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Main author(s):	Giuseppe Ciulla (ENG), Filipe Aranda de Sá (POR), Jaime Ventura (POR), Sofia Peres (POR), Ignacio EliceGUI Maestro (UC), Eunah Kim (UDG), Cédric Crettaz (MI), Paolo Fosci (MIL), Harrie van Zon (HW), Vincent de Waal (HW), Kaisa Sibelius (FVH), Antti Nurminen (Aalto), Adrian Slatcher (MCC), Amir Khorasani (MMU), Koen Kerckhofs (DigiPolis), Dauwe Vannoppen (Rombit)
Internal reviewers:	Andrea Gaglione (DigiCat), Thomas Gilbert (AI), Reza Akhavan (FCC), Martin Brynskov (AU)
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Executive Summary

SynchroniCity project aims to open up a global IoT market to help both cities and businesses developing shared digital services to improve quality of life and the development of local economies.

The aim of this deliverable is to report the initial design of the applications belonging to the three application themes identified by SynchroniCity project: Human Centric Traffic Management, Multimodal Transportation and Community Policy Suite. These applications are designed and developed by the RZs and based on outcomes reported in SynchroniCity deliverables "D3.1 Documentation of service designs" and "D3.2 Suite of baseline implementations - basic". These outcomes are the baseline applications (that define the generic applications for each application theme of SynchroniCity project) and the baseline services (that define the reusable shared services that can be used as customizable building blocks to create the applications of the RZs).

In particular, this document provides an overview about applications of the RZs analysing their typical users, reporting the scenarios that describe their behaviour and how the users interact with them in order to achieve their goals.

On the basis of these information the general functional and non-functional requirements of the applications are reported; then, data sources useful to provide the expected functionalities are reported and described.

Finally, the specific architecture of each application is reported and described, in order to identify and analyse their internal structure and components, with particular emphasis on the baseline services that will be reused for their implementation.

It is important to underline that information reported in this document represents only a first draft of the design of the applications of the RZ; indeed, this process is still not completed and the final design of each application will be reported in SynchroniCity deliverable "D3.6 Customized IoT service prototypes for lead ref. zones – advanced".

Abbreviations

BLE	Bluetooth Low Energy
CPS	Community Policy Suite
D	Deliverable
EC	European Commission
ETA	Estimated Time to Arrival
ETL	Extract Transform Load
GDPR	General Data Protection Regulation
GTFS	General Transit Feed Specification
GTFS-RT	GTFS Realtime
HCTM	Human-Centric Traffic Management
iTLC	intelligent Traffic Light Controller
NGSI	Next Generation Service Interfaces
MQTT	Message Queue Telemetry Transport
NFC	Near-Field Communication
OTP	OpenTripPlanner
POI	Point Of Interest
RZ	Reference Zone
TLEX	Traffic Light EXchange
WP	Work Package
WT	Work Task

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1 Introduction

This deliverable presents the first results of Task 3.3 which aims to drive the design and implementation of the applications of the different Reference Zones (RZs) in the three application themes of the SynchroniCity project: Human Centric Traffic Management, Multimodal Transportation and Community Policy Suite. To achieve this goal, the baseline applications defined in Task 3.1 and baseline services defined in Task 3.2 have been tailored to address the specific needs of the Reference Zones, in order to be coherent with the specific characteristics of the RZs themselves. Furthermore, the customization of baseline applications services has been driven by the underlying IoT infrastructure and by the availability and accessibility of the data source in each RZ.

This deliverable is organized in three main sections, one for each application themes: Human Centric Traffic Management (section 2), Multimodal Transportation (section 3) and Community Policy Suite (section 4); finally, conclusions are reported in section 5.

For each application, the following sections are reported:

- **Reference scenarios**, providing information about the user of the applications and about the expected behaviour of the applications. They describe how the users interact with the application and how it reacts to the commands of the users. This information is reported in two specific templates, a template to describe the users of the application and a template to describe the scenarios in which they are involved in; these templates are reported in Table 1 and in Table 2 respectively.

Table 1: Template to report the users of the applications

User profile ID	User description
ID of the user profile.	Description of the user.

Table 2: Template to report the reference scenarios applications

Scenario title	Title of the scenario.
User profile	ID of the profile of the user(s) involved in the scenario,
Background	Background condition of the scenarios.
Objective	Description of the Objective(s) of the user(s) involved in the scenario.
Storyline	Description of the specific scenario: the action performed by the user(s) to reach their objective and how the application reacts to them.

- **Requirements analysis**, reporting the functional and non functional requirements extracted from the reference scenarios. This information is reported in a specific table and its template is reported in Table 3. Three different keyword (MUST, SHOULD and MAY) are used to classify each requirement, in order to identify those requirements that are mandatory, recommended and optional respectively. In particular: **MUST** keyword identifies mandatory requirements (a functionality that is mandatory and it must be implemented), **SHOULD** keyword identifies recommended requirements (a functionality that is strongly suggested to be implemented, but not mandatory) and finally **MAY** keyword identifies optional requirements (a functionality which implementation is only suggested).

Table 3: Template to report requirements of the applications

ID	Description
ID of the requirement.	Description of the requirement.

- **Available data sources**, reporting and describing data source that have been identified in each RZ in order to feed the applications and to provide the expected functionalities; the data model to represent the information provided by each data source in the application is also

reported. This information is reported in a specific table which template is reported in Table 4.

Table 4: Template to report data sources of the applications

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Title of the specific data source.	Description of the specific data source.	This column reports if the data source is an open data or an API to be integrated in the application.	Data model used to represent the information by the specific data source internally in the application.	Additional information that could be used for the specific data source.

- **Application architecture**, reporting the specific architecture of the applications, their internal structure, components and their relations, in order to depict how the applications are made; moreover, specific details are reported in order to describe the baseline services reused for the implementation of the applications and their role in the applications themselves. In this section, a dedicated table reports the baseline services involved in the application and the rationale for their use. An example is reported in Table 5.

Table 5: Template to report baseline services used in the applications

Name	Description
Name of the baseline service	Rationale: describe the reason why the application is using this baseline service.

It is important to underline that each RZ is not involved in every application theme, because their participation is driven by their specific aims and needs; in particular participation of RZ is so distributed (for a total of eleven applications):

- Human Centric Traffic Management
 - o Antwerp
 - o Eindhoven
 - o Milan
- Multimodal Transportation
 - o Carouge
 - o Helsinki
 - o Milan
 - o Porto
 - o Santander
- Community Policy Suite
 - o Carouge
 - o Manchester
 - o Porto

Finally, this deliverable represents an intermediate report about the design of these applications; their final version will be reported in deliverable "D3.6 Customized IoT service prototypes for lead ref. zones – advances".

2 Application Theme: Human-centric traffic management

Applications belonging to this theme aim to improve bicycle mobility in cities considering factors that can influence this means of transportation, such as traffic generated by cars and air pollutions, in order to setup a "data-driven bicycle mobility", as described in SynchroniCity deliverable "D3.1 - Documentation of service designs". Indeed, applications are conceived in order to leverage different kinds of data from the city that can be analysed and combined in order to provide useful insights and to improve the cycling experience, safety of people and infrastructure planning, enabling a data-driven bicycle mobility.

Three RZs participate in this application theme: Eindhoven, Milan and Antwerp. All these RZs are facing problems related to personal mobility and to the use of bicycles in the city area. In particular:

- Eindhoven focuses on sustainable energy, mobility and energy saving aspects in order to reinforce policies for making the city greener and for stimulating biodiversity; this means also to promote and to facilitate emission-free transportation such as cycling. In particular, because Eindhoven has a lot of bicycles and cars that can conflict, the aim is to provide the most optimal flow to improve bicycle mobility in the city, in a balanced way. (Section 2.1)
- Milan aims to better manage cycle lanes; in particular, in previous years, different bike sharing services started to operate in Milan and bicycles are playing an even more important role in mobility of people living in Milan area. The objective of Milan's application is to help decision makers of the Municipality in the important work of planning new cycle lanes, in order to facilitate and to encourage the use of bicycles for personal transportation. (Section 2.2)
- Antwerp aims to acquire information about the use of bicycles in the city area in order to analyse and use the data to adjust and manage their mobility policies, to take the most appropriate decisions and to improve the infrastructure for bicycle users. (Section 2.3)

2.1 Eindhoven's Application "Data-driven bicycle mobility"

In the coming period, the Municipality of Eindhoven will focus on sustainable energy, mobility and energy saving. The Municipality aims to explicitly link sustainability to economic activity and employment in the city and in the region. There is a substantial task before: disconnecting all homes and commercial premises from natural gas before 2050. A plan will be put forward for realisation: one neighbourhood at a time, setting up a service point to provide tailored advice, and information about subsidy opportunities and complex regulations. Lastly, green is important in the city, which is why it will reinforce the policy of making Eindhoven city greener and stimulating biodiversity¹.

Promoting emission-free transportation through cycling is one of the means to achieve these goals. Eindhoven has a lot of bicycles and many cars, which create conflicts mainly on intersections on the ring road. For both modalities, Eindhoven wants to provide the most optimal flow. The initial application data-driven bicycle mobility aims to improve bicycle mobility in the city, in a balanced way. This means that a balance between all traffic modalities (walking, cycling and motorized vehicles) has to be found. By leveraging and combining data from different IoT systems, 'data-driven bicycle mobility' aims to improve the overall bicycle experience, safety, infrastructure planning and policy making towards the future.

¹ https://www.eindhoven.nl/sites/default/files/2018-05/Coalitie%20magazine_0.pdf, English summary from page 44

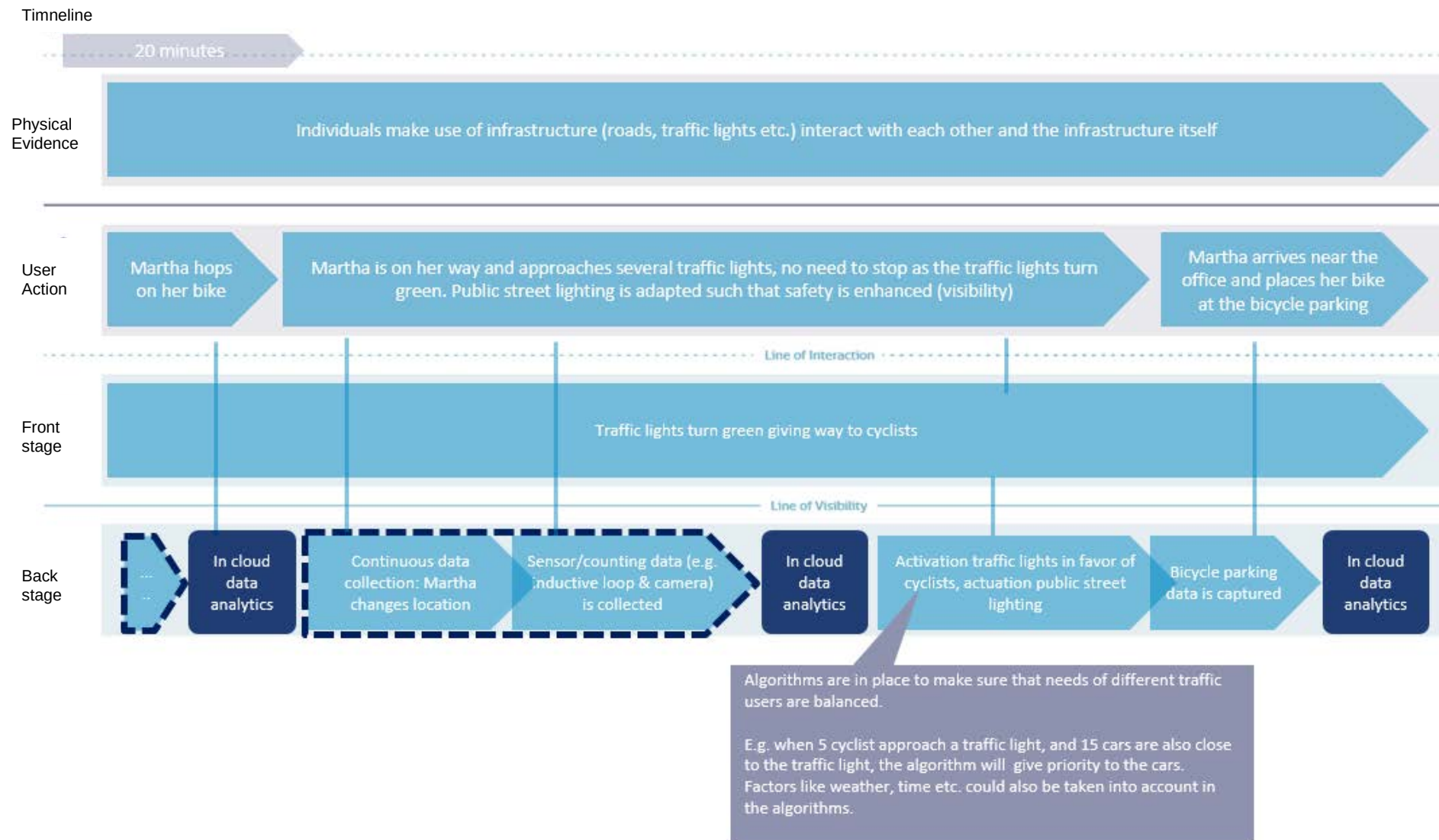


Figure 1: Service Blueprint (SynchroniCity, D3.1 - Documentation of service designs)

As reported in Figure 1, the service blueprint mentions on a conceptual level the collection of user data. In the service design, collection and storage of user-related data has to conform to GDPR (General Data Protection Regulation) guidelines. We strive to adhere to the guidelines of ENISA (European Union Agency for Network and Information Security) (D'Acquisto, et al., 2015).

The application will be tested in selected intersections. Location selection of the intersections, where the application will be tested, is based on historical cycling data of a test group that is depicted in Figure 2, in combination with criteria of the Reference Zone selection: part of the Eindhoven Ring Road. For the ring road, all motorized traffic following the ring road has priority in traffic flow.



Figure 2: Bicycle intensities and intersections

For the WP3 pilot testing site the area around the three intersections on the south-east part of the ring road is selected. These intersections are marked by the blue circles depicted in Figure 2. Implementation wise, the intersections will be adapted in the clockwise direction, starting from the intersection of Geldropseweg – Piuslaan (ring road) followed by the intersections Sint Bonifaciuslaan and Heezerweg with the Piuslaan (ring road) for the advanced scenarios. A screenshot providing a more detailed view of the test site with the associated sensors is given in

Figure 3.

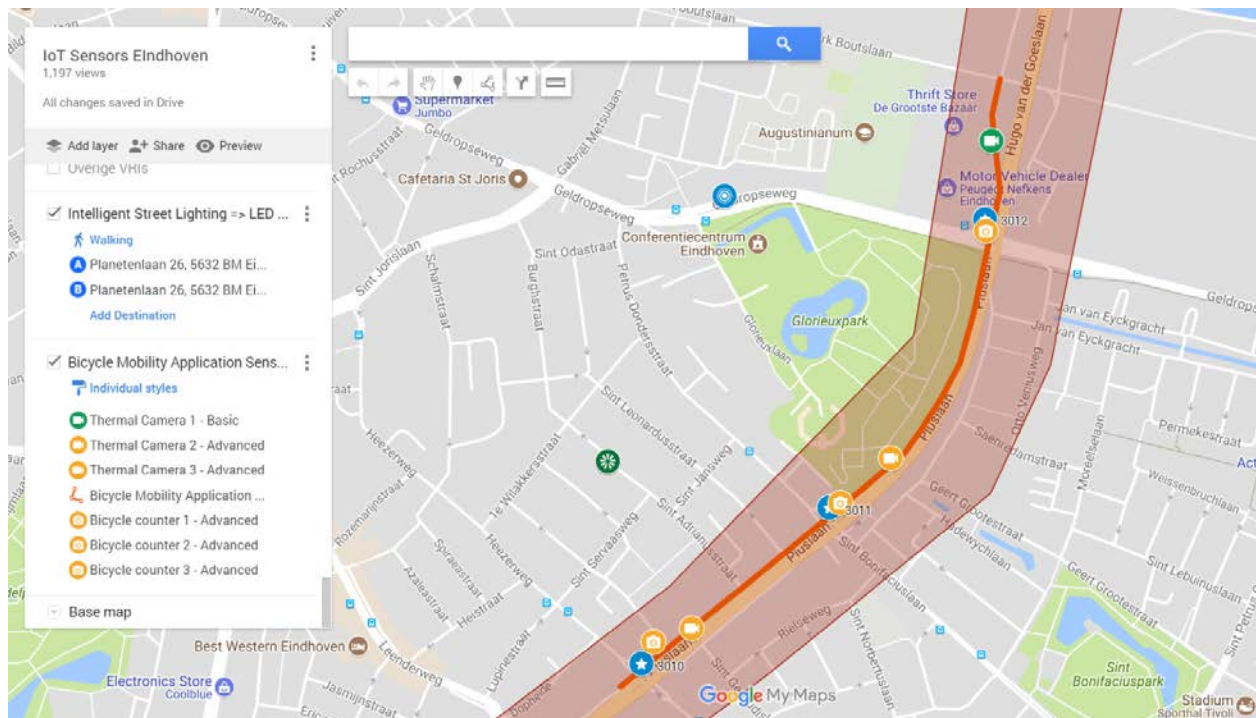


Figure 3: WP3 pilot test site

2.1.1 Application scenario(s)

2.1.1.1 Users profiles:

Table 6: User profiles of Data-driven bicycle mobility application

User profile ID	User description
User01: Martha	Cyclist. A cyclist that wants to cross an intersection coming from a direction parallel to the ring road (not necessarily as the final trip destination).
User02: Max	Motorist. A motorist drives a vehicle on roads crossing the ring road or on the ring road itself, in any direction approaching an intersection.
User03: Marco	Traffic Management Professional. Traffic Management Professional is responsible for efficient use of Traffic Management Installations such as traffic lights to optimize flow of traffic for all modalities (bike, car, pedestrian, emergency, busses, etc.)
User04: Maria	Mobility and Sustainability Policy Advisor. They are responsible for developing and monitoring policy for the municipality with respect to transportation (for instance better cycling corridors, or optimal access of the city centre) and sustainability (for instance, clean air and /or noise reduction).

2.1.1.2 Scenarios

Table 7: Scenario "Basic01 - Counter for Cyclist" of Data-driven bicycle mobility application

Scenario title	Basic01 - Counter for Cyclist
User profile	User01 Martha – Cyclist
Background	Martha is a cyclist and she is using the service road parallel to the ring road. She intends to follow a course along the ring road for one or more intersections.
Objective	Martha wants to stay in shape and have a positive contribution to the sustainability goals.

Storyline	Martha passes a RZ thermal camera installed at circa 125 metres before an intersection, possibly together with other cyclists. The RZ application picks up the RZ thermal camera traffic user data, correlates this data with other relevant data sets in the SynchroniCity platform, calculates the number of daily cyclists passing this intersection. This number is shown on a display besides the service road, so Martha will see the number of cyclists passing the intersection on a daily basis.
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Table 8: Scenario "Basic02 - Dashboard for professionals" of Data-driven bicycle mobility application

Scenario title	Basic02 - Dashboard for professionals
User profile	User 04 Maria – Policy advisor
Background	Maria is a policy advisor who is responsible for mobility and sustainability. She is looking for data that can help her to make informed data driven decisions.
Objective	Maria wants to know how many cyclists cross the intersection in our reference zone.
Storyline	Maria opens the dashboard on RZ application. In the application, she can select information from the thermal camera counter and display it on the map of the intersection. She can also make a report of historical count / number of cyclists over a period of months, weeks, days, hours and 15 min intervals. In this way, she gets insights that help her to report the success of bicycle stimulation measures that are taken.

Table 9: Scenario "Advanced 01 – Counter for waiting Cyclists" of Data-driven bicycle mobility application

Scenario title	Advanced 01 – Counter for waiting Cyclists
User profile	User01 Martha – Cyclist
Background	Martha is using the service road parallel to the ring road, clockwise. She intends to follow a course along the ring road for one or more intersections.
Objective	Martha is a very busy person and wants to know how long (on average) she has to wait on the intersection.
Storyline	As Martha approaches the intersection, the RZ application calculates the average waiting time for cyclists in the last hour. When the cyclist(s) have to wait before the traffic lights a RZ waiting bicycle counter determines (based on movement image/pattern recognition) the number of the observed/detected waiting traffic users. The RZ bicycle counter is connected to the iTLC (intelligent Traffic Light Controller) ² street cabinet which sends this waiting traffic data directly to the SynchroniCity platform. The RZ application picks up the RZ thermal camera traffic users data and the RZ waiting bicycle counter, correlates this data with other relevant data sets in the SynchroniCity platform, calculates and displays a counter of daily cyclist passing this intersection as well as the average waiting time in the last hour, so Martha will be able to know how long she has to wait at the intersection.

² <https://www.ivera.nl/wp-content/uploads/2016/01/Deliverable-F-iTLC-Architecture-v1.2.pdf> (pg 22/23) gives a definition within the context of the Dutch project Better Road Utilisation Next Phase. Multiple sources on iTLC are available from IEEE.

Table 10: Scenario "Advanced 02 – Waiting time advice for Cyclists" of Data-driven bicycle mobility application

Scenario title	Advanced02 - Waiting time advice for Cyclists
User profile	User01 Martha – Cyclist
Background	Martha is using the service road parallel to the ring road, clockwise. She intends to follow a course along the ring road for one or more intersections.
Objective	Martha is in a hurry and it makes her more relaxed to know much time is remaining until the light turns green. (Similar to scenario <i>Advanced 01 – Counter for waiting Cyclists</i>)
Storyline	Martha passes a RZ thermal camera at circa 125 meters before the crossing. This smart device determines (based on thermal image/pattern recognition) her modality, heading and speed. The RZ thermal camera is equipped with a 4G module and sends this traffic users data directly to the SynchroniCity platform. When the cyclist(s) have to wait before the traffic lights, a RZ waiting time bicycle indicator determines (based on movement image/pattern recognition) the number and waiting time of the observed/detected waiting traffic users. The RZ waiting time bicycle indicator is connected to the iTLC (intelligent Traffic Light Controller) street cabinet which sends this waiting traffic data directly to the SynchroniCity platform. The RZ application picks up the RZ thermal camera traffic users data as well as the RZ waiting time bicycle indicator, the RZ application correlates this data with other relevant datasets in the SynchroniCity platform and calculates the waiting time. This waiting time is indicated with a decreasing LED lights, next to or in the (red) bicycle traffic light. In this way, Martha gets a prediction of the time she has to wait before the light turns green.

Table 11: Scenario "Advanced 03 – Speed advice for Cyclists" of Data-driven bicycle mobility application

Scenario title	Advanced03 - Speed advice for Cyclists
User profile	User01 Martha – Cyclist
Background	Martha is using the service road parallel to the ring road, clockwise. She intends to follow a course along the ring road for one or more intersections.
Objective	Martha is still in a hurry, and she wants to know if she has to speed up to catch the next green light.
Storyline	Martha passes a RZ thermal camera at circa 125 meters before the crossing. This smart device determines (based on thermal image/pattern recognition) number, modality, heading and speed of the observed/detected traffic users. The RZ thermal camera is equipped with a 4G module and sends this traffic users data directly to the SynchroniCity platform. A RZ time to green and time to red bicycle indicator is determined using the information sent from the iTLC (intelligent Traffic Light Controller) street cabinet to the SynchroniCity platform. The RZ application picks up the RZ thermal camera traffic users data as well as the RZ time to green and time to red bicycle indicator from the iTLC, the RZ application correlates this data with other relevant data sets in the SynchroniCity platform and calculates the speed advice. This speed advice can

	be indicated through LED lights³ installed circa 125 meters long at both sides next to the bicycle path/service road between the (intelligent) traffic lights and the thermal cameras. Alternatively, this speed advice can be indicated by Flo "poles"⁴ (personalised current cyclist speed indicator to next green light, situated alongside the road), at approximately the same location as the RZ thermal camera's. In this way, Martha gets a clear signal telling her to speed up or just relax, giving her a smoother ride.
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Table 12: Scenario "Advanced 04 - Green wave for Cyclist" of Data-driven bicycle mobility application

Scenario title	Advanced 04- Green wave for Cyclist
User profile	User01 Martha – Cyclist
Background	Martha is using the service road parallel to the ring road. She intends to follow a course along the ring road for at least two intersections.
Objective	The objective is to minimize the stops to wait for a green light for cyclists.
Storyline	Martha approaches the second crossing, the RZ application picks the thermal signature from the sensors and determines modality, heading and speed. Also, the time to green and time to red from the intelligent Traffic Light Controller at the crossing is loaded into the RZ application. Based on this data, if the signal is from a cyclist the application shows an advice for the appropriate speed by providing a running light alongside the road that the cyclist can follow, thus making a series of green lights in a row (green wave for cyclists); so Martha is able to minimize the number of stops.

Table 13: Scenario "Advanced 05- Prioritize time traffic management " of Data-driven bicycle mobility application

Scenario title	Advanced 05 - Prioritize time traffic management
User profile	User03 Marco – Traffic Management Professional
Background	Marco has access to the Traffic Management Platform (Technolution in Eindhoven), which is used to implement traffic management scenario for all intelligent Traffic Light Controllers (ITCs)
Objective	The objective is to efficiently route all traffic for all directions, requiring a balanced view of traffic flows between modalities (e.g.: bikes, motorists) and other factors such as weather and time of the day.
Storyline	As for Marco, the traffic management professional, the data from the RZ application is a new data source that becomes available to him. In the Technolution Platform, Marco implements a new rule that roughly translates to: <i>if no other priority traffic scenario applies, and a real-time signal is received from the RZ application that a group of 5 or more cyclists approach from a specific direction, or the weather is rainy, then a priority green period is activated to obtain a green for cyclists crossing the intersection from that specific direction.</i>

³ For an impression see <https://www.youtube.com/watch?v=IfMp42fS4QU>

⁴ For more information in Dutch only, see <https://www.duic.nl/algemeen/flo-neemt-grootste-fietsfrustratie-weg/>

Table 14: Scenario "Advanced06 – Provide insight to achieve municipal policy objectives" of Data-driven bicycle mobility application

Scenario title	Advanced06 – Provide insight to achieve municipal policy objectives
User profile	User04 Maria - Policy advisor
Background	A diverse range of policy objectives in the domains of mobility and sustainability is set in place in the Municipality of Eindhoven. In general, causality between policy and the measures that are taken to make it a reality is complex and therefore hard to quantify.
Objective	As for Maria, the data that is generated by the RZ application is used to augment policy making and evaluation, by providing analytical tools to predict and evaluate the effect of concrete measures.
Storyline	Maria launches the analytic and visualisation toolkit of the RZ application. The toolkit includes a baseline dataset containing historical traffic patterns in the Eindhoven region which is available for analysis. By comparing historical information with current anonymous cyclist tracking information, the effect on policy KPIs such as cyclist waiting time and traffic flow on the ring-road can be determined. As more data sources become available on the data platform, additional KPIs may be added, such as air quality, noise levels, or a user evaluation of trip and lighting quality.

2.1.2 Requirements analysis

Data-driven bicycle mobility shall leverage data from different (IoT) systems available in the cities to (1) improve overall bicycle experience and (2) provide support to make better and data-driven decisions regarding infrastructure planning and policy making. Functional requirements are applicable to the (B) Basic or (A) Advanced scenario, or both and can be classified in two categories: category 1 "Bicycle Experience" and category 2 "Data Driven Decision". In the description of each requirement a code indicating the category and the type of scenario (Basic or Advance) is reported; for instance the code "(1) (A)" indicate category 1 and scenario type Advanced. Non-functional requirements are for the system as-a-whole.

2.1.2.1 Functional requirements

Table 15: Functional requirements of Data-driven bicycle mobility application

ID	Description
FR-1	Real time & historic sensing data about the location and heading/direction of a cyclist (based on Thermal Camera data (B), induction loop data (A), feedforward from iTLCs) MUST be provided. (1) (B, A)
FR-2	The application MUST process data from real-time (when applicable combined with historic) sources in (near) real-time. (1) (A)
FR-3	The application MUST identify certain traffic situations (eg cyclists approaching) and classify these situations in (near) real-time based on real-time (when applicable combined with historic) sources. (1) (B,A)
FR-4	The application MUST provide optimal traffic light decisions in (near) real-time based on classified traffic situations. (1) (A)
FR-5	The application MUST provide optimal public lighting decisions (indication of remaining green/running lights) based on the time-to-green information from the iTLCs (B) and based on classified traffic situations in (near) real-time (A). (2) (B, A)
FR-6	The application SHOULD support making changes (actuation) to traffic lights based on classified traffic situations in real-time. (2) (B, A)
FR-7	The application MUST provide user identification and access control at least by a username/password basic security. (2) (B, A)

FR-8	The application SHOULD provide user admin features to control settings via admin panels. (2) (B, A)
FR-9	The application MUST provide flexibility in terms of viewing, or having access to, certain data sets (e.g. through dashboard widgets). (2) (B, A)
FR-10	The application SHOULD provide a map as the main way of interaction to superimpose data sets. (2) (B, A)
FR-11	The application MAY provide different manners of visualizations. (2) (B, A)
FR-12	The application SHOULD process information on real-time traffic and make it available on the dashboard. (2) (B, A)
FR-13	The application SHOULD allow selection of specified time window and display corresponding aggregated data over the selected time window on the dashboard. (2) (B, A)
FR-14	The application SHOULD provide advice/prediction based on aggregated historical data. (2) (B, A)

2.1.2.2 Non-functional requirements

Table 16: Non-functional requirements of Data-driven bicycle mobility application

ID	Description
NFR-1	The application MUST adhere to privacy laws (e.g. when it comes to tracking cyclists). This requirement is related to Privacy aspects.
NFR-2	The application MUST demonstrate a high level of security and include latest data encryption methods. This requirement is related to Security aspects.
NFR-3	The application MUST have a response time that is below 500 ms from the moment of sensing until actuation, so the cyclist has travelled <3.5 m (at 25 km/h). This requirement is related to Performance aspects.
NFR-4	The application MUST be backed up, data-loss MUST be prevented. This requirement is related to Availability aspects.
NFR-5	The application SHOULD have up-time higher than 99.5% per year. This requirement is related to Availability aspects.
NFR-6	The application SHOULD be deployed through a cloud-based service. This requirement is related to Deployment aspects.
NFR-7	The application SHOULD consume the minimum amount of resources as reasonably possible. This requirement is related to Efficiency aspects.
NFR-8	The application SHOULD provide enjoyable and intuitive experience to user. This requirement is related to Usability aspects.
NFR-9	The application SHOULD use the latest standards in browser technology (e.g. be responsive independent of device-type and browser). This requirement is related to Accessibility aspects.
NFR-10	The application software & code base SHOULD comply with the most recent, de facto industry standards at time of development. This requirement is related to Compliance aspects.

2.1.3 Available data sources

References reported in the "Title" column of Table 17, refers to the description of the original data sources that are (to be) included and/or adapted through and according to SynchroniCity platform.

Table 17: Data sources used in Data-driven bicycle mobility

Title	Description	Open Data / API	Adopted SynchroniCity Data Model	Notes
Thermal camera data endpoint	FLIR ThermiCam V2X ⁵ (thermal camera) providing following raw data: type of Modality, Count of cyclists, Heading and Speed	API/SDK	Vehicle, Traffic flow observed and/or RoadSegment data model	To be installed, Data Model to be investigated / decided (probably Vehicle)
My040 Routes	Historical Local Traffic Tracking Data from a pilot in 2017-2018, as described in section 3.4.1.2 of SynchroniCity deliverable D2.8	Open Data	Vehicle Traffic flow observed, and/or RoadSegment data model	To be anonymized, method and Data Model to be investigated / decided (probably Vehicle).
VLOG ⁶ (Verkeers-Log – Traffic Log) data endpoint	The number or presence of bicycles form the induction/detection loop in the bicycle lane/service road, as well as the traffic light data, with amongst others the time to green and time to red , are captured in the intelligent Traffic Light Controller at the crossing. The detection loop and traffic light data are combined in VLOG data.	API/SDK	Ivera/VLOG, including the mapping/addition to standard EU/FIWARE data models,	To be investigated / decided whether it is the only source for induction loops and what their exact added value & future-proofness is compared to TLEX (Traffic Light EXchange).
TLEX (Traffic Light Exchange) endpoint	Traffic Light Exchange – central hub of traffic information developed by Dutch consortium Talking Traffic / Beter Benutten as a first step towards nationwide Intelligent Traffic Systems	API/SDK	Vehicle Traffic flow observed, and/or RoadSegment data model	To be investigated / decided what data can be provided by TLEX, and what SynchroniCity can deliver in return.
Aireas air quality data ⁷	Overview and APIs to get air quality measurements of the Airboxes in the city of Eindhoven	Further investig	Further investigation is needed	

⁵ http://www.flirmedia.com/MMC/CSV/Traffic/IT_0013_EN.pdf

⁶ https://www.ivera.nl/wp-content/uploads/2018/04/V-Log_protocol_en_definities_v3.01_WG_techniek_changes_highlighted.pdf, Dutch only
<https://www.ivera.nl/wp-content/uploads/2016/01/Deliverable-G4-IRSIDD-VLOG31.pdf> previous and less complete English version

⁷ <https://data.eindhoven.nl/explore/dataset/realtime-luchtkwaliteit-in-eindhoven/table/>

		ation is needed		
Aireas airbox locations	Locations of the Aireas airboxes	ODP	Not applicable	Also available as chart. ⁸
Aireas air quality end point	End point providing air quality measurements of the Airboxes in the city of Eindhoven	API	Air Quality Observed	Auto update/polling (each 10 minutes) and Security aspects in investigation.

2.1.4 Application architecture

The Data-Driven Bicycle Mobility application developed for the Eindhoven Reference Zone relies heavily on the SynchroniCity APIs (SysnchroniCity deliverable D2.1 "Reference Architecture for IoT Enabled Smart Cities"), as shown in Figure 4. All accesses to SynchroniCity data will be authenticated (and authorised) by the SynchroniCity security layer, through its OAuth2.0 interface. Both the Context Management API (fed mainly by Private APIs) and the Historical Data API (mainly Open Data APIs) are required to provide the necessary data for the application logic. The datasets used for this application are described in Table 17.

Some future scalability issues with the reference implementation are to be expected as the number of tracked cyclists & motorists plus their potential interactions grow exponentially once data-driven bicycle mobility is scaled to the full city. Therefore, the reference implementation has been broadened to include the FIWARE Cosmos Big Data Store⁹ for storing the original raw data (and to provide the future computing power for scaling) besides FIWARE Short Time Historic (STH) Comet¹⁰ for the implemented Data Models themselves.

Two, and if necessary three, SynchroniCity baseline services are expected to be used in this application:

- **Smartcities Dashboard Service:** To visualize information for Traffic Management Professionals and Policy Advisors users.
- **Metrics Visualizer (Grafana) service:** To provide additional visualization options for Policy Advisors user.
- **Traffic status estimator baseline service:** If and only if the recommendations for Advanced scenarios 03, 04 and/or 05 are consistently 'off' by a suitable margin of 5% or more, it is investigated whether including this service will improve the recommendations.

The data-driven bicycle mobility application consists of the following functional building blocks:

- **Information Layer (RT & Historic Data Fusion / Serving Layer):** It combines real-time and historic data from different Data Models (Vehicle, TrafficFlowObserved and if necessary Road / RoadSegment; TrafficRegulationInstallation needs to be developed prior to its inclusion in this layer) and feeds the relevant resultant set for a scenario to one of the following Operations.
- **Operations**
 - o **Reporting (Aggregator):** Any mathematical function that is a direct result of historic data over a certain period (Descriptive Analytics) will be determined here, e.g., counting, averaging, min / max, etc. Measures that are based on one Data Model are

⁸<https://data.eindhoven.nl/explore/dataset/locations-airboxen/map/?location=13.5145748,5.47136&basemap=jawg.light>

⁹ <https://catalogue-server.fiware.org/enablers/bigdata-analysis-cosmos>

¹⁰ <https://catalogue-server.fiware.org/enablers/sth-comet>

expected to be pre-calculated by the Context Broker prior to storing the information in STH Comet.

- o **Prediction:** Any mathematical model that provides a prediction of an event to happen in the (near) future (Predictive Analytics) will be performed here, e.g., the number of seconds until the traffic light will turn to green.
- o **Recommendation system:** Any model that provides a suggestion to the user (Prescriptive Analytics) will run here, eg. the required speed to catch one or multiple green traffic lights and vice versa the way the traffic lights need to adapt to Martha to give her multiple green traffic lights.
- **Signage / Lighting:** Acts as a weather-proof communication channel (possibly through actuation i.e. a round trip through the Context Broker API) with cyclists to give them the information they need for their cycling routine.
- **User Interface (Web/Mobile):** Acts as a communication channel with Traffic Management Professional and Policy Advisor users on the alerts and management information they require.

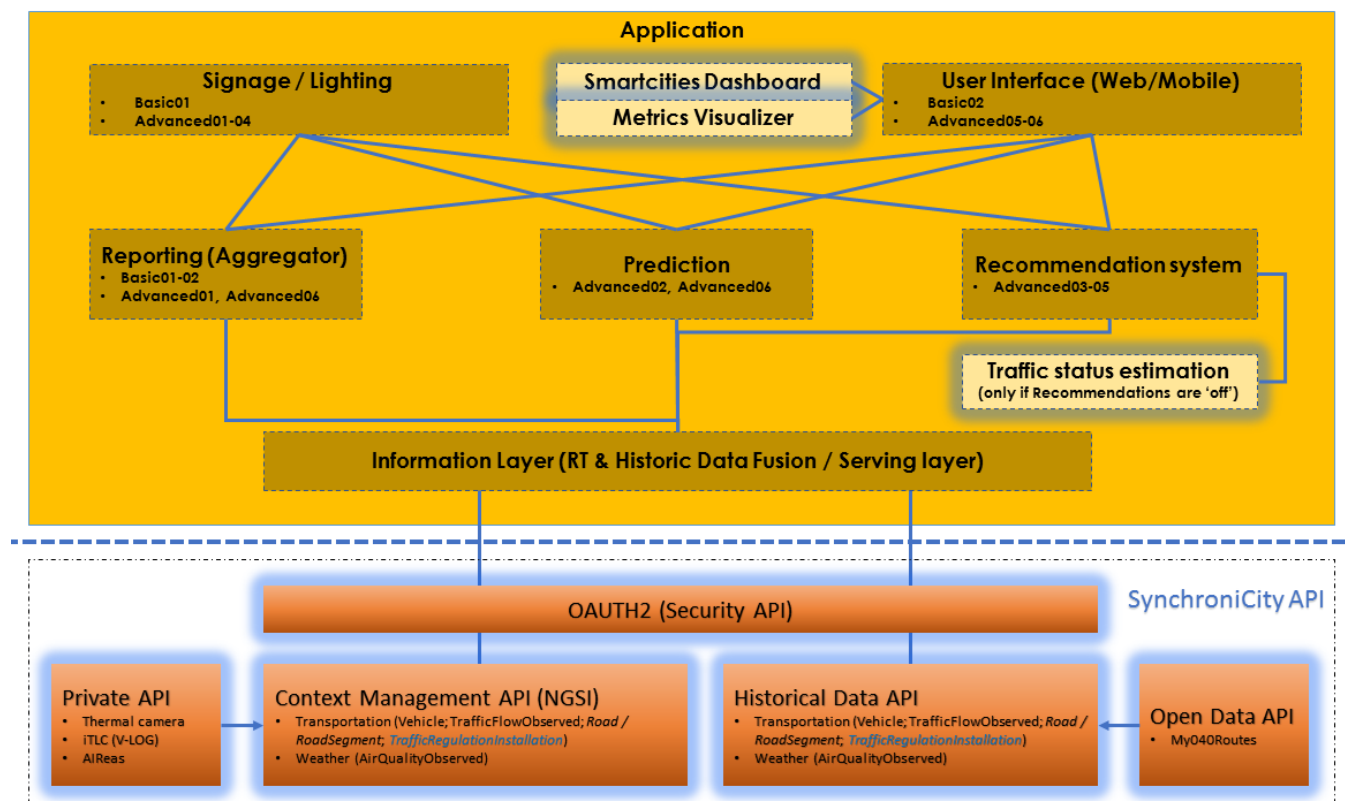


Figure 4: Eindhoven application architecture for Data-driven bicycle mobility application

The Context Management API takes care of interfacing with the overall Technical Infrastructure; the feedback (actuation / closing the loop) towards the cyclists is of particular interest. The following streams have been identified for most, if not all scenarios:

- A cyclist passes a FLIR thermal camera circa 125 meters before the crossing. This smart device determines (based on thermal image/pattern recognition) his/her modality, heading and speed. The RZ thermal camera is equipped with a 4G module and sends this traffic users data directly to the SynchroniCity platform, where it is 'translated' to the standard '**Vehicle**' data model.
- The number or presence of bicycles from the induction/detection loop in the bicycle lane/service road, as well as the traffic light data, with amongst others the time to green and time to red, are captured in the iTLC (intelligent Traffic Light Controller) cabinet at the crossing. The detection loop and traffic light data are combined in VLOG (Verkeers-Log in

Dutch, Traffic Log in English – a data logging protocol for iTLCs) data¹¹ loaded into the RZ application, via a secured endpoint provided by the traffic management system¹² of the company MobiMaestro. Alternatively, the data of any and all iTLCs can be obtained through TLEX (Traffic Light EXchange, developed and hosted by Monotch & SWARCO¹³) which conforms to the European ETSI standards.

The obtained data is (partly) 'translated' to the standard '**Traffic flow observed**' data model. *Please note: for replicability and interoperability purposes to other RZs Eindhoven strives for the use of an EU standard in the realm of iVRI, giving rise to an accompanying mapping into/addition to a standard EU/FIWARE data model.*

The RZ application correlates the RZ '**Vehicle**' data with the '**Traffic Flow Observed**' data and combines that result with other relevant data sets in the SynchroniCity platform to determine the required output for a particular scenario. A suitable feedback device (e.g., information display, waiting time indicator in the traffic light itself, Flo poles or running lights alongside the bicycle road/lane) may be used

Please note: to enable the real actuation of this waiting time indicator the waiting time advice from the SynchroniCity platform must be 'picked-up' by the MobiMaestro traffic management system, either via the 'direct json import or the DVM Exchange module, 'translated' into scenario's and VLOG return message(s) by DTV consultants and '(re)programmed' in the iTLC street cabinet by Dynnic.

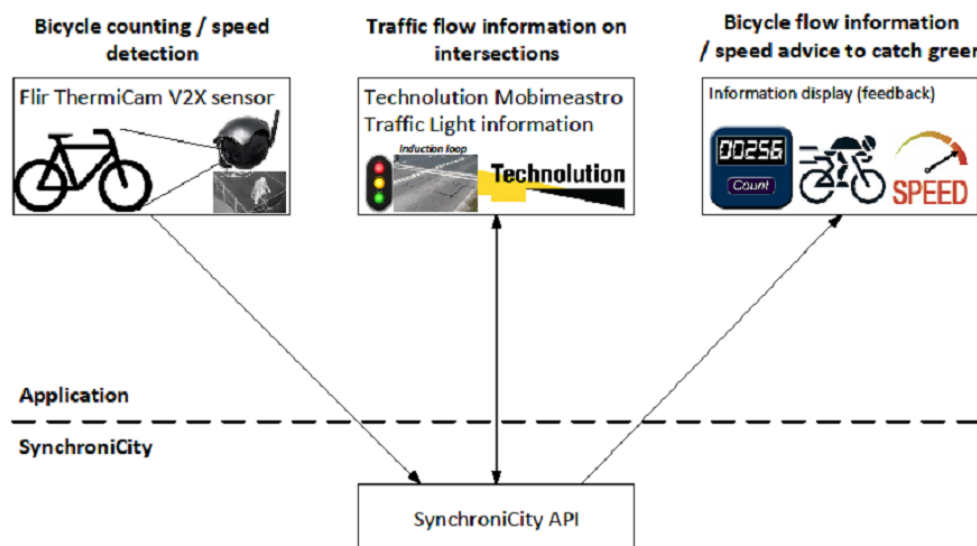


Figure 5: Technical infrastructure

2.1.4.1 Reusable baseline services

Table 18 lists the baseline services under consideration for the Eindhoven Data-Driven Bicycle Mobility application. The Traffic status estimator baseline service will only be considered to enhance recommendations if they are consistently 'off' by a suitable margin of 5% or more.

Table 18: Data sources used in Eindhoven Data-driven Bicycle Mobility application

Name	Description
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¹¹ https://www.ivera.nl/wp-content/uploads/2018/04/V-Log_protocol_en_definities_v3.01_WG_techneek_changes_highlighted.pdf, Dutch only
<https://www.ivera.nl/wp-content/uploads/2016/01/Deliverable-G4-IRSIDD-VLOG31.pdf> previous and less complete English version

¹² <https://www.technolution.eu/en/mobility/5-mobimaestro-from-traffic-management-towards-a-smart-city.html>

¹³ <https://www.swarco.com/>

Traffic estimator service	status baseline	This service analyzes context data (based on TrafficFlowObserved¹⁴ entities, currently available in Santander and Porto RZs) to provide current (near real-time) traffic status and exploit the historical data to estimate traffic status. The use of this baseline service is taken into account to enhance Recommendations (as described in scenarios <i>Advanced03 - Speed advice for Cyclists</i> and <i>Advanced05 - Prioritize time traffic management</i>) if they are 'off' by more than 5%.
Smartcities Dashboard Service		Smartcities Dashboard is a web service interfaces that provides end-users with a simple and user-friendly dashboard allowing a map-based representation of the devices connected. Currently the application is able to represent location, real-time sensor information and aggregated insights in the form of charts. The use of this baseline service is taken into account to support scenarios: • <i>Basic02 - Dashboard for professionals.</i> • <i>Advanced05 - Prioritize time traffic management.</i> • <i>Advanced06 - Provide insight to achieve municipal policy objectives.</i>
Metrics Visualizer (Grafana) service		Metrics Visualizer is a custom deployment of Grafana¹⁵ software working on top of FIWARE Stack services. Through Grafana, a set of databases can be configured as datasources in order to create personalized charts and tables. These databases are filled using QuantumLeap¹⁶ or FIWARE Cygnus¹⁷ as device information subscriber. The use of this baseline service is taken into account to support scenarios: • <i>Basic02 - Dashboard for professionals.</i> • <i>Advanced06 - Provide insight to achieve municipal policy objectives.</i>

2.2 Milan's Application "Decision support system for cycle path planning"

During the latest years Milan has seen and huge increase of bike usage thanks to the various bike sharing services. The first station-based bike sharing service (BikeMi¹⁸) was allowed by the Municipality in 2008. In October 2017 the Municipality allowed two different operators (MoBike¹⁹ and Ofo²⁰) to start a free-floating bike sharing service. In order to support bike usage, the Municipality built reserved cycle paths widespread in the city and new ones are planned to be built. Currently available cycle routes have been mapped on the GeoPortal²¹ system of the Municipality, but in order to design new ones it would be useful to exploit desired lines given by data from bike-sharing usage and, when possible, to exploit useful data, such as traffic incident data in order to determine which are the most problematic areas of the city and improve cyclist's safety.

The application is intended as an internal desktop application, accessible through a web-browser, that will integrate GeoViewer²², the geo-portal of Municipality of Milan (a GIS based system), to help

¹⁴ <http://fiware-datamodels.readthedocs.io/en/latest/Transportation/TrafficFlowObserved/doc/spec/>

¹⁵ <https://grafana.com/>

¹⁶ <https://smartsdk.github.io/ngsi-timeseries-api/>

¹⁷ <https://catalogue-server.fiware.org/enablers/cygnus>

¹⁸ <https://www.bikemi.com/>

¹⁹ <https://mobike.com>

²⁰ <https://www.ofo.com/it/it/>

²¹ <https://geoportale.comune.milano.it/sit/>

²² <https://geoportale.comune.milano.it/geoviewer/>

decision makers in the design and management of bicycle path. The GeoViewer supports a wide set of map operations and it needs to be fed with data (acquired through the Synchronicity platform) that will be processed in order to create interesting and useful information layers.

Possible information layers that could be created to support the decision maker are (non exhaustive list):

- existing cycling path;
- routes of the tram railway tracks;
- existing restricted areas;
- parks;
- pedestrians areas;
- obstacles along streets;
- bike sharing origin-destination;
- road incidents.

The application will be conceived in order to be flexible to add new information layer when new data sources will be available.

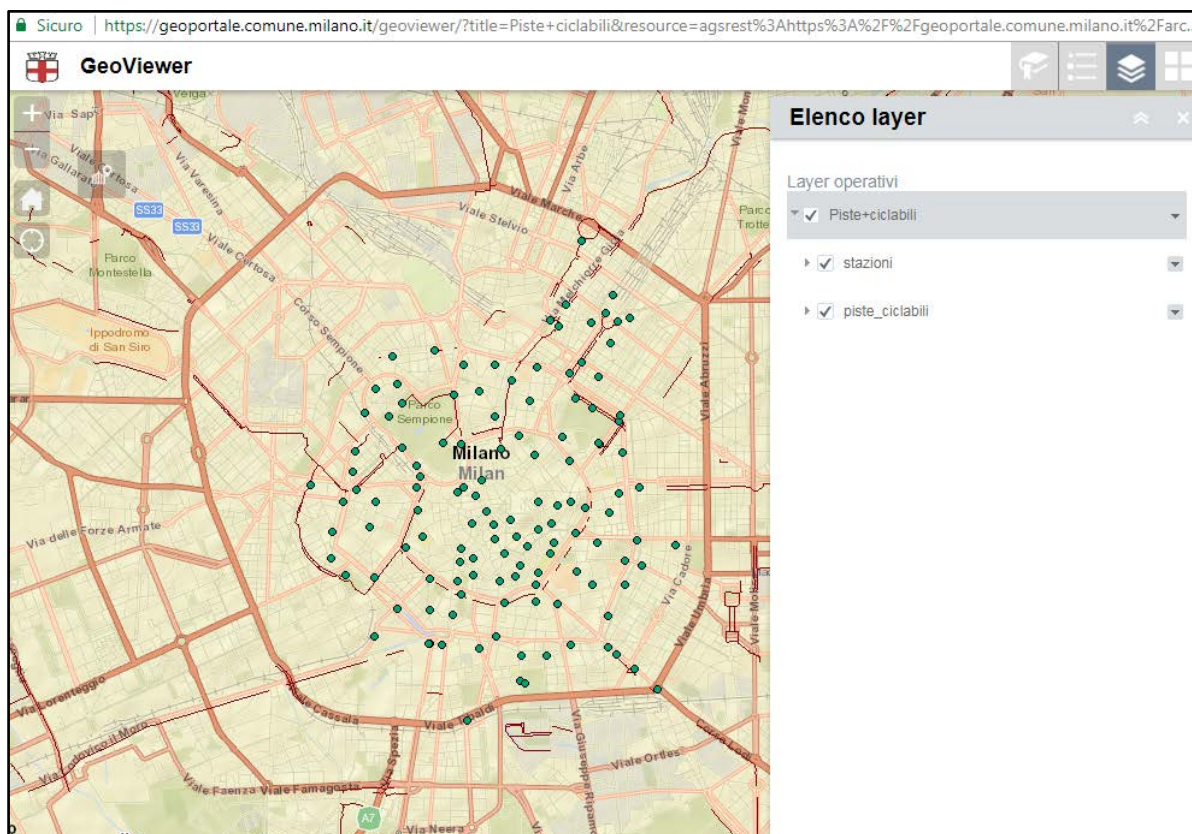


Figure 6: Milan's Geoportal

2.2.1 Application scenario(s)

2.2.1.1 Users profiles:

As this application is intended for internal use, it will have only one user: the Planner. The Planner represent the decision maker of the Municipality of Milan in charge of managing the cycle path.

Table 19: User profiles of Decision support system for cycle path planning application

User profile ID	User description
Planner	A Planner (David) is an employee of the Municipality (or of the Mobility Agency) who is in charge to monitor, modify or design new cycling infrastructure

2.2.1.2 Scenarios

Table 20: Scenario "Sc.1 - Application Access" of Decision support system for cycle path planning application

Scenario title	Sc.1 - Application Access
User profile	Planner
Background	The application is available through the GeoViewer, and accessible only to the allowed employees of the municipality
Objective	David wants to open the application
Storyline	David connects his browser to the GeoViewer by specific URL (e.g.: https://geoportale.comune.milano.it/geoviewer/). In the right up corner David selects the menu-item "Reserved Area". A pop-up menu appears asking David to insert his credentials (userId and password). After David has entered his credentials, he can see the list of available applications and selects the application "Decision support system for cycle path planning". David select this application and the application is provided to him.

Table 21: Scenario "Sc.2 - Map interaction - Zooming, scrolling, and area selection" of Decision support system for cycle path planning application

Scenario title	Sc.2 - Map interaction - Zooming, scrolling, and area selection
User profile	Planner
Background	David launches the applications from his browser. David has special grants to access the application. The application shows a map of the territory of the municipality. David interacts with the application with keyboard and/or mouse and/or any pointing system. David can navigate the map.
Objective	David wants to focus/center the map on a specific point, or an area
Storyline	Scrolling: David scrolls the map up and down or right and left using the mouse. Alternatively David scrolls the map up and down or right and left using the keyboard. Zooming: When David recognizes a suitable area for his needs, David zooms or pans the map using the mouse, or the keyboard. Area selection: David, can select an area directly on the map with the mouse and zoom automatically until the selected area fit the available screen window. To refine his choice David can alternatively use scrolling, zooming and area selection operation until the map is showing the desired area at retrieved.

Table 22: Scenario "Sc.3 - Searching address" of Decision support system for cycle path planning application

Scenario title	Sc.3 - Searching address
User profile	Planner
Background	David launches the applications from his browser. The application shows a map of the territory of the Municipality. David needs to center the map according to a given address
Objective	David wants to center the map on a specific address
Storyline	David selects the form to enter the address he is looking for. Thus David inserts the address in the form, and if the the application founds the address, the application centers the map on the given address to medium zoom level. If the application can not find any match with the given address, the application gives David a message. While David is typing the address, the application provides to David an auto-completion feature that suggests any possible match according to the text that David has entered. If David inserts a complete address (eg. a street or square name with a civic number like "via tortona 16") the map is centered exactly on the given address. If David inserts only a street or square name without a civic number (e.g., "via tortona") the maps is centered on the starting point of the giver street or square.

Table 23: Scenario "Sc.4 - Toggling layers" of Decision support system for cycle path planning application

Scenario title	Sc.4 - Toggling layers
User profile	Planner
Background	David launches the applications from his browser. The application shows a map of the area of the municipality in which David is interested. David needs to see some specific information related to the shown territory.
Objective	David wants to see information related to the territory
Storyline	David presses a button on the screen with the mouse that shows the available information layers for the shown territory. David selects the information layers he needs and the map is updated showing the requested information layer. When David de-selects the information layer, the map is updated hiding the information layer. When an information layer is shown on the map, David can decide the transparency level in order not to hide other information layers.

Table 24: Scenario "Sc. 5 - Layers interactions" of Decision support system for cycle path planning application

Scenario title	Sc. 5 - Layers interactions
User profile	Planner
Background	David launches the applications from his browser. The application shows a map of the area of the municipality integrated with the information layers on which David is interested in.
Objective	David wants to retrieve information from the visible layers.
Storyline	David selects a specific information layer and then draws a polygon (which defines an area) on the chosen information layer on the map. The application shows to David in a separate table all the data of the information layer contained within the polygon. David presses a button to download the data.

Table 25: Scenario "Sc.6 - Recording notes" of Decision support system for cycle path planning application

Scenario title	Sc.6 - Recording notes
User profile	Planner
Background	David launches the applications from his browser. The application shows a map of the area of the municipality integrated with the information layers on which David is interested into. David focuses his attention on a specific information layer.
Objective	David wants to record a note on an information layer
Storyline	David activates the form where he can select all the available information layers and picks one. The chosen information layer will be shown on the map as the active one. After this, David selects a point on the map with the right button of the mouse and a pop-up window appears beside the point asking David if he wants to insert a note. David inserts a label to summarize the note, and then the entire text in the form. When David thinks he finished he click the save button and a pin is shown on the map on the point that David previously selected to indicate David there is a note there. When David passes with the mouse pointer over a pin indicating a note, a pop-up window appears in order to show to David the note. David can also select an existing note with the right button of the mouse and a pop-up window asks him if he wants to modify or delete the note. If David decides to modify the note the form that David previously used to insert the note will appear again filled with the current note and David can change it. And when he finishes he can save the new version of the note. If David decides to delete the note, the pin on the map will disappear. Notes are stored as selected information layers attribute for David usage only, and will be reloaded the next time David activates the selected information layer.

Table 26: Scenario "Sc.7 - Planning new bicycle routes" of Decision support system for cycle path planning application

Scenario title	Sc.7 - Planning new bicycle routes
User profile	Planner
Background	David launches the applications from his browser. The application shows a map of the area of the municipality integrated with the information layers on which David is interested into. David focuses his attention on a specific information layer.
Objective	David draws new bicycle routes
Storyline	David activates the form where he can select all the available information layers and picks one. The chosen information layer shows the already available bicycle routes. David activates a function of the application by clicking a button on the screen that allows him to draw a path on the map. Thus, David selects a point on the map with the mouse as starting point of his new path. When David selects a second point on the map a line is drawn on the map connecting the two points. Every time David selects a further point on the map, a new line is drawn on the map connecting the new point with the previous selected one. While David is drawing the path, there is a small window in the corner of the application screen showing to David the entire length of the path that David is drawing. When David left-clicks on an existing point of his new path, the selected point is deleted from the path together with the lines that arrives in the selected point. If the point is in between with other two point, the previous and next point are directly linked drawing a new line joining them. To stop drawing the path David clicks again the same button he clicked before to activate the drawing function. Beside the drawing button, there is a "save" button that allows David to save the paths he drawn as attributes of the information layers that can be recalled on the next run of the application when David activates again the the selected information layer.

2.2.2 Requirements analysis

2.2.2.1 Functional requirements

Table 27: Functional requirements of Decision support system for cycle path planning application

ID	Description
FR-1	The application MUST provide a map to visualise information.
FR-2	User MUST be able to navigate the map scrolling up/down/left/right or to zoom/pan the map
FR-3	The application MUST provide functionalities to display different information layer on the map.
FR-4	User MUST be able to search for an address by typing it.
FR-5	The application MAY provide possible match addresses while the user is typing an address.
FR-6	The application SHOULD be able to intersect two information layer in order to identify their common points or area on the map.
FR-7	The user SHOULD be able to create, modify and delete notes on the map.

FR-8	The user SHOULD be able to draw a polygon (area) on a visualized information layer on the map, and download in a file the data of the layer contained within the polygon
FR-9	The user SHOULD be able to draw the path of a new bicycle routes on the map.

2.2.2.2 Non-functional requirements

Table 28: Non-functional requirements of Decision support system for cycle path planning application

ID	Description
NFR-1	The application MUST support Italian language.
NFR-2	The application MUST be accessible through a Web browser.
NFR-3	The application SHOULD be intuitive and easy to use.
NFR-4	The application SHOULD be accessible only to authorized users.

2.2.3 Available data sources

References reported in the "Title" column of Table 29, refers to the description of the original data sources that are included and adapted through and according to the SynchroniCity framework.

Open Data are mainly retrieved from Open Data Portal of Milan²³, whereas API data sources are mainly accessed through the API Store²⁴ of Milan or through the platform E015²⁵ (a platform collection and providing access to API for both public and private entities) and then converted in the corresponding data model. It is important to underline that an authorization request has been submitted in order to access API provided by E015.

Table 29: Data sources used in Decision support system for cycle path planning application

Title	Description	Open Data / API	Adopted SynchroniCity Data Model	Notes
Cycle network	GeoJson description of current cycle-network in the city	Open data	Needed further analysis	Data is available in GeoJson format
Bike sharing Stations	Position and description (#bikes) of the stations where to pick bikes up	Open data	BikeHireDocking Station	
Parks	GeoJson description of parks in the city	Open data	Gardens	
Traffic Restricted areas	GeoJson description of traffic restricted areas	Open data	Needed further analysis	Data is available in GeoJson format
Place/Street names	Official place and street naming system associated to geographic position	API	Road	
Point of interests, events and itinerary	Descriptions of valuable places in an area	API	PointOfInterest Events	Further analysis are needed to identify the data model to represent

²³ <http://dati.comune.milano.it/>

²⁴ <https://apisp.comune.milano.it/store/>

²⁵ <http://www.e015.regione.lombardia.it/>

				touristic itineraries.
Tramway network	GeoJson description of tramways network (because of urban train-tracks)	Open data	Needed further analysis	Data is available in GeoJson format
Road accidents	Position and description of road accidents.	Open data	Needed further analysis	Data owned by the municipality but could not be used for privacy reasons. Event defined by Open511 ²⁶ is a candidate data model to represent this information.
Bike trajectories	GPS position of free floating bikes trajectories.	API	Needed further analysis	Data owned by private operators. Milan is working to obtain access to this data.
Bike Origin-destination matrix	Matrix of station based bike sharing usage	Open Data	Needed further analysis	Data owned by private operators. Milan is working to obtain access to this data.

2.2.4 Application architecture

The Human Centric Traffic Management application developed within Milan Reference Zone is based on the SynchroniCity framework. Figure 7 depicts how the application will be built internally and how it will interact with Synchronicity API. The application will receive NGSI Context information coming from Context Management API and will use these data for its core functionalities. Access to this API will be secured by the IdM module/component currently working on the WSO2 platform (WSO2 Identity and Access Management, 2018) of Milan Municipality which is compliant with OAuth2 standard, according to the SynchroniCity Security layer specification.

The application is composed by a set of internal functional components:

- **A set of adapters: Bike Sharing Station Adapter, Existing Cycle Network Adapter** and other possible adapters. Each adapter will convert the particular NGSI context information (JSON), as reported in Table 29, to an intermediate representation in GeoJson, which will be converted by Information Layer Producer in the appropriate format in order to be used by the GeoViewer to show information to final user of the application.
- **New Cycle Network Proposer:** this is a specific adapter used to propose new cycle routes as new informational layer. It will use and convert incoming NGSI context information about the usage and traffic of bike sharing network, to be sent in input to the baseline Routing Service. This service will use these data to calculate a new possible cycle route that will be packed and issued in output by this Proposer.
- **Information Layer Producer:** it will create all the Shapefiles that will be used by the application to visualize graphical information layers in the GeoViewer map. It will take in input the GeoJson representation produced by the particular adapter and it will convert the GeoJson to a Shapefile representation. In addition, it will receive data produced by the New

²⁶ <http://www.open511.org/>

Cycle Network Proposer, containing proposals for new cycle lines/routes, which will be also represented as new informational layers. Produced Shapefiles will be save in the Storage, in order to be used to visualise information to end users.

- **Storage:** it will keep in a persistent way the shapefiles representing produced informational layers.
- **Layer Manager:** this component will be in charge of managing the lifecycle of stored layer representations, including issuing them to the GeoViewer.
- **User Interface:** this component will mainly consist of the GeoViewer component. It is a geographical tool provided by the GeoPortal of Milan Municipality. It enables the user to visualize a map, by selecting several information layers; they can be overlapped and mixed together. In addition, the user can draw and edit directly on the map, both textual labels and new geometric shapes. Thus, this component is the user interface that enables the user to visualize new layer produced by the core of the application.

NodeJS framework and related utility libraries will be used in order to implement the main components of the application (such as the adapters) and in order to realize the different data conversions performed by described components.

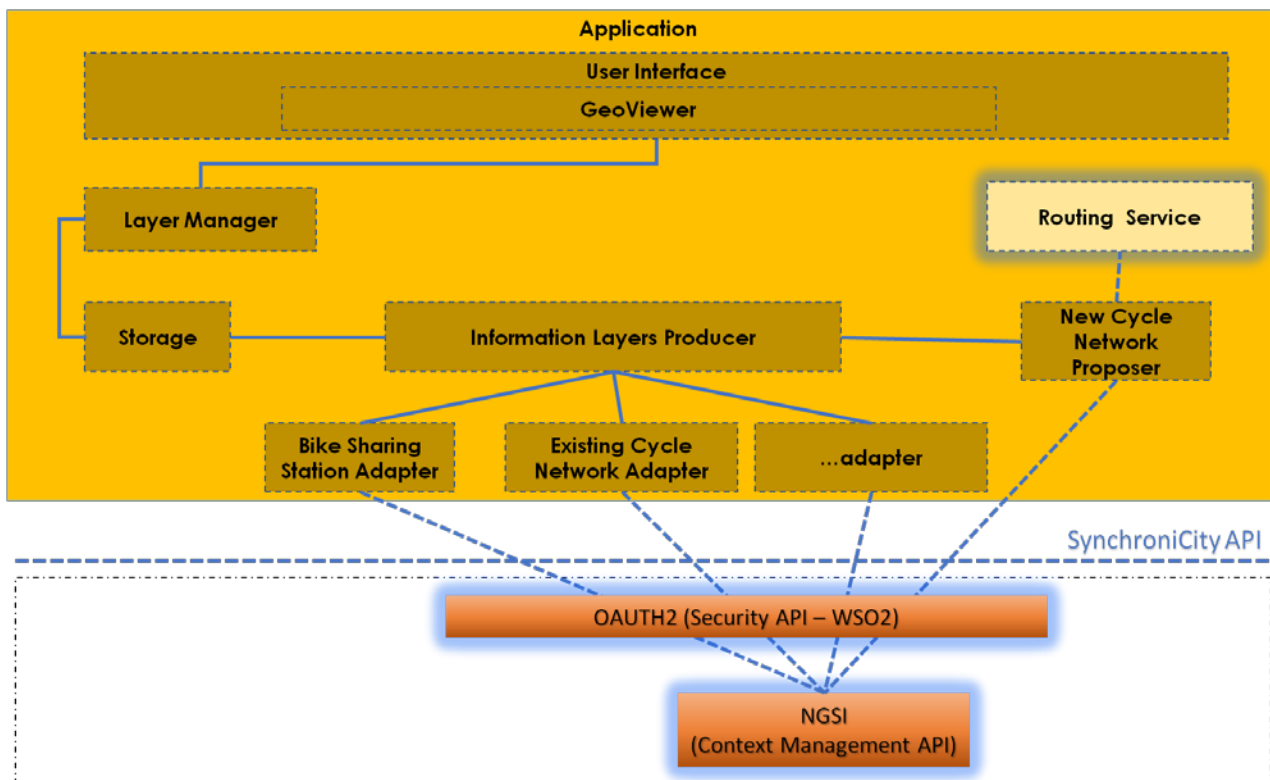


Figure 7. Milan Decision support system for cycle path planning application architecture

2.2.4.1 Reusable baseline services

As depicted in Figure 7, Milan's Decision support system for cycle path planning application will leverage on one baseline service, that will be integrated with the other components of the application and that will support the provision of the foreseen functionalities. The baseline service adopted in this application is the Routing Service.

Table 30: Baseline services adopted in Decision support system for cycle path planning application

Name	Description
Routing Service	The integration of this baseline service will provide the possibility to calculate new possible cycle path within the city; in particular it will be tailored in order to provide as accurate as possible estimation of new cycle path according to constraints already existing pedestrian areas in the city.

2.3 Antwerp's Application "Bycycle patterns in the city of Antwerp"

The application is intended as an open web-application, it provides improved estimations of speed and bicycle users in the city of Antwerp. The data will be NGSI compliant and can be used to improve route planners. In addition, the data can be used by the Department Of Mobility for extended reporting to influence policy decisions. In the city of Antwerp, the infrastructure for bicycle users can be improved. The platform will be public, only approved data will be disclosed. The City of Antwerp (Department Of Mobility) wants to analyse and use the data to adjust and manage their mobility policies to create better traffic conditions within the city. As it is unclear whether the data, which will be provided by different sources, is of good quality, it is also unclear which analyses are fit for the purpose. It is more important to start with an inductive phase to explore the data than to build a solution with some fixed analyses in it. The City of Antwerp has its own data warehousing and reporting solution, IBM Cognos²⁷. Rombit will provide the data to the Cognos platform so that the Department Of Mobility can explore the data, extract meaningful results and create reports of it, unlocking the full potential of the already stored data. The application will be the start for the Department Of Mobility to visualise and share their data.

2.3.1 Application scenario(s)

2.3.1.1 Users profiles:

Table 31: User profiles of Bycycle patterns in the city of Antwerp application

User profile ID	User description
Public User	Every user can use the web application to view data regarding bicycle usage in the city. Citizens can view information on bicycle count points, accidents, bicycle speed in the city, etc.
Subscribed Velo user	Citizens that are subscribed for the service of Velo ²⁸ (a bike sharing service in Antwerp). Users can hire bicycles from docking station throughout the city of Antwerp.
Mobility department User	All personnel from the mobility department has access to the IBM Cognos BI tool to have access to reports of the data. The user can gain insight in the data and use the data to prove the needs of cyclist in the city, e.g. the influence of construction sites on the average cycling speed or number of accidents. Data for the mobility department will be available in the Cognos BI tool where only these users will have access to it.

²⁷ <https://www.ibm.com/products/cognos-analytics>

²⁸ <https://www.velo-antwerpen.be/en>

2.3.1.2 Scenarios:

Table 32: Scenario "Sc.1 – Map component" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc.1 – Map component
User profile	Public user
Background	The application is an open web application where people can gain insight in the bicycle use in the city of Antwerp. The application shows a map of the city of Antwerp with different data sources regarding bicycle use. Different layers are possible to be selected for the map component.
Objective	User can select different map layers to have a different view.
Storyline	The user clicks on a map icon to see the different potential layers. The user can switch on or off the different views, open street map will be used as a basic map component.

Table 33: Scenario "Sc.2 - Zooming, scrolling and navigation" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc.2 - Zooming, scrolling, navigation.
User profile	Public user.
Background	The data that can be visualized will be visualized on a map which can be scrolled and zoomed. The application is an open web application where people can gain insight in the bicycle use in the city of Antwerp.
Objective	User can navigate on the map.
Storyline	The User scrolls the map up and down or right and left using the mouse. The User scrolls the map up and down or right and left using the keyboard. The User zooms or pans the map using the mouse scroll function.

Table 34: Scenario "Sc. 3 – Live interaction with IOT devices" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 3 – Live interaction with IOT devices
User profile	Subscribed Velo user.
Background	Extraction, transformation and loading of data.
Objective	Enable communication with IOT devices in the form of bicycle docking stations. Data extraction process will be coupled to the SynchroniCity framework and will be NGSI compliant.
Storyline	Subscribed users can hire bicycles from the docking station. After a user hires or put backs a bicycle in the docking station, the docking station communicates their capacity to the platform.

Table 35: Scenario "Sc. 4 – View bicycle docking station information in real time" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 4 – View bicycle docking station information in real time
User profile	Public user
Background	Visualisation of data in open web application.
Objective	Enable communication with IOT devices in the form of bicycle docking stations. Data will be made visual in a web application.
Storyline	The user views the different bicycle docking stations on a map.

	The user clicks on a bicycle docking station and a pop-up appears providing the latest received information.
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Table 36: Scenario "Sc. 5 - Visualisation of Ring Ring data" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 5 – Visualisation of Ring Ring data
User profile	Public user
Background	The GPS data of the Ring Ring application ^{29 30} (an application to promote the use of bicycle) and bicycle count points need to be transformed in the correct NGSI format and will be open to the public.
Objective	Visualisation of Ring Ring data on basis of speed or heatmap.
Storyline	When the application is launched the user can view the data of the Ring Ring application; the data is displayed using different colours that provide information about the speed. The user can see average speed of bicycles in every street on every street the average speed of bicycle users. User can switch to a heatmap to view the data after selecting this view.

Table 37: Scenario "Sc. 6 – Filter function on data sources" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 6 – Filter function on data sources.
User profile	Public user
Background	The application is web application for Mobility department employees. The application shows a map of the city of Antwerp with different data sources regarding bicycle use. The user can filter on the different data sources shown on the map.
Objective	The user can choose what data is displayed on the map.
Storyline	User can click on a checkbox to indicate what data needs to be displayed. When the user indicates a checkbox of data source, it is displayed on the map. In this way the user can choose what data to be displayed on the map.

Table 38: Scenario "Sc. 7 – Partial street selection" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 7 – Partial street selection
User profile	Public user
Background	The application is a web application open for the public. The application shows a map of the city of Antwerp with different data sources regarding bicycle use. Gaining insight in the bicycle traffic in the city of Antwerp.
Objective	Enable possibility to select a particular segment of the street.
Storyline	User can draw an arrow on the map to indicate a particular street segment. After selecting a street segment information, number of users and the average speed will be shown to the user.

²⁹ <https://ring-ring.nu/>

³⁰ <https://www.slimnaarantwerpen.be/en/bike/ring-ring-app> (English)

Table 39: Scenario "Sc. 8 – Bicycle count point" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 8 - Bicycle count point
User profile	Public user
Background	The application is a web application open for the public. The application shows a map of the city of Antwerp with different data sources regarding bicycle use. Gaining insight in the bicycle traffic in the city of Antwerp.
Objective	Enable the option to view information on bicycle count points.
Storyline	When selecting the data source, the user can see the different bicycle count points in the city. After clicking on a bicycle count point the user will see the number of cyclists counted by the point.

Table 40: Scenario "Sc. 9 – Date selection" of Bicycle patterns in the city of Antwerp application

Scenario title	Sc. 9 - Date selection
User profile	Public user
Background	The application is a web application open for the public. Users can search on date level to change the dates.
Objective	Date selection and correct visualisation of data.
Storyline	The user can navigate to the menu bar where she can define a date range for the application. The user selects two dates of the same month and their format, than the application shows the data collected from the different sources and corresponding to the date range.

2.3.2 Requirements analysis

2.3.2.1 Functional requirements

Table 41: Functional requirements of Bicycle patterns in the city of Antwerp application

ID	Description
FR-1	The application MAY be open for the public.
FR-2	Data regarding bicycle docking stations MUST be provided in real time.
FR-3	The application SHOULD visualise different bicycle accidents in the city.
FR-4	The application MUST provide improved average speed for road segments in the city.
FR-5	The application MUST provide improved average speed on street level.
FR-6	The application MUST be integrated with the synchronicity framework.
FR-7	The application SHOULD provide different overviews of the data sources.
FR-8	Users SHOULD be able to select a street segment.
FR-9	The application MUST visualise different data sources.
FR-10	The application SHOULD provide extended reporting.
FR-11	The application SHOULD have additional data sources, e.g., construction sites in the city, bicycle accidents in the city.
FR-12	The data MUST be transformed and loaded in the marketplace.

2.3.2.2 Non-functional requirements

Table 42: Non-functional requirements of Bicycle patterns in the city of Antwerp application

ID	Description
NFR-1	The application MUST be available in Dutch.
NFR-2	The application SHOULD be compliant with the house style of the city of Antwerp.
NFR-3	The application MUST be GDPR compliant.
NFR-4	The application SHOULD be user friendly and easy to use.
NFR-5	The application MUST be NGSI compliant.
NFR-6	The application SHOULD be incorporated with the different city services.
NFR-7	The GPS data provided MUST be reliable.

2.3.3 Available data sources

Table 1: Data sources used in Bicycle patterns in the city of Antwerp application

Title	Description	Open Data/API	Fiware model	Notes
City bicycle stations.	Data regarding shared bicycle stations.	Open data	Bike Hire Docking Station	
Data of the Ring Ring application.	Gps tracking data of a mobile application.	CVS	Bike, traffic flow observed	Might be available through API in the future. Traffic flow observed as output
Bicycle count point.	Data regarding bicycles counted on permanent locations.	Open data	Device	API might be available in the future.

To setup and test the whole ETL (Extract Transform Load) process primarily bicycle point data will be used because it is static data.

2.3.4 Application architecture

The application is an open web application for the public to gain insight of bicycle use in the city of Antwerp. The different components of the application ensure that a NGSI compliant data model is used and improved estimations on street segment level can be provided for external route planners. The data is open for the public and can be improved in the future with live coupling of GPS tracking data. A general overview of the architecture is reported in

Figure 8, whereas a more detailed view is reported in Figure 9.

The components of the application are the following:

Extraction transform and load of the different data sources. The different data sources need to be transformed in NGSI models. The GPS data will be transformed to the vehicle model and bike docking station will be coupled to the bike hire docking station. After the data is transformed to the correct format it is stored and distributed to the market place.

Data is validated on correctness and validated and filtered on what data can be shown public. After the validation the GPS data is transformed to the NGSI model traffic flow observed, here the GPS data will be coupled to street segments. For every street segment the average speed is calculated on basis of the GPS data.

The transformed and enriched data is coupled to the Cognos BI tool of the city of Antwerp. Here extended reporting can be done on basis of the gained data and other datasets of the city of Antwerp.

The data on street segment will give insight on the average speed of bicycles over time. This can be used to assess the impact of city policies or major construction sites in the city of Antwerp.

A map component is used to visualise the different data sources. Different views are available on basis of the data. In addition, a GUI is setup to ensure that users can use functionalities like date selection in the web application. The main goal of the application is improved average speed on street segment level and visualisation of data for the mobility department. There were no tools for the mobility department available to visualise their data on bicycle count points or mobility applications.

Which reusable baseline services will be exactly used is still under investigation.

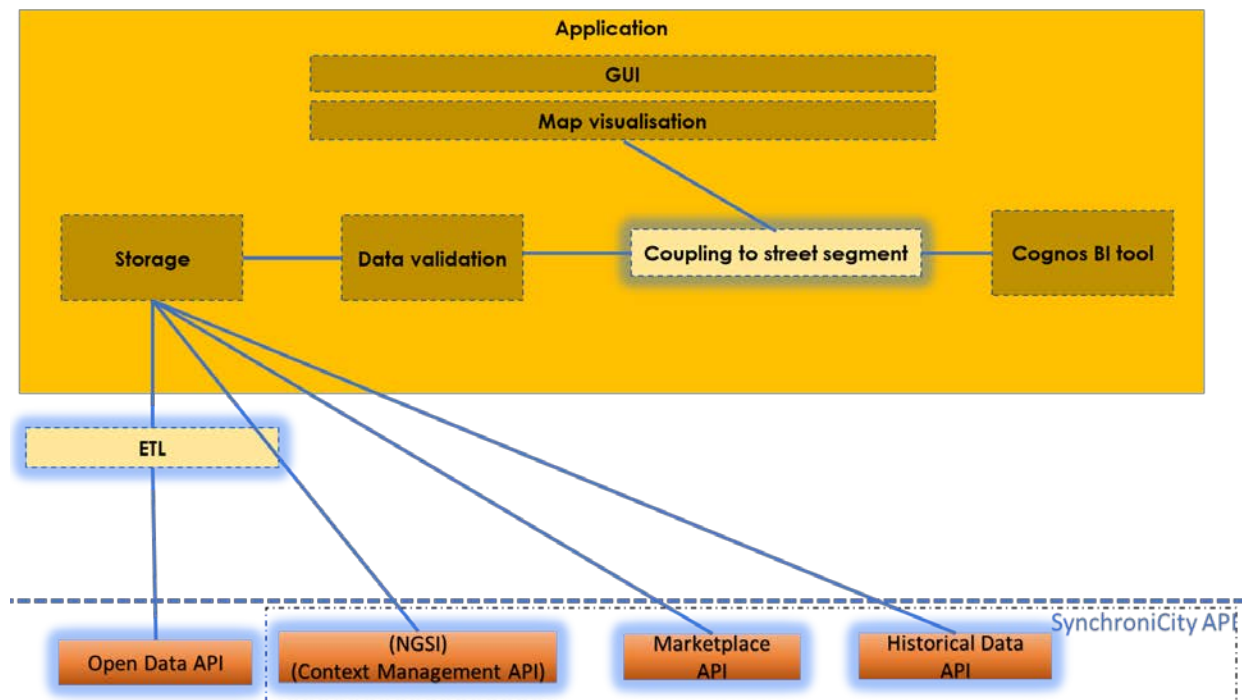


Figure 8: Overview of Antwerp application architecture for Bicycle patterns in the city of Antwerp

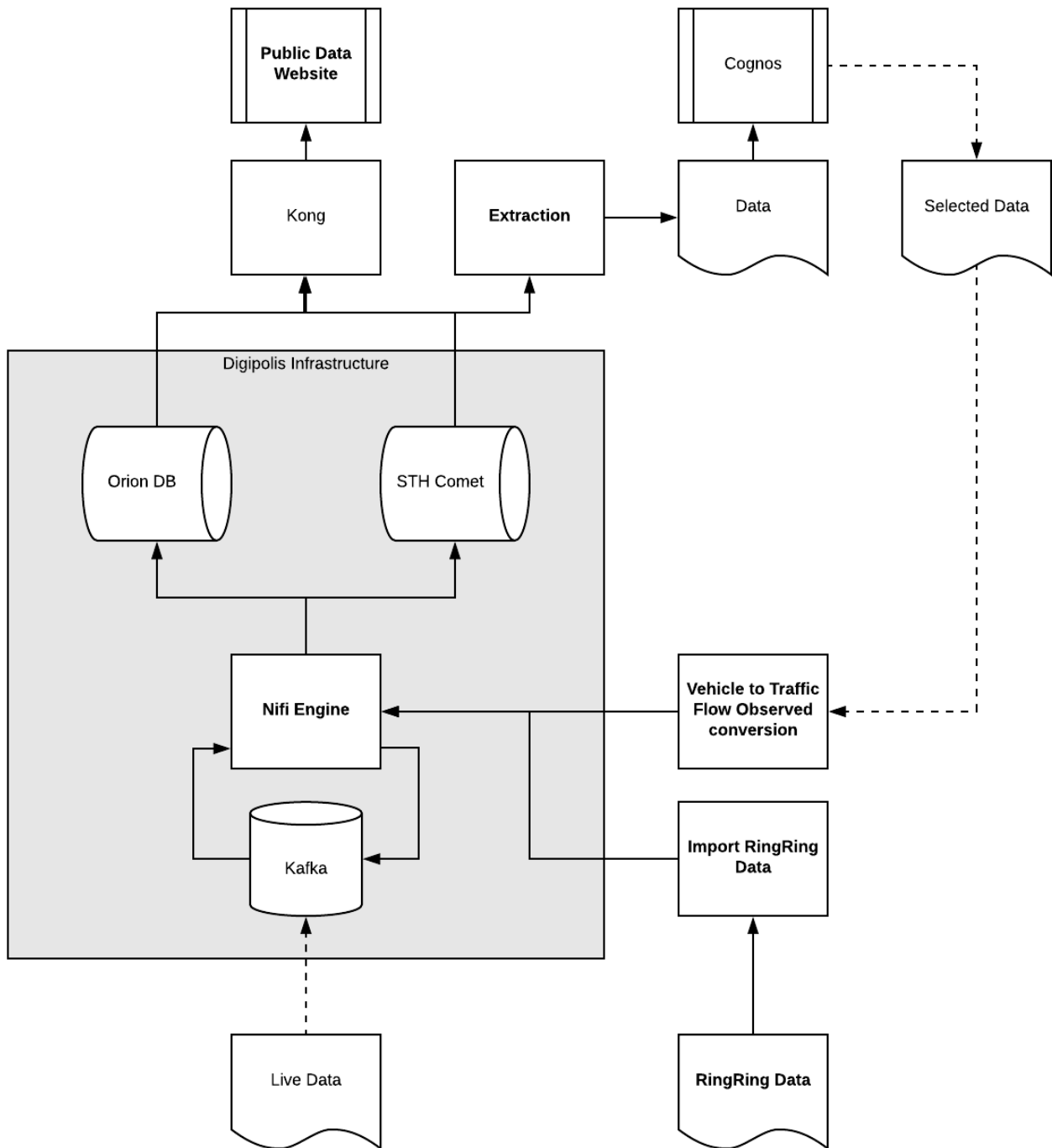


Figure 9: Technical overview of the components for application Bicycle patterns in the city of Antwerp

3 Application Theme: Multimodal transportation

Modern cities are continuously grow and one of the main challenges is urban mobility, because it impacts not only on sustainability, but also on quality of life. The aim of this application theme is to find solutions and approaches that take into account the different aspects of mobility in the cities and the different needs of people.

Appropriate tools could engage a positive switch of behaviours in both citizens and visitors in order to encourage the use of public transportation instead of the private one and to make urban transportation in general more sustainable and easy to use. This means to support citizens and visitor to take advantages of the different means of transportation and of the facilities offered by a city.

Five RZs participate in this application theme: Porto, Santander, Helsinki, Milan and Carouge; all these RZs are facing problems related to mobility in the city area and they are looking for solutions that fit their specific need and characteristics. In particular:

- Porto is dealing with the development of a comprehensive journey planner that takes into account not only different means of transportations (e.g.: public transportations, vehicle-sharing), but also informations and event that can impact how people uses them, such as location of POIs, events within the city, environment conditions (e.g.: noise, air pollution, weather forecasts, traffic jams (Section 3.1).
- Santander aims to improve the sustainable mobility within the City, taking advantages of new mobility premises (such as escalators and lifts that have been deployed) and reinforcing and redistributing city public transportation to better adapt to needs of visitors and citizens. (Section 3.2)
- Helsinki's goal is to reduce emissions by 60 per cent by 2030; to reach this objective one of the strategies is the promotion of both cycling and pedestrianism by reduction of disadvantages linked to poor air quality. Provision of walking and cycling route with good air quality for a more enjoyable cycling experience in the city is the aim of Helsinki's application. (Section 3.3)
- Milan is aiming to realize a multimodal navigator to help disabled people moving around the city; in particular disabled people in Milan are allowed to traverse restricted traffic areas in the city with their vehicles, and currently available navigators usually don't include this kind of feature. (Section 3.4)
- Carouge is dealing with limited number of parking slots in the city area; in particular its aim is to reduce the time for finding free parking slots providing adequate information to drivers such as real-time information about status of parking slots and short term predictions about their availability. (Section 3.5)

3.1 Porto's Application "Porto Multimodal Assistant"

Over the last few years, Porto has been affirmed as an excellence touristic destination. This has a huge impact on the way people move around the city. Upfront, more people means more traffic, more pollution, more incidents, more places requiring interventions, etc.

These problems are being solved with different approaches, and following the SynchronicCity's goals, Porto decided to make available an application based on its Urban Platform (FiwareFIWARE based Platform).

Besides, although Porto already has a multimodal navigator³¹ which provides mobility information about all the public transportation network of the Metropolitan Area of Porto (AMP), it lacks several features and is not very user friendly.

Accordingly, the *Porto. Multimodal Assistant* application will be more than an ordinary route journey planner! It will be a mobility solution which will better inform citizen's mobility choices and ease the citizen's mobility experience from, within and to the city of Porto.

The application will gather city data and user data, and thus provide a personalised and customised multimodal assistant, based on the user's preferences, requirements and choices.

The main city data sources that are expected to be handled by this application are: public transportation network (schedules, stops and stations, routes and lines, ticketing and pricing, etc.) and vehicle-sharing systems (docking and parking locations and status, vehicle availability); POIs (Point Of Interest); events; environment (noise, air quality and meteorological parameters); weather forecasts and alerts; traffic flow and constraints; and geographical data (highway, city roads and streets, bicycle path, sidewalk, public transport lines, etc.). Some of this data will be static (from a database), other will be provided in real-time (from sensors).

The route planner will enable search by different and complementary parameters, namely, single or multi-point destinations; POIs names; street names; different transportation modes; personal choice criteria (such as minimum price, minimum time, minimum distance, scenic, etc.); complementary use of private or shared vehicles with public transportation; etc. Other search features may be implemented at a later stage, such as, search by event name and date (such as concerts, festivals, exhibitions), search by taking into consideration user's temporary or permanent preferences and requirements (such as, low mobility, covered connections between intermediate points, air quality and noise levels), search by taking into consideration the real-time environment conditions and weather forecast.

The routes, user's real-time location and complementary information (such as POIs) will be displayed on a map.

Apart from the route planner features, the application will also provide other transportation information, such as, timetables at stops and stations, nearby stops and stations, parking information, and price and ticketing information. Furthermore, the user will also have access to complementary information (not related to the transportation needs), such as, POIs, events and geographic information. Other features may be implemented at a later stage, such as, the display of the weather forecast at the destinations(s), real-time alerts and notifications, interaction with NFC (Near-Field Communication) and BLE (Bluetooth Low Energy) beacons and integration with the user's own calendar.

Another innovative functionality that is planned to be implemented at a later stage is to embed an electronic wallet and a MaaS feature in the mobile app version. This will enable the user to check-in and out of several mobility services with the smartphone and only one app (the *Porto. Multimodal Assistant*) within the city of Porto. With a single app, the user will be able to check-in and out of: i) the public multimodal transportation network (instead of using a pre-charged wireless card), ii) several vehicle-sharing systems (instead of using several apps or cards), iii) car parks (instead of using a ticket), and iv) on-street parking machines (instead of using another app or a ticket). In the end, the user will receive a monthly mobility bill which will gather all the used mobility services (public, shared or private).

As a start, the *Porto. Multimodal Assistant* will provide direct links to other mobility services and apps (transportation ticketing, parking ticketing, etc.), in order to ease the user's mobility experience and to inform the user of all the digital payment and ticketing options available.

³¹ MOVE-ME.AMP, available online (<http://move-me.mobi>), and as an app for Android OS (<https://play.google.com/store/apps/details?id=com.move-me&hl=en>) and iOS (<https://itunes.apple.com/us/app/move-me-amp/id528984094?mt=8>).

This application will also enable the user to provide valuable information to the city and transportation operators, in particular, by reporting traffic events, road conditions, occurrences and malfunctions (crowdsourcing), and also to rate and comment the journey experience.

The application may also generate and provide valuable user data to the user herself/himself, in particular, the mobility historical, behavioural indicators and comparison with other users, trip summary and cost, 'green' behaviour grade, etc.

Another innovative functionality that is planned to be implemented at a later stage is to award the users with 'green credits' and incentives by using the public transportation network and vehicle-sharing systems, by parking the owned car outside the city and using the public network to enter the city, by reporting relevant and important malfunctions with the systems, etc. The credits and awards will be later exchanged by city products and services, such as, a concert ticket, a bike-sharing extended use period, e municipality service, etc.

The use of this app will also provide valuable mobility data to the city authorities and public transportation operators (anonymized data), which will enable all the mobility stakeholders, in particular the City Council, to have better informed decision and policy making in the areas of mobility, environment, urbanism and tourism.

3.1.1 Application scenario(s)

3.1.1.1 Users profiles:

Table 43: User profiles of Porto Multimodal Assistant application

User profile ID	User description
User Porto 1 (Commuter)	This user is a local inhabitant (lives and works in the Metropolitan Area of Porto) and daily commutes between home and job locations twice a day (at the beginning of the day in one direction and at the end of the day in the opposite direction), using the same schedules every day. This user has very limited time flexibility and is mainly familiar with one route (same departure and arrival destinations) and a few schedules . He/she uses the same transportation mode(s) every day, checks-in and out of the transportation network twice a day, and uses a monthly subscription ticket or the MaaS app . This user is mainly interested in price, speed, total time of transportation, and on-time arrivals and departures. The most relevant information he/she requires is real-time information about traffic constraints, estimated time to arrival (ETA), vehicle location, and departure and arrival time.
User Porto 2 (Expert)	This user is a local inhabitant (lives, works and has other regular activities in the Metropolitan Area of Porto), daily commutes between home and job locations , and also daily uses public transportation for many other activities (before, after or in between the two locations). He/she uses different schedules every day and along the day , has semi-limited time flexibility and uses a monthly subscription ticket or the MaaS app . This user is totally familiar with the global multimodal transportation network : uses different routes, schedules and transportation modes; uses different departure and arrival destinations along the day and week; and checks-in and out of the transportation network several times a day. This user is mainly interested in price, flexibility (multimodal system) and on-time arrivals and departures. The more relevant information he/she requires is real-time information about traffic constraints, estimated time to arrival (ETA), vehicle location, and departure and arrival time.
User Porto 3 (Sporadic)	This user is a local inhabitant (lives and works in the Metropolitan Area of Porto) and has a sporadic use of the public transportation network. He/she uses a pre-charged occasional ticket to travel along non-frequent or planned schedules, and has semi-limited time flexibility . He/she uses the public transportation

	system for a particular need or due to a temporary restriction (for example, the car is broken); uses specific routes and transportation modes (for each use); is not very familiar with the ticketing and transportation modes options. This user is mainly interested in transportation availability and clear information. The most relevant information he/she requires is bus/station location, route map, route options and ticketing prices, and real-time information about estimated time to arrival (ETA), vehicle location, and departure and arrival time.
User Porto 4 (<i>Outsider</i>)	This user lives and works outside the Metropolitan Area of Porto (visitor) or abroad (tourist). He/she has a very sporadic use, and uses the public transportation network to travel to pre-defined locations (hotel, main POIs, airport, etc.). He/she uses non-frequent or planned schedules and has significant time flexibility, and uses a tourist ticket or a pre-charged occasional ticket. This user: • is not familiar with ticketing options, transportation modes and the global multimodal transportation network; • uses different routes, schedules and transportation modes; • uses different departure and arrival destinations along the day and stay period; • checks-in and out of the transportation network several times a day. This user is mainly interested in transportation availability, and clear and multilingual information (in particular, in English language). The most relevant information he/she requires is bus/station location, route map, route, modes and ticketing options, and real-time information about departure time, next exit (according to desired/planned destination).

3.1.1.2 Scenarios:

Table 44: Scenario "Estimated time of arrival (ETA) and schedules" of Porto Multimodal Assistant application

Scenario title	Estimated time of arrival (ETA) and schedules
User profile	User Porto 1
Background	Maria lives and works in the Metropolitan Area of Porto and she daily commutes between home and job locations. Usually, apart from the bus schedules tables available at each bus stop, she doesn't have real-time information regarding the ETA, bus location, and/or departure time.
Objective	Maria wants to know if the bus she needs to take is on-time and/or has already departed. In the latter case, she wants to know when she can pick up the next one.
Storyline	As a daily commuter, Maria has routine schedules. In particular, she normally picks up the same 999 bus that will take her back home at the end of the day: she arrives at the bus stop around 18:20, and the bus leaves around 18:30. Sometimes, she arrives later to the bus stop and/or the bus departs sooner than expected. When she arrives at the bus stop some minutes later than usual, Maria is not sure if the bus has already departed or not. Then, Maria uses the Multimodal Assistant app to check the ETA of the next 999 bus. She opens the app, which automatically detects her location by GPS (in particular, the bus stop). The app provides her information about the available buses at that particular bus stop, and then she selects the 999 route. The app provides her information about the ETA (real-time data) of the next 999 bus, and the scheduled departure times of the next ones. Maria finds out she has just missed the bus by a few minutes, and the ETA of the next 999 bus is 25 minutes. Instead of waiting at the bus stop for almost half an hour, she takes the opportunity to go the nearby grocery and buy a few supplies.

Table 45: Scenario "Real-time mobility information" of Porto Multimodal Assistant application

Scenario title	Real-time mobility information
User profile	User Porto 2
Background	João lives, works and has other regular activities in the Metropolitan Area of Porto. He daily commutes between home and job locations, and also daily uses public transportation for many other non-routine activities (for example, go to the supermarket, pick-up the kids, meet with friends downtown or play football). Once João uses different schedules every day and along the day, he needs to have real-time information regarding the ETA, vehicle location, and/or departure time of different transportation modes, at different locations and different times.
Objective	João want to know when and where he can get the most adequate transportation mode(s) that allow him to reach the desired destinations.
Storyline	João works in the city centre, but is going to have lunch with a few friends close to the beach. Before leaving the office, he uses the Multimodal Assistant app to plan his route between the office and the restaurant: he opens the app, which automatically detects his location by GPS, and then João inserts the desired arrival location. The app provides him optimized route suggestions, based on the departure/arrival destinations, his actual location, and informs him: when he should leave the office, where he must pick up the bus (bus stop location) and the ETA (real-time data) of the next bus. After lunch, he decides to use the app to plan his return to the office. Based on real-time traffic, transportation and events data, he finds out that there has been a car accident, and the same route (in the opposite direction) will take him more than twice the time he took to get there. Instead, he chooses another route, which will make him walk a little more, but will take him to a Metro station. The app provides him ETA of the next Metro train. He picks up the train, and reaches his destination without any delays, because the Metro train is not affected by traffic.

Table 46: Scenario "Route planning by departure/arrival locations" of Porto Multimodal Assistant application

Scenario title	Route planning by departure/arrival locations
User profile	User Porto 3
Background	Ana lives and works in the Metropolitan Area of Porto but has a sporadic use of the public transportation network, because she only uses it for a particular need or due to a temporary constraint. Usually, apart from the bus numbers and bus schedules tables available at each bus stop, she doesn't have real-time information regarding the ETA, bus location, and/or departure time.
Objective	Ana wants to find out where she can pick up the nearest bus and if the bus she needs to take is on-time and/or has already departed. In the latter case, she wants to know when and where she can pick up the next one.
Storyline	Ana is driving to the work office, but she suddenly hears a weird noise in her car. She decides to go to a nearby auto repair shop to check the problem, which detects a major break failure. Accordingly, she is strongly advised to leave the car to be repaired, which she does. This is the first time she has been at this shop, so she has no idea how to go from here to the office. Before leaving the shop, she uses the Multimodal Assistant app to plan her route between the shop and the office: she opens the app, which automatically detects her location by GPS, and then Ana inserts the desired arrival location. The app provides her the only available route, based on the departure/arrival destinations, and informs her: where she must pick up the bus (bus stop location) and the ETA (real-time data) of the next bus; where she must check-out of the bus and pick-up a Metro train and the ETA (real-time data) of the next train. The app also informs her which multimodal pre-charged occasional ticket she must buy/use (number of zones)

	for this full route. During the journey, Ana receives a real-time notification from the app, informing her that she must leave at the next bus stop, the ETA of the Metro train and a reminder that she must check-in the ticket again at the Metro station. She picks up the train, and during the journey, Ana receives a real-time notification from the app informing her that she must leave at the next Metro station. She leaves the station and then walks to the office.
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Table 47: Scenario "Route planning by POI" of Porto Multimodal Assistant application

Scenario title	Route planning by POI
User profile	User Porto 4
Background	Alex is a British tourist visiting Porto for the first time and for a few days. He only knows the name and address of the hotel where he will stay, and he has just arrived at the city's airport.
Objective	Alex wants to know how to reach his hotel and after that, how to go from the hotel to the city's Cathedral, which are both located in the city and historical centre, respectively.
Storyline	Alex has just arrived at Porto's airport, which is actually located in the nearby city of Maia. He wants to know how to reach his hotel, which is located in Porto's city centre. Alex uses the Multimodal Assistant app (which is also available in English language) in order to plan his route: he opens the app, which automatically detects his location by GPS, and then Alex inserts the desired arrival location: "Allies Hotel". The app database comprises several POIs, including hotels, and provides him with the most appropriate route, based on the departure/arrival destinations, and informs him: where he must pick-up the Metro train and the ETA (real-time data) of the next train. The app also informs him which multimodal pre-charged occasional ticket he must buy/use (number of zones) for this route, and reminds him he must check-in his ticket at the Metro station. During the journey, Alex receives a real-time notification from the app, informing him that he must leave at the next Metro station ("Allies"). He then leaves and walks to his hotel, where he checks-in and leaves his bag in the room. After that, he wants to find out how to reach the city's Cathedral. He uses the Multimodal Assistant app in order to plan his route: he opens the app, which should automatically detect his location by GPS, but since he is in the room (indoor), he has to provide his departure location ("Allies Hotel"); then he provides the desired arrival location ("Cathedral Porto"). He then realizes that he is very close to the Cathedral, because the two route options provided by the app are to take the Metro for a 5 minute travel distance, or to walk for 15 minutes. He decides to walk to the Cathedral, and the app provides him the walking route and his real-time location on a map. Finally, he reaches the Cathedral, and feels amazed by its beauty by the unique view of the city from the top of the Cathedral!

3.1.2 Requirements analysis

3.1.2.1 Functional requirements

Table 48: Functional requirements of Porto Multimodal Assistant application

ID	Description
FR-1	The application MUST enable the creation of a user account
FR-2	The application MUST enable the user to set mobility preferences and requirements
FR-3	The application MUST enable saving user's mobility historical
FR-4	The application MUST provide user's behaviour indicators (based on mobility historical) and comparison with 'average' user
FR-5	The application SHOULD enable the user to create an avatar
FR-6	The application SHOULD be integrated with the phone calendar, and provide suggestions and warnings, based on the agenda scheduled events
FR-7	The application MUST provide POIs for a given location, in particular, near the start and end locations
FR-8	The application MUST provide parking info for a given location, in particular, near the start and end locations
FR-9	The application MUST provide geographical info (street name) and mobility info (nearby lines, stops and stations) for a given location
FR-10	The application MUST provide bus, metro/tram and train timetables at the nearby stops and station
FR-11	The application MUST enable single or multi-point routes
FR-12	The application MUST enable route search and planning by street name
FR-13	The application MUST enable route search and planning by POIs name
FR-14	The application SHOULD enable route search and planning by event name and date
FR-15	The application MUST enable route choice based on the use of different transportation modes, such as, buses, trains, metro/tram, taxis, car-sharing, bike-sharing, scooter-sharing (when available)
FR-16	The application MUST enable route choice based on several criteria, such as, minimum price, faster, minimum distance, minimum number of transfers, ecological, scenic, etc.
FR-17	The application SHOULD provide customized route suggestions based on user's preferences and requirements
FR-18	The application MUST provide a map visualization for all the route suggestions
FR-19	The application MUST provide price and ticket information for each route
FR-20	The application SHOULD take into consideration real-time traffic constraints (such as, accidents, disruptions) on the route search and planning
FR-21	The application SHOULD take into consideration real-time meteorological, noise and air quality data on the route search and planning
FR-22	The application SHOULD take into consideration weather forecast on the route search and planning
FR-23	The application SHOULD provide weather forecast on the start, intermediate and end locations
FR-24	The application MUST enable route choice based on the use of own car and parking, complemented by the use of public transportation modes
FR-25	The application MUST take into consideration scheduled timetables of public transportation modes on the route search and planning
FR-26	The application SHOULD take into consideration real-time location and schedules of public transportation modes on the route search and planning
FR-27	The application SHOULD update the route suggestions based on real-time traffic constraints
FR-28	The application SHOULD provide alerts and notifications, in particular, during the trip

FR-29	The application SHOULD enable the user to post and update traffic and road conditions (crowdsourcing)
FR-30	The application MUST display the user's real-time location on a map (if user's GPS is enabled)
FR-31	The application SHOULD update the route based on real-time traffic alerts and notifications
FR-32	The application MUST provide estimated time of arrival and check-out warnings, based on the route and real-time location
FR-33	The application SHOULD enable manual or automatic check-in/check-out of the chosen route
FR-34	The application MUST provide a trip summary (distance travelled, time, calories burned, CO2 emissions, cost, etc.) at the end of the trip
FR-35	The application SHOULD provide a comparison between the trip and the same trip made by car (for example, cost, CO2 emissions)
FR-36	The application SHOULD enable the user to provide feedback of the journey experience (review, rating, comment, etc.)
FR-37	The application SHOULD enable the user to report occurrences and malfunctions of the stops, stations and vehicles' conditions (review, rating, comment, photos, etc.)
FR-38	The application MUST provide shortcuts to other useful apps or websites, such as, public transportation ticketing and payment, parking payment, payment services.
FR-39	The application SHOULD enable a MaaS service, where users can check-in/out of several public transportation modes with the same electronic ticket
FR-40	The application SHOULD enable a MaaS service, where users receive a monthly bill
FR-41	The application SHOULD enable the connection with BLE beacons
FR-42	The application SHOULD enable the connection with NFC beacons
FR-43	The application SHOULD provide 'green credits' and awards (incentives), based on the frequent use of public transportation, low use of private (owned) transportation and for reporting stops and stations conditions and malfunctioning
FR-44	The application SHOULD enable the exchange of incentives by city services
FR-45	The application MUST open an info bubble when a marker is clicked

3.1.2.2 Non-functional requirements

Table 49: Non-functional requirements of Porto Multimodal Assistant application

ID	Description
NFR-1	The application MUST support Portuguese (Portugal) language
NFR-2	The application MUST support English (UK) language
NFR-3	The application SHOULD support Spanish (Spain) language
NFR-4	The application MUST provide the terms and conditions of use
NFR-5	The application MUST provide the data privacy policy
NFR-6	The application MUST have a mobile app version for the Android operating system
NFR-7	The application MUST be available for download and installation at the Google marketplace (Google Play)
NFR-8	The application MUST have a mobile app version for the iOS operating system
NFR-9	The application MUST be available for download and installation at the Apple marketplace (App Store)
NFR-10	The application MUST have a web app version
NFR-11	The web app version of the application MUST be responsive
NFR-12	The mobile app versions MUST work without Internet connectivity
NFR-13	The application MUST provide a user's assistance service by email or contact form
NFR-14	The application SHOULD provide a FAQs list
NFR-15	The application SHOULD provide general news related with the mobility in the city

3.1.3 Available data sources

Table 50: Data sources used in Porto Multimodal Assistant application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Noise	Noise levels (LAeq, 5 min)	Open data	NoiseLevelObserved	
Air pollutants	Information about air pollutants measurements such as: PM2.5 particles, PM10 particles, Ozone (O3), Nitrogen dioxide (NO2), Carbon monoxide (CO)	Open data	AirQualityObserved	
Meteorological parameters	Data coming from meteorological measurements: Solar radiation, ultraviolet radiation, wind direction and speed, rainfall, atmospheric pressure, air temperature and humidity measurement	Open data	WeatherObserved	
Vehicle location and speed	Data about vehicle location and speed	Open data	Vehicle	
Vehicle count	Data about number of vehicle (count) in a road segment.	Open data	TrafficFlowObserved	
POIs	Data about Points of interest (POIs)	Open data	PointOfInterest	
Events	Information about events (concerts, football games, cultural events, etc.)	Open data		W3C / Schema Data model: Event No FIWARE data model available
Public transportation	Public transportation data (schedules, routes, lines, stations/stops, etc.)	Open data	To be defined	
Traffic constraints	Data about temporary traffic constraints (scheduled events, accidents, etc.)	Open data		Data model: Open511 (To be confirmed) No FIWARE data model available
Weather forecast	Precipitation probability, relative humidity, temperature, weather type, wind direction, wind speed	Open data	WeatherForecast	

3.1.4 Application architecture

Porto Multimodal Assistant is an application built with Digitransit Platform³². Digitransit Platform is an open source journey planning solution that combines several open source components into a modern, highly available route planning service. Route planning algorithms and APIs are provided by OpenTripPlanner³³ (OTP).

OTP is a great solution for general route planning, but in order to provide top-notch journey planning other components such as Mobile friendly user interface, Map tile serving, Geocoding, and various data conversion tools are needed. Digitransit platform provides these tools, as illustrated in the Figure 10.

The following figure depicts the matching layers between the overall architecture of Porto's SynchroniCity framework and the multimodal transportation application one. From bottom-up, the layers are the following:

- Bottom (blue rectangle): Data sources for the services supporting the application, and Porto's SynchroniCity framework (namely all the FIWARE components, sensors and other city's databases).
- Intermediate (green rectangle): Baseline services. Note the "conversion" process between this and the layer below. Given that these services are not really consuming data directly from a NGSI interface, this data conversion is required. The reason why this process is included in the green rectangle is because, most probably, it will be handled by a service (although it is not a baseline service).
- Top (red rectangle): Application layer, where the multimodal transportation application will sit.

³² <https://digitransit.fi/en>

³³ <http://www.opentripplanner.org>

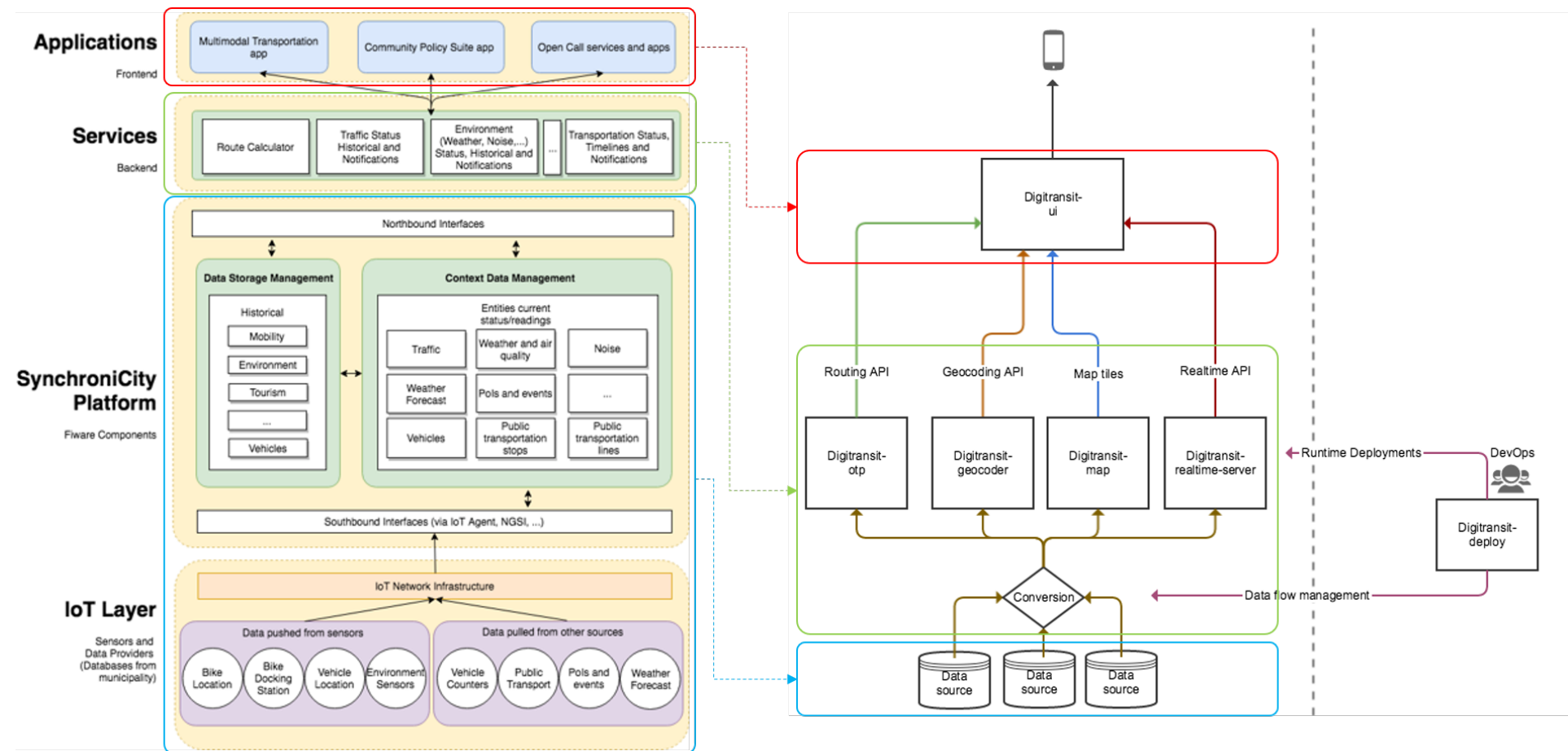


Figure 10: Matching layers between the overall architecture of Porto's SynchroniCity framework (left) and the MMT application architecture (right, © digitransit)

This application itself is built with React³⁴, a JavaScript library for building user interfaces, following an application architecture (for building client-side web applications) named Flux³⁵ React components (responsible for UI and I/O with the user) query underlying services as follows:

- using Relay³⁶ (a JavaScript framework for building data-driven React applications) for querying the OpenTripPlanner service, through the Routing API³⁷ (which supports GraphQL)
- with Fluxibe³⁸ (a pluggable container for universal flux applications) for querying other service's API (Realtime HSL³⁹, Map⁴⁰, Geocoding⁴¹ and eventually⁴² the Traffic Flow Estimator).

The following figure shows the interaction between the components.

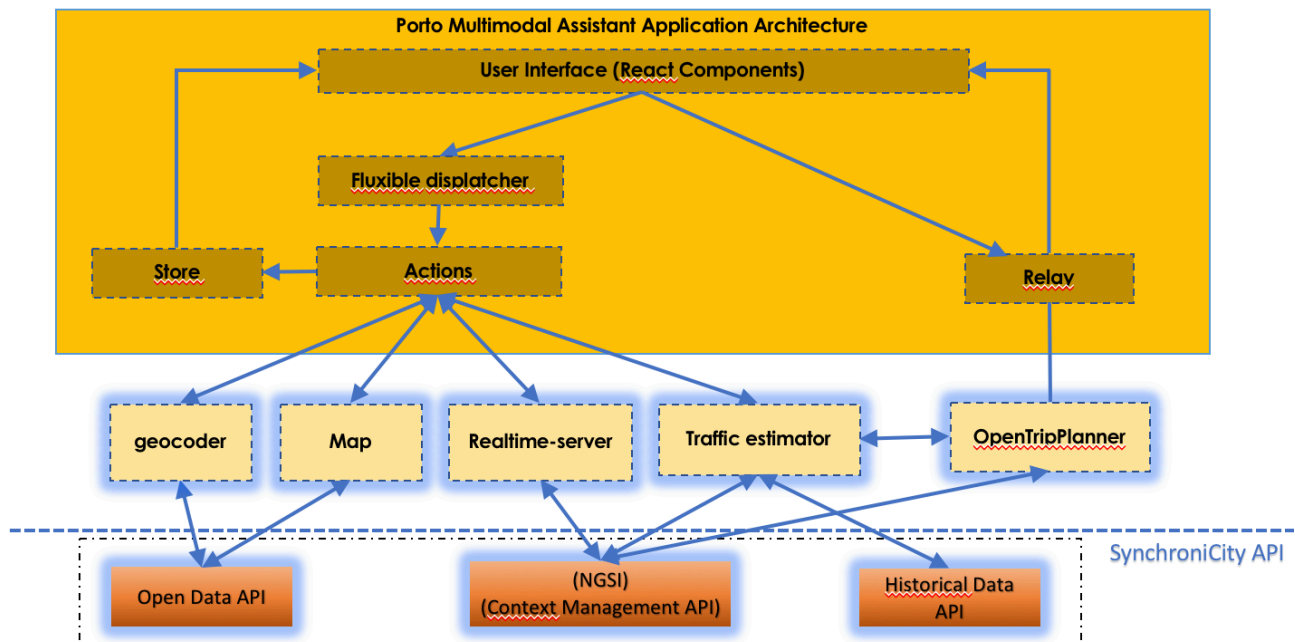


Figure 11: Porto Multimodal Assistant Application Architecture

As mentioned, querying servers through APIs other than GraphQL, is done through a Flux model, implemented with Fluxibe. In this model, the view component (React components), using an action creator method, invokes the dispatcher component (Fluxibe Dispatcher), which will then trigger an action. In our app, this action is responsible for querying the service and send the result in a store component.

The result of the queries is delivered back to the React components through 'notifications'.

³⁴ <https://reactjs.org/>

³⁵ <https://facebook.github.io/flux/>

³⁶ <https://github.com/facebook/relay>

³⁷ <https://digitransit.fi/en/developers/apis/1-routing-api/>

³⁸ <https://github.com/yahoo/fluxible>

³⁹ <https://digitransit.fi/en/developers/apis/4-realtime-api/>

⁴⁰ <https://digitransit.fi/en/developers/apis/3-map-api/>

⁴¹ <https://digitransit.fi/en/developers/apis/2-geocoding-api/>

⁴² The usage for this service is still under discussion.

3.1.4.1 Reusable baseline services

Table 51 reports the baseline services used for Porto's Multimodal Assistant.

Table 51: Baseline services adopted in Porto Multimodal Assistant application

Name	Description
Routing baseline service	Provides a way to plan itineraries and query public transportation related information about stops and timetables. Routing is the main Digitransit service, with OpenTripPlanner (OTP) as the core. (Digitransit name in Figure 10: Digitransit-otp)
Geocoding and Reverse Geocoding Service	Provides a way to perform address searches and address lookups (also known as reverse geocoding). Digitransit uses Pelias(Pelias, 2018) as Geocoding and Reverse Geocoding service. (Digitransit name in Figure 10: Digitransit-geocoder)
Map Service	Provides background maps in Tile Map Service format ⁴³ . Map data is based on vector export of OpenStreetMap. (Digitransit name in Figure 10: Digitransit-map)
GTFS (General Transit Feed Specification) RealTime Service	Provides GTFS-RT (GTFS-RealTime) updates, such as service alerts, trip updates and vehicle positions. Currently, real-time public transport trip predictions are available via the Routing Service. (Digitransit name in Figure 10: Digitransit-realtime-server)
Traffic Estimation Service (Traffic Estimator)	Provides estimation for traffic conditions in specific location, road or road segment.

3.2 Santander's Application "Park & Move"

Santander City Council is investing to improve the sustainable mobility within the City. In this way, new mobility premises such as escalators and lifts have been deployed to ease the access different parts of this hilly city, as well as reinforce and redistribute city public transportation to better adapt to citizens requests. This is the reason why Santander RZ selected Multimodal Transportation use case, within Synchronicity scope, to exploit these new infrastructures and provide better mobility resources to its citizens and visitors.

The current (Figure 12) Santander RZ's application represents 2 combined scenarios/use cases within the Multimodal Transportation SynchroniCity. umbrella:

- **Smart Parking** app intended for users that arrive at Santander city by car. The user will introduce a desired area within the city to park and the system will estimate the probability of finding a free parking lot (in e.g. 20/30 minutes). Once the user has selected the area where they will drive to, the system will provide the best route (by car), considering traffic and weather conditions and giving a route in the zone in a way it maximizes the odds of finding a parking place.
- **Multimodal Navigator** app given point A (starting point) and point B (destination) the app will (initially) combine Buses (SMTU, Urban Transportation Municipal Service) info (lines, stops, estimations and routes) and mobility premises (initially starting and ending points - sections-) to provide a multimodal route within the city and will allow users to select the optimization criteria (time, cost, carbon footprint, etc).

These two initial applications can be merged to include private car as a multimodal option: the city area where the drivers (users) will park their cars can be considered as the "Point A" for the city-multimodal route. This way, the whole system will recommend an area to park, including a route (by

⁴³ https://wiki.osgeo.org/wiki/Tile_Map_Service_Specification

car) from outside the city plus the corresponding multimodal route to the destination, offering also arrival estimation times.

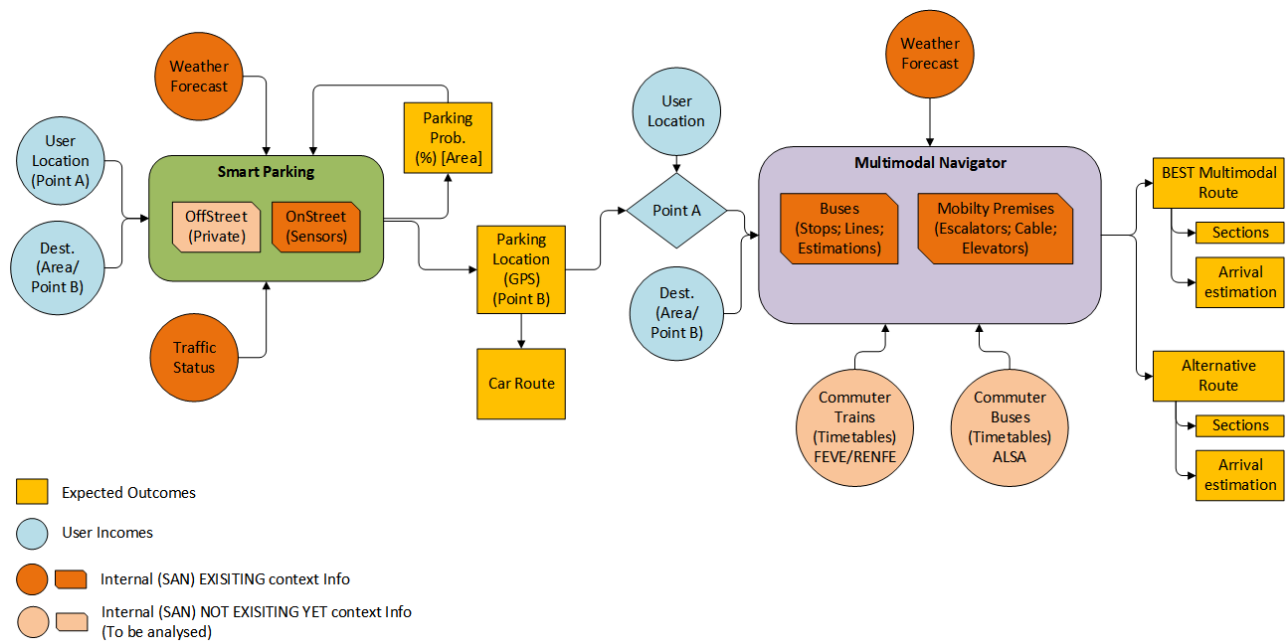


Figure 12: Santander Scenario diagram

3.2.1 Application scenario(s)

3.2.1.1 Users profiles:

Table 52: User profiles of Park & Move application

User profile ID	User description
Car driver	End user that comes to the city by car (driver). In order to save time and fuel (money) he/she wants to know what the best area of the city would be to quickly park his/her car, including the best route to get to this area, depending, among others, on traffic/weather conditions, time and date.
Pedestrian	A user that moves within the city by foot and/or using public transport. Combining bus lines, stops, time estimations and availability of mobility infrastructures, he/she wants to find out the best/adapted route to move from one point to another.
Tourist	A user that arrives (for first time) to the city and wants to move within the city by foot and/or using public transport. Combining bus lines, stops, time estimations and availability of mobility infrastructures, he/she wants to find out the quickest/adapted/safest/nicest route to move from one point to another.

3.2.1.2 Scenarios:

Table 53: Scenario "Where do I park?" of Park & Move application

Scenario title	Where do I park?
User profile	Car Driver
Background	Juan lives outside Santander city, just 20 minutes from downtown by car. This afternoon he plans to drive to the city centre for shopping and have some beers with his friends. They are meeting in 45 minutes in front of the city hall, so Juan wants to know, in 25-30 minutes from now, what would be the best options to find a parking lot and get to the city hall, plus the best route now, considering traffic status and its estimated evolution, to get there.
Objective	Juan wants to reduce the time (and money) he wastes when he drives to the city trying to find a free parking lot, as well as be informed about what would be the quickest/safest route to drive downtown, considering traffic behaviour. This way it would be possible for him to estimate how long will take him to get his destination.
Storyline	Juan launches the app on his smartphone; initially the application shows a map of Santander City divided in city areas (so far, considering ONLY those areas with parking sensors) showing the current (number) available free spots. Then, the application requests for the Starting point (Point A) and "when" (expected time) the user plans to go to the city. Juan provides requested information and based on "when", the application calculates the parking probabilities for the defined city areas and paints them on the Santander's Map (on the screen). Based on probabilities shown, Juan selects the area to search for parking, what would be used as Point B (destination). Context information (traffic status, weather conditions, incidences, etc.) would be considered to calculate the best route (and alternatives). After that, the application offers (paints) the calculated options (routes) to the user: 1 main + 2 alternatives.

Table 54: Scenario "Transport me!?" of Park & Move application

Scenario title	Transport me!
User profile	Pedestrian (citizen or tourist)
Background	Alice lives on outskirts of the city. As Juan, she is meeting her friends in the city hall this afternoon in about 45 minutes. Alice will use public transport to get there, as she has a bus stop next to her home. As today is sunny, she would not mind doing part of the whole route on foot. Taking her bus stop as the starting point and the city hall as her destination, Alice request for the combinations of bus lines that takes her less than 0,5 km from the city hall, considering also the cable that connects with the city centre. She is interested on the arrival estimations for the different options, so she can choose the one that allows her to be in time.
Objective	According a set of initial user's requirements (don't mind walking, use bicycle, wheelchair rider, etc.) and other context information (weather forecast, incidences, buses delays, etc.), Alice wants to know the best route, combining public transports, mobility premises and walking, to get from point A to point B within the city. She also requests all available info about the proposed options, as arrival estimations, transfers, whole path, weather forecast, etc. so she can choose the one that works better for her. This way, she can estimate when she is arriving to destination.
Storyline	Alice launches the app on her smartphone. The application shows a map of Santander City and requests for an "starting point" (captured from the Alice's smart device) and an "end point" (destination) Alice provides the end pint and

	then the application ask her for preferred means of transport (e.g., pedestrian route including mobility premises, buses, buses + mobility premises): Alice selects her preferred means of transport and based on transport info (mainly buses) and routing service, the application provides a main route (e.g., the quickest one) plus two alternatives; all of them include (when appropriate): 1. Pedestrian route to initial Bus Stop with estimated time taken. 2. Bus line to take and estimated arrival time. 3. Route followed by the bus to the proposed bus stop to get off plus estimated arrival time. 4. New bus line to take and (if needed) the pedestrian route to get to the new proposed bus stop. 5. Route followed by the second bus to the final proposed bus stop plus estimated arrival time. 6. Pedestrian route (if needed) to get the destination. Furthermore, the proposed pedestrian routes include also mobility infrastructures (when available and appropriated). The application also provides Alice with the estimated arrival times to each step on the route besides the estimated arrival time to destination. It may also offer the estimated arrival times for next buses corresponding to the lines included in the proposed routes and in the selected bus stops.
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Table 55: Scenario "Come & Go!" of Park & Move application

Scenario title	Come & Go!
User profile	Car Driver, Pedestrian from outside of the city, tourist
Background	As Juan, Bob lives outside the city and he is also meeting with Juan and Alice in the city hall. But Bob hates driving downtown, so he prefers to get by car to a park & ride area not so close to the city centre and get the meeting point by bus.
Objective	Either, Bob gets the city by car or using public transport, the application will combine his first option (car route to park & ride premise or commuter train/bus information) with the city multimodal navigator to provide Bob with the best route and arrival estimation times from Bob's "home" (starting point) to the city hall (destination), allowing Bob to save his time (and money), reducing car traffic in rush hours and crowded areas and increasing air quality and safety feeling.
Storyline	Bob launches the app on his smartphone; initially the application shows a map of Santander City divided in city areas (so far, considering ONLY those areas with parking sensors) showing the current (number) available free spots AND the available park & ride areas. Using his home as the starting point, Bob selects one of the available park & ride premises and "when" he wants to arrive at the desired destination. Then the application calculates the best car route, considering traffic (current and estimated) status to get the parking premise plus the multimodal city route, considering bus stops and mobility premises near de "middle point". The application offers 1 main option + 2 alternatives.

Table 56: Scenario "Visit my City!" of Park & Move application

Scenario title	Visit my City!
User profile	Car Driver, Pedestrian from outside of the city, tourist
Background	Cindy is a friend of Alice that lives abroad and is visiting Alice city for her first time. She has just arrived at the airport and she will meet Alice and her friends at the city hall.
Objective	Either, Cindy gets the city by car or using public transport, the application will combine her first option (car route to parking place or commuter train/bus information) with the city multimodal navigator to provide Cindy with the best route and arrival estimation times from the airport (starting point) to the city hall (destination).
Storyline	Cindy launches the app on her smartphone; The application shows a welcome screen and asks to select the way she is arriving to the city (train, bus, car). Cindy selects "train" and the applications requests for the initial train station and the destination within the city. Cindy points to the airport and the city hall as Point A and Point B. The application calculates what's the estimated arrival time to the airport station for the train/s that takes Cindy to the city train station and the corresponding multimodal routes (with associated info) to later get to the meeting point (Point B) plus the estimated arrival times to destination for all offered options.

3.2.2 Requirements analysis

3.2.2.1 Functional requirements

Table 57: Functional requirements of Park & Move application

ID	Description
FR-1	Sensed parking lots: real time info about parking lots status, including location MUST be provided.
FR-2	Pre-defined city areas: that group referred parking lots MUST exist. These SHOULD be defined/provided by the city.
FR-3	Historical data referred to Parking in defined city areas SHOULD be provided
FR-4	The system MUST provide Parking Prob. Estimation info, referred to a city area and a specified time slot.
FR-5	A Routing Service MUST exist: This routing service MUST provide a valid route between point A and point B . This service SHOULD be able to consider different routes profiles (trekking, bicycle, car, etc.) and support mobility premises consideration (lifts, escalators, etc.).

3.2.2.2 Non-functional requirements

Table 58: Non-functional requirements of Park & Move application

ID	Description
NFR-1	Traffic info: real time & historical data about traffic status MAY be considered within the route calculation process.
NFR-2	Weather forecast: real time & historical data about weather status MAY be considered within the route calculation process.
NFR-3	Required data MUST be accessible through a NGSI interface.
NFR-4	Historical data available referred to parking lots and city areas MUST be accessible through SynchroniCity Historical data access API

3.2.3 Available data sources

Table 59 lists all available information sources considered to feed the scenarios described for Santander RZ. Some of them will be included in a first version of the applications whilst some others are feasible to be used in further versions that upgrade the initial functionalities and final information offered to the end user. These information sources and their corresponding IoT deployments are detailed in deliverable "D2.8 Report on Basic Reference Zones platform deployment and operational plan".

Table 59: Data sources used in Park & Move application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
AirQualityObserved	An observation of air quality conditions (temperature, CO, NO, NO2, etc.) at a certain place (location) and time	Open Data. NGSiv 2	Environment (Air Quality Observed)	To be considered for 2nd version of SAN Multimodal APP
BikeHireDockingStation	Describes a place where subscribed users can hire and return a bike	Open Data. NGSiv 2	Transportation (Bike Hire Docking Station)	Included in first SAN Multimodal APP version
BusArrivalEstimation	Provides arrival times estimations for the bus lines linked to a bus stop	Open Data. NGSiv 2	UC-Transportation (Bus Arrival Estimation)	Included in first SAN Multimodal APP version
BusStop	Describes a bus stop (location and linked bus lines)	Open Data. NGSiv 2	UC-Transportation (Bus Stop)	Included in first SAN Multimodal APP version
NoiseLevelObserved	It represents an observation of those acoustic parameters that estimate noise pressure levels at a certain place and time	Open Data. NGSiv 2	Environment (Noise Level Observed)	To be considered for 2nd version of SAN Multimodal APP
ParkingSpot	Well delimited area where one vehicle can be parked	Open Data. NGSiv 2	Parking (Parking Spot)	Included in first SAN Multimodal APP version
OnStreetParking	A site, open space zone, on street, (metered or not) with direct access from a road, intended to park vehicles	Open Data. NGSiv 2	Parking (On Street Parking)	Included in first SAN Multimodal APP version
PointOfInterest	Harmonised geographic description of a Point of Interest	Open Data. NGSiv 2	Point of Interest (Point Of Interest)	Included in first SAN Multimodal APP version
TrafficFlowObserved	An observation of traffic flow conditions at a certain place and time	Open Data.	Transportation (Traffic Flow Observed)	To be considered for 2nd

		NGSiv 2		version of SAN Multimodal APP
WeatherObserved	An observation of weather conditions at a certain place and time	Open Data. NGSiv 2	Weather (Weather Observed)	To be considered for 2nd version of SAN Multimodal APP
WeatherForecast	harmonised description of a Weather Forecast, including different parameters, for current day and current week (7 days ahead)	NGSiv 2	Weather (Weather Forecast)	To be considered for 2nd version of SAN Multimodal APP
busLine	Describes a public transport bus line, including the related bus stops	Open Data. NGSiv 2	UC-Transportation (bus Line)	Included in first SAN Multimodal APP version
Programacion TUS (GTFS info) ⁴⁴	Data related to Santander bus lines routes description and timetables	Open Data. GTFS	Transportation (programacion-GTFS)	Included in first SAN Multimodal APP version

3.2.4 Application architecture

The Park & Move application developed within Santander Reference Zone fully relies on the SynchroniCity APIs, as illustrated in Figure 13. In this sense, NGSi context information and related Historical Data will mainly feed the core functionalities of this combined application. Required datasets for baseline implementation are detailed in SynchroniCity deliverable "D3.2 Suite of baseline implementations - basic" for all the SynchroniCity services involved, as well as in Table 59 where also further datasets for updated versions of the app are listed. All accesses to SynchroniCity data will be authenticated (and authorised) by the SynchroniCity security layer, through its Oauth2.0 interface.

SynchroniCity framework will also contribute to this app by providing two core baseline services:

- **Routing Service:** to obtain the best route (or routes) according to end user's conditions. These conditions may include, apart from starting/ending points directly or indirectly (best parking place, list of POIs, etc.) provided by the user, the profile of the route (car, pedestrian, bike, multimodal. etc.), the public transportations to use or the type (touristic, fastest, shortest, etc.).
- **Parking Estimation:** based on how parking evolves according different factors, it calculates the probability of parking a car within a specified area and in a given time window.

This way Park & Move app is internally composed by a set of functional building blocks:

- **Data Composer:** it captures all data required to both, composes the final information set to be shown through the user interface and to feed the other components. To get this, it:
 - o gets information from the user (through the user interface) to feed the routing and parking services with user preferences;

⁴⁴ <http://datos.santander.es/resource/?ds=programacion-tus&id=92f4a4e9-6132-4666-b673-ae4524dee3e>

- o queries the Context Broker to get required and updated context information to capture status (e.g., parking, traffic, timetables) to feed the *Routing Service* and the *Recommendation System*;
 - o obtains the proposed routes by the routing service to feed the *Itinerary Planner*;
 - o captures the *Parking Estimation* outcomes, using also related user preferences (city area and time slot).
- **Recommendations System:** based on user preferences and profiles and on analysis of the parking status and probabilities, it recommends best places and relative alternatives to park. These can be used as end points to calculate routes.
 - **Itinerary Planner:** according to multimodal options, user preferences and calculated routes, it elaborates a set of possible itineraries, using different transportation options to get from A to B. These would be the final routes presented to the end user.
 - **User Interface:** acts as the communication channel, between the end-user and the core of the app. It captures user preferences needed to calculate valid routes and presents the outcomes elaborated by the recommendations system and the itinerary planner, adapted by the *Data Composer*.

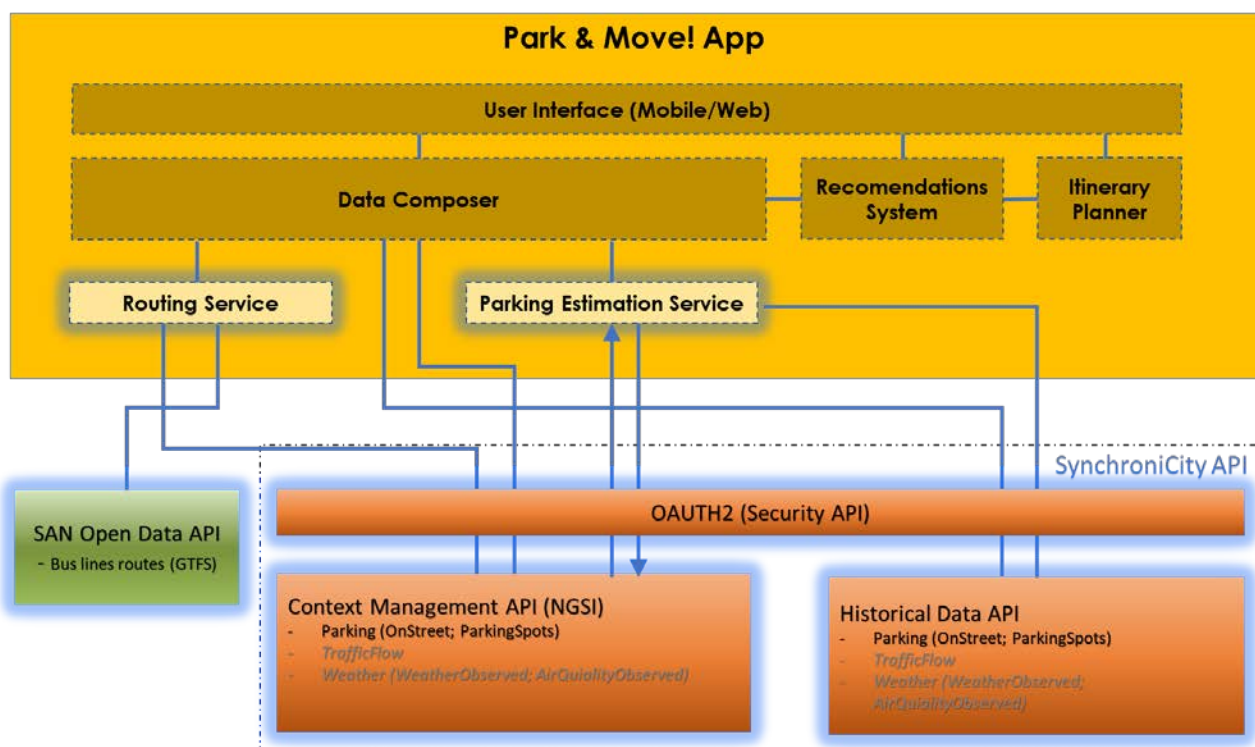


Figure 13. Santander Park & Move architectural approach.

3.2.4.1 Reusable baseline services

Table Table 60 lists the baseline services supporting the SAN Park & Move app that can be also reused by other solutions/apps. These services are further described in SynchroniCity deliverable "D3.2 Suite of baseline implementations - basic".

Table 60: Baseline services adopted in Park & Move application

Name	Rationale
Routing baseline service	Based on OpenTripPlanner (OpenTripPlanner - Multimodal Trip Planning, 2018), it calculates multimodal routes within a city (and surroundings) involving public transportation (GTFS format), bicycle lanes and mobility premises. The provided routes consider

	also special requests (e.g., points to/not to go, sections to/not to cross, profiles, etc.) from the service consumer.
Parking Estimation Service	It calculates and provides the probability of parking your car within a given area in the city and in the requested time window (e.g.: the parking prob in the city centre in 20 minutes from now). Thought to be easily evolved to include more data sources and innovative algorithms, a first version will be based on current parking status and historical data referred to city areas.

In case of Santander RZ, these two baseline services have been customised according to Santander city context:

- **Santander's deployed routing service:** although it is possible to use a common instance of the Open Trip Planner service that supports the SynchroniCity's baseline routing service, Santander RZ has deployed its own instance. This way, using OTP configuration capabilities based in turn in OpenStreetMap (OpenStreetMap, 2018), this instance includes:
 - o updated OpenStreetMap maps for Santander City (and surroundings);
 - o background maps in Tile Map Service format (Tile Map Service Specification, 2018) (used by OpenStreetMap/OTP) to include mobility premises, bike hiring docking stations and other elements needed to perform routing capabilities;
 - o Bus lines info in GTFS format, to include Santander public transportation info in routing calculation process. This info is provided by the Santander Open Data Portal (green box in Figure 13).

This basic service customisation enables the routing service to obtain the best routes in Santander City that include all Santander mobility resources.

- **Santander's Parking estimation:** its set up is linked to Santander's Context Information component and Historical data sources. OnStreetParking and ParkingSlot entities defined in Santander RZ will feed the first version service. The estimations obtained will be also available to external apps/services through these components, and according to Synchronicity specifications.

3.3 Helsinki's Application " Clean Air Journey Planner"

Helsinki underlines ecological values and consequently takes its own responsibility for the prevention of climate change seriously and ambitiously. Helsinki has set the goal of reducing emissions by 60 per cent by 2030, and bringing forward its target of carbon neutrality to 2035 (Huuska, Lounasheimo, Jarkko, & Viinanen, 2017). Street dusts and the inversion phenomenon estimated 1600 pre-mature death in Finland 2013 (New report: over 1,000 premature deaths in Finland every year due to air pollution, 2017).

Traffic emissions will be reduced across the city's transport system by promoting both cycling and pedestrianism.

Air quality and noise have impact on our wellbeing. Helsinki reduces the disadvantages of poor air quality by demonstrating the link between air quality and quality of life, by creating a model to avoid poor air quality areas and by an option to select the walking and cycling route considering real-time air quality data thanks to Clean Air Journey Planner.

The aim of this application is to provide a lower threshold for choosing walking cycling for personal mobility. The application provides a more enjoyable cycling experience in the city although a clean air route may be longer/slower. Through the use of the application, the city supports citizens in pursuit of sustainable modes of transport and healthier lifestyles.

Figure 14 depicts the interface of Helsinki's Clean Air Journey Planner application.

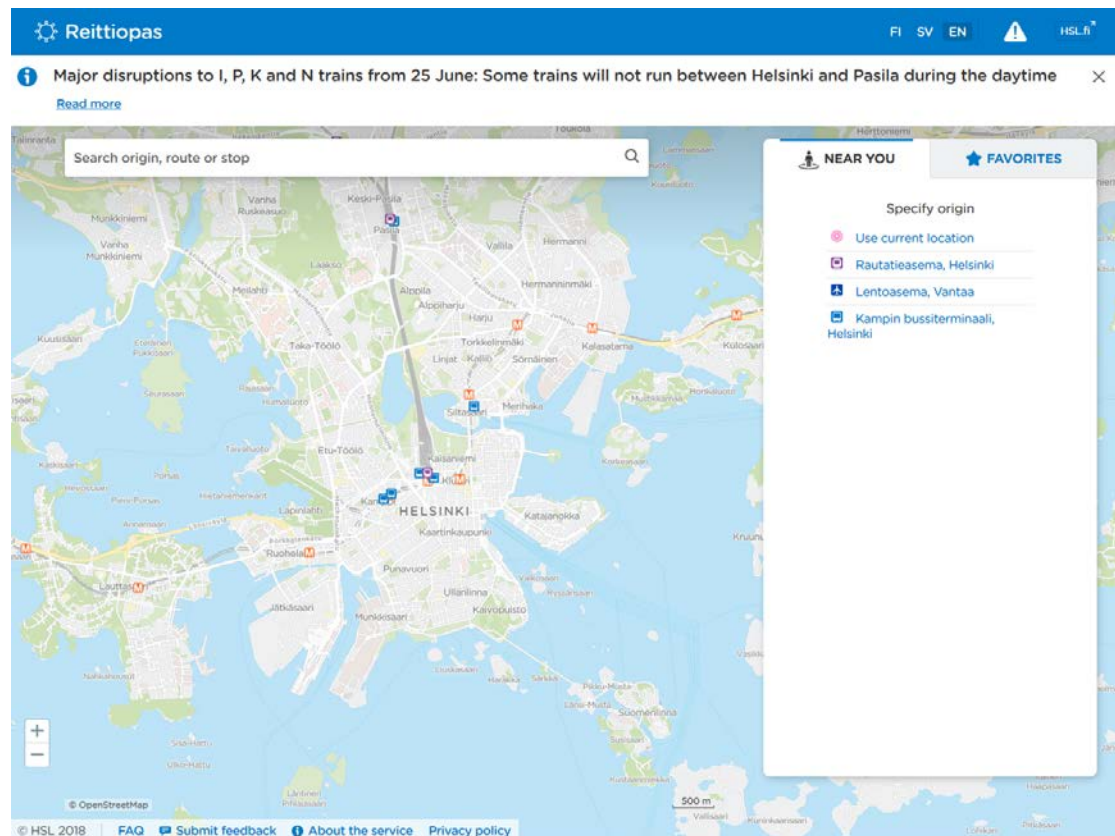


Figure 14. The Helsinki Clean Air Journey Planner interface. The interface is similar to the existing Journey planner prior to setting up Clean Air parameters.

3.3.1 Application scenario(s)

3.3.1.1 Users profiles:

Table 61: User profiles of Helsinki Clean Air Journey Planner

User profile ID	User description
Cyclist	Cyclist is a local inhabitant who use bicycle regularly or occasionally while travelling in Helsinki. Bicycling is an alternative for driving a car. He is using the bike from different departure and arrival destinations along the day and week. He has a flexible time schedule but wants always choose the shortest route.
Commuter	Commuter is a local inhabitant who commutes every weekday to work by bike. He has some health problems and wants to avoid the polluted areas. He will select the cleanest route although it is longer or slower comparing to the fastest and the shortest.
The young mother	The young mother prefers to shop in the city center, but is worried about her baby's health due to the pollutants in the air.

3.3.1.2 Scenarios:

Table 62: Scenario "The best time to bicycle the shortest route" of Helsinki Clean Air Journey Planner application

Scenario title	The best time to bicycle the shortest route
User profile	Cyclist
Background	The user uses bike as often as possible while travelling few kilometers trips in Helsinki region.
Objective	The user wants to avoid exposure to pollutants
Storyline	Andy needs to visit a bank in the city centre, but without a scheduled appointment. The day seems nice, so he chooses to use a bicycle instead of a car. He launches the Clean Air Navigation App to find the shortest route. He then opens Air Quality tab, enables Air Quality and observes the total pollution on the route at the moment. It seems relatively high, so he moves the timeframe forward, one hour at a time. In three hours, the pollution levels are estimated to be the lowest, so he chooses that time for his visit.

Table 63: Scenario "The least polluted bicycling route" of Helsinki Clean Air Journey Planner application

Scenario title	The least polluted bicycling route
User profile	Commuter
Background	John likes to cycle to the work, but recently he has suffered from a lot of dust and sand on his route, irritating his eyes and lungs.
Objective	John wants to avoid exposure to pollutants as much as possible for health reasons.
Storyline	This morning, John launches the Clean Air Navigation App and turns on the map layer Air Quality. The map is now overlaid with a pollution chart. Switching back to normal map view, he then enables Clean Air Routing, and fetches possible routes for his work. Each route is colour coded according to pollution levels along the route, with a separate colour tab indicating the total inhaled pollution along the route. There is a nice route through a small forest with very little pollution, so for extra fun he picks up his fatbike and cycles a route he didn't know about.

Table 64: Scenario "The multimodal clean air trip" of Helsinki Clean Air Journey Planner application

Scenario title	The multimodal clean air trip
User profile	The young mother
Background	Helen is used to shop in the city center, but is now worried about air quality due to her small baby
Objective	Helen needs to know that her shopping trip is the least polluted one.
Storyline	Helen needs more baby clothes, and knows a good shop in the city center. Prior to her trip, she goes to the Clean Air Journey Planner web page on her phone and selects her route. A set of alternative routes appears. She then sets preferences to maximize air quality importance in routing, and checks a 'visualize air quality' box, saving her selections. The map now shows the air quality as a coloured overlay. The first suggested bus connection ends in the most polluted area. She refreshes the search with her new parameters, and redefines her search to a bus stop away from the polluted area. The new alternatives avoid this area, so she chooses that.

	Later, when returning, she simply makes a route request, and the first suggestion seems reasonable. Her preferences are stored on her smartphone so she no longer needs to set any parameters.
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3.3.2 Requirements analysis

3.3.2.1 Functional requirements

Table 65: Functional requirements of Helsinki Clean Air Journey Planner application

ID	Description
FR-1	The application MUST be able to provide capabilities to select a route where the air quality is the best
FR-2	The application MUST provide capabilities to check the air quality
FR-3	The application SHOULD provide capabilities to estimate and the air quality for a specific day
FR-4	The application MUST provide several route alternatives e.g. the shortest and the fastest route
FR-5	The application SHOULD provide measures of pollutants along route alternatives (the shortest and the fastest route)

3.3.2.2 Non-functional requirements

Table 66: Non-functional requirements of Helsinki Clean Air Journey Planner application

ID	Description
NFR-1	The app MUST be available from the web for free without registration
NFR-2	The app MUST support at least one of the most common mobile platforms (i.e. Android OS 7) or be based on web pages (i.e. HTML5)
NFR-3	The app MUST be easy to use
NFR-4	The app MUST respond to queries swiftly in 4G or wifi networks
NFR-5	The application MUST be multilingual

3.3.3 Available data sources

The main data sources (Table 67) for the Clean Air Journey Planner include air quality data from Finnish Meteorological Institute, map data from OpenStreetMap and public transport data from Helsinki Region Transport.

Table 67: Data sources used in Clean Air Journey Planner application 1-2

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
ENFUSER Air Quality data(Johansson, Karppinen, & Dong, 2016)	Air pollutants such as: PM2.5 particles, PM10 particles, Ozone (O3), Nitrogen dioxide (NO2), and generalized Air Quality Index.	Closed until Sep 2018	WFS2.0(Inc., 2010-11-02) (Web Feature Service) NetCDF (Network Common Data Form) ⁴⁵	ENFUSER data, 475 million data points in an hourly update.

⁴⁵ <https://www.unidata.ucar.edu/software/netcdf/>

Map data	OpenStreetMap ⁴⁶ map data to generate a graph for routing algorithm	Open Data	OSM model data	Pre-processed prior to launching the service
Public transport schedule data ⁴⁷	Schedule, line and stop data for public transport	Open Data	GTFS ⁴⁸	Pre-processed prior to launching the service
Public transport tracking	Data about vehicle location and speed	Open API	To be identified	MQTT/JSON: current data model is proprietary. Processed into GTFS-RT for Digitransit
Events and accidents	Service alerts and trip updates	Internal APIs	To be identified	Access still under investigation. Processed into GTFS-RT for Digitransit.

Other open dynamic data sources (Table 68) that are intended to be available at the Helsinki RZ include city bike rental availability, noise and air quality measurements (direct sensor data), weather, and possibly tracked public transportation vehicles. They are already available via APIs like WFS 2.0, MQTT and GTFS-RT. Wrappers to NGSI are prioritized for the less standardized interfaces.

Table 68: Data sources used in Clean Air Journey Planner application 2-2

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Weather	Precipitation probability, relative humidity, temperature, weather type, wind direction, wind speed	Open Data	To be identified	API wrapped from WFS 2.0/GML to NGSI. Data model close to FIWARE will be identified.
Noise	Noise levels	Open data	FIWARE: Noise Level Observed	Only 3 sensors
BikeHire	City bicycle rental data	Open data	FIWARE: Bike Hire Docking Station	Wrapped from Digitransit GraphQL API ⁴⁹

⁴⁶ <https://www.openstreetmap.org/>

⁴⁷ <http://dev.hsl.fi/gtfs/>

⁴⁸ <http://gtfs.org/>

⁴⁹ <https://graphql.org/>

Air Quality	SO2,NO,NO2,O3,TRSC,CO,PM10,PM25,AQINDEX	Open Data	To be identified	API wrapped from WFS 2.0/GML to NGSi. Data model close to FIWARE will be identified.
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3.3.4 Application architecture

Helsinki's Clean Air Journey Planner is built on the existing open source *Digitransit* platform by integrating city-wide air quality data from Finnish Meteorological Institute's Environmental Information Fusion Service (ENFUSER). These platforms are mature and maintained at product level. Figure 15 depicts the architecture of Clean Air Journey Planner, its components and relations among them. Dotted connection lines represent potential interactions.

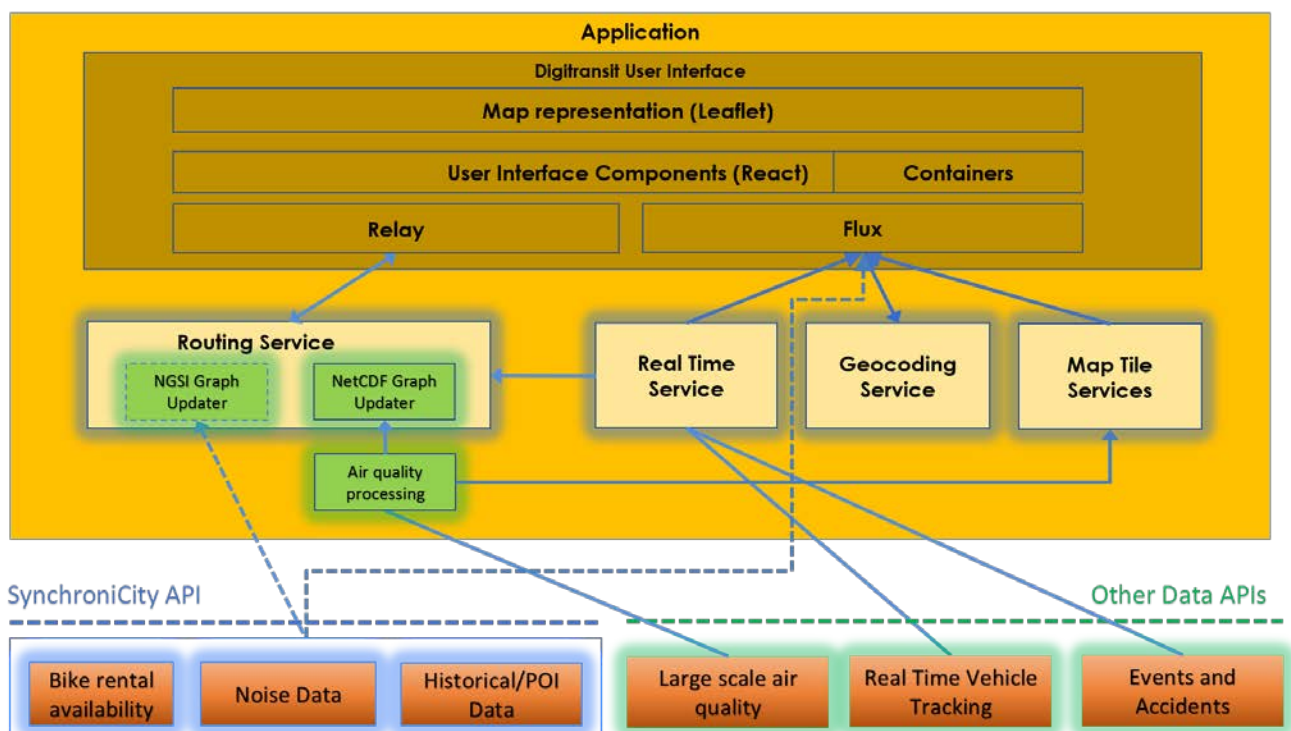


Figure 15. The Helsinki RZ Initial App *Clean Air Journey Planner* architecture

Digitransit is based on a *micro service architecture* with four distinct services: *Routing*, *Maps*, *Geocoding* and *Real-time Updates*. Routing is provided by *OpenTripPlanner* (OTP), a Synchronicity baseline service, modified for Digitransit. OTP inputs OpenStreetMap map data and GTFS schedule data at a pre-process stage. These data sets are combined into a routable graph that is held in memory, and stored on disk for faster restart of the service. The Map and Geocoding services use multiple static data sources, which are integrated at a pre-process stage. The Real-time service provides public transport tracking and service alerts in GTFS-RT format. The OTP also inputs this GTFS-RT feed for routing purposes.

For Helsinki Clean Air Journey Planner, the OTP routing core is being modified to allow external data sources to manipulate weights of the edges within the routing graph as an on-line process. In our case, we use large scale air quality data (475 million data points), which emerges from the ENFUSER model hourly via a WFS 2.0 API in compressed binary NetCDF format. OTP routing graph's new data structures for air quality are fully updated every hour.

The ENFUSER model inputs over 20 data sources, one of them being air quality sensor data from sensors deployed in Helsinki metropolitan area. Others include current weather, land use, traffic flow, 3D buildings and SILAM, a global-to-meso dispersion model for atmospheric composition and air quality⁵⁰.

ENFUSER visualization as a map overlay might also be transmitted to the Map Tile Service, to allow air quality visualization on the map background of the Navigation App. However, our recent discussions with Helsinki Region Environmental Services indicate that direct overlays will not yield a feasible result, but a more thorough visualization scheme would need to be developed. This direction will be investigated further.

Due to the large scale of the ENFUSER data and the lack of need for other necessary data sources, NGSiv2 connection to Digitransit is currently not being implemented. The initial app could be extended with suitable data sets such as point-of-interests and city bike rental availability, i.e. by an Open Call partner. Some of the related data sources such as noise, air quality measurements from sensors, weather and weather forecasts are planned to be available via NGSiv2 for Open Call purposes.

Digitransit User Interface (UI) is a React⁵¹ based web application, written using modern ES2015 JavaScript. It supports older browsers too, because the code is compiled to ES5 using Babel⁵².

React is a library developed by Facebook, Inc. for building reusable user interface components. It minimizes the number of document modifications, which leads high performance and low battery usage. React can be used as a base in the development of single-page or mobile applications. Complex React applications usually require the use of additional libraries for state management, routing, and interaction with an API.

React components are written using pure JavaScript, or a JavaScript extension called JSX which provides a thin syntactic sugar layer for more HTML-like developer experience.

DigiTransit UI uses Leaflet for visualizing maps, itineraries and air quality data published by a web map service. It also contains the following additional components:

- Flux (<https://facebook.github.io/flux/docs/overview.html>)
- React-Router (<https://github.com/rackt/react-router>)
- Relay (<https://facebook.github.io/relay/>)
- GraphQL (<https://facebook.github.io/graphql/>)

The UI provides a map interface with search capabilities, disruption information and preference configuration (Figure 14) Once the start and end points of a trip have been defined (i.e., right clicking on the map), users may configure their search parameters (Figure 16). These parameters include preferred mode of transport, walking speed, number of transfers, transfer margin, and our addition of *Air Quality Importance*. All user preferences are stored into a local container; no registration or authentication is needed nor available.

When a user interacts with the Digitransit UI, Digitransit microservices act independently, with the map service providing background maps, geocoder resolving addresses to lat/lon coordinates or vice versa, real-time service providing public transport vehicle position updates and OTP providing the actual routing and itinerary creation.

⁵⁰ <http://silam.fmi.fi/>

⁵¹ <https://reactjs.org/>

⁵² <https://babeljs.io/>

Figure 16. User preferences for Clean Air Journey Planner

3.3.4.1 Reusable baseline services

The OpenTripPlanner, providing multimodal itineraries, has been chosen as one of the baseline Synchronicity services. Helsinki Region Transport (HSL) has modified it at a separate source code fork to better suit local needs. These modifications are mostly new features, and the Digitransit's OTP source code tree⁵³ is routinely updated from the OTP master source code tree⁵⁴. However, the Clean Air Routing features are implemented in the master OTP, making this generic OTP version directly applicable to other parties without HSL specific extensions or dependencies to Digitransit UI. For Helsinki, the HSL Digitransit version will be used for the Clean Air app to provide Clean Air routing and itineraries for end users. Other reusable services include Geocoding and Reverse Geocoding Service, Map Service and GTFS-RT Service (Table 69).

⁵³ <https://github.com/HSLdevcom/OpenTripPlanner>

⁵⁴ <https://github.com/opentripplanner/OpenTripPlanner>

Table 69: Baseline services adopted in Clain Air Journey Planner application

Name	Rationale
Routing baseline service	Provides a way to plan itineraries and query public transportation related information about stops and timetables. Routing is the main Digitransit service, with OpenTripPlanner (OTP) as the core. (Digitransit name: Digitransit-otp)
Geocoding and Reverse Geocoding Service	Provides a way to perform address searches and address lookups (also known as reverse geocoding). Digitransit uses Pelias ⁵⁵ as Geocoding and Reverse Geocoding service. (Digitransit name: Digitransit-geocoder)
Map Service	Provides background maps in Tile Map Service format ⁵⁶ . Map data is based on vector export of OpenStreetMap. (Digitransit name: Digitransit-map)
GTFS (General Transit Feed Specification) RealTime Service	Provides GTFS-RT (GTFS-RealTime) updates, such as service alerts, trip updates and vehicle positions. Currently, real-time public transport trip predictions are available via the Routing Service. (Digitransit name: Digitransit-realtime-server)

3.4 Milan's Application "Multimodal-navigator for disabled people"

Disabled people in Milan are eligible to achieve special permits to traverse restricted areas in the city with their vehicles. Restricted areas can be of various types, from the ones accessible only to pedestrians, to the ones accessible only by resident people, to the ones that deny the access to old polluting vehicles. Disabled people special permits make available these areas to disabled people and their vehicles.

Moreover, disabled people have reserved parking lots wide spread across the city and the Municipality is planning to install parking sensors (expected in September 2018) in order to monitor their free/occupied status.

Currently available navigators usually don't include special features for disabled people that take into account their special permits and reserved parking lots. Moreover, when disabled people are moving across the city, they may want to use both their vehicle and the public transport system, so they need information about the closest available parking lot for their vehicle and all the information to get and to access to public transport stop or station they want to reach.

In order to provide to the citizen a better service that will take into account all the information and disabled people's special needs, the Municipality is intended to develop a multimodal navigator especially designed to be helpful for disabled people and their companion.

⁵⁵ <https://pelias.io>

⁵⁶ https://wiki.osgeo.org/wiki/Tile_Map_Service_Specification

3.4.1 Application scenario(s)

3.4.1.1 Users profiles:

Table 70: User profiles of Milan Multimodal-navigator for disabled people

User profile ID	User description
Disabled Citizen	A wheelchair person. This person can be a commuter, a citizen or tourist and can drive or not a car.
Registered Disabled Citizen	A wheelchair person registered to the application. This person can be a commuter, a citizen or tourist and can drive or not a car; moreover, this person can have special permits to go through specific zones of the city while driving a car.

3.4.1.2 Scenarios:

Table 71: Scenario "Sc.1 - Registering Preferences" of Milan Multimodal-navigator for disabled people application

Scenario title	Sc.1 - Registering Preferences
User profile	Disabled Citizen
Background	Alice just downloaded the application on her mobile phone. Alice runs the application for the 1st time, and the application shows to Alice a menu where she can set her preferences in order to take advantages of application benefit. Registration is local and doesn't send any information to a cloud server.
Objective	Alice set the application preferences on the 1st run
Storyline	After downloading the application on her smartphone, Alice is asked to enter her preferences. The application shows to Alice the form to enter her preferences: • home location and work location; • option to find best solutions for wheelchair people; • special permits for her vehicle to pass across restricted city zone. • add a new bookmarks by address and categorize it as she prefers (e.g. "dad", "mom", "favourite restaurant"); Alice sets the preferences and confirms them; alternatively, she can decide to postponed this activity or change it later.

Table 72: Scenario "Sc.2 - Changing preferences" of Milan Multimodal-navigator for disabled people application

Scenario title	Sc.2 - Changing preferences
User profile	Registered Disabled Citizen
Background	Jane is normally running the application
Objective	Jane may change her preferences in the application
Storyline	Jane open the section of the application to manage preferences and the application shows to Jane the form to manage preferences with her previous settings: • home location and work location; • option to find best solutions for wheelchair people; • special permits for her vehicle to pass across restricted city zone; • bookmarks: add, modify or delete and categorize (e.g. "dad", "mom", "favourite restaurant").

	Jane sets the preferences and confirms them.
--	--

Table 73: Scenario "Sc.3 - Adding bookmark from the map" of Milan Multimodal-navigator for disabled people application

Scenario title	Sc.3 - Adding bookmark from the map
User profile	Registered Disabled Citizen
Background	Jane is running the application and the application shows her a map where she recognizes an important point for her
Objective	Jane wants to save a new bookmark
Storyline	Jane is running the application and looking at the map. Jane noticed an interesting point on the map and wants to save it as a bookmark. Jane selects the point on the map and then the application shows her a form where she is asked if she wants to save the selected location as a bookmark. Jane answers confirm the operation and the application shows her the coordinates and the address and a form to add a description of the location and to and categorize it (e.g.: "restaurant", "cinema"). Jane inserts a description and categorizes the bookmark and then she confirms the provided information. Finally, the application save the new bookmark.

Table 74: Scenario "Sc.4 - Finding free parking lots for a not registered user" of Milan Multimodal-navigator for disabled people application

Scenario title	Sc.4 - Finding free parking lots for a not registered user
User profile	Disabled Citizen
Background	Alice is going to the city centre; she is planning to leave her car in a parking area and to take public transportation.
Objective	Alice wants to find free parking lots near a bus stop or a metro station accessible for wheelchaired people.
Storyline	Alice is running the application that shows her a map. Alice presses the button to visualize on the map parking areas; for each parking area, the application shows a marker on the map indicating; each marker has a different colour: green if the parking lots of the area are free, yellow if some parking lots are free, and red if the area has no free parking lots. The application show markers on the map indicating public transport stations; each marker has different icons/signs for the different means of transportation. Alice alternatively scroll the map up/down/left/right or zoom/pan the map with her fingers until she finds the point she is interested into at the zoom level she prefers. Alice selects a specific transportation stations and the application opens a pop-up showing her the facilities for wheelchaired people of the selected station. Alice selects a marker representing a parking area and the application opens a pop-up providing information about the parking lots of the selected area.

Table 75: Scenario "Sc.5 - Finding free parking lots for a registered user" of Milan Multimodal-navigator for disabled people application

Scenario title	Sc.5 - Finding free parking lots for a registered user
User profile	Registered Disabled Citizen
Background	Jane is going to the city centre; she is planning to leave her car in a parking area and to take public transportation. Jane is a registered user of the application, so she can access more functionalities.
Objective	Jane wants to find free parking lots near a bus stop or a metro station accessible for wheelchair people.
Storyline (Note: this storyline adds some details to scenario "Sc.4 - Finding free parking lots for a not registered user" in order to describe functionalities accessible by a registered user)	Jane is running the application that shows her a map. Jane presses the button to visualize on the map parking areas; for each parking area, the application shows a marker on the map indicating; each marker has a different colour: green if the parking lots of the area are free, yellow if some parking lots are free, and red if the area has no free parking lots. Jane presses button to display on the map her bookmarks and the application show markers on the map indicating Jane's bookmarks. Jane presses button to display on the map the zones of the city she can traverse with her car and the application paints on the map those zones putting them in evidence. Jane presses the button to display on the map public transport stations (e.g.: metro, bus, trams, train). The application show markers on the map indicating public transport stations; each marker has different icons/signs for the different means of transportation. Jane alternatively scroll the map up/down/left/right or zoom/pan the map with her fingers until she finds the point she is interested into at the zoom level she prefers. Jane selects a specific transportation stations and the application opens a pop-up showing her the facilities for wheelchair people of the selected station. Jane selects a marker representing a parking area and the application opens a pop-up providing information about the parking lots of the selected area.

3.4.2 Requirements analysis

3.4.2.1 Functional requirements

Table 76: Functional requirements of Multimodal-navigator for disabled people application

ID	Description
FR-1	Application MUST provide functionalities to create a user account
FR-2	Application MUST be able to manage user's preferences
FR-3	User MUST be able to set and edit home and work location among the preferences
FR-4	User MUST be able to set and edit permits for her vehicle to pass through restricted city zone among the preferences
FR-5	User MUST be able to add a new bookmark by address and to categorize it (e.g. "dad", "mom", "favourite restaurant")
FR-6	User MUST be able to edit an existing bookmark
FR-7	User MUST be able to delete an existing bookmark
FR-8	User MUST be able to enable an option to find best solutions for wheelchair people
FR-9	The application MUST provide a map to search for a destination.
FR-10	User MUST be able to navigate the map scrolling up/down/left/right or to zoom/pan the map
FR-11	User MAY be able to navigate the map with fingers.
FR-12	User MUST be able to add a new bookmark selecting a point on the map.
FR-13	The application MUST provide functionalities to display parking areas on the map

FR-14	The application SHOULD display parking areas on the map with different colours to indicate their status: green if the parking lots of the area are free, yellow if some parking lots are free, and red if the area has no free parking lots.
FR-15	When the user selects a parking area on the map, the application MUST provide its related information.
FR-16	The application SHOULD display public transport stations on the map.
FR-17	The application SHOULD display public transport stations on the map with different markers to indicate the different means of transportation (e.g., bus, metro, train).
FR-18	When the user selects a public transport station on the map, the application MUST provide its related information.
FR-19	The application MUST be able to display user's bookmarks on the map.
FR-20	The application MUST be able to display on the map the restricted zones of the city user can traverse driving a car.

3.4.2.2 Non-functional requirements

Table 77: Non-functional requirements of Multimodal-navigator for disabled people application

ID	Description
NFR-1	The application MUST support Italian language.
NFR-2	The application MUST be accessible on mobile devices.
NFR-3	Required data MUST be accessible through a NGSI interface.

3.4.3 Available data sources

References reported in the "Title" column of Table 78, refers to the description of the original data sources that are included and adapted through and according to SynchroniCity platform.

Open Data are mainly retrieved from Open Data Portal of Milan⁵⁷, whereas API data sources are mainly accessed through the API Store⁵⁸ of Milan or through the platform E015⁵⁹ (a platform collection and providing access to API for both public and private entities) and then converted in the corresponding datamodel. It is important to underline that an authorization request has been submitted in order to access API provided by E015.

Table 78: Data sources used in Multimodal-navigator for disabled people application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Place/Street names	Official place and street naming system associated to geographic position.	API	Road	
Point of interests, events and itinerary	Descriptions of valuable places and events in an area, and also the suggested	API	PointOfInterest Events	Further analysis are needed to identify the data model to represent

⁵⁷ <http://dati.comune.milano.it/>

⁵⁸ <https://apisp.comune.milano.it/store/>

⁵⁹ <http://www.e015.regione.lombardia.it/>

	touristic itinerary.			touristic itineraries
Traffic Restricted areas	GeoJson description of traffic restricted areas.	Open Data	Needed further analysis	Data is available in GeoJson format
Public transport metro network	GeoJson description of metro network and stations.	Open Data	Needed further analysis	Data is available in GeoJson format
Public transport terrestrial network	GeoJson description of terrestrial bus/tram network and relative stops.	Open Data	Needed further analysis	Data is available in GeoJson format
Car sharing parking areas	GeoJson description of car-sharing parking areas, with parking lots.	Open Data	On/OffStreetParking	Data is available in GeoJson format
Parking areas	GeoJson description of parking areas.	Open Data	On/OffStreetParking	Data is available in GeoJson format
Parks and gardens	GeoJson description of public parks and gardens.	Open Data	Gardens	Data is available in GeoJson format
City facilities	GeoJson description of facilities such as pharmacie, school, congress centres.	Open Data	PointOfInterest	Data is available in GeoJson format
Metro lines status	Real time status of metro network.	API	Needed further analysis	E015 API. Accessible only under E015 authorization
Interchange parking status	Real time status of interchange parking areas.	API	OffStreetParking	E015 API. Accessible only under E015 authorization
Public transport status and waiting time	Real time status of buses and trams and waiting time for each stop.	API	Needed further analysis	E015 API. Accessible only under E015 authorization
Point of interest	Information about point of interest in the city area.	API	PointOfInterest	E015 API. Accessible only under E015 authorization
Airport parking availability	Real time status of interchange parking areas.	API	OffStreetParking	E015 API. Accessible only

				under E015 authorization
Train time schedule	Real time status of urban train network.	API	Needed further analysis	E015 API. Accessible only under E015 authorization
Traffic status	Information about the status of the road traffic (possible disruption of service soon).	API	TrafficFlowObserved	E015 API. Accessible only under E015 authorization
Traffic events	Traffic information	API	Needed further analysis	E015 API. Accessible only under E015 authorization
Parking lots status	Information about status of parking lots, such as occupancy.	API	On/OffStreetParking	Parking sensors are planned to be installed (09/2018)
Electric car charging stations	Information about location of electric cars charging stations	API	Needed further analysis	E015 API. Accessible only under E015 authorization
Weather Stations and weather measurements	Information about weather stations and real-time measurements for each station.	API	WeatherObserved	Legacy LAMPPOST APIs are available

3.4.4 Application architecture

Milan's Multimodal-navigator for disabled people application leverages on SynchroniCity APIs exposed by the Municipality of Milan itself; in particular it will consume two of these APIs: Context Management API and Historical Data API.

Figure 17 depicts how the application will be built internally and how it will interact with Synchronicity API. In particular, the application will use data retrieved from Synchronicity API for its core functionalities whereas the access to this API will be secured by the IdM module/component currently working on the WSO2 platform (WSO2 Identity and Access Management, 2018) of Milan Municipality which is compliant with OAuth2 standard according to the SynchroniCity Security layer specification.

The application is dedicated to mobile devices and it will be based on frameworks such as Apache Cordova (Apache Cordova, 2018) in order to ensure the possibility to be released for different mobile devices.

The application is composed by a set of internal functional components:

- **User Interface:** this component will provide the interaction point with the end users and will provide the possibility to manage all the aspects of the application, such as preferences, bookmarks. It will enable the user to visualize a map and to look for Point of Interests.
- **App Core:** this component represents the heart of the application and it will manage all the requests made by the end users and by means of the User Interface; for this reason it will also coordinate all the other components of the application. This component will also interact

through a REST interface with the baseline services adopted by the application: in an early stage the Parking Estimator Service and in a second stage also with the Routing Service.

- **User Preferences Manager:** this component will manage the user preferences; in particular it will be in charge of saving, retrieving, updating and deleting user preferences as requested by the App Core on the base of user's actions; for these goals it will leverage on functionalities offered by App Internal Storage.
- **Bookmarks Manager:** this component will manage the bookmarks of the user; in particular it will be in charge of saving, retrieving, updating and deleting bookmarks as requested by the App Core on the base of user's actions; for these goals it will leverage on functionalities offered by App Internal Storage.
- **App Internal Storage:** this component will provide storage functionalities to manage both *user preferences* and *bookmarks*, as requested respectively by User Preferences Manager and Bookmarks Manager

All these components will be packaged together in order to be deployed and executed in mobile devices, whereas the two baseline services (the Parking Estimator Service and the Routing Service), even if, from a logical point, of view they are part of the application, they will act as remote services.

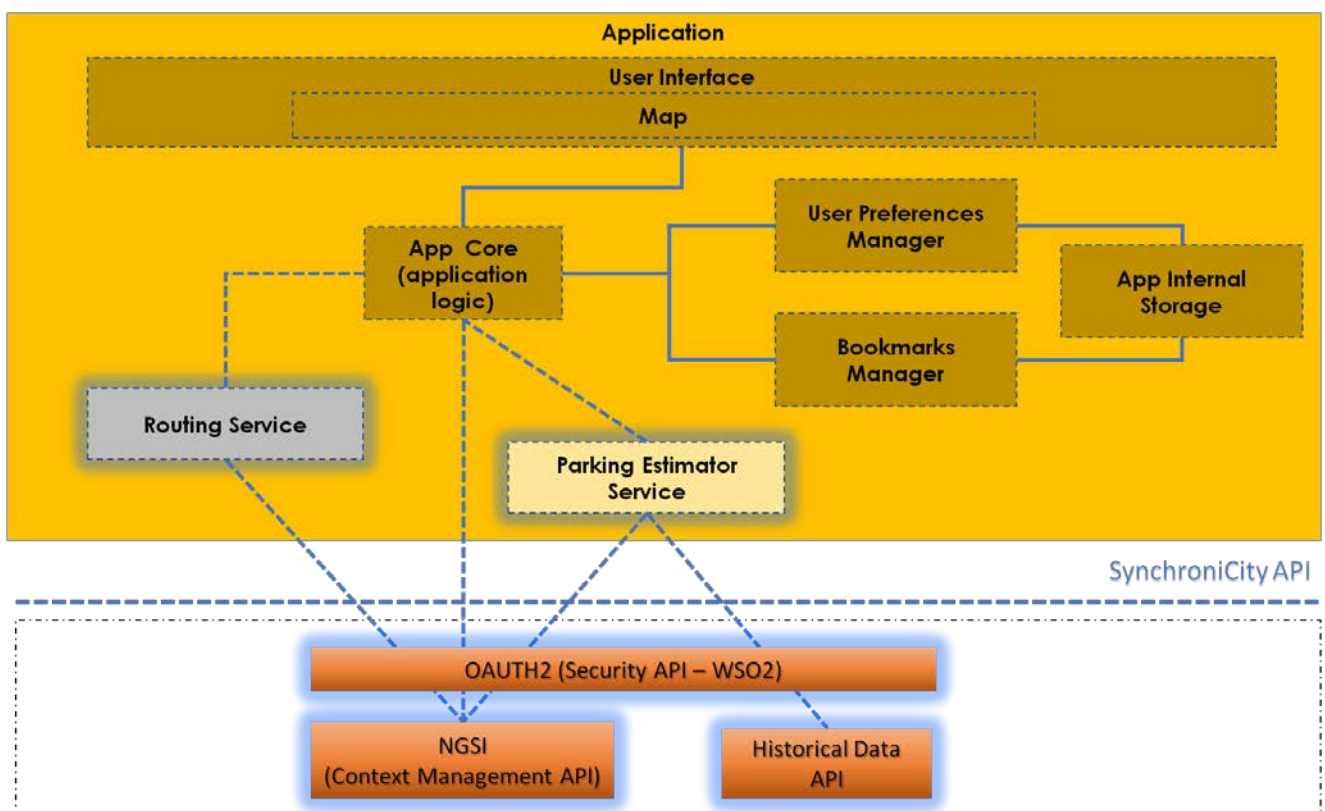


Figure 17. Milan Multimodal-navigator for disabled people application architecture

3.4.4.1 Reusable baseline services

As depicted in Figure 17, Milan's Multimodal-navigator for disabled people application will leverage on two baseline services, that will be integrated in two different steps with the other components of the applications and that will support the provision of the functionalities of the application itself. These two baseline services are: Parking Estimator Service and Routing Service, reported in Table 79: Baseline services adopted in Multimodal-navigator for disabled people application.

Table 79: Baseline services adopted in Multimodal-navigator for disabled people application

Name	Description
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Parking Service	Estimator	This baseline service will provide the forecasted free parking lots in a parking area in a specific time window. It will be tailored in order to provide support to disabled people, for instance providing adequate information about parking lots dedicated to wheel-chaired people. Indeed, its functionalities will help the users to plan and optimise their routes within the city.
Routing Service		The integration of this baseline service is planned for the final version of the application; it will be used in order to provide route to be followed by users of the application in order to arrive at their desired destination. It is based on OpenTripPlanner and it will be customised in order to provide tailored routes for wheel-chaired people.

3.5 Carouge's Application "Smart Parking"

Reference Zone: Carouge

Carouge is an old city, the number of parking slots on the streets is quite limited, and it is not easy to find a free parking slot in Carouge. Therefore, Carouge is encouraging citizens and visitors to use public transportation such as tramways or buses.

Often drivers spend a long time to find a free parking spot in Carouge, and a part of the traffic is generated by driving around the city in order to search a free parking spot.

The application for the smart parking developed by SynchroniCity will help to reduce these unnecessary traffics and provide a convenient service to the citizens and visitors coming in Carouge by cars. Drivers know in advance if there is an available parking spot or not, and get guided to find a free parking spot near the destination. The parking estimation service provides probability to have a free parking spot in a particular area of Carouge in a certain time frame. For instance, when a driver who is in a city located at 20 minutes away from Carouge wants to come in Carouge, the user uses this application to get predicted availability of free parking spots before leaving to Carouge, and drives toward the free parking spot. Real-time data of the parking availability is also provided and the driver can confirm the parking availability when he arrives to the destination. In this way, drivers can save time and energy to find a free parking spot and the city can reduce unnecessary traffics caused by searching parking spots.

3.5.1 Application scenario(s)

3.5.1.1 Users profiles:

Table 80: User profiles of Smart Parking application

User profile ID	User description
User01	City mobility services: they manage the traffics in Carouge and put in action the political decisions about the mobility.
User02	Car drivers
User03	Truck drivers: they drive their truck into the city of Carouge when delivering goods to the shops in Carouge.
User04	Shops: they can benefit from a good mobility. Their clients (the car drivers for example) can easily reach them using the application. The truck drivers can optimise their delivery to the shops through the application.

3.5.1.2 Scenarios:

Table 81: Scenario "New Parking Solutions" of Smart Parking application

Scenario title	New Parking Solutions
User profile	User01
Background	The City of Carouge is responsible for managing the parking indoors and outdoors.
Objective	To optimise the experience of parking in city. To improve the time drivers are looking for a parking spot and understand the behaviour of the drivers to optimise the parking management.
Storyline	Searching an available parking slot in the city takes some time and generates unnecessary traffics in the streets. The city retrieves all the data to get a better knowledge of the current situation. Then, they can propose new solutions or adapt to the needs of the population.

Table 82: Scenario "Find a free parking place" of Smart Parking application

Scenario title	Find a free parking place
User profile	User02, User03
Background	The car drivers search free parking slots in the city of Carouge and it is not always easy to get one quickly.
Objective	To help the car drivers to find a free parking place. To give useful information to the car drivers. Prediction of available spots in the next 30 minutes.
Storyline	A car driver comes in Carouge and is searching a free parking slot for his car. Street signs and an application give drivers parking information including available parking slots.

Table 83: Scenario "Better use of parking slots" of Smart Parking application

Scenario title	Better use of parking slots
User profile	User01
Background	The Parking management has become very important to maximize the utilisation of the parking slots in the City and to diminish the traffics.
Objective	To give strategic information to the municipality and optimize the use of the parking slots
Storyline	The municipality of Carouge needs the facts and real numbers to fully understand the behaviour of drivers. By collecting real data, it is easier to understand the problems and to solve them.

Table 84: Scenario "Increase the parking rotation of cars" of Smart Parking application

Scenario title	Increase the parking rotation of cars
User profile	User04
Background	A lot of shops depend on their accessibility by their customers. Some are coming with the public transport, and others come by car. It is important to facilitate the direct access to the shops or restaurants and bars.
Objective	To increase the rotation of cars in the same parking slot especially after 16h00 when people are coming for shopping

Storyline	In certain street, it is crucial to increase the parking rotation of cars. In some place, it is ok to have one car per day. But in busy shop or restaurant areas, the rotation should be accelerated. Max one hour or in certain case 30 min.
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3.5.2 Requirements analysis

3.5.2.1 Functional requirements

Table 85: Functional requirements of Smart Parking application

ID	Description
FR-1	Pre-defined city areas and parking lots information MUST be provided in advance.
FR-2	Real time sensing data about the status and location of the parking places MUST be provided.
FR-3	The security and integrity of the sensing data MUST be provided avoiding wrong information to be delivered.
FR-4	The parking location SHOULD be precisely indicated into a map tool.
FR-5	Historical data SHOULD be provided.
FR-6	The parking service MAY provide parking estimation information when will be possible to find free parking spaces.

3.5.2.2 Non-functional requirements

Table 86: Non-functional requirements of Smart Parking application

ID	Description
NFR-1	The service MUST be compliant with privacy data protection policy in EU and Switzerland.
NFR-2	The service MUST be secure and reliable.
NFR-3	Required data MUST be accessible through a NGSI interface.
NFR-4	The service SHOULD have low latency.
NFR-5	The service SHOULD be intuitive and easy to use.
NFR-6	The service SHOULD be easy to extend itself and easy to integrate into other city services.
NFR-7	The service SHOULD provide multiple languages used in Switzerland.
NFR-8	The service MUST be accessible in diverse mobile devices and web browsers.

3.5.3 Available data sources

Table 87 reports a brief summary of the data sources that will feed the application; more details about these data sources and the data model can be found respectively in deliverable *D2.2 Guidelines for the definition of OASC Shared Data Models* and in deliverable *D2.8 Report on Basic Reference Zones platform deployment and operational plan*.

Table 87: Data sources used in Smart Parking application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Parking Slot Status	Last status of a parking slot	API	ParkingSpot	
Available Spot Number	Number of free parking slots in an off-street parking	API	OffStreetParking	
Bus Stop	Information about the next departures from a bus stop	API	UC-Transportation (BusStop)	
Occupancy Rate	Measurement of the traffic flow	API	TrafficFlowObserved	

3.5.4 Application architecture

The architecture of the Smart Parking application is based on the SynchroniCity general architecture. The data can be retrieved using the NGSiv2 API used by Orion context broker and Comet STH. The access to the data is protected through KeyRock⁶⁰ and Wilma⁶¹ that are a part of the SynchroniCity security framework. The data sets are described in the deliverables D2.2 and D2.8.

The Parking Estimation baseline service will be used in this application and permits to calculate the probability to find a parking slot in a given area and in a given time frame.

The components of the application are as following:

- **Recommendations System:** This component gets all the data from the Parking Estimation baseline service and provides some recommendations to the user on the parking slots with the most probability to be free. Of course, the component takes into account the user's preference.
- **Itinerary Planner:** This component provides to the user the itinerary to the free parking slots or to the parking slots with higher probability to be empty when the user will arrive in Carouge by car.
- **User interface:** This component displays all the collective information provided by the other components. Users can see the occupancy of the parking spots near the destination and choose a preferred spot or an available spot using smartphones, other mobile devices or PC.

⁶⁰ <https://catalogue-server.fiware.org/enablers/identity-management-keyrock>

⁶¹ <https://catalogue-server.fiware.org/enablers/pep-proxy-wilma>

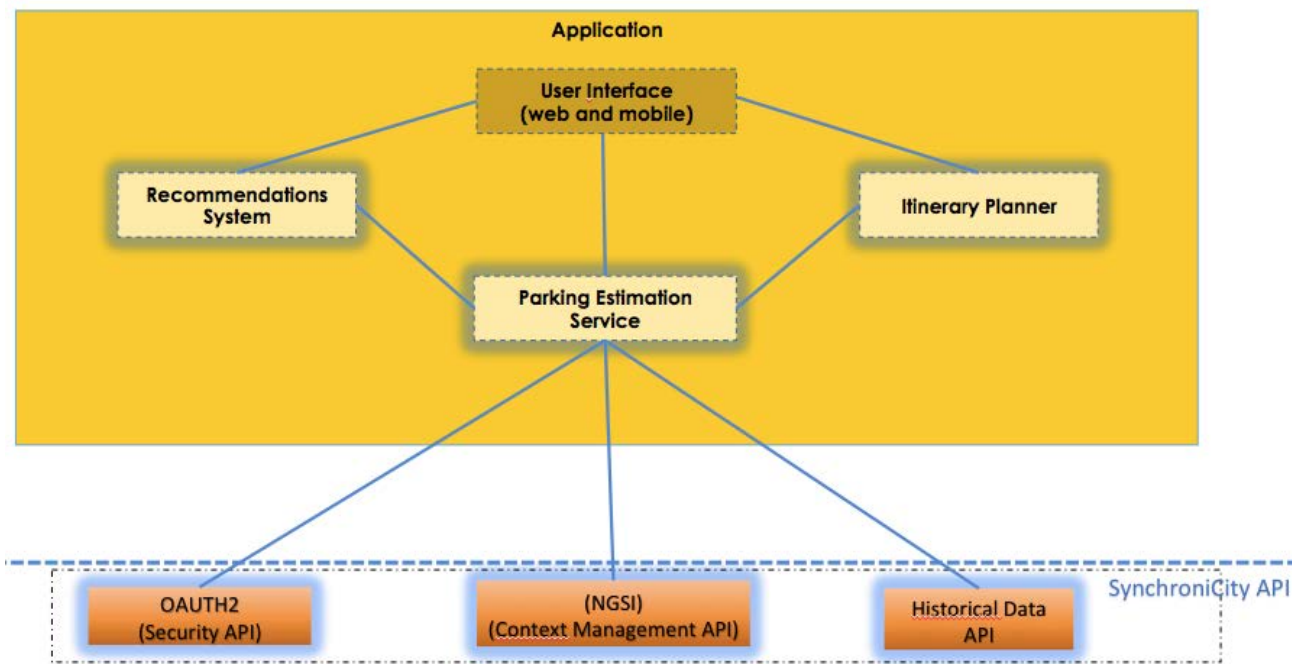


Figure 18. Carouge Smart Parking application architecture

3.5.4.1 Reusable baseline services

Table 88: Baseline services adopted in Smart Parking application application

Name	Description
Parking Estimation Service	This service calculates the probability to find a free parking slot in a given area of Carouge and takes into account when the user will come in the city with his car.

4 Application Theme: Community policy suite

Main aim of this application theme is the design and implementation of an approach to develop innovative IoT-based solutions that enables local authorities in management of policies, in decision making and in management and administration of the city. Leveraging on real-time information provided by IoT sensor and on historical collected data, cities can 1) identify hidden problems to be solved or new and more efficient solution for well know problems and 2) improve efficiency of day-to-day operational functions.

Three RZs participate in this application theme are Carouge, Manchester and Porto. In particular:

- Manchester aims to break information silos by the application of an agile approach to city governance, in order to obtain a more efficient system to coordinate cross-departmental teams; this objective will be reached leveraging on existing infrastructures and data and on the application of a new methodological approach. (Section 4.1)
- Porto aims to implement a solution to enable a proactive approach for problem solving and for a more agile management and policy processes, but also to increase transparency and to enable a bidirectional interaction and communication between the Municipality of Porto and the local communities, citizens, companies and institutions; the objective is to support the digitalization process and to break information silos of the traditional approaches, in order to realise a integrated and more effective management system. (Section 4.2)
- Carouge aims to realise a noise monitoring application in order to monitor noise pollution and to detect which commercial activities (such as bars and restaurants) have a significant impact on noise level; this application will help Carouge to identify noise sources and to adopt adequate decisions in order to reduce the generated noise. (Section 4.3)

It is important to underline that Manchester and Porto are approaching this application theme through the implementation of new methodologies, whereas Carouge is designing a more classic application to facilitate day by day activities.

4.1 Manchester's Application "Agile Governance"

OVERVIEW

As detailed in SynchroniCity deliverable D3.1 "to better inform the city's governance" it is critical to provide a mechanism where IoT data can be combined with historical and static data to better inform: (a) management decisions (b) strategic decisions."

The development of a suite of tools (a "Community Policy Suite") aims to leverage existing infrastructures and data and apply a new methodological approach to how these are used by policy makers, providing an agile approach to city governance.

Manchester City Council (MCC), like many municipal organisations, often works in silos and would benefit from a more agile and efficient system to coordinate cross-departmental teams.

Agile methods of management have received a considerable attention, dominated by the fields of software development (Abrahamsson et al., 2002(Abrahamsson, Salo, Ronkainen, & Warsta, 2002)). Adopting Advanced Institute of Management Research definition (Voss and Wang, 2009 (Voss & Wang, 2009)), we define agility in the context of local councils as:

The ability to respond rapidly and effectively to unpredictable change in a turbulent city and citizens' demands.

To be agile, we see two different but complementary capabilities as essential to be developed and enabled by IoT (Table 89):

1. Responsiveness:

The ability to anticipate, and rapidly respond to externally-induced change by mobilising processes, people and service offerings

2. Multi-competence teams:

The capability to excel simultaneously on multiple capabilities, and mobilize people from different silos and units within the city, in a coordinated manner so councils can rapidly re-align to meet changed demands.

Table 89: Responsiveness and Multi-competence teams as complementary capabilities

		<u>Multi-Competence</u>	
		Low	High
<u>Responsiveness</u>	Low	Non-agile	Multi-Competent
	High	Responsive	Agile

Manchester was chosen as the UK's IoT demonstrator, "CityVerve", providing £16 million investment over a 2-year period from 2016-18 (Vaizey, 2018). This investment saw a multi-partner consortium, including Manchester City Council and Manchester Metropolitan University (partners on Synchronicity), develop an underlying smart city architecture and platform; develop a wide range of applications and services; and onboard over 200 datasets to a standards-based data hub(BT CityVerve Portal - Smart. Innovative. Inspiring. Manchester., 2018).

In developing a baseline application for Synchronicity, we are planning to use these datasets to inform the implementation of the Community Policy Suite. We want to see how data, sensors, devices and cloud and mobile services can use IoT to quickly adapt the deployment of policy to the local needs of a specific area of the city. Although the methodology and platform (to be developed by Bronze Labs) have been architected to accommodate a range of problem statements; data sources; team structures and workflows; we have worked with city officers through a number of stakeholder co-creation workshops to identify a problem to be solved. Following this process, we are now focusing on supporting organisational change within one of twelve recently outlined neighbourhood areas for Local Care Organisations (LCO) ⁶². LCOs are part of a newly developed integrated health and social care system for which the National Health Service (NHS) and MCC will be working together to create place-based responses to local needs.

With rapid changes in demands of citizens and increasing complexity of the challenges cities face, greater and faster access to data, and timely response enabled by insights generated using such data is required. The Community Policy Suite is designed in such way to enable us to test, challenge and drive community-led needs, through analysis of data, deploying of policy in a real-world situations and testing efficacy of the solutions, enabling us to dynamically improve the services we provide through the collection and analysing of data, and dynamic service design.

To respond to urban challenges, and facilitate and accelerate adoption of new services, integration of IoT data sources into policy making requires advanced **visualisation** and **analytical** tools for data to become **insights**, as well as a greater **absorptive capacity** by the relevant stakeholders which

⁶² <https://healthiermanchester.org/how-health-and-care-services-will-change/making-it-work/#healthier-manchester-the-our-manchester-approach>

can only be achieved by changes in existing practices and **streamlining** support services. In other words, the city requires to become more **agile** and incorporate an '**Agile Governance**' approach in its management and policy making process.

The agility application is intended to:

- Enable faster realization of challenges (or rising challenges)
- Make data visible to the relevant stakeholders
- Enable faster and more intelligent way of forming cross-functional teams between the council, the NHS and other organisations that make up the LCOs
- Facilitating a faster and more efficient way of responding to challenges
- Enable organizational learning and dissipation of such learnings by making expertise visible

These points are summarised in Figure 19, that depicts the four elements of agile governance methodology.

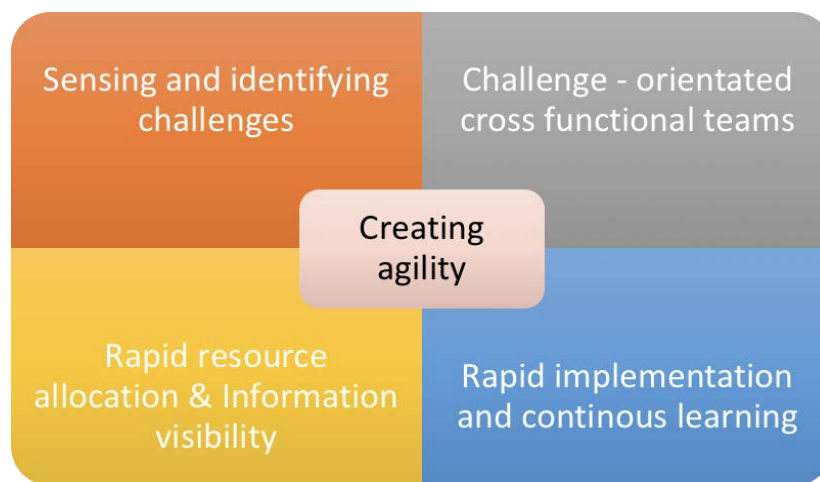


Figure 19. Four elements of agile governance methodology

CO-CREATION

Following existing collaborations in projects such as CityVerve, Manchester Metropolitan University (MMU) and MCC's Policy, Partnerships and Research team (PPR), have identified organizational structures and workings in silos, lack of coordination, and inefficiencies in team creation, among others, as just some of the barriers to adoption of new services and the IoT technologies. In October 2017, Manchester Metropolitan University (MMU) held 2 half-day co-creation workshops with MCC to first validate the problem identified by MMU and MCC's PPR team, second to identify the needs of MCC at an operational level and how the SynchroniCity project could respond to those needs using the Bronze Labs software, and third to further develop and customize the Community Policy Suite's methodology as developed by MMU. The workshops involved service-mapping, brainstorming and reflective/ backstaging case studies. These workshop provided an understanding of historic structure of "problem-based" teams and a validation for the need and desire of the Agile Governance method. In response to this workshop, MMU created a customisation of the Agile Governance methodology to align the city's needs with the software output.

Following the co-creation workshop, MMU and MCC met with Bronze Labs to discuss the needs identified in the Co-creations workshop and how those needs could be addressed using the Bronze Labs software.

The methodology provided a basis for moving on with the development of the specification for the "community policy suite", (SynchroniCity deliverable D3.1), where Manchester and Porto (two of the three participating cities in this theme) worked together to develop a common set of needs. Because

of the commonality between the two cities' approaches, the adoption by both cities of Bronze Labs software to provide a platform for delivering on the baseline application was agreed.

A further workshop in Manchester with Bronze Labs and Digital Catapult and Future Cities Catapult, further defined the requirements for this theme, and further meetings in Brussels and Porto were used to identify the differences between the two cities' applications.

MANCHESTER INTEGRATION

Manchester's IoT platforms are managed by non-Synchronicity partners - as the data collected through CityVerve remains on the BT owned and controlled platform, and provide access to data, a city API, and an open marketplace (cityverve, 2018) for 3rd party companies, which are fully in line with OASC principles. Manchester data has already been standardised using the Hypercat standard (Hypercat standard, 2018) which was mandated as part of the IoT demonstrator. Hypercat is a Global Alliance and standard (PAS212) driving secure and interoperable Internet of Things (IoT) for industry and cities. Data from a wide range of sources and providers is converted to Hypercat standard within the Manchester data platform in order to maximise the potential for re-use.

In order to ensure compliance with the Synchronicity framework and architecture (WP2), we are currently identifying the data sources required by the initial service (from the 200 or so on the city's data hub), and converting these to Synchronicity approved formats which will then be re-published on a local FIWARE endpoint installation. This will provide Hypercat to NGSI conversion, enabling other cities who are not FIWARE to more easily adopt the Synchronicity framework.

The Bronze Labs software will access data via a middleware interface which will enable replication between different cities using the Synchronicity framework.

Given the functional needs of this theme, determined through the city co-creation workshops, and the nature of the generic shared services (D3.2), there was no requirements to use any shared services at this point, beyond integration with the Synchronicity framework.

In May 2018, MCC and MMU met with internal stakeholders within the MCC to follow up the co-creation workshop and discuss potential use cases for the methodology. Members from the Performance, Research and Intelligence team within MCC and OS joined to discuss the decided methodology, and how to deploy that methodology through the Bronze Labs software with a use case that was relevant, viable and useful.

PROBLEM IDENTIFICATION TO TEST THE METHODOLOGY

Over the last 12 months MCC and MMU have been identifying with stakeholders a range of potential "problem statements."

Throughout this, it has been necessary to work with stakeholders to ensure that the "problem statement" to be tested within the baseline application has the following characteristics:

- "Buy in" from internal stakeholders to ensure that there is commitment to use the community policy suite tool in a real world situation
- Availability of "real time" data for populating the application
- Need to develop "virtual team" structures to improve decision making
- Timescales of the "problem" aligned with Synchronicity deployment timetable (D3.4)
- The problem is specific and the impact is measurable

In May 2018, MCC and MMU met with internal stakeholders within the MCC to follow up the co-creation workshop and discuss potential use cases for the methodology. Members from the Performance, Research and Intelligence team (they key departmental stakeholders within the local authority) within MCC and OS joined to discuss the decided methodology, and how to deploy that methodology through the Bronze Labs software with a use case that was relevant, viable and useful.

Several potential use cases were identified and the relevant departments managers and operational staff are being contacted and communicated with to ensure that a feasible use case is chosen and that there is buy in from MCC to adopt the methodology and software for the duration of the project to test the value of the Community Policy Suite tool. Upon follow-up, the LCO use case was identified as the best aligned and most beneficial use case.

Manchester is currently undergoing transformational changes to its health and social care services. As part of the Our Manchester Strategy, MCC and the NHS have endeavored to integrate health and social care services using a place-based approach to reform services so that they are built around citizens and communities rather than organisational silos. The LCOs are made up of 12 neighbourhood areas, for which cross-organisational teams, 'Integrated Neighbourhood Teams' (INTs), have been developed to offer integrated services. The roll out of this new service is in alignment with the SynchroniCity timeline and provides a unique opportunity to test the methodology and Bronze Labs technology in one INT as a pilot alongside INTs which are at the same stage of development allowing for a comparative evaluation.

The technology intends to allow the collection and dissemination of data to inform cross-departmental team creation for the deployment of integrated and place-based health and social care services. As was outlined in the methodology, live data on challenges when shared with all of the relevant stakeholders in a time-efficient manner, has the potential to provide strategic insight which enables day to day operation staff to be guided by concrete evidence, and allows the flexible allocation of resources through frequent evaluation of performance which should inform decision makers of where they should increase or decrease efforts in response to local needs in the particular INT. The methodology and technology should allow for high level decision makers and relevant senior operational managers to develop responses and teams based on data and outcomes relevant to the local area. Currently the data is static and not accessible to all the relevant stakeholders, meaning that the decision-making process in response to local needs is siloed and often not tailored to the locality.

4.1.1 Application scenario(s)

4.1.1.1 Users profiles:

Table 90: User profiles of Agile Governance application

User profile ID	User description
User Manchester 1 (City Council Officer)	The user is a City Council Officer who works in the Growth and Neighbourhoods directorate. Operational officers work within the processes that have been agreed for their service, but the same problems reoccur time and again. They need access to data and be able to analyse citizen needs Officers know what the problems are and are unable to alter their patterns of working. It can be difficult for the team to get an overview of the problems and ensure that they are making the best decisions with the limited data available and the reduced resources to address the problem. Cross-department communication can be difficult and knowledge of who has the best skills and experience to address a specific challenge in the city is usually based upon their tacit knowledge and personal connections. They also don't have good feedback loops to show effectiveness of a policies applied in their day to day work.
User Manchester 2 (City Council Team Leader)	Team leader is working with a diffuse team that are set in their ways and they meet them only occasionally. They have limited resources and staff and have to use them in the most effective way. They know that certain staff have "easier" workloads and want to encourage better understanding amongst the team. They want to ensure that the resource is in the right place at the right team and the data can help them do this. They need access to one transversal platform in

	order to give access to the necessary data and reduce piecemeal research and guesswork .
User Manchester 3 (Policy Maker)	Senior manager is receiving regular complaints from citizens and from elected politicians and each one needs investigating taking up a lot of time. There is poor record keeping , and sometimes the monthly data from subcontractors doesn't give a picture that is the same as people are feeling in the city, they need to understand the present situation in the city. On the other hand, the service has recently improved with more resource and better training - yet people's complaints are based on isolated incidents. The policy maker wants to use good practice in this part of the city to influence strategy elsewhere in the city. There is a need for one transversal platform for city data.
User Manchester 4 (Citizen)	The User is living in the city centre with a small child. He is interested in how his family can get more involved in the decision-making processes of the city. He wants to give constructive feedback on the pain points that he experiences in the city and would like a safe and quiet street that provides a healthy environment for his children growing up. He would like more real-time info about the events in his neighbourhood. He does not have time to join council meetings, but he wants to be able to participate remotely while he is on the move. He would like his family to be involved in the exploration, design and implementation of new policy solutions.

4.1.1.2 Scenarios:

Table 91: Scenario "Monitoring the City / Real-Time Response" of Agile Governance application

Scenario title	Monitoring the City / Real-Time Response
User profile	User Manchester 1 – City Council Officer
Background	John is meeting his team for their weekly meeting reviewing the status of projects and new issues that need addressing.
Objective	John wants to get a better handle of what they should be prioritise and to gain better situational awareness of current activities.
Storyline	John is new in the team. He is dealing with a situation that he is sure must have been encountered before. He is able to bring up the necessary data on dashboard and filter it according to location . The software generates real-time insights from the data-feeds and surfaces the qualitative feedback from citizens that are participating on the platform. He can compare with the data from his own situation and identify similarities. He is able to contact the appropriate team to find out how the situation was solved.

Table 92: Scenario "Management Information" of Agile Governance application

Scenario title	Management Information
User profile	User Manchester 2 – Team Leader
Background	Ann has recently joined a team that has been looking after events in the city for a number of years. They have an established approach to event management and will have a debrief after each event.
Objective	Ann wants to easily assign tasks, assess the effectiveness of their response and enable them to better plan for future events where there are unexpected numbers attending.
Storyline	She has asked for data to be provided to the Agile Governance software for the weekend of the event. She is then able to sit down with her team to identify how the data confirms and enhances their understanding. They had previously underestimated how quickly people arrive and depart the event, and this gives them valuable information for planning future events. She can also recommend to the agile governance software what new data-feeds would help to gain better understanding of the issue.

Table 93: Scenario "Dynamic Strategy" of Agile Governance application

Scenario title	Dynamic Strategy
User profile	User Manchester 3 – Policy Maker
Background	Atif has been working for the council for twenty years and holds the position of Strategic Director. The Council has grown in size and has become increasing siloed with this expansion. He feels he doesn't have enough awareness how each department is addressing the systemic challenges and how effectively they are implementing policy.
Objective	Atif wants to assess how successfully policy is been implemented across the various departments that he oversees.
Storyline	Atif accesses the Agile Governance dashboard that enables him to view the variety of projects that are in progress and the associated policy with each. He reviews insights from officers that are tackling the problems on the ground and reviews the suggestions for policy amendments in the Live Policy Document . He can also view what issues citizens are most concerned with and the areas in the city that are affected. He is able to compare these with historical figures and see that certain things have improved, but other areas have bigger problems because of changes in population density since the strategy was written. He is able to present a refresh of the strategy based upon these changes and able to show where improvements have been successful, and where the new priorities are meant to be.

Table 94: Scenario "City Participation – Real-time feedback" of Agile Governance application

Scenario title	City Participation – Real-time feedback
User profile	User Manchester 4 - Citizen
Background	Phillip is a resident of Manchester, he is made aware of the policy participation platform through his children's school. The council are looking for citizens to have greater participation in policy development to address the health and safety concerns of the city. The family can also gain credits from providing feedback.
Objective	He would like his children to take more time in observing the city and its challenges and get involved in addressing improvements for their locality.

Storyline	As he walks his children to school, he opens his phone to the participation platform, he is able to submit a notification on the heavy traffic congestion on the road, he takes a video that provides noise and visuals. On another day he is notified to participate in a pilot to assess new routes in the city and the roll-out of new policy. He can gain 10 credits from participation and he happily accepts to join the pilot. This data is then fed into the agile governance suite for use by officers.
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4.1.2 Requirements analysis

4.1.2.1 Functional requirements

Table 95: Functional requirements of Agile Governance application

ID	Description
FR-1	Real time data feeds from the Synchronicity framework MUST be provided
FR-2	Users MUST be able to setup a data feed project
FR-3	Users MUST be able to document information in a “live” policy document
FR-4	The application MUST be able to pull in historical data from the Synchronicity framework

4.1.2.2 Non-functional requirements

Table 96: Non-functional requirements of Agile Governance application

ID	Description
NFR-1	The application SHOULD be accessible via the latest Safari and Chrome browsers
NFR-2	The application SHOULD be accessible via android and iOS tablet devices
NFR-3	The application SHOULD be available in English and Portuguese
NFR-4	The application MUST be compliant with EU data protection laws
NFR-5	The application SHOULD have intuitive and easy to use UI
NFR-6	The application MUST be secure

4.1.3 Available data sources

Data sources that will feed the application (Table 97) will be APIs provided by the "BT CityVerve Portal" (BT CityVerve Portal - Smart. Innovative. Inspiring. Manchester., 2018) through Hypercat

Table 97: Data sources used in Agile Governance application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Cycle parking spots	Brompton Docking Station Locations	API	OnStreetParking	
Location of traffic signals	Transport for Greater Manchester (TfGM) Traffic Signals	API	TBC	
Location of roadworks	TfGM Roadworks	API	TBC	
Location of Metrolink Routes	TfGM Metrolinks	API	TBC	

Timetables of transportation	TfGM Journey Times	API	TBC	
Location of Car Parks	TfGM Car Parks	API	TBC	
Cycle journey data	Manchester Cityverve See.Sense Cycle Trial Hourly Stats	API	TrafficFlowObserved	
Location of Traffic Signals	Manchester Traffic Signals	API	TBC	
Location of Manchester Cycle Routes	Manchester Cycle Routes	API	RoadSegment	
Location of Manchester Cycle Hubs	Manchester Cycle Hubs	API	OnStreetParking	
Location of Manchester Cycle Lockers	Manchester Cycle Lockers	API	OnStreetParking	
Cycle journey data	Manchester Cityverve Mobike Hourly Journeys Stats	API	TrafficFlowObserved	
Cycle journey data	Manchester Cityverve Mobike Daily Journey Stats	API	TrafficFlowObserved	
Cycle parking spots	Manchester Cycle Parking	API	OnStreetParking	
Air quality monitors - Defra	Manchester Air Quality Data - Piccadilly	API	AirQualityObserved	
Air quality monitors - Defra	Manchester Air Quality Data - Sharston, Wythenshawe	API	AirQualityObserved	
Air quality monitors - Defra	Manchester Air Quality Data - Hazel Grove, Stockport	API	AirQualityObserved	
Air quality monitors - Defra	Manchester Air Quality Data (M60 Roadside) - Salford	API	AirQualityObserved	
Air quality monitors - Defra	Manchester Air Quality Data - Manchester South	API	AirQualityObserved	
Air quality monitors - Defra	Manchester Air Quality Data - Manchester Piccadilly	API	AirQualityObserved	
Car Park Occupancy Data	Manchester Parking Data	API	TBC	
Pedestrian Counts	Pedestrian Counting	API	CrowdFlowObserved	
Air Quality monitors - CityVerver	Manchester AQ Clarity Monitor	API	AirQualityObserved	

4.1.4 Application architecture

Bronze Software Labs is deploying a version of its smart city middleware, Framework42, with features specifically developed for SynchroniCity for use by Porto and Manchester. Architecture depicted in Figure 20 in common between Manchester and Porto applications (Porto application Open Interactive Map is described in section 4.2). Framework42 is a cloud based, IoT platform that will accept NGSI formatted data from the SynchroniCity API to answer the various scenarios put forth by the cities.

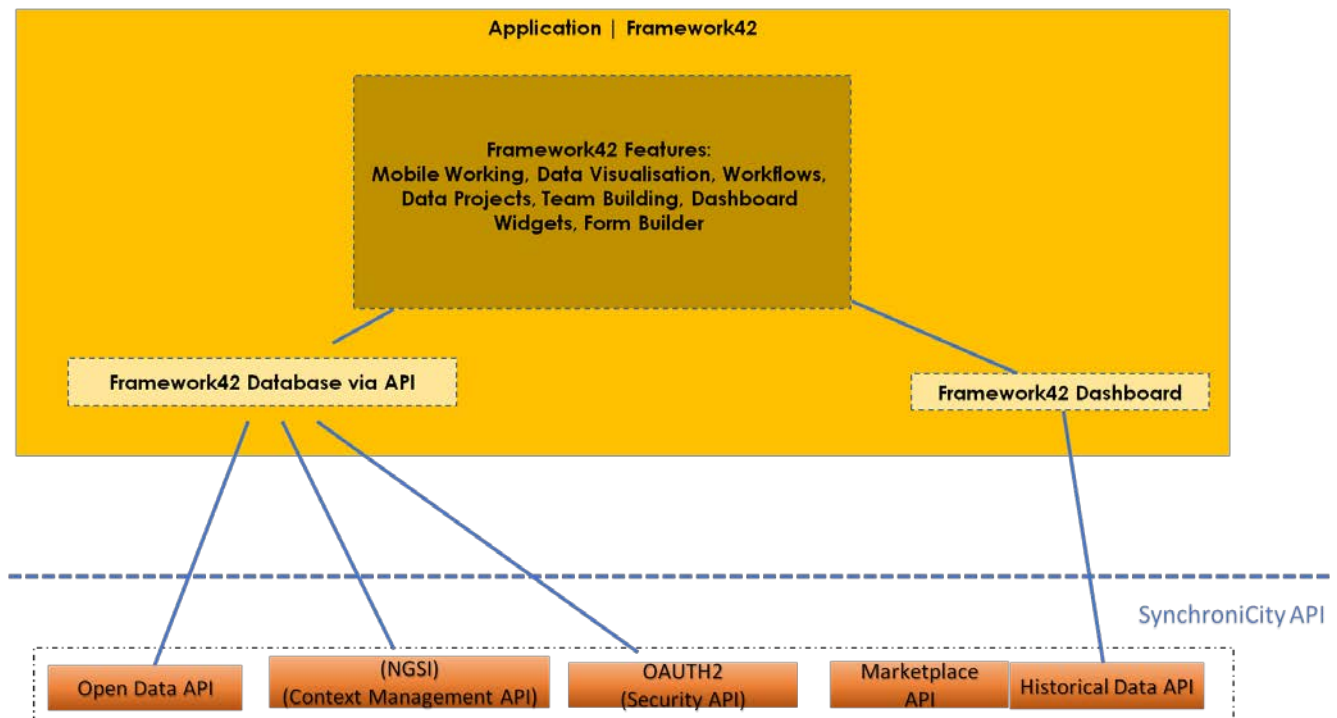


Figure 20. Architecture of applications Agile Governance and Open Interactive Map (Manchester and Porto)

Framework42 is not a reusable baseline service, it is an end to end solution for the delivery of the methodological approach as explained in D3.1 of the Community Policy Suite; it offers a set of features reported in Table 98.

Table 98: Framework42 features

Name	Description
Bronze Labs NGSI API	This maps the incoming NGSI data from SynchroniCity to a format that Framework42 can use.
Framework42 Dashboard	This will interact with the Historical Data API to display historical data within the map widget(s).
Feature: Mobile Working	This feature, along with a companion app (android), allows a user to be tasked jobs and complete them remotely.
Feature: Team Building	Allows a team leader user to build an ah-hoc team and assign them jobs, works hand in hand with Mobile Working.
Feature: Data Visualisation	A visualization of the incoming NGSI datasets, overlayed on a map widget.
Feature: Workflows	User editable workflows that send alerts within the system and externally via email.
Feature: Data Projects	This allows an admin user to pull in datasets from the SynchroniCity framework and create a "project". This project is time-bound and allows them to see, in real-time, the effect policies are having within the city.
Feature: Dashboard Widgets	A series of counters and calendars that can be useful as a quick view.

Feature: Form Builder	A drag and drop form builder for creating digital paperwork for Mobile Working, this also works with Workflows, where a certain input could trigger an alert.
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4.2 Porto's Application "Porto Open Interactive Map"

The Porto Open Interactive Map application will gather, process and analyse city data, providing valuable information to the City Council, local business owners and citizens (both inhabitants and visitors).

The main city data sources, that are expected to be handled by this application, are: public transportation network (schedules, stops and stations, routes and lines, ticketing and pricing, etc.) and vehicle-sharing systems (docking and parking locations and status, vehicle availability); POIs; events; environment (noise, air quality and meteorological parameters); weather forecasts and alerts; traffic flow and constraints; and geographical data (highway, city roads and streets, bicycle path, sidewalk, public transport lines, etc.). Some of this data will be static (from a database), other will be provided in real-time (from sensors), and will be showcased on a contextualized dashboard and map.

This application will be a useful analysis tool of updated, real-time and trusted city data to: i) the City Council (in particular, managers, administration and policy makers) and Municipal companies, in order to better inform and implement decision and policy making; ii) local business owners, in order to take informed operational and strategic business decisions and identify future opportunities, challenges and threats or constraints; iii) citizens, in order to have access to contextualized city data, report city problems, occurrences and other civic issues, to suggest new ideas and problem solutions, and to get feedback from the Municipality of Porto about them. This solution will enable a proactive approach to problem solving contributing to a more agile management and policy processes.

Besides, this tool will ease and increase the transparency, interaction and communication between the Municipality of Porto and the local communities, citizens, companies and institutions, in both directions (from and to the Municipality). The flow of information available will not only support the digitalization process but also improve the “de-siloing” trend of the traditional structures, thus promoting an integrated and more effective management system.

The innovative character of this application is based on the fact that it brings a new “intelligent” layer to city governance augmenting the impact of the IoT network deployed in the city. This solution enables a reliable and more consistent usage of interconnected data which enables all the actors (City Council, Municipal Companies, Citizens, Businesses and other relevant stakeholders) to interact with each other by identifying and reporting city’s events and transformations. Trends and patterns can be integrated in the decision-making process and result in an improvement of the quality of life (or quality of the journey, in the case of visitors) of the citizens.

Rewarding and gamification processes are foreseen for a second stage in collaboration with the municipal services and local businesses to maintain the interest of the users in a long-term perspective. The interfaces will be developed with a user-friendly approach enabling not only easy access but also a clear value perception from the User's point of view aiming at supporting a sustainable use.

4.2.1 Application scenario(s)

4.2.1.1 Users profiles:

Table 99: User profiles of Porto Open Interactive Map application

User profile ID	User description
User Porto 1 City council (<i>Strategic managers & administration</i>)	This user is an inhabitant (works for the Municipality of Porto) who knows exactly what he needs to do a good job, but can be frustrated by not having the right information and the right time. Part of its job motivation is to have access to city data, analyse citizens' needs , and provide a quick and effective answer to city occurrences and activities. He/she wants to feel confident doing his/her job and for that to happen, he/she believes that related data must be provided in just one transversal platform to reduce need for piecemeal research and guessing work . This user is mainly interested in finding particular information to analyse, without being distracted by other data information; keep up to date with latest data information; looking for time series and comparison data (e.g. noise levels, air quality, pollution levels) in order to be able to predict future opportunities ; having a powerful research tool to quickly find data information and apply a data analysis process simple and straightforward , to support and answer different situations.
User Porto 2 City council (<i>Local policymakers</i>)	This user is an inhabitant (works for the Municipality of Porto) who works daily to identify and develop key policy areas and to interpret and analyse information . This user job involves understand the present situation of the city and the factors that contribute to it, to be able to develop, and implement policies and strategies. This user believes that the city data must be provided in just one transversal platform to reduce the need for piecemeal research and guessing work . This user is mainly interested in using data for benchmarking or comparison amongst local communities; having access to clear and trusted information ; to see high level summaries, narratives and key charts that provide local context; keeping up to date with latest data information; finding long time-series of data to create personalised over-time series of data analysis , in order to be able to predict future opportunities .
User Porto 3 Business owner	This user is an inhabitant (lives and has is own business in the city of Porto) who has a proactive attitude and is motivated to help the community and his/her company to be successful . This user is aware of general events or activities that will happen in the city, but has a lack of knowledge on what kind of logistics and/or practical strategic decisions need to be taken to have a good business management. Right now, this user's behaviour is based on predictions and guessing work about present and future city conditions. He/she doesn't know exactly what to search for and where to search. This user is mainly interested in data that can be used to make practical decisions for his/her business; having high level summaries, narratives and key charts that provide local context information; keeping up to date with latest data information (e.g. population information, traffic data, cultural and events data); looking for time series and comparison data (e.g. people counting) in order to be able to predict future opportunities and have just one platform with collected and related data to reduce need for piecemeal research.
User Porto 4 Citizen (<i>Active citizen</i>)	This user is a local inhabitant (lives and works in the city of Porto) who wants to make a difference in the community. He/She increasingly believes that citizens like him/her need to be more involved in the life of the city , using human actions and technology to take action and become involved in defending his/her community, its ideas and quality of life. This user believes that the community must work together to build a shared city that reflects the aspirations of its citizens and meets their practical needs . Right now he/she uses the municipality contacts and website to report city problems and occurrences (e.g. bins

	management, street cleaning and report excessive noise levels on his street) directly to the Municipality of Porto. But, he/she is quite frustrated with this current service because, normally he/she doesn't receive any feedback or sees any changes on the reported situations. Because of his/her limited time to spend on these topics , this user is interested in have a real-time information about his/her neighbourhood area, have a quick feedback about the reported occurrences, wants to keep up to date with latest data information, have web app with push notifications neighbourhood accomplishments , and space to suggest new ideas for the community .
User Porto 5 Citizen (Observer citizen)	This user is an inhabitant (works in the centre city of Porto, but lives outside) who never actually got involved in any citizen participation activity , but there are certain situations that worry him/her, e.g. street maintenance and safety, environmental issues and welfare. This user is interested to integrate citizen participation and co-creation activities if it is about something that really concerns him/her or that will have a great impact in his/her daily life. This user is mainly interested in have an easy and effective interaction and communication with the municipality of Porto to be able to quickly report occurrences or visualize city conditions with high level summaries of issues, and planning future activities.

4.2.1.2 Scenarios:

Table 100: Scenario "Noise monitoring" of Porto Open Interactive Map application

Scenario title	Noise monitoring
User profile	Porto 1 (City council / Strategic managers & administration)
Background	The Integrated Management Center (CGI) of the Municipality of Porto provides real time information and promotes an integrated action amongst different public stakeholders and services, such as, security (national and municipal Police), emergency (civil protection, medical emergency and fire department), public transportation, and services of the Municipality of Porto (e.g., environment and waste, mobility and traffic, public space management and fleet management).
Objective	Monitor noise in residential areas close to nightlife zones , and take the necessary measures when the noise levels reach or exceed a defined threshold for a given amount of time.
Storyline	Noise levels are measured by noise sensors, which are part of the city's Environmental Sensor Network (ESN). A workflow, available in the platform provides alerts and displays on the interactive map, mapping the location and noise levels every time they reach or exceed defined thresholds for a given amount of time, during the night. This workflow also emails a person located within the council that is able to deal with it.

Table 101: Scenario "Policy assessment" of Porto Open Interactive Map application

Scenario title	Policy assessment
User profile	Porto 2 (City Council / Local policymakers)
Background	The Municipality of Porto measures the traffic levels with vehicle counters and speed meters, and the pollution levels with noise and air pollutant sensors. The latter two are part of the city's Environmental Sensor Network (ESN).
Objective	Detect correlations and causalities between traffic and pollution levels , and assess (validate) targeted mobility policies after they have been put in place (<i>ex-post</i> assessment).
Storyline	The platform gathers and processes data from the mobility sensors (vehicle counters and speed meters) and from the ESN (noise and air pollutants, the latter

	including gas and particle pollutants). This data is reviewed by the Mobility Department of the Municipality of Porto via the interactive map. Accordingly, the Mobility Department decides to take appropriate measures in order to restrict or close the traffic in those two streets during the day. After that, the Municipality of Porto continues to monitor thoroughly the traffic and pollution levels in those two streets, in order to assess these mobility policies. The platform provides real time feedback, via the sensors on the state of these streets allowing the Municipality to take informed conclusions and measures: 1) there was a real causality between traffic and pollution in street A, and thus decides to keep the street A with traffic restrictions; 2) although there was a correlation between traffic and pollution in street B, the results show that there is not a causality between the two (the pollution levels remain more or less the same), and thus decides to reopen the street B; 3) the high levels of pollution measured in street B are actually caused by an industry located nearby (which only works during the day), and the issue is now handled to the Environmental Department of the Municipality, so that it can take the appropriate measures.
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Table 102: Scenario "Preventive action" of Porto Open Interactive Map application

Scenario title	Preventive action
User profile	Porto 3 (Business owner)
Background	Several major events take place in the city of Porto during the year, such as, music festivals, football matches, student festivities, Saint John's Eve and New Year's Eve. These events involve significant amounts of people, traffic and noise in the event area, but also have significant impacts in the overall city in terms of traffic.
Objective	Take preventive actions in order to: 1) control the traffic and manage bottlenecks; 2) avoid high traffic close to the hospitals, and assure the emergency lanes of the hospitals closer to the event are accessible; 3) avoid and punish unauthorized parking; 4) assure the safety of the high amounts of citizens by restricting or closing some of the streets; 5) dispatch preventive emergency teams; 6) assure the public order and citizens' safety, by dispatching national Police teams.
Storyline	An event organiser informed the Municipality of Porto that a music festival will take place on a given date, at a given time and locations. The platform gathers live footfall and traffic data from sensors around the city and sends alerts to the Municipality when a certain threshold is hit for a certain period of time. Based on this data, the Integrated Management Centre (CGI) of the Municipality of Porto takes the following actions during the event day: 1) the Municipal Police locally monitors and controls the traffic and parking infractions, in particular, close to the venue; 2) the national Police locally assures the safety of the citizens; 3) the mobility and traffic services take the necessary measures in order to increase the public transportation offer and restrict or close some of the nearby streets; 4) the emergency services (civil protection, medical emergency and fire department) are informed and put on-hold (including making available some vehicles and teams nearby) for any eventual and emergency need. Besides, during the event, the CGI monitors the area with traffic sensors and video cameras, and monitors the main events in a map.

Table 103: Scenario "Citizen reporting" of Porto Open Interactive Map application

Scenario title	Citizen reporting
User profile	Porto 4 and 5 (Citizen)
Background	Manuel is a local inhabitant of the city of Porto, and uses a service that allows him to report city problems directly to the Municipality of Porto.
Objective	Enable the citizens to report city problems directly to the Municipality of Porto ; gather city problems through a dedicated digital platform; process the problem's provided data (e.g. identify, locate, validate and rank in terms of urgency and importance); handle the report and the list of required actions to the appropriate service of the Municipality of Porto; and provide feedback, acknowledgement and rewards to the participant citizens.
Storyline	According to the city's environmental rules, all the waste must be placed inside the bins, and never left outside; in case the bins are full, citizens are asked and expected to look for another available bin, or to take the waste back home. One day, Manuel takes four bags of waste (undifferentiated, glass, plastic and paper) to the waste containers and finds two problems: 1) the undifferentiated waste bin is not functioning, many waste bags have been left outside, and the street is dirty; 2) the glass waste bin is full. Accordingly, after leaving the paper and plastic waste on the appropriate bins, Manuel takes the undifferentiated and glass waste back home. When Manuel reaches home, he reports these two problems to the Municipality of Porto through a digital platform. This data is gathered and processed by the platform, which later informs the waste and street cleaning services of the Environmental Department of the Municipality of Porto of the problems. After the problems are validated and fixed <i>in-loco</i>, the service operators report to the platform that the problems have been fixed. In the end, the platform provides feedback and status of the reported problems to Manuel.

4.2.2 Requirements analysis

4.2.2.1 Functional requirements

Table 104: Functional requirements of Porto Open Interactive Map application

ID	Description
FR-1	Real time data MUST be provided
FR-2	Alerts based on data thresholds MUST be enabled
FR-3	Access to datasets MUST be able to be set by admin level users
FR-4	A public dashboard MUST be available without a login wall
FR-5	All data sets MUST be made available to the map widgets
FR-6	Workflows MUST be customized and generated
FR-7	An info bubble MUST open when clicking on an object
FR-8	Time-lapse animation ('data scrubber') of historical data MUST be enabled

4.2.2.2 Non-functional requirements

Table 105: Non-functional requirements of Porto Open Interactive Map application

ID	Description
NFR-1	The service SHOULD be accessible via the latest Safari and Chrome browsers
NFR-2	The service SHOULD be accessible via android and iOS tablet devices
NFR-3	The service SHOULD be available in English and Portuguese
NFR-4	The service MUST be compliant with EU data protection laws
NFR-5	The service SHOULD have intuitive and easy to use UI
NFR-6	The service MUST be secure
NFR-7	The service MUST have a search tool

4.2.3 Available data sources

Table 106: Data sources used in Porto Open Interactive Map application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Noise	Noise levels (LAeq, 5 min)	Open data	NoiseLevelObserved	
Air pollutants	Information about air pollutants measurements such as: PM2.5 particles, PM10 particles, Ozone (O3), Nitrogen dioxide (NO2), Carbon monoxide (CO)	Open data	AirQualityObserved	
Meteorological parameters	Data coming from meteorological measurements: Solar radiation, ultraviolet radiation, wind direction and speed, rainfall, atmospheric pressure, air temperature and humidity measurement	Open data	WeatherObserved	
Vehicle location and speed	Data about vehicle location and speed	Open data	Vehicle	
Vehicle count	Data about number of vehicle (count) in a road segment.	Open data	TrafficFlowObserved	

POIs	Data about Points of interest (POIs)	Open data	PointOfInterest	
Events	Information about events (concerts, football games, cultural events, etc.)	Open data		W3C / Schema Data model: Event No FIWARE data model available
Public transportation	Public transportation data (schedules, routes, lines, stations/stops, etc.)	Open data	To be defined	
Traffic constraints	Data about temporary traffic constraints (scheduled events, accidents, etc.)	Open data		Data model: Open511 (To be confirmed) No FIWARE data model available

4.2.4 Application architecture

Architecture of Porto application Open Interactive Map is in common with Manchester's application. The architecture is reported in section 4.1.4. Bronze Software Labs is deploying a version of its smart city middleware, Framework42, with features specifically developed for SynchroniCity.

4.3 Carouge's Application "Noise monitoring near bars"

In general, Switzerland is taking care of the noise pollution more and more produced by different sources (e.g., commercial aviation, trains, trucks and cars) including the noise produced in the cities by the crowd. Typically, each city applies a strict regulation on opening hours of bars and restaurants. This allows reducing the noise affecting the neighbours of the bars and restaurants. However, there was no technical automated solution to measure the noise near the bars and the restaurants in Carouge.

The noise monitoring application enables to measure each area of Carouge and detects which bars and restaurants are noisy more than allowed level producing noise pollution. The mobile application of the noise monitoring service will inform the city council where are the noisiest areas in Carouge to help the city council to take some decisions on reducing the noise generated by the bars and the restaurants. As an example, the schedule for opening and closing time of the noisiest bars and restaurants could be adapted based on the measurements results and the information provided by the noise monitoring mobile application.

Also, the owners of the bars and the restaurants will be aware of the noise produced by their clients and could take some actions to reduce the noise in the frame of their commercial activities. Eventually, the comfort of the Carouge inhabitants will be increased.

4.3.1 Application scenario(s)

4.3.1.1 Users profiles:

Table 107: User profiles of Carouge Noise monitoring near bars application

User profile ID	User description
User01	City manager: this user is interest in the monitoring of noise level caused by commercial activities in the city, for instance by bars and restaurants.
User02	Owner of restaurant or bar: this user manages a commercial activity such as a bars or a restaurant and he/she is aware of the noise level cause by his/her commercial activity.

4.3.1.2 Scenarios:

Table 108: Scenario "Noise monitoring near bars" of Carouge Noise monitoring near bars application

Scenario title	Noise monitoring near bars
User profile	User01
Background	The application shows the current noise measurements near restaurants and bars in Carouge. The city managers can see which locations have the most severe noise levels, and take a decision on the city policy on reducing the noise level related to opening hours of restaurants and bars.
Objective	To apply the noise level on making a policy on opening hours of restaurants and bars.
Storyline	A city manager should decide the opening hours of a new bar where noise sensors are installed in Carouge. Through the application, the city manager checks the sensing values from the noise sensors near the bar on each evening and night, and also obtains accumulated noise level data on certain period of the time. The city manager can make an optimal decision using the inputs provided by the noise monitoring application.

Table 109: Scenario "Aware of noise near bars" of Carouge Noise monitoring near bars application

Scenario title	Aware of noise near bars
User profile	User02
Background	The owner of a restaurant can see the level of noise near her restaurant/bar and take measures to inform her customers
Objective	To inform the bar manager about the noise generated by her customers outside their premise.
Storyline	The noise generated by the customers of bars and restaurants sometimes creates tension with the neighbours. By collecting real data, the city can take adequate measures and inform the owners of the bar if the noise level is indeed too high or in the average.

4.3.2 Requirements analysis

4.3.2.1 Functional requirements

Table 110: Functional requirements of Noise monitoring near bars application

ID	Description
FR-1	Real time sensing data about the noise level MUST be provided.
FR-2	The security and integrity of the sensing data MUST be provided avoiding wrong information to be delivered.
FR-3	Noise monitoring service MUST provide average noise level per cluster.
FR-4	The noise level SHOULD be indicated into a street-view level of map.
FR-5	Noise monitoring service MAY provide that user select interesting areas to be monitored.
FR-6	Historical data SHOULD be provided.
FR-7	The service SHOULD provide different types of user management for city authorities, restaurant/bar owners and citizens.
FR-8	The service MAY provide news related to the cause of noise (e.g., city plan on new constructions).

4.3.2.2 Non-functional requirements

Table 111: Non-functional requirements of Noise monitoring near bars application

ID	Description
NFR-1	The service MUST be secure and reliable.
NFR-2	The service MUST be accessible in diverse mobile devices and web browsers.
NFR-3	The service MUST be compliant with privacy data protection policy in EU and Switzerland.
NFR-4	The service SHOULD be intuitive and easy to use.
NFR-5	The service SHOULD be easy to extend itself and easy to integrate into other city services.
NFR-6	The service SHOULD provide multiple languages used in Switzerland.

4.3.3 Available data sources

Table 112 reports a brief summary of the data sources that will feed the application; more details about these data sources and the data model can be found respectively in deliverable D2.2 *Guidelines for the definition of OASC Shared Data Models* and D2.8 *Report on Basic Reference Zones platform deployment and operational plan*.

Table 112: Data sources used in Noise monitoring near bars application

Title	Description	Open Data/API	Adopted SynchroniCity Data Model	Notes
Sound Level Average	Sound level average measured in a areas of the city	API	NoiseLevelObserved	

4.3.4 Application architecture

The architecture of the Noise monitoring near bars (Figure 21) application is based on the SynchroniCity framework. The major target of the noise monitoring is near the bars and the restaurants in Carouge. The data set used by this application is already described in the

SynchroniCity deliverables D2.2 and D2.8. The data are available through Orion context broker and STH Comet using the NGSIv2 API defined in the frame of the project. KeyRock⁶³ and Wilma⁶⁴ that are a part of the SynchroniCity security framework protect the access to the data.

The components of the application are as following:

- **Noise monitoring service:** This component gets all the data coming from Orion context broker and STH Comet through a secure communication channel.
- **Noise data analyser:** This component aggregates the data provided by the noise monitoring service and defines the acceptable noise levels near the bars and the restaurants in Carouge.
- **User interface:** This component shows collective information provided by the other two components. Users can see which areas are the noisiest ones using smartphones, other mobile devices or PC. As an example, users may take into account the noise level when they select a restaurant.

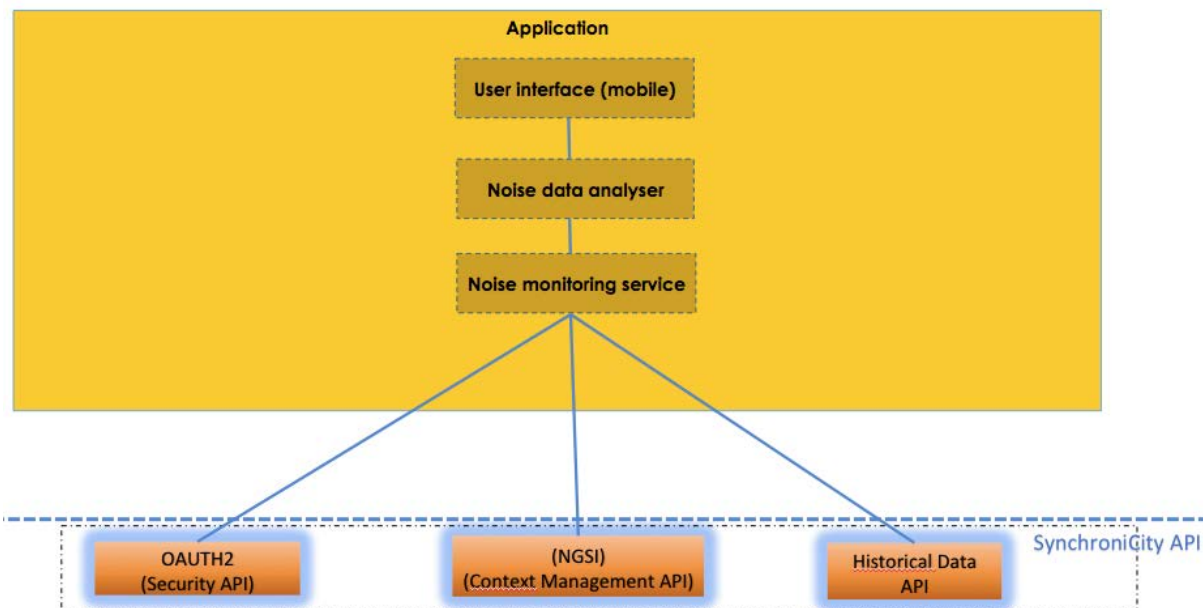


Figure 21. Carouge Noise monitoring near bars application architecture

4.3.4.1 Reusable baseline services

In this initial stage, baseline services defined in deliverable D3.2 are not taken into account for the design of this application; the use of currently existing and of potential future baseline services will be investigated in a second stage of the design of this application.

⁶³ <https://catalogue-server.fiware.org/enablers/identity-management-keyrock>

⁶⁴ <https://catalogue-server.fiware.org/enablers/pep-proxy-wilma>

5 Conclusions

This deliverable reports a first overview of the initial design of the application belonging to the three application themes (Human Centric Traffic Management, Multimodal Transportation and Community Policy Suite).

Eleven applications are reported in this document, specifically:

- three applications for the Human Centric Traffic Management theme and designed by Antwerp, Eindhoven and Milan;
- five applications for the Multimodal Transportation theme and designed by Carouge, Helsinki, Milan, Porto and Santander;
- three applications for the Community Policy Suite theme and designed by Carouge, Manchester and Porto.

These applications mainly leverage on two key concepts of the SynchroniCity project: the SynchroniCity framework/APIs and the baseline services; these are two important factors because they aim to ensure and promote the replicability of the solutions in different cities and contexts, often having also different priorities and objectives.

Indeed, applications, baseline services and data models can be adapted and contextualised for different purposes; for instance, the baseline service "routing service" has been conceived for providing routes to be used by multimodal journey planners, however in Milan it is intended to be also used for estimating new potential cycle paths.

A summary of the use of the baseline services in the different applications reported in this document is provided in Table 113; in particular, it is possible to notice that mainly applications belonging to the Human Centric Traffic Management and Multimodal Transportation themes make use of such baseline services, in fact the Community Policy Suite theme is primarily focused on the implementation of a methodology. For most of these applications, a set of baseline services to be reused has been identified (green cells), whereas, in one case, the use of a baseline service must be evaluated in the future (yellow cell).

Certainly, the Community Policy Suite theme calls for a special mention, because it presents two applications (Manchester and Porto applications, respectively reported and described in section 4.1 and in section 4.2) based on the implementation of an agile methodology and the relative approach, whereas a third one (Noise monitoring near bars application designed by Carouge and described in section 4.3) is based on technological solutions. The agile methodology and the relative approach allow to break information silos among departments of a Municipality and the creation of cross-departmental teams and their coordination.

The design of applications reported in this document will be completed in the upcoming months. The final scenarios, requirements, data sources, and architectures will be detailed, further investigated, and reported in SynchroniCity deliverable "D3.6 Customized IoT service prototypes for lead ref. zones – advanced". Furthermore, applications will take advantages also from the advanced baseline services, that will be provided in the upcoming months. They will offer the opportunity not only to enhance the functionalities already planned for each application but also to enrich them with new and more advanced ones.

		Consolidated Baseline Services					Candidate/Incubated Baseline Services		
		Routing Service	Parking estimator service	Traffic flow estimator service	Map visualization of service data	Timeseries visualization service	Geocoding and Reverse Geocoding Service	Map Service	GTFS (General Transit Feed Specification) RealTime Service
Human-centric traffic management	Antwerp								
	Eindhoven								
	Milan								
Multi-modal transportation	Helsinki								
	Milan								
	Porto								
	Santander								
	Carouge								
Community Policy Suite	Carouge								
	Manchester								
	Porto								

Table 113: Adoption map of baseline services in applications designed by RZs

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