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DORA: An Experimental Platform for Smart Cities

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Abstract (LUT). DORA (Door-to-Door Information for Airports and Airlines) is a mobility platform that aims to seamlessly integrate the real-time multimodal information flows for air mobility from airports, airlines, and regional transport. The main goal is to optimise the total travel time of air-passengers encompassing navigation from the point of origin to the departure airport, navigation within airports and finally navigation to the final destination. DORA offers a unified solution by assimilating scheduled and real-time services of all flights, terminal events (departure gates, luggage-belt, security gate), and regional transport modes. The mobility platform uses the assimilated information to assist in a door-to-door journey planning, to book or purchase tickets for regional transport of cities, and to monitor the trip in real-time. This paper presents the DORA platform and modules that enabling the concept of smart city.

Keywords: Experimental platform · Air passengers · Airports · Airlines · Public transport · Multimodal transport · Indoor navigation · Trip monitoring

1 Introduction

Since the early 90s, the concept of smart cities has been considered as the future of urban development [1]. A smart city is modelled from different perspectives and often debated for a widely accepted definition. The most eminent and frequently deliberated features are networked infrastructure, business driven development, social inclusiveness and a focus on the natural environment [2]. Urban mobility is connected to all four of these features and is gaining attention from industry, policymakers and scholars. Therefore, the technological mobility solutions with profitable potential are justifiable [3]. With economic and technological developments, air mobility has expanded and reached considerable population in developed countries. The European air mobility plays an essential role in linking people, exchanges for business, leisure and culture

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within Europe and worldwide. The EU has 918 million air passengers in 2015, a growth of 4.7% from 2014 [4]. Air travellers spend considerable time in gathering information from assorted sources such as transport options and schedules between city and airport, airport navigation maps, and ticketing to commence the journey. The solution to minimize the efforts and time of air travellers is investigated through the DORA project and presented in this research paper.

The project aims to develop a seamless multimodal mobility information system that helps in optimising the total travel time of air passengers starting from point of origin to departure airport and from arrival airport to the final journey's endpoint. It includes not only the outdoor part of the trip but also the indoor part in airports. To reduce the total travel time of an average European traveller, DORA innately combines information on flights, all available modes of cities' transport and provides optimized routing and navigation to and inside airports directly to passengers' handheld devices. Moreover, the DORA platform has capabilities to integrate real time information from airports (flight information: departure and arrival times, gate information; security check queues, etc.) and ground transport system (incidents and delays on route, rerouting) to ensure timely arrival of air passengers on departure gates. To support the objectives of time optimisation within airports, the DORA platform provides technologies and services to ascertain waiting times at security check queues and estimate indoor location for use in indoor navigation (Fig. 1).

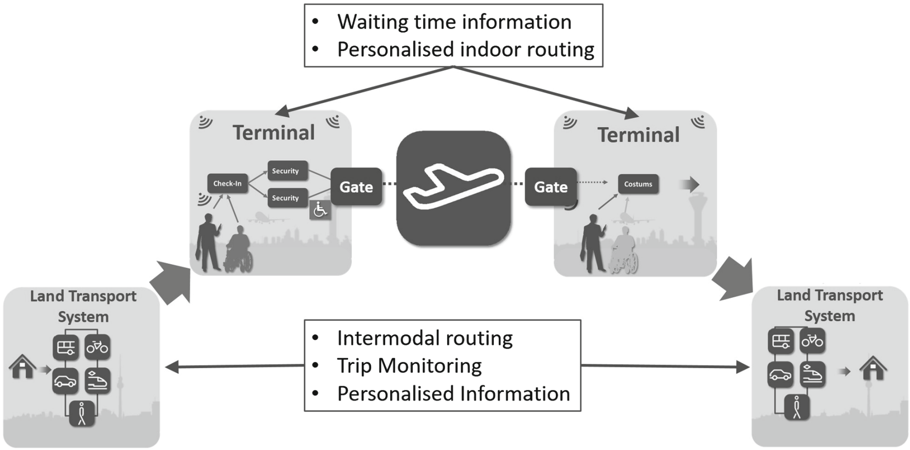

Fig. 1. DORA functionality schematic

The DORA system is under implementation between the respective airports of Berlin (TXL, SXF) and Palma de Mallorca (PMI) and real tests are envisioned to start in September 2017. The DORA platform architecture has been developed using widely adopted information technology standards to promote future expansion or third party integrations through open Application Programming Interfaces (APIs).

2 DORA Platform

The DORA platform is the central system layer integrating the different mobility data and services in order to provide those to the DORA end-user applications. With its open platform approach DORA is easily transferable to other cities and airports, and supports a straightforward integration of all transport modes and local urban mobility services such as public transport, car- and bike-sharing, taxis, charging infrastructure, ticketing, car rentals or parking facilities over the open DORA interface. The open platform is non-discriminatory as well as provider-independent and can due to its transparent and multimodal approach be harmonized with the transport strategies of cities.

All local urban mobility information and services in the both project test sites Berlin and Palma de Mallorca have been integrated and bundled in the DORA city nodes, which provide the landside mobility information for the overall door-to-door system. In this process, the transferability of the data integration approach has been successfully demonstrated in both test sites. To make all mobility information and routing services consistently available for the DORA door-to-door trip planning system, a DORA API has been specified which allows accessing all services and data sources in a common format. All cities can join and benefit from the DORA community by providing local mobility information in the defined API format.

Based on this API a DORA marketplace has been set up which will enable third parties (e.g. public transport authorities, travel portals, airports, airlines, etc.) to use the entire DORA system or single components of it for their own mobility information strategies. The DORA architecture consists of three layers: local city nodes, a service platform and end-user applications.

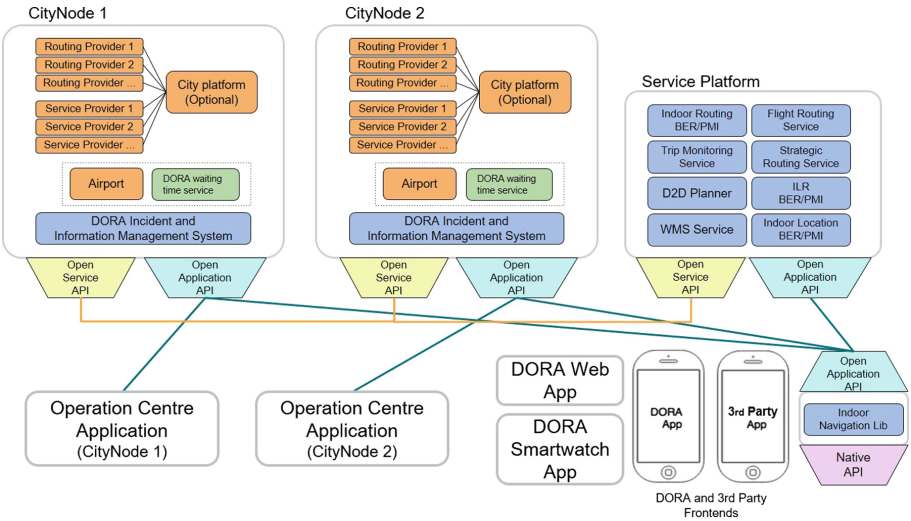

Fig. 2. DORA system architecture

The DORA service platform contains all central, not test site specific DORA services, that contribute to the route calculation, information and monitoring. Unlike the City Nodes, the DORA service platform can be located in a cloud environment since it is independent from local infrastructure and hardware. Figure 2 shows the City Nodes, the service platform as well as the end-user applications, and how they are interrelated. The service platform is connected to the City Nodes via the DORA Open Service API. Through this interface, the central platform services receive the local data and services required for the door-to-door route calculation and information from the City Nodes. The indoor router and the landside router, for instance, receive the required waiting time detection data and the local mobility information respectively via the Open Service API.

Different applications will be connected to the system. These include a Web-GUI, mobile applications as well as an Operation Centre Application. All applications, both internal and third party applications, communicate with the service platform and the City Nodes over the Open Application API. This interface is especially designed to meet the requirements that applications have regarding communication processes. Over this API to the DORA service platform the applications request and receive the central door-to-door information provided by the Door-to-Door Journey Planner. From the City Nodes the applications receive, for instance, detailed information on specific POIs of a route, for example on relevant car-sharing vehicles or parking facilities.

The DORA Open Protocols (Service API and Application API) developed within the project will enable easy integration of additional City Nodes into the DORA system and of DORA services into third-party applications. They will provide a state of the art open data exchange format for mobility services and applications.

2.1 Outdoor Module

Mobility outdoors is mainly handled by two Central Service components: (i) Intermodal Landsite Router for the intermodal landside part and (ii) Flight Routing Service for the flight part. Multimodality is probably the most relevant and challenging feature for the outdoor part of a trip, as there are many different ways (e.g. public or private transport) to get from one intermediate place to another. However, at the same time it is also a driven factor for potential business cases.

The mobility options of a city are included in the landside routing features covering all available transport modes, such as Car, Car sharing, Public Transportation, Walking and Bike. Regarding data for the road network, the entire routing system in general and the specific local modal routers in particular, are provided with intended and real time traffic situation as well as planned events and construction sites. This is realized in both DORA test sites and no manual data handling was necessary for adapting them to the Door-to-Door Routing. In addition, the local modal routers will use unforeseen accidents and other not plannable real time events as well. That means all plannable and unforeseen real time events are covered in DORA. With regard to the public transport network, the same granularity has been used for Berlin and Palma de Mallorca. With regard to the modern, flexible mobility options, listed below:

- Station based bike sharing service
- Free-floating vehicle sharing service
- Free-floating other sharing service.

The real departures and arrivals of the flights in combination with actual terminal and gate information are available just 48 h (Palma airport) and 24 h (Berlin airports) in advance. The Flight Routing Service uses the data provided by the local Departure and Arrival Services from the airports in both test sites. The situation looks different if the Flight Routing Service is requested earlier in advance than mentioned. In that case, the accompanying information is completely unavailable for check in, luggage drop off or gate information at the departure airport as well as luggage belt information at the arrival airport. Therefore, default average values have been collected. In the entire routing planning system, default values and scheduled time plans require different types of data and services in comparison to real time requests or trip plan updates during the current trip.

Figure 3 depicts a web (desktop) interface where the traveller can schedule in advance the trip considering different mobility options. The look-and-feel is similar to the mobile app, which is mostly used in real time situations.

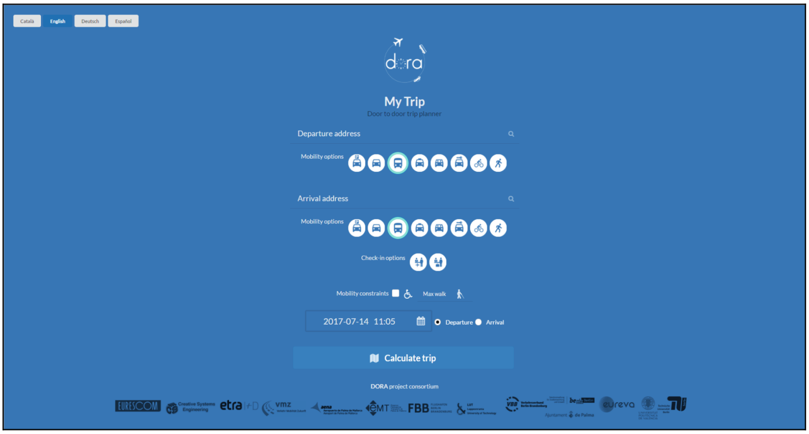

Fig. 3. Trip planning - mobility options in DORA web GUI

2.2 Indoor Module

The indoor part of DORA involves all services that may assist the traveller during the trip inside the airport. From the user perspective, it mainly relates to indoor location and navigation, but there are other services to be considered:

- Indoor maps: indoor maps are an essential part to present a friendly User Interface (UI) during indoor location and navigation modes. In DORA, there has been a conversion process from the initial design (CAD) maps into the resulting vectorial web representation (SHP) that can be offered via a standard OGC WMS (Open Geospatial Consortium Web Maps Service).

- Indoor Data: Indoor data covers all POIs (Points of Interest) available in airports. It includes not only the location of such POIs but also additional information (name, category, business hours, etc.). A key aspect of this service is that it is not static and may change according to changes in airports.
- Monitored data: Some mechanical POIs (elevators, travellators and escalators) and incidents need to be continuously monitored in order not to guide the traveller through a POI that may be out of service. Additionally, waiting times at baggage check-ins and security checkpoints, if available, need to be integrated in order to provide the fastest route to the traveller.
- Trip monitoring: this is an overall service (outdoor, indoor) that permanently monitors whether the traveller will be able to fulfil the trip in time alerting the user in case of incidents that may affect its initial travel plan.

The indoor location service is able to provide an acceptable accurate position inside the airport. DORA utilizes a Commercial Off-The-Shelf (COTS) scheme using available wireless infrastructure as well as mobile phones. An increasing number of airports are equipped with Wi-Fi infrastructure along with BLE (Bluetooth Low Energy) beacons. The indoor location service merges both technologies (readily available in modern mobile phones and tablets) in order to provide a better estimation of the traveller's position. Furthermore, in special areas that have weak or no wireless signals, there is also the possibility to deploy DORA Wi-Fi beacons, a small device easy to install without interfering with other Wi-Fi networks, and provides a stable signal strength. Initial results (with BLE technology and Wi-Fi combined) have shown superior performance compared to the estimation of the internal geolocation plugins available in mobile devices, as depicted in Fig. 4.

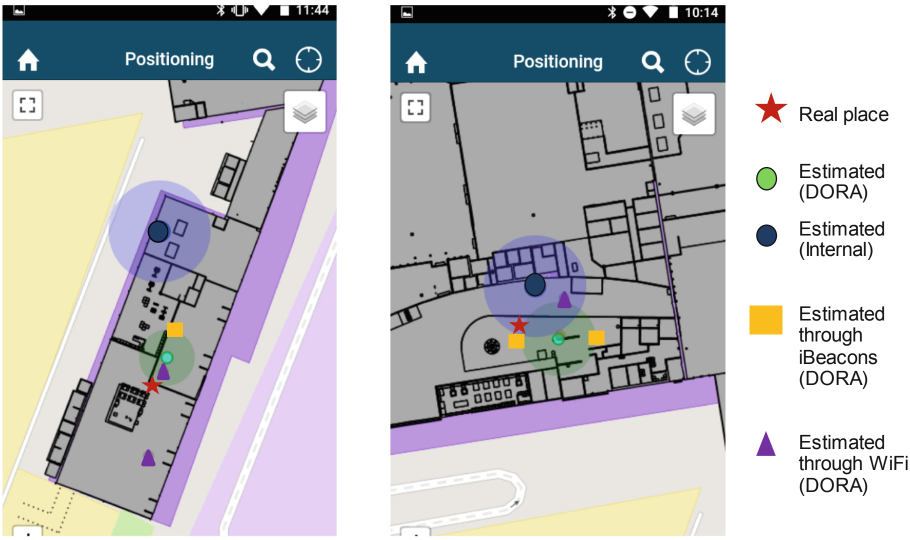

Fig. 4. Positioning estimations in different places at TXL airport

The indoor router service provides a path from an origin node (typically the current position of a user) to a destination node according to certain settings. Such settings allow travellers to search for the shortest path in terms of duration or distance. All implied nodes in the path (origin, destination and transitional ones) are georeferenced, and can be displayed in an indoor map. The usage of transitional nodes allows setting up intermediate points along the path that correspond to certain events (e.g. check-in, baggage belt, car rental) a traveller has or wants to perform in the airport.

In order to provide real time navigation, the indoor navigation graph (a set of nodes and weighted edges) is constantly updated according to the obtained real time monitored data. This may cause unavailability of certain nodes during a certain time (e.g. due to dynamic incidents) or that the time to pass a security checkpoint may increase the overall travel time.

The indoor router service provides a complete 'mobility' response considering the transition across different terminals, the use of different POIs, such as mechanical POIs (e.g. travelators) and transitional POIs (e.g. baggage belts and rental car services), as depicted in Fig. 5. Furthermore, the indoor service provides turn-by-turn indications as guiding points in order to guide travellers on their way within airport terminals.

Besides real time navigation, the indoor service also offers scheduled navigation by the time the traveller is planning the trip beforehand (few days in advance). In this case, mechanical POIs are not considered, but predictive waiting time values are used as well as scheduled incidents if they fall under the same timeframe.

The integration of outdoor and indoor router is performed by means of sharing a set of transitional nodes for each airport in order to provide a seamless mobility transition for the traveller. In fact, internal routes within the airport (e.g. shuttles to nearby parking sites) are also covered by the indoor router service.

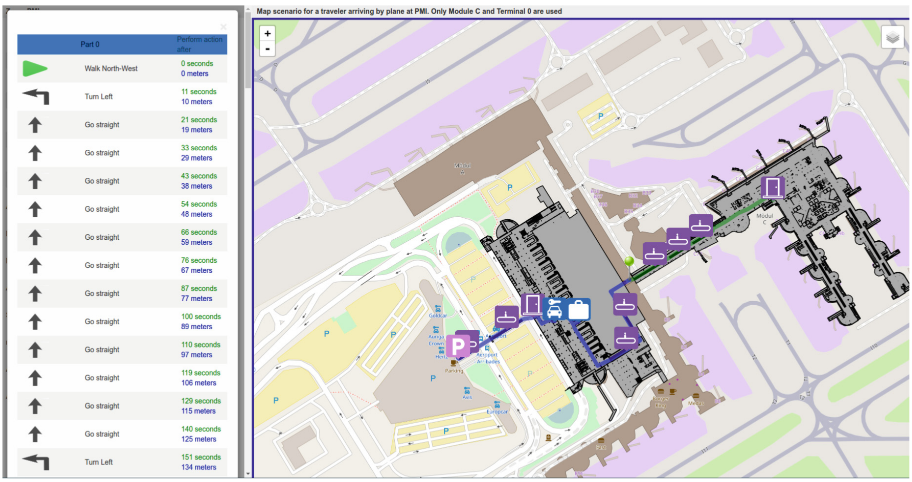

Fig. 5. Routing path example at PMI airport

2.3 Door-to-Door Journey Planner

The core service in the DORA system will be a seamless and integrated Door-to-Door Journey Planner, which integrates existing transport mode specific real-time information services in one single intermodal routing platform for air- and landside transport. This service provides the DORA user with the optimal door-to-door route to a given cost function. For the calculation of the overall route, the Door-to-Door Journey Planner integrates the three DORA routing services for the landside, the terminal and the flight part of the trip. It combines the results of these three routing services to suitable door-to-door route suggestions. The route calculation also takes into account personal mobility preferences so that individual requirements of passengers and specific user groups, for instance, mobility impaired people, travelling families or business travellers, can be met. The Door-to-Door Journey Planner finally provides the route suggestions to the DORA frontends (see Fig. 6).

The route chosen by the user is monitored by the Trip Monitoring Service. In case of disruptions in the public transport network or if there are gate changes or flight delays, the user will be informed about these issues and provided with alternative route suggestions if possible.

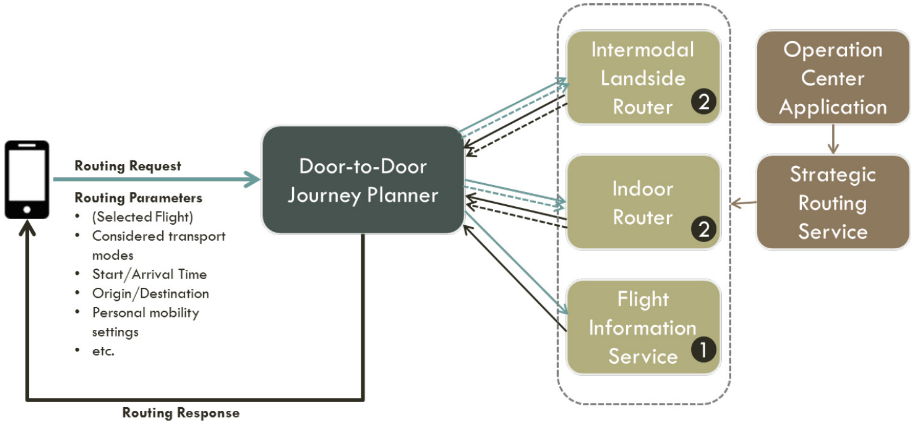

Fig. 6. Door-to-Door Journey Planner

3 DORA Platform Testing Overview

The airports of Berlin (SXF, TXL) and Palma de Mallorca (PMI), respective regional public transports, and passengers (real time end users) are selected for the testing of the DORA platform in realistic environments. The test duration is of one year starting from September 2017 and aimed to recruit at least 500 passengers. These two cities together handled more than 50 million air passengers in 2015 that is roughly equal to 13% of intra-EU flights [4, 8, 9]. There are approximately 12 flights on average per day between both cities, and more than 700,000 passengers in 2015 travelled between these two destinations (Fig. 7).

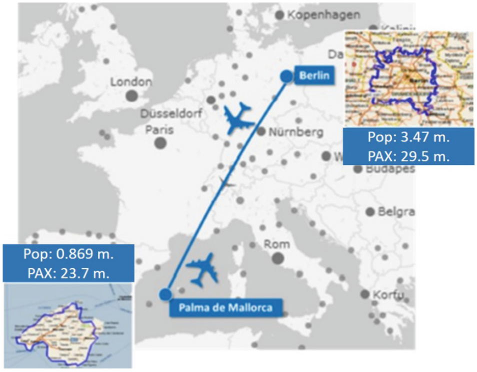

Fig. 7. DORA test locations

A free smartphone application of DORA will be available for android and iOS. This application will be evaluated based on the feedback from user questionnaires, performance of DORA web GUI, and evaluation of Operation Center Application. These tests will help in evaluating the user-friendliness, user interfaces, app performance on different operating systems and devices, functionalities, and improvement ideas. The gathered information will further used to improve the DORA platform and highlighting the results to actors interested in this platform for exploitation.

4 DORA Business Framework

DORA business framework consists of the business model, decisions connected to ecosystem's characteristics and elements, and decisions pertaining to sustained cooperation and innovation within the ecosystem. The framework considers the requirements of a business, mobility trends, and value proposition to each core stakeholder.

A business model illustrates the approaches of an organization to create, deliver and capture value [10]. DORA's business model is founded on the sustainable value creation and fair value distribution among actors with idiosyncratic requirements as well as the competitive strengths of the DORA solution. This basis led to the creation of a three-stage progressive business model, starting from technology licensing through mobility information services to third parties and eventually to an ecosystem management and coordination system. The DORA platform utilizes a modular suite of technologies, which potentially have multiple applications or usability. Licensing of such technological modules and their developments may provide a stream of revenue. The second model based on mobility information services utilizes standardised DORA platform and technologies to offer individual or bundled services to third party app developers through an API. The final model utilizes principles of a business ecosystem to capture, manage, and deliver value using mobility information to several customer segments. A business ecosystem signifies the cooperation and competition among group of organizations, which pooled their capabilities and resources to develop specific solutions for the market [11].

In addition to the business model of the hub firm managing the DORA ecosystem, decisions need to be taken and anticipated that account for the ecosystem development. These decisions will be touching the aspects of ecosystem design, governance and health. Therefore, it is safe to conclude that the framework extends beyond considering the needs of only the hub firm in isolation [12].

The framework also considers the longevity and sustainability of the solution and the ecosystem that supports it by explicitly considering the requirements for continued collaborative innovation at the ecosystem level as well as its components. This requires coordination efforts from the hub firm (Fig. 8).

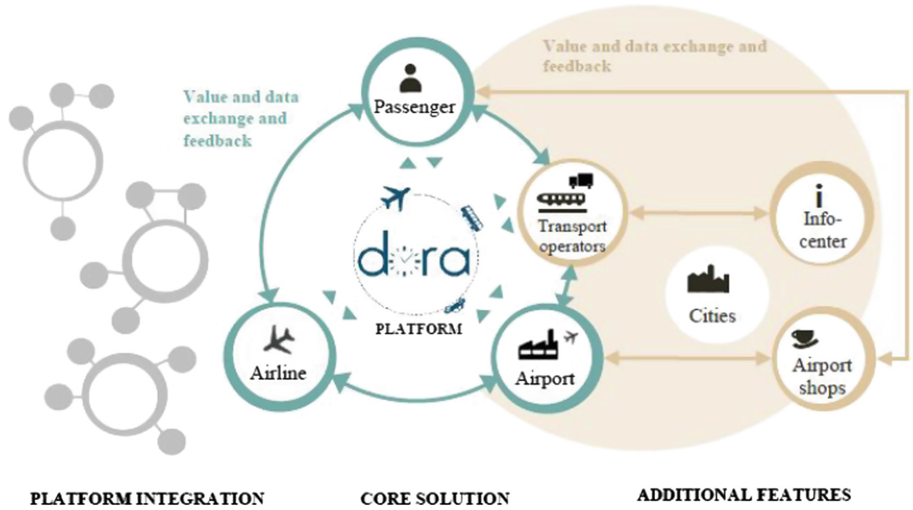

Fig. 8. DORA ecosystem and value flow [13]

DORA business framework consists of core (passengers, airline, airport, and transport operators) and potential extended stakeholders (cities, airports shops, information centre, businesses in shared economy, and technology platforms). The DORA business model offers value creation in multiple ways and distributes value among all the involved stakeholders, which cooperate to manage costs in lieu of information and revenue.

5 Conclusion

The emerging trends and preferences in mobility services driven by technological developments (ICTs, Internet of Things, etc.) and societal requirements (environmental sustainability, sharing economy) demands new solutions and services. The DORA mobility platform integrates on a scalable system various information sources from different mobility operators in order to provide the best multimodal trip recommendation according to user preferences. The management of the trip encompasses both outdoor and indoor parts of a journey and considering the flight between European cities (Berlin and Palma de Mallorca).

The architecture of the DORA system is modular and can be easily transferred, extended or adjusted to meet not only the mobility requirements of any smart city but also the requirements of potential collaborators operating within the city. This open architecture enables a framework encompassing principles of business models and ecosystems that empower the value chain of mobility trends such as Mobility as a Service (MaaS).

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