REPLICATE PROJECT

REnaissance of PLaces with Innovative Citizenship And Technology

Project no. 691735

H2020-SCC-2015 Smart Cities and Communities

Innovation Action (IA)

D3.8 Report on the use of the ITS

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1. EXECUTIVE SUMMARY

The purpose of this document is to describe the use of ITS in the San Sebastian city pilot, in particular, describing the Smart Mobility platform that has been developed in the project framework. This solution will allow the managers and technicians of the mobility department of San Sebastian optimizing urban mobility services. Applying Business Intelligence and Big Data technologies, the information collected from the sensors and operating systems of the city will be exploited. In this way, managers, service operators, municipal planners and citizens can obtain information in a simple and orderly way, which allows them to better understand the reality of the city.

The solution has a comprehensive web tool that allows users to exploit the ability to analyze and interact with different content through a centralized, secure and multi-user global vision. This interface shows information adapted to the needs of the different municipal departments (public transport, parking, traffic, etc.). The information can be displayed in different formats, such as dashboards or key performance indicators. All this information can be filtered to access only the specific data that interests the user. It also includes a tool to generate reports and a module to manage the events (incidents that occur in the city).

Regarding data analytics, the platform includes predictive capabilities. For this, several multiclass classification models can be implemented and trained with the data coming from the city. In this context, a prediction model has been developed to predict the level of bicycle occupancy of each station in the bicycle sharing system of San Sebastian.

The platform is highly replicable in other cities. Data models and indicators implemented can be applied in other municipalities. Only, it would be necessary to implement data connectors and perform some configuration tasks with dashboards and reports.

2. REPLICATE

The main objective of REPLICATE project is the development and validation in three lighthouse cities (**San Sebastián** - Spain, **Florence** - Italy and **Bristol** - UK) of a comprehensive and sustainable City Business Model to enhance the transition process to a smart city in the areas of the energy efficiency, sustainable mobility and ICT/Infrastructure. This will accelerate the deployment of innovative technologies, organizational and economic solutions to significantly increase resource and energy efficiency improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

REPLICATE project aims to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens, and prove the optimal process for replicating successes within cities and across cities.

The Business Models that are being tested through large scale demonstrators at the three cities are approached with an integrated planning through a co-productive vision, involving citizens and cities' stakeholders, providing integrated viable solutions to existing challenges in urban areas and to procure sustainable services. Sustainability of the solutions is fostered in three areas: economic and environmental and finally, fostering transparency in the public management.

In addition, the Model features the replicability of the solutions and their scale up in the entire city and in follower cities, particularly in three follower cities (**Essen** - Germany, **Laussane** - Switzerland and **Nilüfer**-Turkey) that are involved in the project and therefore, have access to know-how and results achieved on the project so they can apply the developed model. At the moment, there are 2 observer cities, Guanzhou (China) and Bogota (Colombia).

3. INTRODUCTION

3.1 Relation to Other Project Documents

The definition of the work plan of the REPLICATE project is essential for achieving an effective innovation management system. Apart from the reference documents described below the deliverable has no specific relation to other project documents.

3.2 Reference documents

This document is based in the following projects level documents:

Ref.	Title	Description
REPLICATE Grant Agreement signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	REPLICATE Annex 1 – DoA to the GA	Description of the Action
REPLICATE Consortium agreement signed December 2015 (7th December version)	Consortium Agreement	REPLICATE project – Consortium Agreement
REPLICATE Project Management Plan	D1.1 Project Management Plan (v.1) (29/04/2016)	REPLICATE Project Management Plan
REPLICATE District Management Plans	D1.4 District Management Plan San Sebastian D1.5 District Management Plan Florence D1.6 District Management Plan Bristol	REPLICATE District Management Plans
REPLICATE Communication Plan	D11.1 Communication Plan	REPLICATE Communication Plan

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Where there are contradictions, the documents listed above supersede this deliverable. The Grant Agreement is the contract with the European Commission so takes precedence over all other documents.

3.3 Abbreviations list

API	Application programming interface
BI	Business Intelligence
CSV	Comma-separated values
ESB	Enterprise service bus
FTP	File Transfer Protocol
ICT	Information and communications technology
IoT	Internet of Things
JMS	Java Message Service
JSON	JavaScript Object Notation
PNG	Portable Network Graphics
RF	Random Forest
SDK	Software Development Kit
VPN	Virtual Private Network
WP	Workpacakge

4. DELIVERABLE DESCRIPTION

The document divides into the following sections, each of which addresses the following aspects:

- Section 5: establishes the main concepts for urban management in an intelligent city. In addition, how data can help managers make better decisions.
- Section 6: introduction to the data sources available in the project and the need to have this information integrated in the platform.
- Section 7: detailed description of the mobility platform, as well as its modules and their corresponding functionalities.
- Section 8: presents the predictive analytics capabilities of the platform. In addition, the use case of cyclist mobility implemented in the project is described.
- Section 9: main benefits provided by the solution developed. Its impact is taken into account as an innovative, replicable and safe solution.
- Section 10: summary of the conclusions reached after the implementation of the mobility platform.

5. URBAN MANAGEMENT IN A SMART CITY

5.1 Intelligent transport systems and urban mobility management

The emergence of new technologies and trends such as the IoT, the analytics of large volumes of data or cooperative communications in smart cities, represents an unbeatable opportunity to manage urban mobility services in a much more efficient way. The detection, acquisition, processing and communication of data from different urban data sources (sensors, operational systems, knowledge base, etc.) establishes a solid base so that municipal managers can obtain the information that allows them taking the most accurate actions in each case, with the aim of offering the best services to the citizens.

Within the framework of this WP3, a solution has been implemented (Mobility Platform) that captures, analyzes and integrates information from multiple sources and displays monitoring, optimization and prediction processes to understand the global status of the city and thus perform detailed monitoring of the parameters of improvement and performance that are defined in each case.

5.2 Decisions based on information and data

The value proposition of the platform focuses on offering to managers and technicians of the Mobility Department answers providing useful information for the performance of their services (What has happened? Where is the problem? What actions are required?).

The platform provides Business Intelligence mechanisms for the exploitation of the data and dashboards for its visualization. In addition, it provides massive data storage and processing capabilities for descriptive and predictive analytics.

Thanks to this information, operators can make decisions based on real and truthful data. This facilitates their daily operations, because they can easily access macro indicators that establish the service level of each mobility service in the city. In the necessary case, they can access more detail through analytical tools (graphics, filters, reports, etc.).

It is therefore about advancing in an objective and reliable data processing to increase confidence and consensus in decision-making. In short, establish a comprehensive and effective management of urban services for optimal use of available resources.

5.3 Ecosystem for the efficient management of mobility

Considering previous sections, it is clear that an appropriate exploitation of the data can facilitate a much more efficient management of urban services. The proposed solutions for the optimization of urban mobility services (such as the Smart Mobility Platform developed in Replicate) must offer a set of common management modules that are integrated and a set of solutions that facilitate a global vision and comprehensive management to the following recipients:

- Providers of urban services, for the improvement of their own services, among which stand out: bicycle rental services, public transport, etc.
- Urban managers, to control the management and decision making by the managers of the City Council, the Municipal Departments and other public companies.
- Citizens, both residents and tourists, to improve the quality of the services they receive.
- The ICT sector and local companies, for the promotion of innovation, cooperation and the development of new businesses.

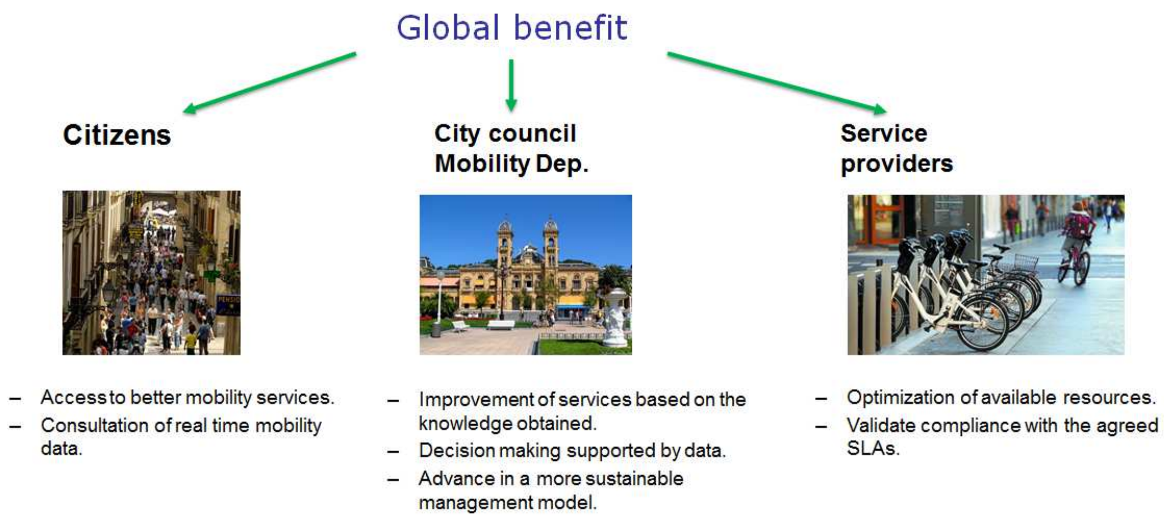

Figure 1: benefit obtained by main actors of the urban mobility

An example of this could be the bicycle rental service of San Sebastian, an integrated system in the Mobility Platform, and whose information management optimizes the following activities associated with the service:

- Service providers: can optimize the operation of the system (for example, moving bicycles to an empty station from another that is full) and thus improve the service provided to users. In the event that a situation of risk is detected, the managers can anticipate this situation and make decisions to avoid this incidence or at least minimize its impact. In short, they can increase the efficiency of the service, be more competitive in the face of future tenders and make more effective use of their resources.
- Municipal managers: they can monitor and manage more effectively the rental service offered to citizens. They can also validate that suppliers comply with the SLAs established in their concession contracts. In the event that there is a special event that affects the availability of the service (for example, an event organized by the tourism department that can increase the demand for bicycles) an effective coordination can be planned between municipal departments to visualize the alternative which best suits the city (break down "silos").
- Citizens: Citizens benefit from the improvement of renting services (greater ease in reserving or parking a bicycle, more efficient technical service, etc.). In addition, they can access the Open Data information processed by the platform and can plan their journey more effectively based on the same (availability of bicycles at stations near their location, prediction of demand in the hours consulted, etc.).

In conclusion, it is clear that the platform allows optimizing the management of the service and, in general, to improve the efficiency and satisfaction of all the actors involved in urban mobility.

6. Sources of data and operational systems

6.1 Identification of systems and sources

The benefits and capabilities of the platform are largely determined by the availability of data that allow modelling the different services of the city. Next, the data sources that have been identified in the city of San Sebastian and the operational systems that collect them are established for each of the urban mobility verticals worked in the Replicate project:

- Cycling mobility:
  - System of gauges for counting of bicycles.
  - Public bicycle rental system.
- Parking:
  - Underground parking management systems: mainly occupancy data. Complexity to extract the detail of the individual data of time entries / departures / nationalities (for administrative, not technical reasons).
  - Surface parking management systems.
- Circulation and Traffic:
  - Gauges for vehicle counting (intensities)
- Public transport:
  - Operating system for urban public transport.
  - Operating system for ticketing data.
- Electric Vehicular charging points:
  - Stations that supply electric energy for the recharging of electric vehicles
- External data sources: the following data sources have been identified, as information of common interest for the whole set of verticals:
  - Meteorology (historical, not forecast).
  - Calendar of holidays and special days (annual calendar with detail by municipalities).
  - Census information (demographic and socioeconomic data).

6.2 Integration of the data

The sources identified in section 6.1 are integrated into the platform through the integration and interoperability layer. This requires the connectivity modules and protocols, as well as the ETL module to allow collection of information from the various data sources.

In a generic way, the systems identified have a set of REST APIs to read and act on the information handled and allow other applications to use them and integrate them with their functionalities. The APIs support different access modes, including Push (subscription and notification) and Pull (request and response) modes, as well as georeferenced queries.

In some legacy systems, there are no standardized integration interfaces, so other integration mechanisms have been used as FTP services to allow secure access to the information (archives) extracted from the operational systems.

In any case, the Mobility Platform adjusts to the type of extraction process that is most efficient for each subset of data. For example, reducing the time spent in extracting and loading information, minimizing the impact of extractions in the origin systems (scheduling, if necessary, the extractions in times when the impact is zero or minimal), preserving the consistency and integrity of the information during loading, minimizing interference in the operation or falls in performance of the origin systems.

Thus, for example, the integration of IoT devices using the ESB of the platform allows decoupling between suppliers and consumers, regardless of the transport protocol used (HTTPS, JMS, TCP, etc.) through the use of open standards (JSON, XSLT, XPath, etc.) that allow the transformation and homogenization of information.

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7. INTEGRAL VISION OF THE MOBILITY

7.1 Smart Mobility Platform

Based on the urban management needs identified in chapter 5, the Mobility Platform of the Replicate project has been conceived from a holistic viewpoint. Unique information is integrated into a single platform to facilitate comprehensive monitoring of all services, including the management of devices and events, wider strategic management and decision making.

As will be seen in the following sections, the Mobility Platform centralizes, processes and exploits data multimodally with advanced Business Intelligence tools. The solution is based on a robust, open, horizontal and highly scalable management approach. The information and communication architecture allows the development and deployment of advanced, efficient and sustainable services and applications for mobility service management. For this, the platform is able to monitor and analyze a large volume of data from multiple sources and operational systems from the different departmental services: public bicycles, public transport, road traffic, etc.

7.1.1 Architecture

The technical solution of the Mobility Platform makes use of the layer model shown in Figure 2 that ensures the achievement of all the objectives set in the scope foreseen for the solution.

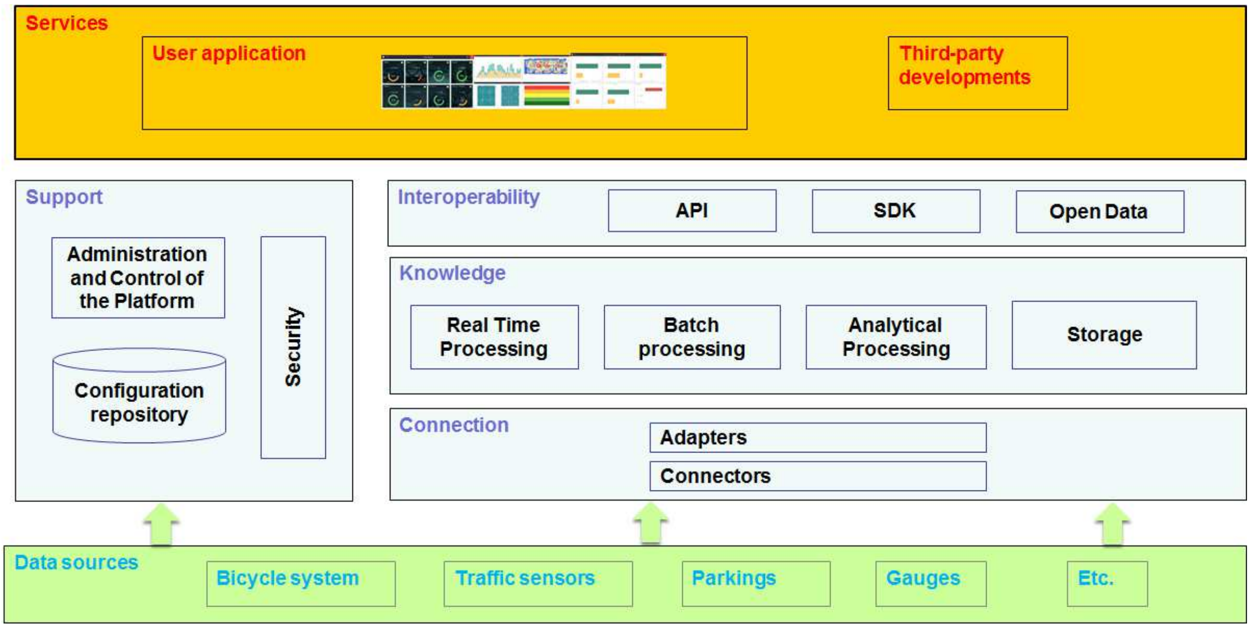


Figure 2: high-level architecture of the Mobility Platform

The layers that can be distinguished (and that comply with the provisions of the main regulations of the sector such as the UNE 178104 standard of AENOR) are the following:

- Systems capture Layer: it is responsible for the collection of information sources that feed the platform (sensors, structured and unstructured information, data flows, etc.) and may include geo-referenced information associated with them.
- Connection Layer: includes components and open source tools that facilitate the aggregation of information from the different data sources that feed the different repositories of the platform, being able to work with connected devices through a virtual private network (VPN). The objective of the tools of this layer is not only to provide information to the knowledge layer independently of the devices giving a semantic view of the acquired data, decoupled from the acquisition protocols, but also the management of the devices that they do not have their own operational systems that are already in charge of their management.
- Knowledge layer: it offers the elements of treatment, management and exploitation of the information provided by the data acquisition layer independently of the devices, giving a semantic view of the acquired data and decoupling from the acquisition protocols. On the one hand, this layer includes information persistence tools that will be used depending on the scope (historical, real-time or geo-referenced), the required latency of access to the data or the distribution and scalability of the information of a secure form, including ability to analyze and process large amounts of data. On the other hand, this layer also includes tools for processing the data received from the acquisition layer in real time and Batch, through ETL processes, Machine Learning. Finally, this layer includes tools for the analytical treatment of data through BI tools, such as Dashboard and Reporting tools.
- Interoperability Layer: collects the functionalities corresponding to the tools that allow exposing the functionality of the platform based on services that can be consumed by the Mobility Platform itself or external applications. Exposing the functionality of the platform implies providing standard and open interfaces, based on web service technologies, that guarantee the sending of data by devices and other information environments and access to them by different applications, both in real time as deferred. For this, in this layer there is an API manager that exposes the set of open programming interfaces API REST to read and act on the information handled, as well as a kit of development tools (SDK and APIs) and templates and modules for develop advanced applications and services.
- Smart Services Layer: collects the functionalities corresponding to the applications and business services and/or added value, interacting with the platform through the Interoperability layer. This layer includes the transverse tool of the Integral Control

Panel, which is based on the rest of the layers and transversal tools to offer georeferenced visualization features, dashboard, strategic plans, indicators, analytics, reports, event management and administration and configuration.

- Support Layer: allows having a unified control of the operation of the platform. The security module collects the rest of the Capabilities of the Support layer related to security, this is privacy, confidentiality, authorized access, authentication, traceability and security and encryption of stored data and managed by the Mobility Platform, as well as with the management of roles, users and permissions to limit access to information that each user can view according to their profile.

7.2 Modules and tools of the platform

The platform's visualization tool is conceived from a holistic, unique and integrated viewpoint of all the urban mobility information stored in the solution to facilitate global and individual monitoring through dashboards and indicators of all the services, the management of the devices in a geo-referenced way, elaboration and edition of reports, etc. To achieve all these objectives, it has the following modules:

- Publication and dissemination of information: global vision of the city and the Mobility Departments.
- Geo-referenced visualization: georeferenced monitoring and supervision.
- Control panels: integral dashboards.
- Indicators: management and evaluation of indicators (KPIs).
- Strategic plans: planning and monitoring of strategic plans.
- Analytics: data analytics.
- Reports: generation and consultation of reports.
- Event management: events, incidents and support for decision making.

Next, the characteristics and the visual aspect of the different modules that make up the holistic vision will be detailed, which will allow the managers and technicians involved to interact with all the elements and contents of the platform, from users with a mayor profile, to councils and municipal departments with their respective technicians.

7.3 Visualization of the information

The management of information on the platform has been raised taking into account the current regulations regarding the protection of personal data both at European and national level (especially; the current regulations and the recommendations of the Spanish Agency for

Data Protection, and the normative described by the European General Data Protection Regulation). Thus, considering that managers and technicians of different levels and with different responsibilities will use the mobility platform over multiple fields of action, it is necessary that the authentication access is carried out through role control.

The platform has a web interface through which users can access and manage all the functionalities. To enter the visual interface, users must have a user account and password. In this way, all the functionality of the Mobility Platform related to the management of information such as conducting consultations, creating reports, filter dashboards, etc. is restricted to the permissions and preferences of the user who accesses. Therefore, the first of the screens when accessing the application will be the one that contains the Authentication Area, which includes a general image of the city of San Sebastian. This screen allows doing the following:

- Login: the user can access the application by entering his username and password. If both fields are correct, the user will access the application with the authorizations assigned to them based on their user roles. On the other hand, if these are not correct, an error message will be shown.
- Remember password: the users can make their user data and password remembered in the computer, in this way the successive times they try to access the application, it will not be necessary to enter the password since it will be stored in the computer.
- Restore forgotten password: if the user has forgotten his password, there is the functionality to recover it. The user will click on the link called "I forgot the password", and after entering the email or username, will receive the password in the authorized email.

Figure 3: Home screen of the Smart Mobility platform

7.3.1 Global vision

Once authentication is done, the global vision of the city is the initial screen that is accessed. It is superimposed on the map, because it is the first step to show the real-time map for monitoring and visualization.

The overall vision of the city aims to jointly visualize the information of all the areas managed by the municipality and mobility departments that have been integrated into the platform. These areas, can be understood as the different departments that exist in the organization, and from now on, we will also call them "vertical". Through the global vision, all departmental areas contemplated simultaneously are presented together in a panel, and with the map as a background.

The global vision is represented through macro indicators: quantitative measures that are considered key in the functioning of each department. In this way, a card summarizing the value of the macro indicator in real time is associated to each department or scope of action. The content of the information in this first panel serves to provide the most relevant information of each of the verticals at a glance, which will be identified by a representative icon and a name.

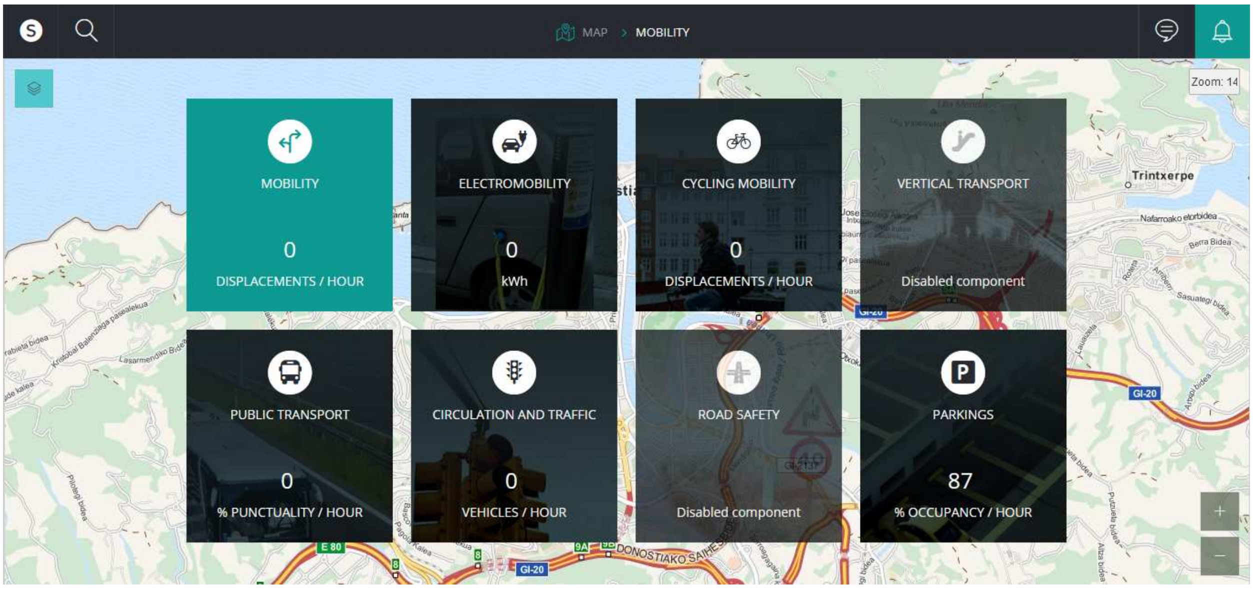


Figure 4: Global vision with cards for each departmental scope or "vertical"

On the other hand, when the role of the user accessing the tool has permissions to manage a single vertical (for example, managers or technicians of the mobility department of the City of San Sebastian), when entering will directly access a vertical vision, which shows information related to that department only. This vision is analogous to the global vision, but corresponds to the key aspects that are already managed within that department.

By means of the selection of cards in the global visualization, the geo-referenced map can be accessed. The map presents a view offered by the open source map server, OpenStreetMaps:

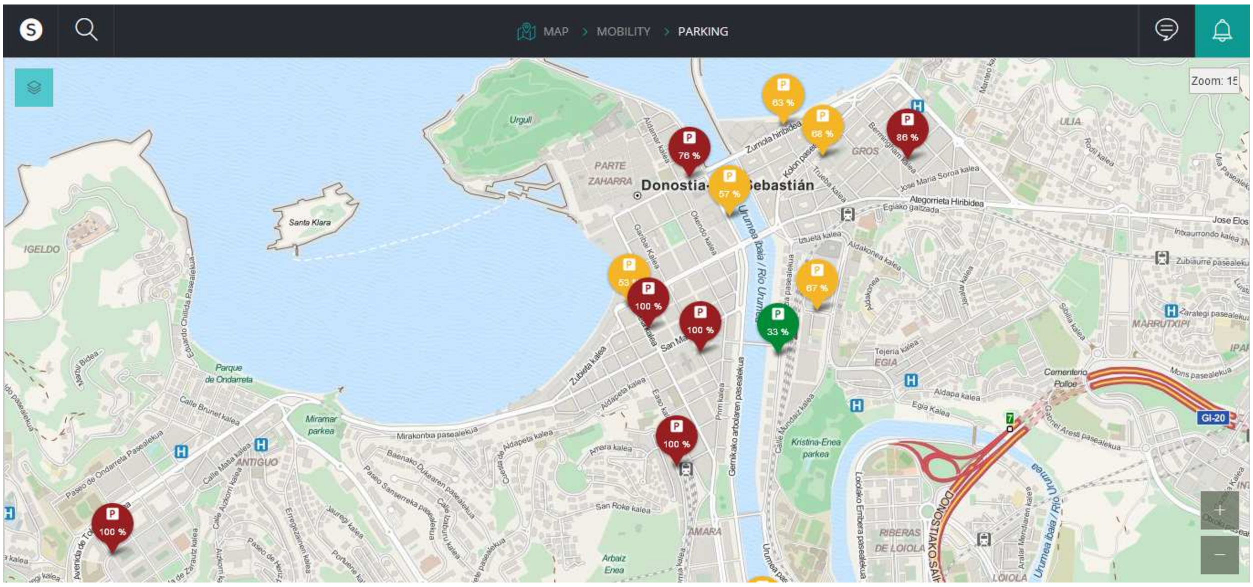


Figure 5: General view of the map for the example of the parking service

The usual operation of any type of web map is maintained: zoom in(+) and zoom out (-), as well as browsing for different areas. However, additionally, the platform also includes the following capabilities in terms of managing real-time monitoring:

7.1.1.1 Representation of punctual markers with information

The application will have different types of markers; these will be used to mark on the map from train stops, bicycle stations, points of interest, etc. Depending on the zoom level, some markers can be grouped under a global indicator that adds up all the elements. Clicking on it zooms in until you see the markers it contains. Other points could simply be hidden. The configuration of the markers is the following:

- Icon with data: It contains the text (number of stop, free places, time of arrival) associated to this type of marker.

Figure 6: Marker for public bicycle

When clicking on a marker a legend with information of the selected marker will be displayed. The legend will be composed of the following elements:

- Title
- Indicators
- Graphic
- Update frequency

An example of this contextual legend would be the following:

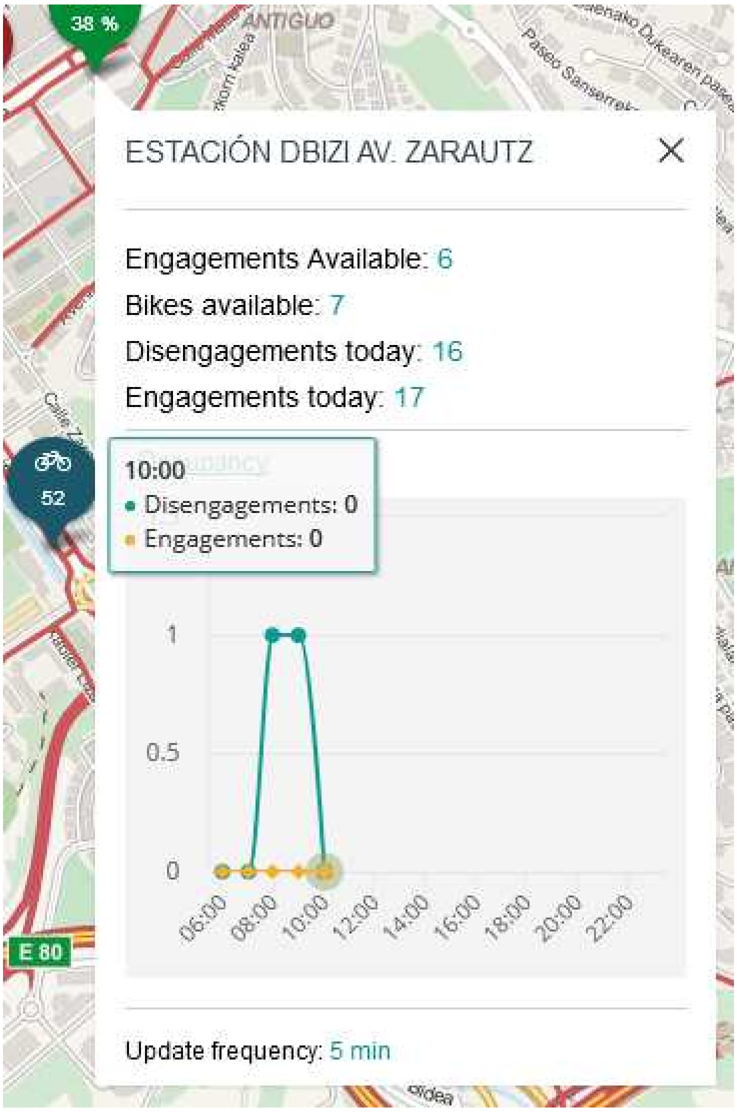


Figure 7: Context legend on public bicycle marker

To close a legend, the user can click on the close icon or click outside the legend, or on another marker located on the map. The user can also set a legend to be able to compare one set of data with another one. When it is fixed, this can be only hidden when the user clicks on the "close" icon, not when the user clicks outside or on another marker. That is, once the legend is set, it will only be closed when the "close" button of the legend is pressed.

7.1.1.2 Representation of alarms

Colors or movement effects on the marker will represent alerts. They will have several states: Unread, Read, Running, Finished. In addition, there is a special kind of technical alert for the case when no data is received.

The reserved colors to indicate level cannot be used to distinguish some markers from others. The fundamental element that will distinguish some markers from others should be the icon. There will be two ways to distinguish markers from each other. These are by the icon and color; or only by color.

7.1.1.3 Representation of lines

Lines describe trajectories and routes that connect certain predetermined places, passing through specific points. Indicating the routes or roads and describing them with their attributes i.e. models of travel between two points (bike lanes, bus lines, metro, etc.). In the project environment and according to requirements, these lines will allow representation of transport networks, but also priority routes, etc.

Figure 8: Routes for the passage of bicycles

7.1.1.4 Representation of areas

In the application, it can be drawn areas of the map of different colours to mark parking areas, areas of action, etc. They can be filled with different colours to differentiate them or leave them without filling to mark the limits. The areas may carry overprinted texts (name of the car park, name of the area, etc.).

Different tones in each area can be used to show occupancy levels. When the zoom level causes the area to be very small, it can become a point or tear. Clicking on the areas you can show highlights showing more information.

Another concrete utility of representation in the form of areas is to establish the division of neighborhoods in cities to be able to manage cities in different geographical hierarchies:

neighborhoods, districts and any management areas, both at the level of visualization on the map with monitoring objectives, such as at the level of exploitation of that information. This is permitted by the existence of the location dimension in the data model.

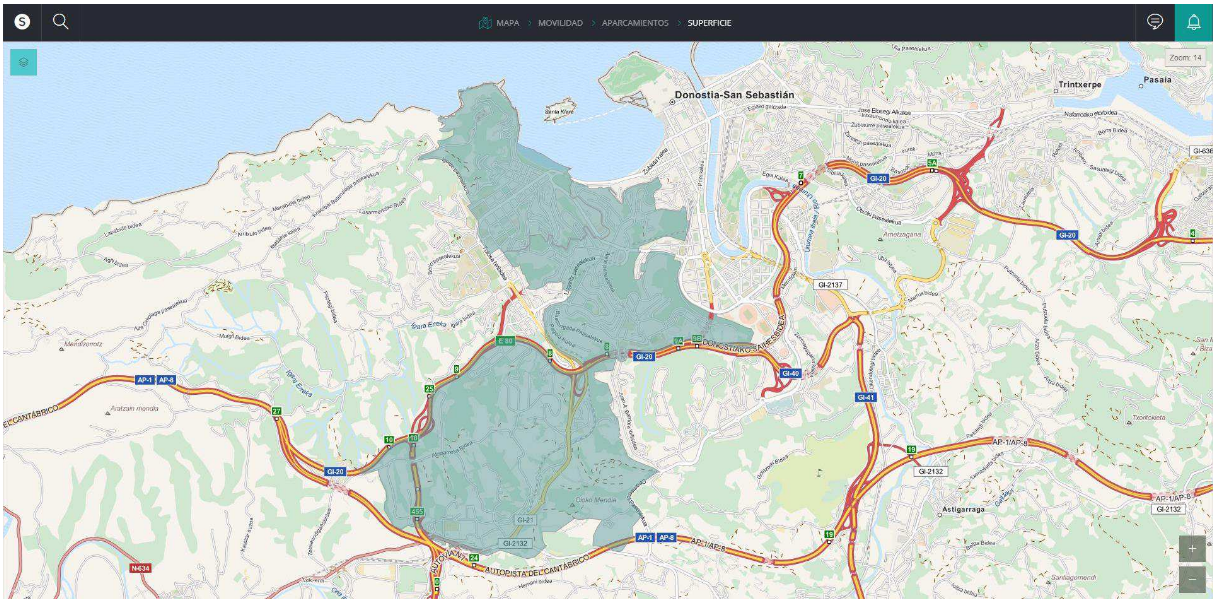


Figure 9: Map view with representation of areas

7.3.2 Dashboards

The dashboards aim to show in an integrated way a panel that rapidly summarizes the situation at all times in visual mode.

Within the platform, this is achieved through dashboards that are based on the most important indicators from a manager's point of view. Through a single number, the level of operation of each service that is managed through a department is shown quantitatively. In this case also, visualization is allowed from two points of view (holistic global or particular by departments), and through additional more detailed indicators. These control panels are accessed through the corresponding menu option.

The purpose of the integral scorecard function is to summarize the situation of all verticals. To allow a quantification that helps to evaluate and apply comparisons, for each department there will be a macro indicator.

An integral Vertical Control Panel is intended to show in summary form the situation of a specific department or area. In this case, to allow a quantification that helps to evaluate and apply comparisons, for each area that the department manages, there will be a macro indicator.

The macro indicator of a department will be a linear combination of these macro indicators of each area (within the same department).

In turn, a scorecard of vertical indicators, is not intended to show macro indicators as such, but the detail of each of the indicators that have been used to compose this macro area indicator.

These macro indicators will be displayed as a percentage so they are easier for the user to understand. There is an associated a color code that will make the user aware at all times of the current state of the verticals. In addition to showing the status of the macro indicator of each of the verticals, the trend (positive or negative) of the indicators will also be shown.

A color code associated to the percentages shown in the graphics is used (configurable based on the user's criteria). For example:

- Red: It will be applied for percentages greater than 80%.
- Orange: It will be applied to percentages between 50% and 79%
- Green: It will be applied for percentages lower than 50%.

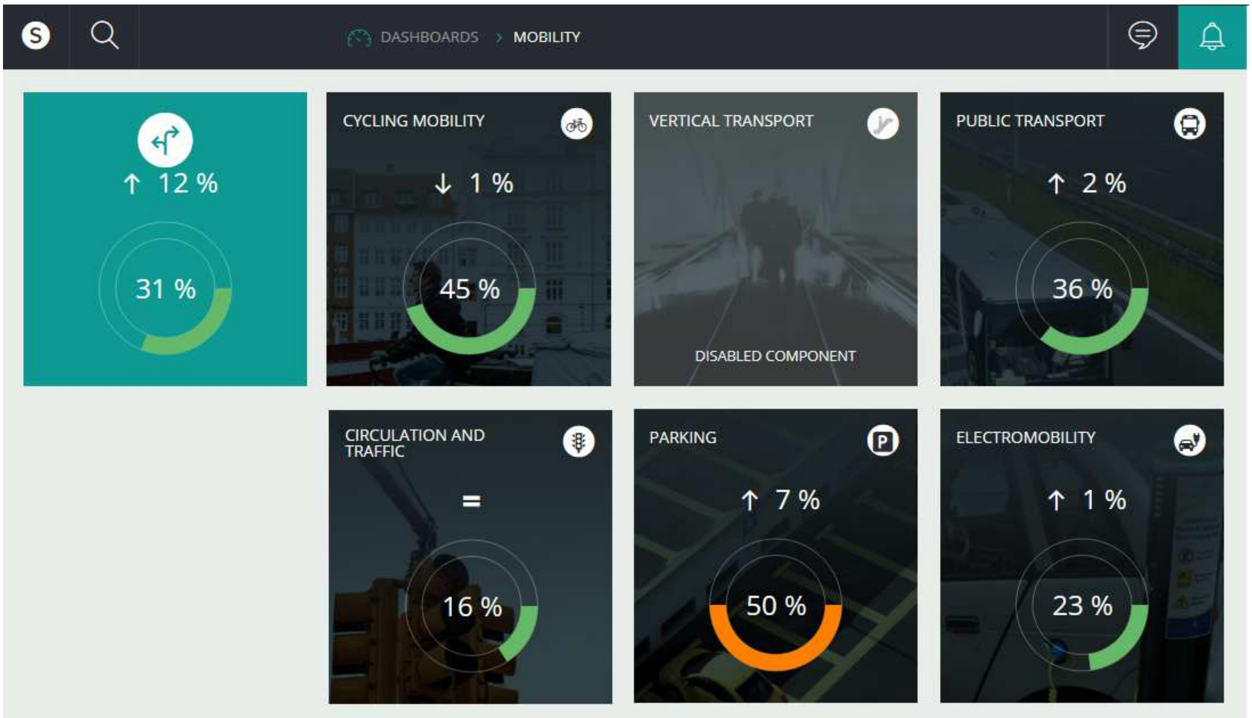


Figure 10: mobility dashboard

In the design of the scorecard, criteria of logical grouping of the services have been taken into account, trying to make these criteria have a meaning and a temporary validity beyond the organizational structures that the Department of Mobility of San Sebastian has at a certain moment. Thus, the impact of the organizational changes on the maintenance costs of the scorecard are minimized.

7.1.1.5 Indicators of a dashboard

By clicking on the panel of a macro indicator of a vertical, the user can directly access the corresponding dashboard indicators. Each indicator is represented as a graphic that allows the following utilities through its toolbar:

- Export: indicators can be exported in different formats. The formats to be exported are: JPG, PDF, PNG, CSV, etc.
- Expand: table or indicator can be expanded for better viewing by the user. This extension will cover the entire central part of the screen.
- Apply filters globally: in the upper right part of the header, the filter button will be located. Pressing it opens a modal window with the filter tool, using this filter the user can see the information of each of the indicators in different situations (by type of day, by meteorology, etc.).

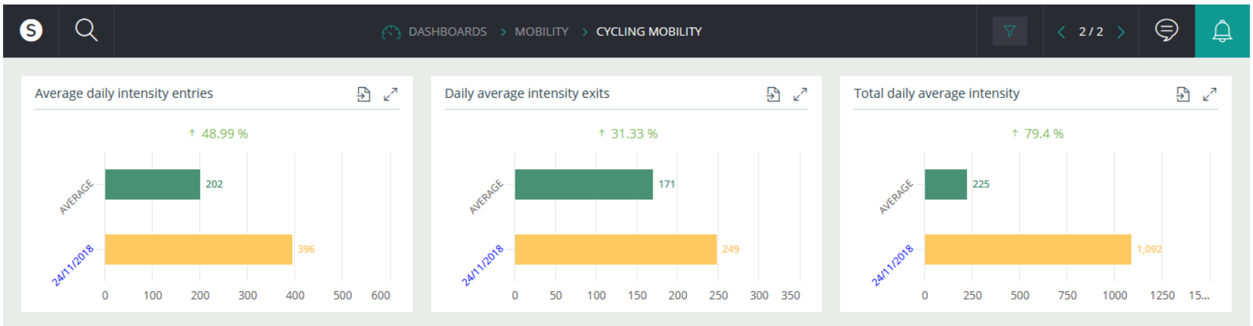


Figure 11: Indicators for the public bicycle scorecard

It should be noted that the filter of the dashboard indicators is applied simultaneously to the entire set of graphics. In the following figure, as an example, a filter for the Cyclist Mobility indicators is shown:

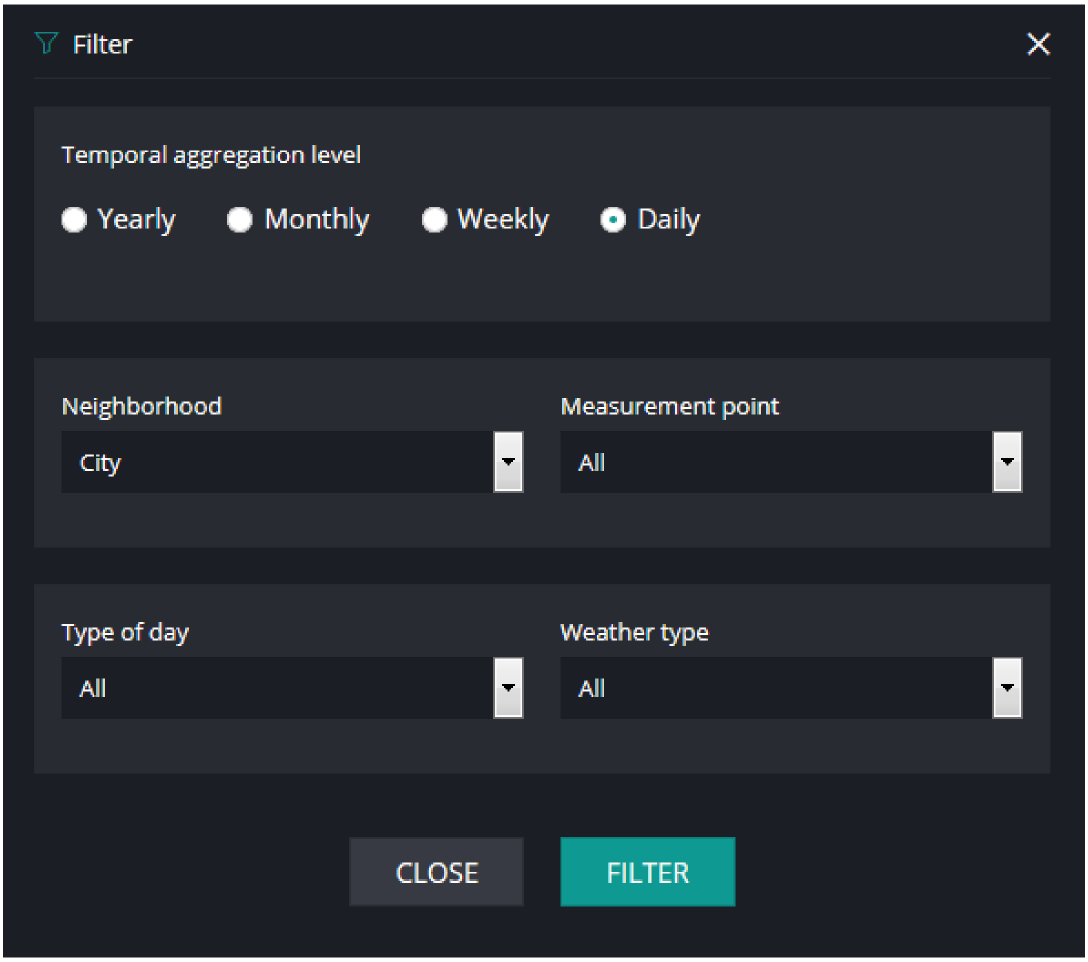


Figure 12: Dashboard filter in detail (Cycling Mobility)

As can be seen in the image, there are a series of filters for cyclist mobility information:

- Filter of dates:
  - Annual: A specific year (year) is selected.
  - Monthly: A specific month (month / year) is selected.
  - Weekly: A specific week (year) is selected from Monday to Sunday.
  - Daily: A specific day is selected (day / month / year).
- Station filter: List of public bicycle stations.
- Day type filter: Weekday, Saturday, Holiday, etc.
- Weather type filter: Clear, cloudy, rainy.

The examples listed above belong to the cyclist mobility vertical, for other verticals there will be other filters, although there will always be a filtering by dates.

7.3.3 Business indicators for urban services management

The management and evaluation of indicators is the most versatile capacity offered by the Mobility Platform to access advanced queries to both current and historical data. The user from the main menu, will select the option "Indicators", in doing so, all the verticals to which he has permission will be displayed.

The fundamental objective of the functionality of management and evaluation of indicators (KPIs) is to show the indicators of the different verticals and of the strategic objectives of the city. The visualization is very flexible, since this section of the tool is designed to allow playing on the different possible dimensions of the data, allowing establishing relationships between the elements of the different indicators. In this way, the indicators can be viewed in different periods: day, weeks, months or range of dates according to the needs of each user, as well as playing with multiple filters and other selectors.

7.1.1.6 Operational indicators

The user can access the operational indicators of each of the verticals. These operational indicators will show information to the user of each of the verticals, such as, for example: number of trips by public bicycle, evolution of the average daily traffic intensity or the availability of parking spaces. To complement this information, the user will have different tools with which to cross information such as, for example, the type of day, temperature, etc. In this way the user can contextualize the information displayed in a better way.

In the operational indicators, the user can only see those for which she/he has permission. That is, the user with the role of mayor will have access to all operational indicators, while the user with a department role can only see those operational indicators belonging to the corresponding area. However, these permits can always be modified according to the preferences of the end user.

Below are three examples of indicators designed and implemented with different areas of the Mobility Department of San Sebastian:

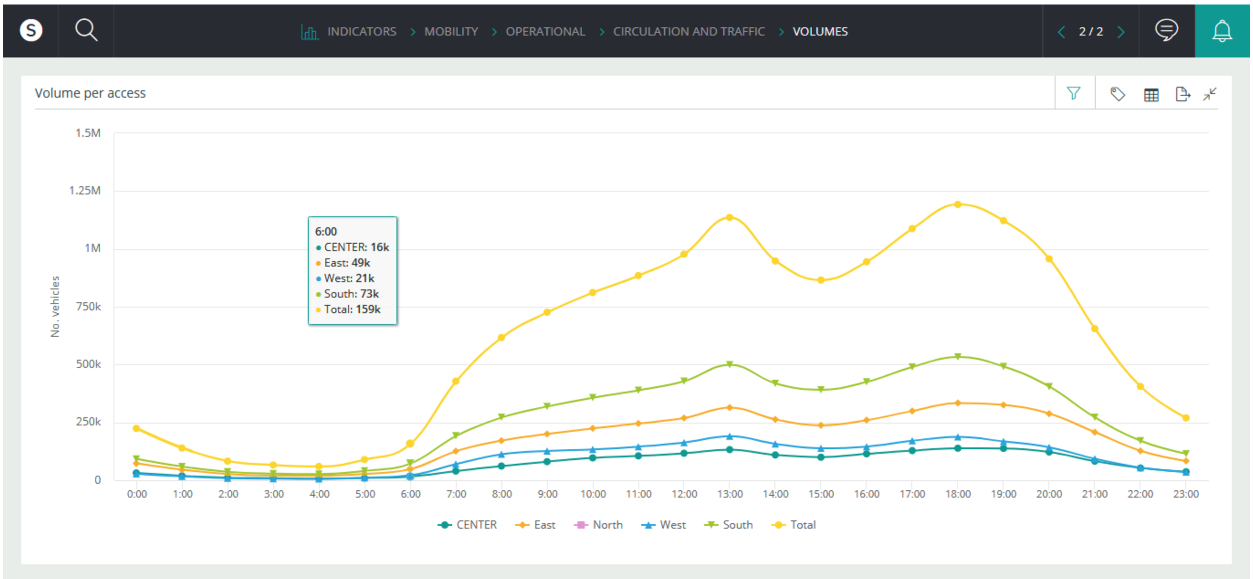


Figure 13: volume of vehicles per city access

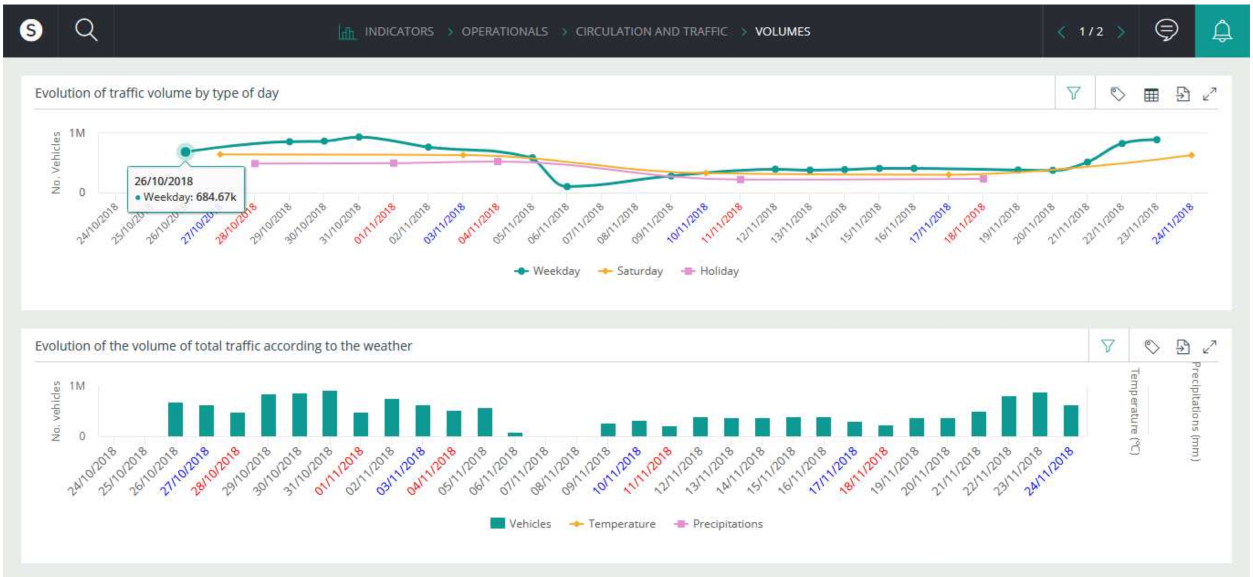


Figure 14: evolution of traffic volume by type of day and weather conditions

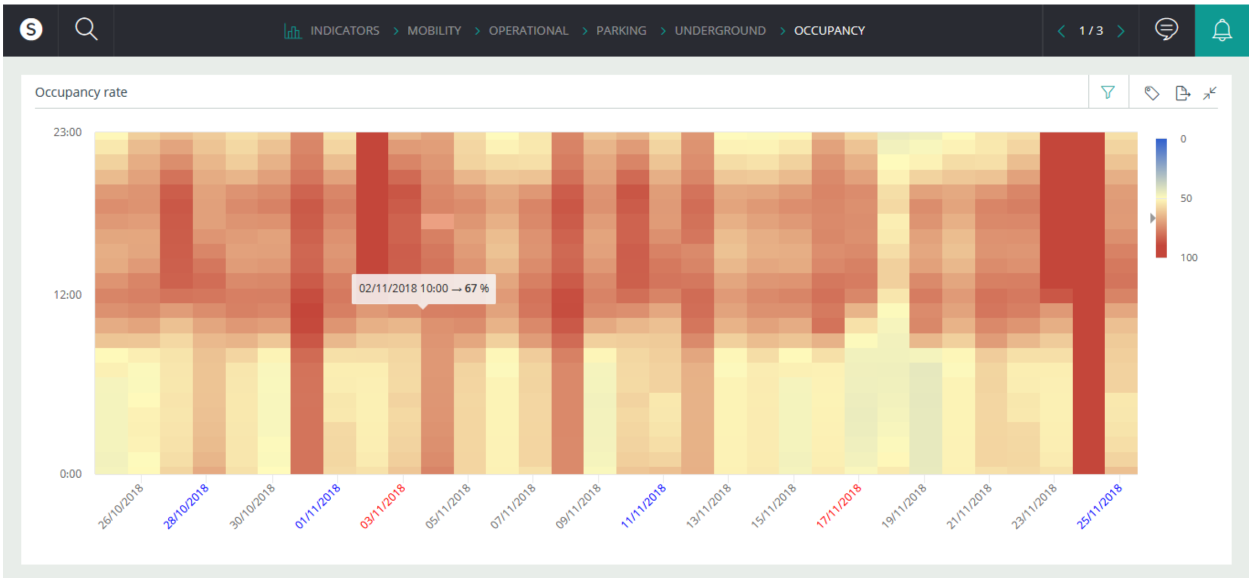


Figure 15: parking occupancy rate heatmap

7.3.4 Report and notifications

From the reports section of the application menu, user accesses the reports and statistics module, which is responsible for allowing the generation of documentation automatically (periodic reports) and on demand. The purpose of the functionality of the reports and statistics module is to exploit the stored information received from the different data sources. These data can be related to consumption, number of travellers, environmental impact, events, incidents, etc. The reports can be grouped according to different criteria: date or date intervals, periodicity, priorities, geographical areas, or others. About the body of the report, the following utilities can be considered: browse the pages, zoom, search, export to other formats (PDF, Excel, CSV, etc.), print and send as an attachment by mail.

The structuring of the report window is shown in Figure 16 where can be seen two main features: the query is on the left and the generation on the right.

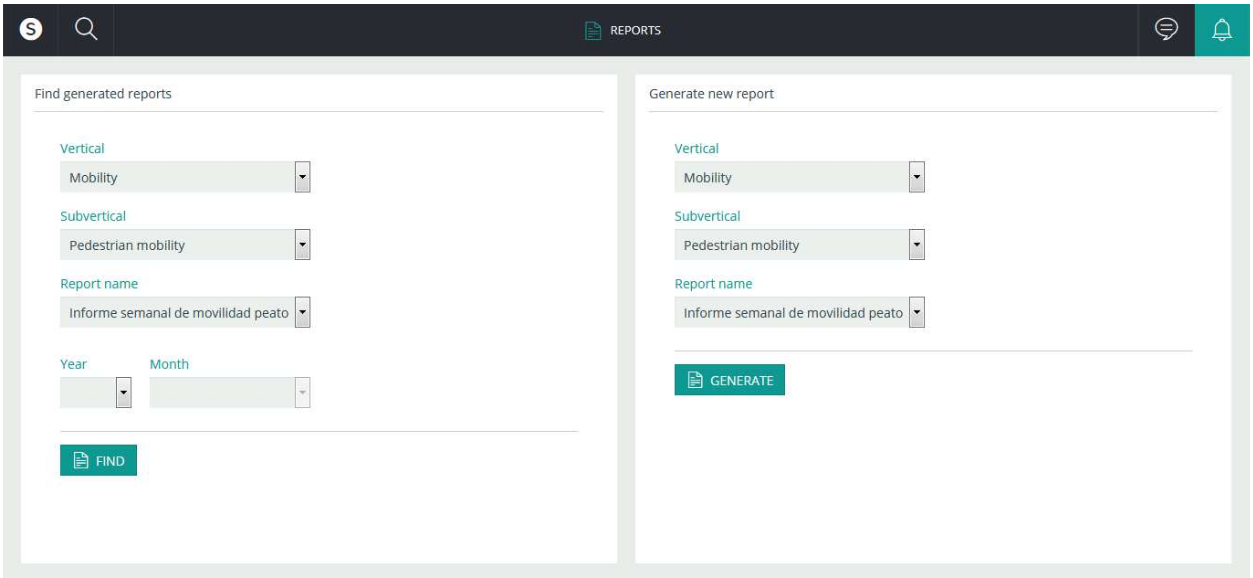


Figure 16: report's module main window

7.1.1.7 Consultation of the reports

On the left side of the report screen, the user has the functionality to query generated reports. The user will only be able to consult the reports of the verticals to which he/she has access.

For this purpose, a filter with the next fields is used:

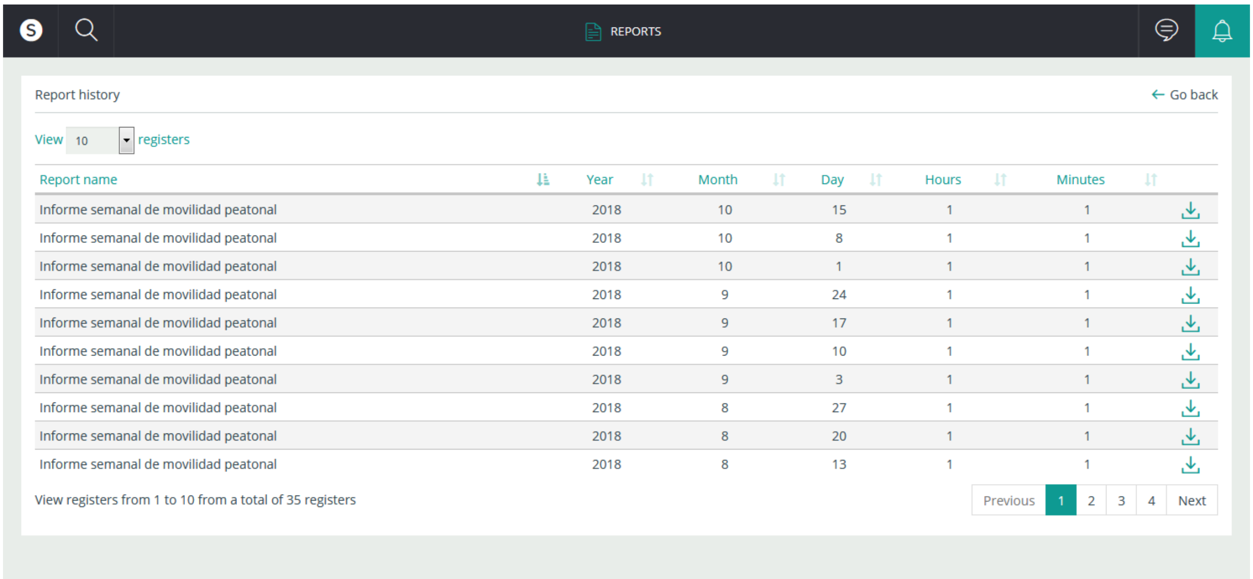
- Vertical (mandatory).
- Sub-vertical (mandatory).
- Report name (required).
- Year.
- Month.

In the "Vertical" field, the Mobility option will be loaded. In the "Sub-vertical" field, all the sub-verticals associated with the vertical selected in the first field will be loaded. In the "Report Name" field, the reports available for the selected vertical-sub-vertical combination will be loaded. These three fields will be mandatory to select, they can never go empty. On the other hand, the user can select both the year and the month in the report query.

Once the desired filter has been selected, by pressing the "Consult" button, in another screen the reports that fulfill the filter requirements will be loaded. This new screen will consist of a table in which all the reports that fulfill the requirements introduced in the filter will be listed.

By default, 10 records will be displayed in the report-listing table. If user wants to consult more records in the table, in the upper left there will be a drop down so that he can select the desired number of records (10, 25, 50 or 100 records).

On the other hand, a message indicating how many records are being shown with respect to the total number of records will appear in the lower left of the table. In the lower right part of the table, the total number of pages that the list has will be shown. If the number of records shown is less than the total number of records, the number of pages will be one. On the other hand, if the total number of records is greater than the number of records shown in the table, the number of pages will be greater than 1 and the operator can paginate the records. If the number of pages is greater than 1, the "Previous" and "Next" buttons will be enabled, this will allow the operator to consult the following (or earlier) records of the table. The "Previous" button will not be enabled on the first page and the "Next" button will not be on the last page either.



Report name	Year	Month	Day	Hours	Minutes
Informe semanal de movilidad peatonal	2018	10	15	1	1
Informe semanal de movilidad peatonal	2018	10	8	1	1
Informe semanal de movilidad peatonal	2018	10	1	1	1
Informe semanal de movilidad peatonal	2018	9	24	1	1
Informe semanal de movilidad peatonal	2018	9	17	1	1
Informe semanal de movilidad peatonal	2018	9	10	1	1
Informe semanal de movilidad peatonal	2018	9	3	1	1
Informe semanal de movilidad peatonal	2018	8	27	1	1
Informe semanal de movilidad peatonal	2018	8	20	1	1
Informe semanal de movilidad peatonal	2018	8	13	1	1

Figure 17: list of downloadable reports

The table with the list of reports contains the following fields:

- Name of the report.
- Year.
- Month.
- Day.
- Hours.

- Minutes
- Report download link.

In the last column of each of the registers, a button will be displayed with the download link of each report matching the requirements of the filter. If the user clicks on the link, the report will be downloaded to the user's computer in the selected format (PNG, JPG, PDF, CSV or XLS).

As an example, Fig. 1.141 shows a monthly report for the traffic of San Sebastian developed in the project.

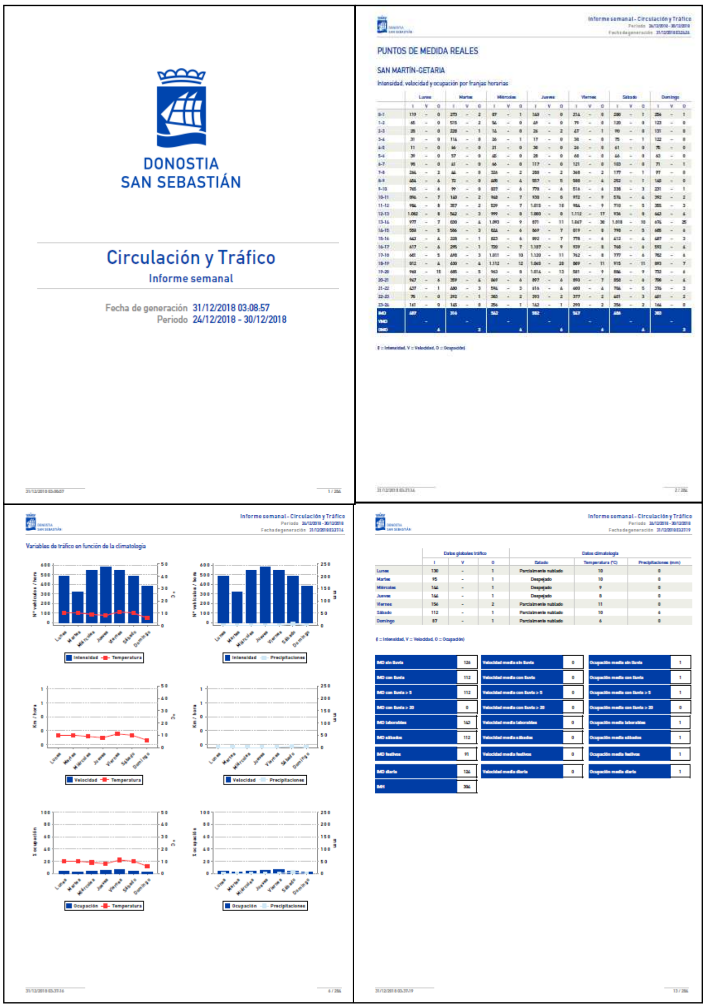


Figure 18: example of a report

7.1.1.8 Report generation

On the right side of the Reports screen, the user has the functionality of generating reports on demand generated previously. The user can only generate the reports of the verticals to which he has access.

For this purpose, a filter containing the following fields will be used:

- Vertical (mandatory).
- Sub-vertical (mandatory).
- Report name (required).

In the "Vertical" field, the Mobility option will be loaded. In the "Sub-vertical" field, all the sub-verticals associated with the vertical selected in the first field will be loaded. In the "Report Name" field, the reports available for the selected vertical-sub-vertical combination will be loaded. These three fields will be mandatory to select, they can never go empty. On the other hand, the user can select both the year and the month in the report query.

Once on demand report has been selected, user can press "Generate" button. Next, a new screen will be loaded with the generated report.

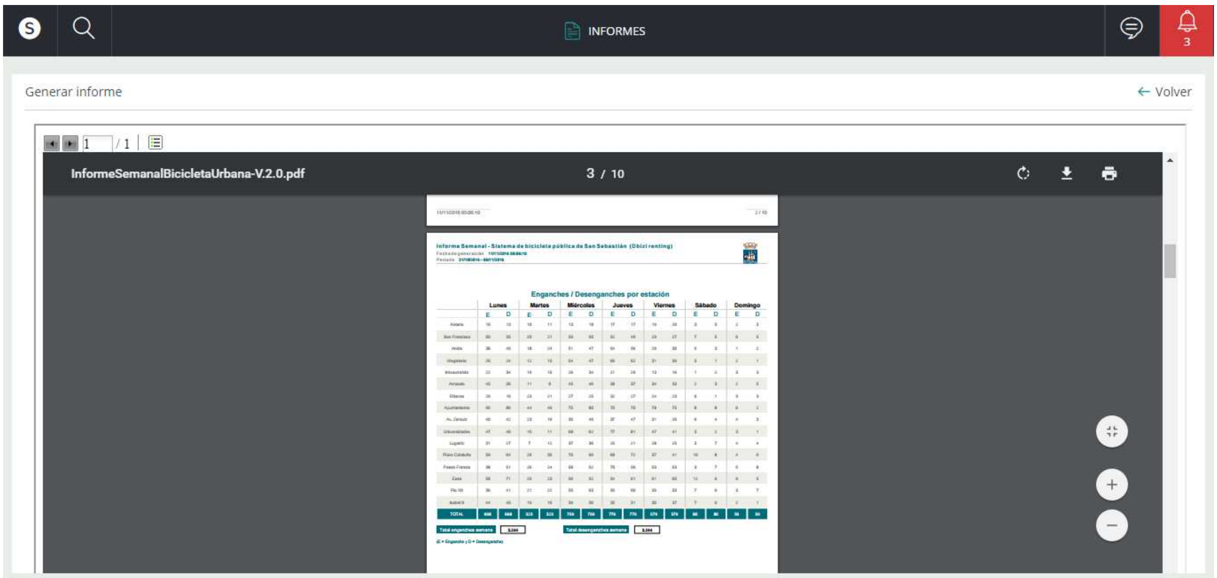


Figure 19: report example

7.3.5 Event management

In the visualization layer and components, there is also the Event Management module: events, incidents and decision support that has the objective of centralizing all the incidents and conditions that occur in the space that is being monitored, integrating information from different data sources and / or systems that may exist. This module provides common capabilities to other services taking into account their particularities and needs, and provides both a partial vision for management, and a global vision to determine the scope of events and incidents by expanding the information with content and capacity geo-referencing of them.

7.1.1.9 General concepts

The platform differentiates the following concepts:

- Event: occurrence of a situation different from the usual, bounded in time with a relatively long duration (from a few hours to several days) and space. Events can be scheduled or not scheduled.
    - Scheduled events: these are events whose date is known, either because every year is the same date or because they are scheduled in advance (football matches, concerts, fairs, etc.). They can be used to plan the demand based on past situations and to analyze the situation a posteriori.
    - Unscheduled events: they occur without having been previously planned (strikes, concentrations, etc.). In this case, this information is used to analyze the situation a posteriori.
- Incidence: it is a specific type of event that is associated with an alarm of variable severity, generally related to the incorrect operation of something (technically or at a business level), including incidents in the public road. In principle, although the cause of the incident may have had a prolonged action over time (deterioration of a detector, prolonged decrease in the use of public transport, etc.), the incidents correspond to a specific moment in time. There are no scheduled incidents.

The platform allows the establishment of an action protocol. These protocols are the set of actions that must be performed to solve an event or incidence, and will be composed of an ordered sequence of actions that will carry a short description and an estimate of the time in which said action should be performed. These times (which will be configurable), will be used during the event / incident management process to control the time of resolution of the same. An event / incident may have one or no associated action protocol, but never more than one.

8. PREDICTIVE ANALYSIS OF THE MOBILITY

8.1 Turn urban data into predictive intelligence

The Mobility Platform can be integrated with tools to perform advanced analysis of data and analytics from the information treated or from the integration with external simulators, that is, it allows using Big Data, BI, Machine Learning and data mining techniques over large volumes of information previously stored on the platform. By linking the data coming from sensors, operational systems and other management systems with the common dimensions existing in the data model, advanced data analysis allows the discovery of patterns. Based on this, the following high-level capabilities can be considered:

- Integration with large volumes of data in both continuous and batch flows from different heterogeneous sources without the need for programming.
- Flexibility when adding add-ons and generating own algorithms.
- Detection of trends from time series.
- Detection of spatial and temporal correlations.
- Discovery of patterns within a vertical and between verticals, for example, that the increase of one indicator is highly correlated with the decrease of another.
- Allow inference of possible future situations based on the current situation and past situations.

For all this, the knowledge layer contains available tools within the advanced analysis and analytical module.

8.2 Application in urban use cases

In section 8.2.1, use case implemented in the project for the public bicycle rental service of San Sebastian is detailed.

8.2.1 Public bicycle service

In this section, predictive use case applied to public bicycle renting service in the city of San Sebastian is described. The objective was to establish a prediction of the demand to be able to optimize the service and offer a better experience to users. The dataset available for the case of use, is a 4 year historical (February 2014 - February 2018) with 9 permutations (bicycle, user and station). In addition, the following additional data has been taken into account:

- Calendar of holidays of Spain
- Calendar of holidays of France

- Calendar of San Sebastian events
- Weather data with granularity of day and hour
- Geolocation data of 16 bicycle stations

As a first task, the records with anomalous data that can generate noise in the predictive analytics phase have been eliminated. The additional variables are generated both with transformations of the main 9, and with those of additional data sources. The final dataset has more than 60 variables for descriptive analytics and around 20 variables for predictive analytics.

On a descriptive level, this analysis allows to establish the evolution of the number of unique users (by dates, meteorology, holidays, stations, etc.).

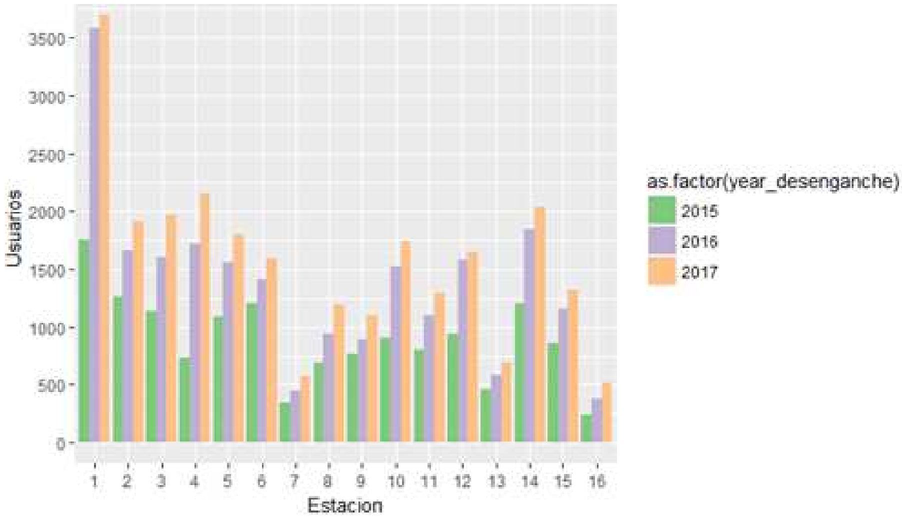


Figure 20: number of users per station

With regard to predictive analysis, the process begins with a reprocessing of the data. The availability of bicycles in each station per hour is calculated in the historical dataset (variable class_hours). This variable can have 5 levels:

- L1 = 1 empty
- L2 = 2 almost empty
- L3 = 3 balanced
- L4 = 4 almost full
- L5 = 5 full

The relevant variables are identified and the correlated variables are eliminated. For this process, Cramer's rule is used, which allows solving a linear system of equations in terms of determinant. Once the data cleansing is completed, the model training can start.

After evaluating several models, **Random Forest** has been chosen. Random forest is a method that combines a large number of independent decision trees tested on random datasets with equal distribution. The learning phase is to create many separate decision trees, building them from slightly different input data.

To try improving the accuracy of the model, different tests have been carried out (Upsample, SMOTE, variation of weights to calculate class_hours).

From the trained predictive model, an accuracy of 74.4% has been reached in the demand precision in each of the stations.

Prediction	L1	L2	L3	L4	L5
L1	221	251	150	62	17
L2	298	1030	608	324	55
L3	64	658	2383	643	97
L4	31	302	461	480	198
L5	18	63	135	143	236

Accuracy	0.4872
95% CI	(0.4768, 0.4977)
No Information Rate	0.4186
P-Value [Acc > NIR]	< 2.2e-16
Kappa	0.2801
Mcnemar's Test P-Value	< 2.2e-16

	Class 1	Class 2	Class 3	Class 4	Class 5
Sensitivity	0.34968	0.447	0.6377	0.29056	0.39138
Specificity	0.94214	0.806	0.7184	0.86366	0.95688
Pos Pred Value	0.31526	0.4449	0.6198	0.32609	0.39664
Neg Pred Value	0.95004	0.8073	0.7336	0.84281	0.95596
Prevalence	0.07079	0.2581	0.4186	0.18504	0.06754
Detection Rate	0.02475	0.1154	0.2669	0.05376	0.02643
Detection Prevalence	0.07852	0.2593	0.4307	0.16487	0.06664
Balanced Accuracy	0.64591	0.6265	0.678	0.57711	0.67413

Figure 21: Results obtained with the predictive model

From the different trained models, (Support Vector Machine, Multiclass Logistic Regression, Artificial Neural Networks and Random Forest), the model that obtained the best results was the Random Forest (RF).

Based on the accuracy obtained, this work demonstrates that it is possible to predict occupancy level in order to provide knowledge to the different actors involved in the city; i.e., Citizens, Service Providers and the City Mobility Department. On the one hand, the prediction of occupancy levels can help citizens obtain better status information on bicycle availability in order to better plan their trips by providing citizens information about where they should go to pick up or return a bike; i.e. by providing information about whether bikes will be available in the station of origin and whether there will be free slots at destination. On the other hand, the prediction of occupancy levels can also help the service provider better optimize the bicycles comprising the bike sharing system by giving advance information on what stations are going to lack bicycles and what stations are going to be full. Consequently, the operator itself can either transport bicycles between these or encourage citizens to take bikes from full stations and return them to empty stations using benefits or discounts for doing so. Lastly, the prediction of occupancy levels can also help the city mobility department provide better service.

9. INNOVATIONS, IMPACTS AND SCALABILITY

9.1 Innovation solution

The activities developed in this work package have allowed the design and implementation of an innovative platform for the management of urban mobility services. The solution is conceived from a holistic and integrated viewpoint of all information to facilitate comprehensive monitoring of all services, management of devices and events, strategy management and decision making. It is an innovative concept, since it breaks the restrictions imposed by the operational systems centered on a single vertical of the city. The platform combines information available from various data sources, to show information contextualized to the global status of the city and its various departments. In this way, a better coordination of available resources and a clearer visualization of the behavior patterns of the mobility services can be achieved.

9.2 Replication and scalability potential

The Mobility Platform allows easy scaling of services by requiring only a provisioning and configuration process, facilitating the integration of new data sources and services by evolving the solution. The architecture is designed in a modular way so that, without needing to modify the same, it can scale its processing and storage capacity and respond in real time to a greater number of sensors and actuators without affecting its performance. The platform supports the joint access of all the users created for the mobility department (20 users) maintaining an optimal performance.

Regarding replicability, the platform has been designed as a highly replicable solution. The data models created for vertical are applicable in other cities and with the integration of the corresponding data provider systems, an instance could be configured for each city. In this context, the horizontal scalability of the platform allows starting the deployment with a certain number of compute nodes and scale up according to the needs that may arise.

Also, is important to note that platform can be easily scaled adding other data sources not directly related to mobility but to other management areas for the municipality. Such as environment, energy, water, etc. In this way, it can provide services to other municipal departments in addition to mobility area.

9.3 Security of data

The platform incorporates the security module which, in a transversal way, provides agnostic resources for the management of security aspects related to privacy, confidentiality, authorized access, authentication, traceability and security of stored and managed data. It also manages roles, users and permissions. With this module it is controlled at all times who, when and how to access the different resources of the platform, forming an encrypted communication in which each user of the platform can access only the data, dashboards and reports to which previously they have been given access. The security module not only guarantees access to the different resources of the platform, but also guarantees the security of each of the modules that make up the platform and the interconnection between them by encrypting the data. In this way, it is possible to monitor the different hardware and software components deployed, so that based on their logs, it can be determined whether or not the system is at risk.

9.4 Accessibility and usability

The platform interfaces for managers, urban service providers and citizens comply with the W3C accessibility standards, specifically the "Web Content Accessibility Guidelines 2.0" standard that has been in force since 2012. This makes the platform strongly aligned with Directive (EU) 2016/2102.

Accessibility consists of access to information without limitation due to deficiency or disability reasons. However, it is important to emphasize that the accessibility of the platform is not of interest only for perle with disabilities, but improves general access for any user of the same. In addition, in the operational sections focused on a user with a more technical profile, where the functional requirements are more restrictive, the interface complies with usability principles:

- Facilitate user activity and learning: attractive, multimedia and consistent content. Low incidences rate, avoiding frustration.
- Identifiable homepage: let the user know where he is, what services the platform offers and what his lines of work are.
- A design with intelligence and in tune with the image of the institution, and with its main activity.
- Web layout following accessibility standards, adapted to all types of devices, well-focused information architecture, clear and concise content, etc.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

10. CONCLUSIONS

The integration and exploitation of data from urban systems using Business Intelligence and Big Data techniques, provides vital information for an optimal and correct management of municipal services. In the Replicate project, a Mobility Platform that allows municipal technicians and managers increasing the efficiency and experience of citizens has been developed.

The platform has tools for extracting and transforming the data captured by the sensors and operational systems of the city. Several connectors with the main sources of mobility data of San Sebastian have been developed (cycling mobility, parking, public transport, etc.). Through them, data models have been implemented to show the information in the formats defined by the managers and technicians of the mobility department.

The solution has a comprehensive web tool that allows users to exploit the ability to analyze it and interact with the different contents through a centralized, secure and multi-user global vision. Through the application's interface, all mobility information can be accessed in real time with the most recent data processed:

- Dashboards: relevant management indicators for the proper management of urban mobility services.
- Indicators: set of graphics that, combined with a simple color code, will allow the user to interpret, visually and intuitively, the data and measure the degree of compliance with them and the deviation with the expected results.
- Reports: reports and statistics of the information stored in the different repositories of the platform.
- Event management: module to centralize all the alerts and incidents that occur in the city, integrating information from the different data sources and / or existing operational systems and allowing the configuration of planned events to which action plans are applied.

The platform includes capabilities for the implementation of algorithms that can perform predictive actions, combining data from various subsystems, extracting correlations between them, or combining data extracted at different moments of time, in addition to analyzing mobility with time series (detecting trends and / or seasonal effects). For its validation, a use case centered on the public bicycle rental service of San Sebastian has been implemented. Algorithm trained allows the prediction of the demand with values close to an accuracy of 75%.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

The mobility platform therefore represents an innovative solution that combines information available from various data sources, to show contextualized information on the global state of the city and its various departments. In this way, a better coordination of the available resources and a clearer visualization of the behavior patterns of the mobility services can be achieved.

The use of data models for the representation of services also allows this solution to be replicable in other municipalities through the development of field connectors and some specific configurations of each city (reports, events, images, etc.). These models can be replicated but also extended based on the knowledge that the local mobility department wants to incorporate to the platform.