those are the service frequency and the connection with other transport modes, especially the bus:

Frequency: Services on the Swiss railway are integrated with each other and with other forms of public transport. Unlike its European neighbours, Switzerland has not developed a comprehensive high-speed rail network, with the running speed on its one stretch of relatively high-speed line being 200 km/h. Instead, the priority is not so much the speeding up of trains between cities, but the reduction of connection times through the nodal system. Journey times

[82] Ibid.

on main lines between hubs are multiples of 15 minutes so that on the hour or half-hour all trains stand in the main stations at the same time, thus minimising connection times.

Connection: Rail timetables are integrated with the extensive network of postal buses (fr. Car Postal ger. Postauto) which serve both plain and high mountain villages. For example on postal bus line 12.381 the 10:35 from the mountain village of Les Haudères is planned to arrive in the regional city of Sion at 11:20 where a train departs the station (located next to the bus station) at 11:24 for Visp. Indeed, it is a familiar sight to for the postal cars to be already lined up outside the station for the arriving train. From this perspective, the Swiss rail network functions as the core of a wider public transport network.

Al these circumstances have permitted an important increase of the use of the public transport, in a reality where journeys distances have also increased.

Notes and references

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiUtYSTvMzKAhUKthoKHVAtCsAQFggiMAA&url=http%3A%2F%2Fwww.are.admin.ch%2Fdokumentation%2Fpublikationen%2F00016%2F00433%2Findex.html%3Flang%3Dfr%26download%3DNHzLpZeg7t%2

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj2sIKzvMzKAhWKiRoKHWTlDqoQFggiMAA&url=http%3A%2F%2Fwww.bfs.admin.ch%2Fbfs%2Fportal%2Ffr%2Findex%2Fnews%2Fpublikationen.Document.171396.pdf&usg=AFQjCNEYOCEFeIpa47JHqYe

https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj_zvq-vMzKAhXJPBoKHbwDDZIQFgggMAA&url=http%3A%2F%2Fwww.voev.ch%2FT600_f&usg=AFQjCNEutYeTLbMvsnk9IPq7IuTIFGSCag&sig2=A3-WrW43NhgpTAoWHCoMeQ

OV-Chipkaart

Tariff model/initiative/policy analysed

- responsible transport operator/municipality: Trans Link Systems

- city/location where the tariff model/initiative/policy is in place; All the public transport of the Netherlands

- starting date of implementation: First introduced in the Rotterdam metro in April 2005,It fully replaced the national strippenkaart system for buses, trams and metros in 2011 and the paper ticket system for rail travel in July 2014.

Description of the Tariff model/initiative/policy

« Soring rules:

The OV-Chipkaart works in two ways; as a stored-value card or as storing of "travel products". There are also three types of cards; dispensable, anonymous and personal. In 2012 it was introduced Business type.

Boarding fare: If you travel on credit, the boarding fare will be debited from your card when you check in. When you check out, the boarding fare will be refunded and you will be charged for the number of kilometres you travelled. If you do not check out, you will pay the full boarding fare.

Travel products:

- Travel on preloaded credit (e-purse): all mode of transports. Anonymous and personal OV-Chipkaart.

-Single or return journey: Rail. Dispensable.

- Weekend unlimited travel year pass: Rail. Personal.

- Off-peak discount plan: Rail. Personal.

- One-hour unlimited travel: Metro, tram, lightrail, bus. All types of OV- Chipkaart.

- Three-day unlimited travel: Metro, tram, lightrail, bus. All types of OV- Chipkaart.

- Student unlimited travel weekdays: All modes of transport. Personal OV-Chipkaart.

Discounts:

-3 years and younger: Free

- 4-11 years: Train (free with Kids Vrij subscription), Other transports (34% discount)

- Older than 60 years: Train (40% discount)

- Older than 65 (40% discount) Other transports (34% discount)

Transport operators municipalities partnerships:

Tranpsot operators: Netherlanden Spoorwegen, Arriva, Veolia, GVB Gemeenteljik Vervoerbedrijf, RET Rotterdamse Elektrische Tram, HTM Haagsche Tramweg Maatschappij »[83].

Targeted users

« Identified users current behaviour in terms of mobility choices.

Car (driver): % 33

Car (passenger): % 14,7

Train: % 2,1

Bus/Tram/Metro: % 2,7

Motobicycle: % 0,8

Bicycle: % 26,1

On foot: % 19,2 »[84].

Ex-ante/current situation

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[83] http://abstracts.aetransport.org/paper/download/id/3419

[84] Ibid.

Travellers had the choice between a wide range of paper tickets with different fare levels.

The fare price was amongst others dependent on distance travelled (the number of zones (regional public transport) or the number of train kilometres), frequency of travel (e.g. monthly travel passes), the purchase location, age of the traveller and time of day (railways).

There was no fare integration between regional public transport and national railways.

Results achieved/forecasted

« Description of results achieved since the introduction of the tariff model

- Offer ease & convenience to passengers
- Improve public safety & combat fraudulent travel
- Provide up-to-date management information
- Reduce operating costs & facilitate network optimization
- Enable market liberalisation
- Opportunities for fare differentiation

Description of results achieved compared to envisaged expected impacts and results (defined at the moment of tariff model

- Travel time savings from ticket purchase
- Less molestation & harassment for personnel
- 'Spin-off' benefits for employers e.g. sick leave
- Increase revenues & reduce fraudulent travel
- Savings from the paper ticketing system
- Opportunities to rationalise network & services
- Possibilities for refinements & fare differentiation

Description of the extent, scope of the change, emphasizing if the change has been positive or negative.

Card use is demonstrated to be fully operational & stable

- Ticket distribution in the region is on course as agreed
- Proven & shown to be flexible in the transition for all passengers
- Student OV-CK are readily available to all SOV-holders
- Season tickets are embedded into the OV-CK
- Companion to handicapped passenger and people eligible to free

travel will be issued with appropriate travel document

- Security & safety must be in order
- Fare for the average passenger in the service area must be revenue neutral in the first year of transition »[85].

[85] Ibid.

Cause-effect relation hypothesis

Description of the hypothesis on a cause-effect relation between existing tariff models/initiatives/policies and users mobility choices and demands, in order to understand how specific tariff models can influence or push passengers to prefer and choose specific transport modes.

- Window of opportunity: 'win-win' situation
- Successful migration nationwide usage
- Co-ordinated efforts by all parties concerned
- Close partnership between PTA & operators

Willingness to introduce smartcard

Readiness to optimize network & services

Effective communication to staff + passengers

Imaginative & effective marketing

Notes and references

http://abstracts.aetransport.org/paper/download/id/3419

http://www.emta.com/IMG/pdf/brochure.pdf

http://www.internationaltransportforum.org/Proceedings/KOTI2012/CHEUNG.pdf

https://www.translink.nl/en-GB/Home

https://www.ov-chipkaart.nl/home-1.htm

http://www.iamsterdam.com/en/visiting/plan-your-trip/getting-around/public-transport/public-transport-chip-card

T-Mobilitat

Tariff model/initative/policy analysed

- responsible transport operator: TMB (Transports Metropolitans de Barcelona) & ATM (Autoritat del Trasnport Metropolitá - Barcelona);

- location where the tariff model is in place: Barcelona metropolis, 296 cities divided in 6 zones;

- starting date of implementation: Second semester 2016 in Zone 1 (Barcelona), and then progressively.

Description of the Tariff model/initiative/policy

« 296 cities from Barcelona Metropolis are included under T-Mobilitat tariff model, at the same time as 74 transport companies.

This new tariff model will be introduced to obtain a more sustainable mobility in the region and to offer a better public transport service in Barcelona and its metropolis, as different transport means could be used with a single travelcard (tube, city-urban buses, tram and different rails).

These are the integrated transport tickets:

T-10: Multi-person, timed ticket for 10 integrated journeys on all modes of transport

T-50/30: Single person, timed ticket for 50 integrated journeys on 30 consecutive days

T-70/30: Multi-person, timed ticket for 70 integrated journeys 30 consecutive days

T-MONTH: Personal, non-transferable ticket for an unlimited number of integrated journeys on 30 consecutive days

T-Trimester: Personal, non-transferable ticket for an unlimited number of integrated journeys on 90 consecutive days

T-Young: Personal, non-transferable ticket for young people aged under 25 for an unlimited number of integrated journeys on 90 consecutive days

T-Day: Single person ticket for an unlimited number of integrated journeys during the day

T-12: The T-12 is a transport card for children aged 4 to 14 so that they can make, free of charge, an unlimited number of journeys on the public transport network of the integrated tariff system within the same tariff zone where the child lives.

Each travel card has six different prices (except T-12), depending on the zones passed through. With integrated tickets, you can make up to three transfers during the same journey. You must stamp the ticket each time you transfer.

The maximum time allowed to make a journey is 1 hours and 15 minutes for tickets covering 1 zone. This increases by 15 minutes for each additional zone »[86].

Targeted users

« Data 2014:

[86] http://www.tmb.cat/es/home

Total Barcelona residents journeys in a workday: 5.202.227

Modal split: 50,1% walking or bicycle; 19,7% private car; 30,2% public transport.

Tariff model Choice: (travellers in millions)

Tube: 2014

-Single ticket: 11,0

-T10: 182,2

-T4:22,2

-T50-30:42,2

-T-MONTH: 36,2

- Other: 82

Bus: 2014

-Single ticket: 4,8

-T10:69,8

-T4: 22,8

-T50-30: 15,60

-T-MONTH: 13,9

-Other: 51,5 »[87]

Notes and references

http://www.tmb.cat/es/home

http://www.bcn.cat/estadistica/castella/dades/anuari/cap15/C1510030.htm

[87] Ibid.

Appendix E BONVOYAGE Glossary

The BONVOYAGE Glossary is one of the preliminary documents circulating among partners involved in WP4 since the beginning. In fact, the Glossary has been a fundamental tool for sharing preliminary ideas and basic concepts perceived as deeply heterogeneous according to skills and expertise of different partners. Since WP4 is one of the most innovative and advanced work package in the BONVOYAGE project, setting up a suitable dictionary has been a mandatory step in developing models and methods being able to cooperate each other.

Table 21 lists and describes the terms considered relevant in the work package 4 and adopted over all the deliverable. Please consider that the BONVOYAGE Glossary is a public document made available by the official project web site[88].

BONVOYAGE GLOSSARY	
TERM	DEFINITION
Bundle	A bundle is a trip chain for a seamless journey constituted by n Uni-Modal travel links. Formally, a bundle i, i.e., B_i, can be defined as: $B_i \coloneqq \{(o_{i1}, d_{i1}, mode_{i1}), (o_{i2}, d_{i2}, mode_{i2}), (o_{i3}, d_{i3}, mode_{i3}),$ $\ldots, (o_{in} - 1, d_{in} - 1, mode_{in} - 1), (o_{in}, d_{in}, mode_{in})\}$ where: o_{ij} is the origin of the link j in the bundle $i, j := 1, \ldots n$ d_{ij} is the destination of the link j in the bundle $i, j := 1, \ldots n$ $mode_{ij}$ is the transportation mode used from the origin o_{ij} to the destination d_{ij} (rail, ship, plane, car, local public transport, taxy, bicycle, walk, truck) such that $o_{ij} + 1 == d_{ij}, j! = n$
Data model	A logical representation of entities and relationships between two (or more) entities
Inter-modal transportation	Transportation of passenger [freight] involving multiple modes of transportation (rail, ship, plane, car, local public transport, bicycle, walk, [truck]) where: (i) each mode is offered by a different transport service provider through a specific vehicle [container]; (ii) the bundle of transport at services is considered as one process - addressing the linkages, interactions and movements among modes of transportation - in a combined trip chain for a seamless journey
Membership Management	This functional module is in charge of monitoring and recording the user's usage of the BONVOYAGE platform in order to collect and update user scores according to the current score assignment policy. It must also return the ranked list of the best rated scores as well as the list of Awards for a given user.
Multi-modal transportation	Passenger [freight] involving multiple modes of transportation [rail, ship, plane, car, local public transport, bicycle, walk, [truck]], where each mode is offered by a different transport service provider through a specific vehicle [container]

88 http://bonvoyage2020.eu/bonvoyage-glossary/

Multi-objective programming problem	Mathematical optimization problem involving more than one objective function to be optimized simultaneously
Planning and travel itinerary management	This functional module is in charge of computing optimal or near-optimal route alternatives from a given origin to one or more destinations by taking into account query parameters, user constraints and user commitments. It also monitors and detects the occurrence of dynamic events and chooses whether to calculate a new set of route alternatives, in case such dynamic events severely affect the previously calculated routes or even make them unfeasible (e.g., the previously calculated routes turn out to be not possible anymore, will be delayed, will have to be improved, etc.).
Price discrimination	The practice of setting different prices for the same good or the practice of selling two varieties of a good to two buyers at different net prices, the net price being the price (paid by the buyer) corrected for the cost associated with the product differentiation
Price of the bundle	The price of a bundle B_i, i.e., p_i, is the final price that the functionality BUILD_PRICES gives as output in relation to the bundle B_i Each bundle B_i is characterized by a unique final price p_i
Group Pricing	Price discrimination practice that implies that the same good is sold at different prices to different groups of consumers by the same supplier
Quality of Experience	Quality of Experience (QoE) is the subjective perception of the end user, i.e. the perception that user has about the quality of the service offered by BONVOYAGE platform with respect to a specific service chosen by user
Tariff Scheme	Nonlinear pricing rules according to which the price of each multimodal trip of BONVOYAGE users is built. It takes as input the tariffs charged by transport operators on each origin-destination trip and it builds the price of the multimodal trip on the basis of two dimensions: the profile of the user and the features of the trip and it is aimed at reducing externalities (e.g., congestion and pollution)
Travel	In the user perspective, travel is represented by a user request in the BONVOYAGE platform, i.e. query containing a departure point, an arrival point and a departure time; it can include other travel requirements and preferences expressed by the user
Travel objective/target management	This functional module allows the user to define an objective which will be properly taken into account by the "Planning and travel itinerary management" module. It also allows the user to monitor her/his progress towards the achievement of such objective as well as to accumulate points from achieved targets.
Transport operator's tariff	Tariff charges by the transport operators for a single origin-destination trip
Travel solution	Travel plan proposed by the functionality "Trip planning" (module Planning and travel itinerary management); the travel plan is the answer to the user request (namely, the travel) and consists of all practical information allowing the user to implement a travel
Travel solution management	This functional module is in charge of managing travel solution data. Such management is realized by associating passengers with the requested travel solutions, by "building" prices for all tariffs, offers, promotions and discounts and by allowing any transport operator to modify/update such tariffs, offers, promotions and discounts. As a result, this functional module is in charge of informing the BONVOYAGE platform about the travel solutions that have been chosen, on the basis of a given set of search parameters and of given user profiles.
Trip	In the BONVOYAGE perspective, trip is the technical name indicating the solution to a user request (namely, the travel); in this sense, travel solution and trip are synonymous
Trip Control	The function of ensuring in time that the trip solution suggested to the BONVOYAGE user is feasible and in line with his/her preferences. That is achieved through proper re-computation of the travel solution after one or more monitored parameters suggest that the current solution is

	no longer feasible or good in the above sense.
Trip Planning	The functionality of the module Planning and travel itinerary management being in charge of calculating the profile based ranked list of travel solutions with respect to a user request, i.e. a travel
Uni Modal Link	Uni Modal Link is defined as a single short trip from which the overall Travel is composed; each uni modal link is characterized by a single transport modality
User	End user of the BONVOYAGE platform who (i) looks for a single travel (for present moment or a future one) for him/herself or another user; (ii) asks BONVOYAGE for a freight transportation service (for present moment or a future one) for him/herself or another user
User behavioural attributes	A set of N attributes characterizing the behaviour of a user pre/on/post trip with respect to selected and implemented travel solution according to the User Data Model (UDM) e.g., selected travel solution, preferred transport modality, willingness to pay, etc.
User Data Model	A logical representation of entities and relationships between two (or more) entities describing the user from the personalization point of view
User experience	The experience made by the user while implementing a travel
User feedback	User feedback is an evaluation (e.g., comments or points) by the user about the different services provided by the platform; the profile identification (see profiling) can rely on the user' choices through feedback, and can be used to provide personalized transportation planning and other services
User feedback and profile management	The User Feedback and Profile Management is a module in the BONVOYAGE Reference Architecture that is in charge of collecting, storing and reacting to the user feedbacks and of managing their profile
User Profile	A User profile is a region in the N dimensional space made by the user behavioural attributes
User Profiling	Automatic identification of a user profile, i.e. the region in N dimensional space to be associated to a given user, the user profile being selected in a set of pre-identified user profiles (training phase)

Table 21 - BONVOYAGE Dictionary