Green mobility data models and services for smart ecosystems

D2.2 Extended Smart Data Models v2.0

Document Identification	
Contractual Delivery Date	31/08/2022
Actual Delivery Date	31/08/2022
Responsible Beneficiary	FF
Contributing Beneficiaries	ATOS, FF, IMEC, IMREDD, AIV, HOPU
Dissemination Level	PU
Version	1.0
Total Number of Pages:	42

Keywords
Smart Data Models, standardization, OSLO

Document Information

Related Activity	Activity 2	Document Reference	D2.2
Related Deliverable(s)	D2.1	Dissemination Level (*)	PU

List of Contributors	
Name	**Partner**
Alberto Abella,	FF
Nuria Bernabé	HOPU
Ignacio Elicegui	ATOS
Tom Callens	AIV
Brecht	AIV
Benoit Couraud	IMREDD

Document History			
Version	**Date**	**Change editors**	**Changes**
0.1	06/06/2022	Alberto Abella (FF)	First version to include contributions
0.2	13/06/2022	Alberto Abella (FF)	Contribution to SDM included
0.22	20/06/2022	Nuria Bernabé Alberto Abella	Updated introduction Updated new data models section 5 section 3.3.1 updated OSLO contents removed (to D2.3)
0.3	04/07/2022	Alberto Abella	Update the data models in sections 4 and 5 (NoiseLevelObserved, NoisePollution, AirQualityMonitoring, AirQualityObserved)

Document History			
Version	**Date**	**Change editors**	**Changes**
0.4	05/07/2022	Eduardo Illueca	Updated sections 2.1, 3.1.1, 3.2.1 and 3.3.1
0.5	25/07/2022	Alberto Abella	NoisePollutionForecast,
0.55	27/07/2022	Benoit Couraud	Updated sections 3.1, 4, 5,
0.6	23/08/2022	Alberto Abella Tom Callens	Section 2.4 and others reviewed
0.7	24/08/2022	Alberto Abella	final version of data models and reorganization of chapter 5
0.8	25/08/2022	Alberto Abella	Review data models
0.85	26/08/2022	Benoit Couraud	Updated all data models + reviewed all parts + use cases graphs
0.90	28/08/2022	Alberto Abella	GBFS data models out and OSLO data models in.
0.91	29/08/2022	Tom Callens	Section 2.2 reviewed
0.95	31/08/2022	Alberto Abella	Formatting to template
0.97	30/08/2022	María Guadalupe Rodríguez	Fix format and add information
1.0	31/08/2022	ATOS	FINAL VERSION TO BE SUBMITTED

Quality Control		
Role	**Who (Partner short name)**	**Approval Date**
Reviewer	Nuria Bernabé; Eduardo Illueca (HOPU)	29/08/2022
Quality manager	Maria Guadalupe Rodríguez (ATOS)	30/08/2022
Project Coordinator	Clara Pezuela (ATOS)	31/08/2022

Table of Contents

List of Tables

List of Figures

List of Acronyms

Abbreviation / acronym	Description
AEMET	Spanish State Meteorological Agency
AGORA	Association for Air Quality Monitoring for the region Provence-Alpes-Côte d'Azur
ATMOSUD	Association for Air Quality Monitoring for the region Provence-Alpes-Côte d'Azur
AQI	Air quality index
EEA	European Commission European Environmental Agency
DCAT	An RDF vocabulary designed to facilitate interoperability between data catalogues published on the Web
DCAT-AP	An application profile of DCAT use in the European Data Portal
Dx.y	Deliverable number y belonging to Activity x
ETSI	European Telecommunications Standards Institute
GHG	Green House gases
hP	hectoPascal
IMS	Information Model Structure
INSPIRE	Infrastructure for Spatial Information in the European Community
IoT	Internet of Things
INSPIRE	Directive aimed to create a European Union spatial data infrastructure for the purposes of EU environmental policies and related policies or activities
ISA	Interoperability Solutions for European Public Administrations
ISG	Industry Specification Group
JSON-LD	JavaScript Object Notation for Linked Data) is a method of encoding linked data using JSON.
LDEN	Day Evening Night Sound Level
NABSA	North American Bikeshare & Scootershare Association
NGSI	Next Generation Service Interfaces, Open licensed-API specification by ETSI
NGSI-LD	Last version of NGSI protocol enabling the use of linked data principles
OGC	Open Geospatial Consortium
OSLO	Open Standards for Linked Organisations
PR	Pull Request
RDF	Resource Description Framework. A general method for description and exchange of graph data.

Abbreviation / acronym	Description
SDM	Smart Data Models Program
URI	Uniform Resource Identifier is a unique sequence of characters that identifies a logical or physical resource used by web technologies
UML	Unified Modelling Language
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
UV	Ultraviolet
W3C	World Wide Web Consortium

Executive Summary

This deliverable compiles the reviewed version of the data models identified across the different uses cases of the GreenMov project. The reason for the creation of this deliverable during the project's life and beyond, is to be able to finally share the standardization required for a sustainable and green mobility. The data models were identified thanks to the interviews with the use cases and the collaboration with activity 3 and 5 and the previous inputs of Deliverable 2.1. The main challenge faced is the final consolidation of the data models when the use cases have not finished their implementation.

The identified data models have been classified in two groups. Those belonging to existing data models already available at the Smart Data Models Program, where only some additions were necessary, and those new ones that required their full creation and test across the use cases.

Additionally, in Flanders the OSLO process and method is used to evaluate OSLO core vocabularies and application profiles for the mobility domain. The OSLO[1] Hoppin core vocabulary and application profile, currently being co-created in Flanders will be translated in English to be reusable in the project context of GreenMov and beyond in a shared mobility context.

The identified data models are in the process to be found into the European open data portal and other portals, however due to the preliminary situation of the data models, and the limited progress of the implementation of the pilots, the identified sources are a minimum.

Although it was planned to have the final results, the results presented could not be the final ones because some discussions are being held when the inputs of this deliverable were required. It means that it would be possible, but unlikely, to find some differences between the data models documented here and the final ones implemented in the use cases.

As a summary, this deliverable has identified 7 new data models on top of the 11 already identified in the previous deliverable 2.1. Three of them are brand new, while the rest are already available at the Smart Data Models Program. There has been detected a limited need for new data models and that many elements can be shared between the different use cases event taking into account the quite diverse location and use cases' goals.

1 Introduction

This document is the last version of the data models identified for the GreenMov project. These data models are meant to be shared and to help other users to speed up the data interchange for sustainable mobility projects. The identified data models exceed the scope of mobility by including other terms related to the environment (including pollution) and crowd management, either of vehicles or people.

1.1 Purpose of the document

This deliverable provides the new version set of extended data models actually used across the different use cases from the Smart Data Models repository, including the conducted analysis of data sets, the implementation of the extension and the documentation to be used.

1.2 Relation to other project work

This is the natural evolution of deliverable D2.1 with the new updates and adaptations coming from the actual implementation and integration between use cases. Therefore it has a strong relationship to the services described in Activity 3 and with the actual implementation run in Activity 5. It also contains the description of the OSLO method, which is worked out in concrete terms in D2.3 with the case of Passenger Transport Hubs.

1.3 Structure of the document

After the introduction, the structure of this deliverable includes the description of the methodology for the selection, identification, filtering and consolidation of the different data models. This methodology also includes the mapping of OSLO ontology into regular data models. After that, the list of the data models adopted or extended from the Smart Data Models Program is included. The next chapter describes those brand new data models defined across the project, and finally, the procedure for updating these data models in the Smart Data Models Program. The conclusions remark the main achievements of the document.

1.4 Glossary

The list of acronyms describes the main terminology used across this document.

2 Methodology

The objective of this document pursues the identification and definition of the data models and attributes used to map the data sources and datasets supporting the final mobility services and scenarios. This round of data models will be evolved along with the activity 3 services and activity 5 scenarios' refinement. According to this, the activities carried out to obtain the Smart Data Models are close related and involved in project's activity 5 actions for this first round and in both, activity 3 and activity 5 progresses.

Considering this dependence with activities 3 and 5, the methodology followed to derive the Smart Data Models involved in the scenarios is divided in five main steps:

1. Alignment with activity 5, by participating on the meetings intended to define and integrate the pilots on each city scenario. This will allow to identify the involved sources and possible extensions on each of them.
2. Organize specific meetings with pilots' responsible people to detail the identified data sets, map the attributes with the captured information and propose the valid data models that cover the pilots' requirements.
3. Compare the data models extracted from each pilot and merge them into common Smart Data Models' proposals and extensions, to be compliant with the Smart Data Models process.
4. Check (and evaluate) with pilots the common proposed Smart Data Models, to ensure that all requirements are covered according to pilots' particular objectives, so these can be adopted an integrated in their use cases implementations.
5. Maintain periodical meetings with activity 5 pilots to detect variations on requirements (new attributes/sources raising) and integrate them to obtain the Version 2 of this document.
6. Review the initial allocation and check what attributes will be finally used in the different services
7. Review the naming and data types of the proposed attributes to make it compatible with existing data models and good practices

The relevance, and the impact, of the Smart Data Models provided by Activity 2 remains the same as previous deliverable. It is shown in Figure 1, where the relationship between the data sources and the Smart Data Models that homogenise the gathered information is depicted. This common language used to organise and describe the information guarantees later the portability of the services developed.

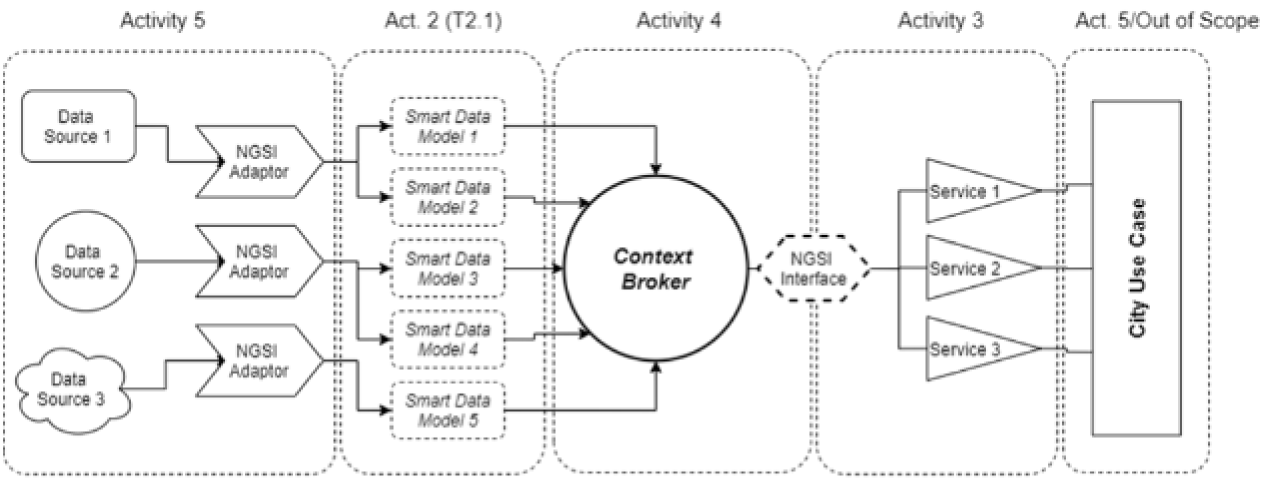


Figure 1. GreenMov Activities' relations

During the dedicated meetings with the pilots, the common process followed to derive the Smart Data Models started with: a) a high level definition of the expected use case that maps the needs of each city; b) identify the microservices that would support this final use case (these will be addressed to activity 3); and c) find the data sources, within the scope of the city, required to feed the corresponding microservices. These data sets would be translated into Smart Data Models, using the existing catalogue or proposing new ones.

By applying this process to each city scenario where the corresponding pilot is to be developed, the outcomes shown in the following subsections were obtained.

2.1 Murcia/Molina de Segura

The city councils of Murcia and Molina de Segura share a similar target in terms of mobility, due to their proximity and their common working and expansion areas. By merging efforts and data sources, they are developing within GreenMov scope a use case to **evaluate and predict the impact of the road traffic in the cities' air quality.**

Their use case rely on a set of three main micro-services (in progress project's activity 3):

- Air Quality Index Calculation, which evaluates different air parameters to provide an Air Quality value.
- Traffic Environmental Impact, that measures and classifies the traffic in the city to calculate and forecast the equivalent emissions due to vehicles.
- Shared bike's availability forecasting, as a complementary branch to help citizens to reduce pollution.

With this approach, and to support the micro-services and the final city use case, we have identified the following set of relevant data sources, either provided by the cities or available for Murcia and Molina de Segura, together with the proposed (existing or new) Smart Data Models:

- AirQualityObserved and AirQualityMonitoring, to capture air parameters. These will be provided by the air quality sensors' network from Molina de Segura city and by the Murcia's region environmental monitoring network.
- AirQualityForecast to model the predictions and forecasting performed by the services.
- TrafficFlowObserved and TrafficEnvironmentImpact measure the traffic intensity using the traffic cams from Murcia and Molina de Segura.
- TrafficEnvironmentImpactForecast to model the predictions and forecasting performed by the services.
- OSLO.bicycleParkingStation to capture the data about location and availability of shared bikes provided by the Murcia's city bike's sharing company.
- WeatherObserved, still under evaluation, it captures periodically the general weather data related to the cities of Murcia and Molina de Segura provided by the Spanish State Meteorological Agency – AEMET.
- TrafficEnvironmentalImpact, as a new proposed Smart Data Model, its objective is to assess the equivalent CO_2 emissions of the traffic observed. This is to be defined and provided within GreenMov scope.

All these dependences are summarised in figure below.

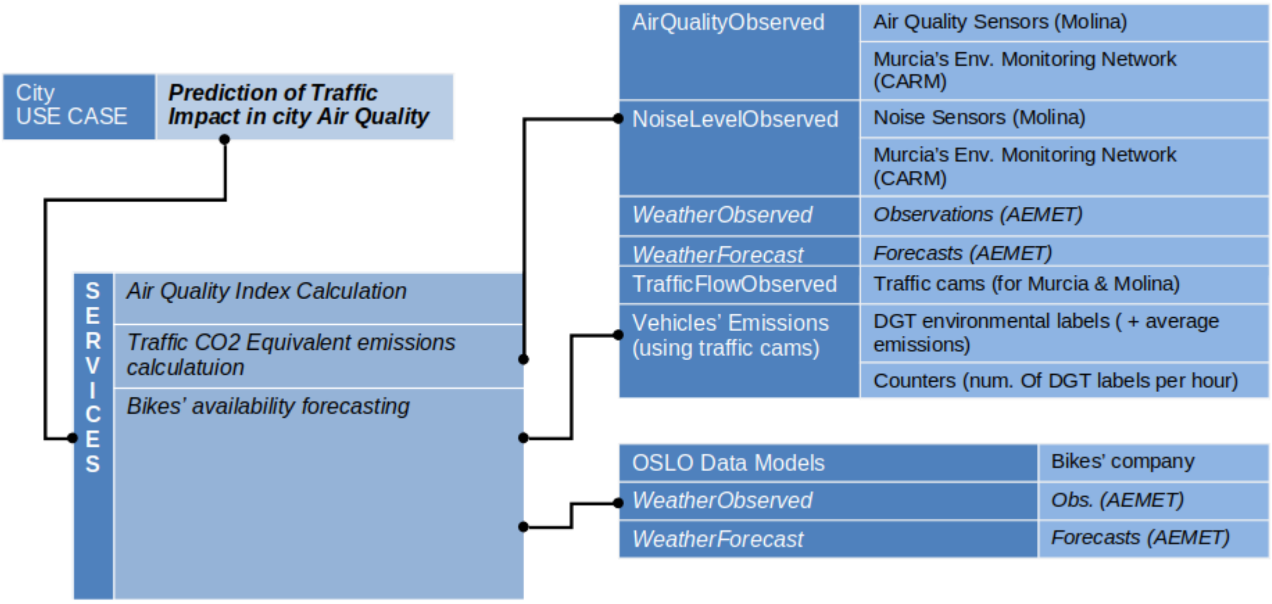


Figure 2. Murcia/Molina de Segura relationships between services and data sources

2.2 Flanders

By providing an **availability forecasting for shared bikes**, Flanders aim to improve the combined use of shared bike mobility and public transportation. In support of this use case a new OSLO data model "Passenger Transport Hubs" was developed (see Deliverable 2.3), based on the "OSLO Hoppin Points" model (see Deliverable 2.1).

In Flanders places of modality cross over are being branded as "Hoppin Points"]. The focus of the use case are Hoppin Points at train stations with "Blue-Bikes".[3] If the availability forecasting works for Blue-Bikes it could also work for other bike sharing systems from other providers. The "OSLO Hoppin Points" model was translated from Dutch in English and extended according to the business needs of GreenMov partners and other stakeholders.

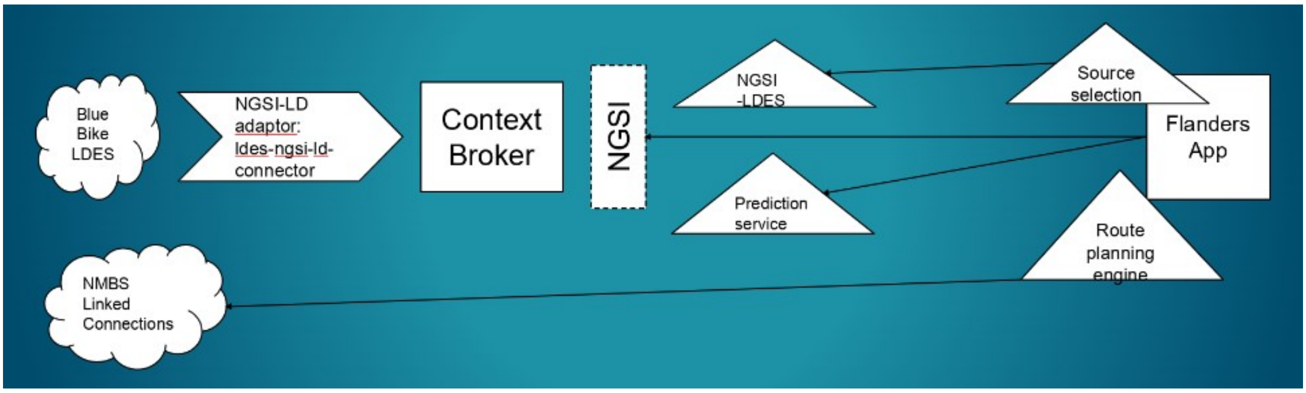


Figure 3. Flanders use case data sources

This use case will consume, within a first design, two main micro-services from Activity 3:

- Bikes' availability in real time, which provides location and current situation (available bikes to share and docks to release bikes) of the bikes' stations in the area.
- Bikes' availability forecasting, that indicates the expected number of available bikes or free docks of the selected bike station when the user is arriving there.

All these dependences are summarised in Figure 4.

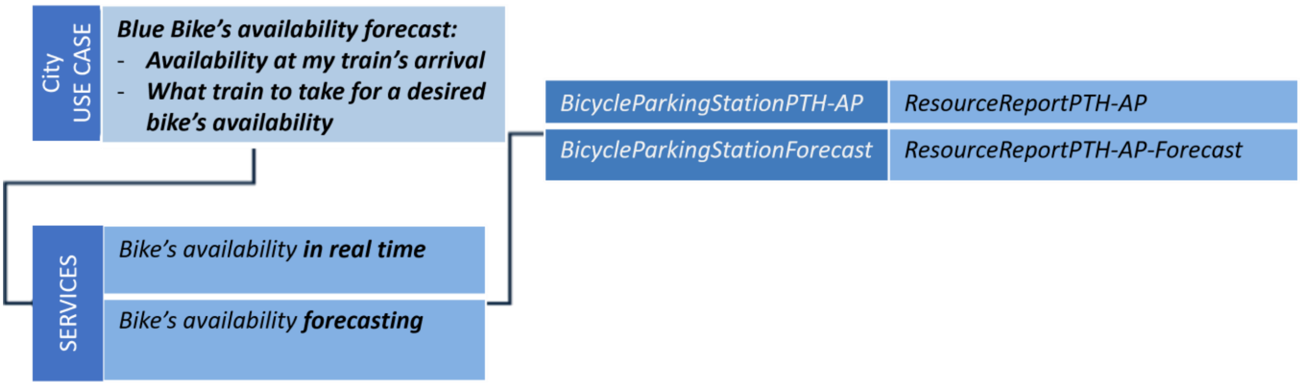


Figure 4. Flanders' region relationship between services and data sources

2.3 Nice

The City of Nice use case is also oriented to reduce the impact of road traffic on city's pollution. This is achieved through a predictive model of Noise and Air pollution, a forecast of the environmental impact of the traffic and of Public transportation availability. This use case aims to:

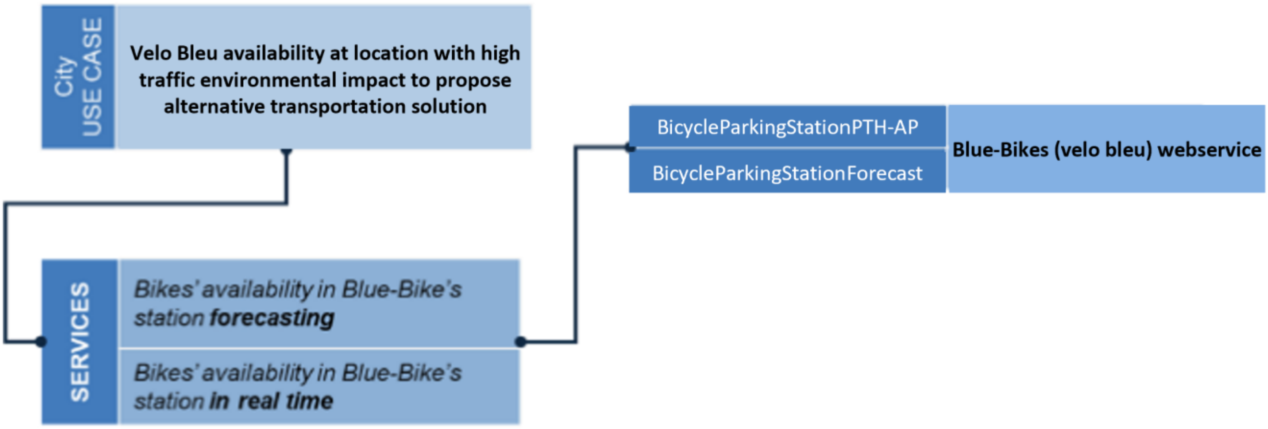
- Support the city's traffic managers decisions (especially through the allocation of more public transport or shared bikes alternatives).
- Act on the behaviour of the citizens by proposing alternative green mobility services.
- Quantify the greenhouse gas emissions (GHG) and Noise emitted on the territory by the traffic.

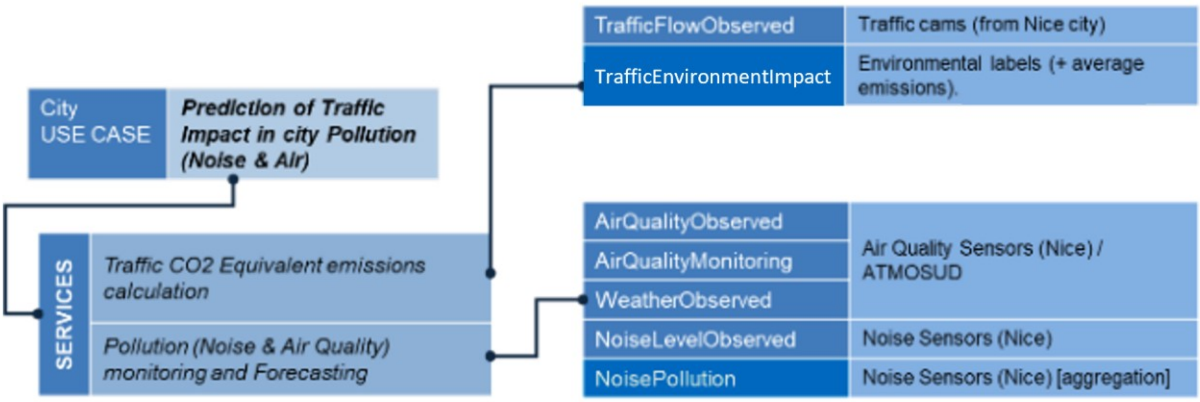
Within this use case, we identified the required data models from the different internal and external available inventories.

The data models identified are the following:

- TrafficFlowObserved: An observation of the traffic flow conditions at a certain place and time.
- AirQualityObserved: Measured data about air quality.
- AirQualityForecast: Forecast of particles pollution and air quality at a certain place and time.
- AirQualityMonitoring: An assessment of the air quality.
- WeatherObserved: An observation of weather conditions at a certain place and time.
- WeatherForecast : A forecast of weather conditions at a certain place and time.
- NoiseLevelObserved: An observation of the acoustic parameters at a certain place and time.
- NoisePollution: An assessment of current noise pollution indicator, at a certain place and time.

- NoisePollutionForecast: A forecast of future noise pollution, at a certain place and time.
- GtfsStopTime: An overview of public transport solution at a specific place.
- BicycleParking Station: An observation about the current status of a bike parking station.
- BycycleParkingStationForecast: A forecast of the shared bikes availability.
- TrafficEnvironmentImpact: An assessment of the traffic environmental characteristics, including the amount of CO_2 emissions per km.





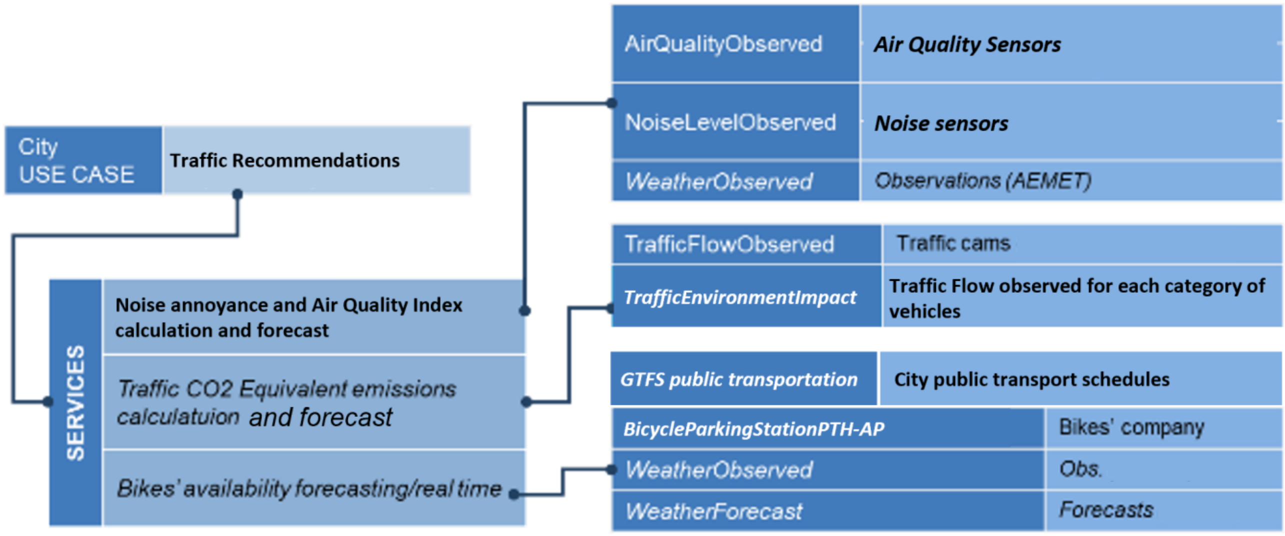


Figure 5. City of Nice relationships between services and data sources

2.4 OSLO vocabulary (Flanders) to re-use in project and European context

2.4.1 OSLO process and method

The focus of this section takes the process of raising and implementing semantic and technical agreements in the Open Standards for Linked Organisations (OSLO) program into account and is builds upon a peer reviewed method [4]. OSLO is an interoperability program in the region of Flanders, which brings together expertise from different business domains and governmental levels, independent of specific thematic use cases. The Flemish Government developed several domain models in line with international standards, including Interoperable Europe[5] (ISA) and INSPIRE[6] enriched by data extensions to comply with the local (European) context [7]. The formal specification is published at data.vlaanderen.be[8] or purl.eu[9]. The thematic working groups, with over 500 authors from the public sector, private sector and academia, demonstrated that it is possible to raise the interoperability and foster the harmonization of data coming from different use cases.

The applied method to raise interoperability on the technical and semantic level is based on the principles of Linked Data[10]. The method includes an implementation framework that describes how to make authoritative data self-describing [11]. The semantic agreements are traceable and aligned to match the different stakeholders: policymakers, domain experts, analysts, and developers. The Resource Description Framework (RDF) can in particular facilitate the semantic agreements and JSON-LD allows developers to work with Linked Data without a high entry barrier [10]. This facilitates the implementation of the semantic agreements across different use cases.

Our peer reviewed approach to raising interoperability combines the process to reach technical and semantic agreements by broad consensus and an end-to-end method based on the principles of Linked Data to maintain the semantic agreements within an operational public sector context. This can be applied in four steps (Figure 6):

1. **Set up a formal governance** by anchoring the standardisation process at an existing governance body or initiating a new governance body. This step is crucial for the trust of the various stakeholders and supports the adoption of data standards.

2. **Agree on a transparent process** to reach semantic and technical agreements. The process outlines the roles of the different actors and specifies how consensus can be reached among stakeholders. Reference implementations of this process are applied and documented in Flanders[12] and on the Belgian interfederal level[13].
3. **Install an end-to-end method** based on the principles of Linked Data. This implies that all records of decisions, discussions and models are publicly accessible online; the latter is documented using a formal language based on RDF. The method must include an implementation framework that ensures semantic agreements are traceable and aligned to match the different stakeholders: policy makers, domain experts, analysts, and developers. Reference implementations of this process are applied and documented in Flanders[14] and on the Belgian interfederal level[15].
4. **Cocreate data standards:** starting from existing international standards, vocabularies and datasets in the European Data Portal, the semantic agreements are reached in open thematic working groups, consisting of domain experts from the public sector, private sector and academia. These working groups follow the process and method within a formal governance framework.

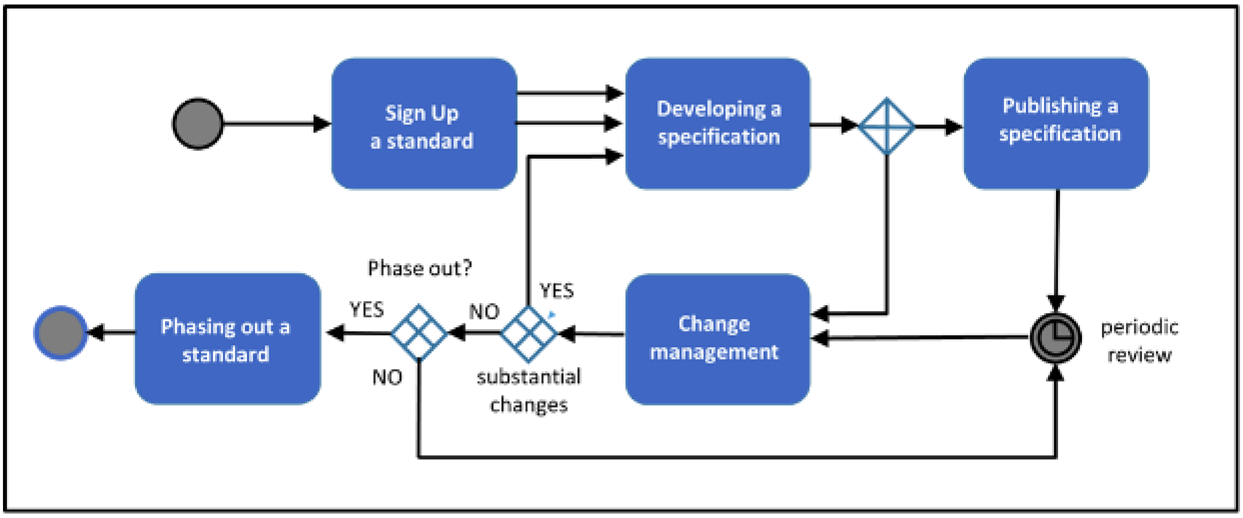


Figure 6. High-level overview of the different processes

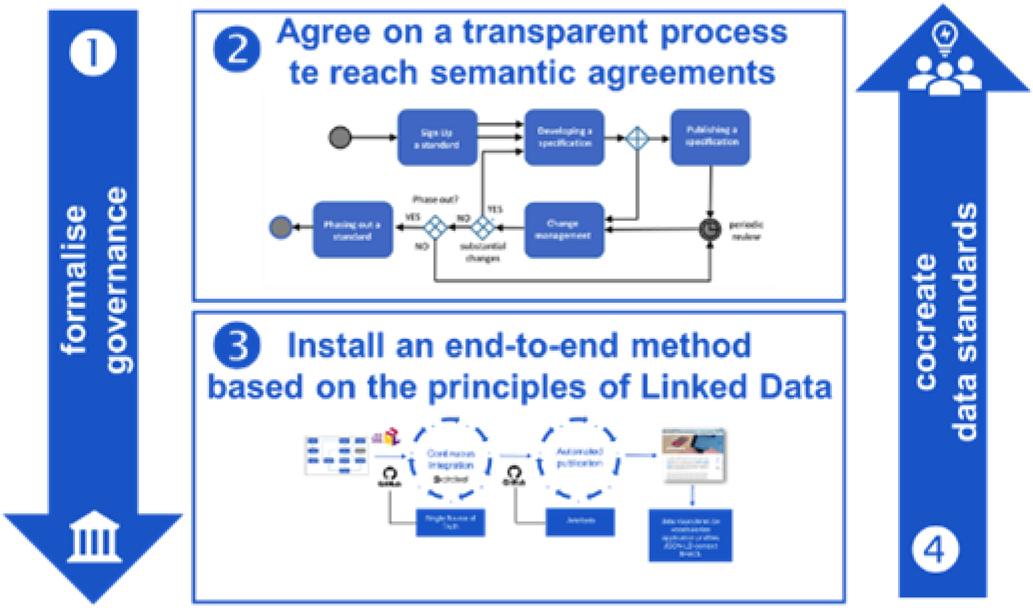


Figure 7. Raising interoperability in public sector

2.4.2 OSLO and Smart Data Models

This section outlines how the OSLO and the Smart Data Models strengthen each other, which fits the main goal: "the definition of harmonized data models for green mobility". While the Smart Data models are fit for purpose in the context of advanced green mobility services, such as traffic flow management, smart management of free-floating mobility, shared mobility and environmental impact", OSLO also facilitates interoperability to other data spaces by linking to existing international standards. First, we provide context on FIWARE, Smart Data models and OSLO, based on a peer reviewed paper [11]. Next, we elaborate on the approach.

In 2016, the European Commission (EC) requested the European Telecommunications Standards Institute (ETSI)[16] to create an Industry Specification Group (ISG) to define a standardised API for Context Information Management (CIM) with Future Internet Ware (FIWARE) Next Generation Service Interfaces (NGSI) as a nominee. FIWARE is an open-source platform, supported by the EC. NGSI is a protocol to manage Context Information. The ISG delivered the Next Generation Service Interfaces as Linked Data (NGSI-LD) standard[5], which enables nearly real-time access to information from different distributed data sources. The NGSI-LD Information Model Structure (IMS) consists of two layers: a core Meta-model and a Cross-Domain Ontology which can be extended with domain-specific logic. The core Meta-model defines a minimal set of constructs which are the basic building blocks of the Cross-Domain Ontology including Entity, Relationship, Property and Value [16, 17]. The Cross-Domain Ontology describes concepts and constraints which provide consistency between the different IoT domains and applications; these concepts include Geographical properties, Temporal properties and Time values [16, 17]. The domain-specific logic can be extended with ontologies for a specific domain[18]. NGSI-LD requires a reimplementation of existing Linked Data domain models to fit the semantics of NGSI. According the FIWARE Foundation[19]: "a smart data model includes three elements: The schema, or technical representation of the model defining the technical data types and structure, the specification of a written document for human readers, and the examples of the payloads for NGSIv2 and NGSI-LD versions".

The OSLO data standards result from a co-creation process, which has a share and reuse-first strategy. OSLO adopts existing data standards from data standardisation bodies such as ISO, OGC, W3C. The OSLO modelling guidelines ensure that this reuse is done in such a way that further reuse is facilitated. For instance, OSLO modelling guidelines consider the following reuse levels: (i) a vocabulary, (ii) an application profile and (iii) an implementation model. A vocabulary is a collection of terms having a persistent identifier and definitions, which an application profile describes the use of the terms in the context of a broad application area, and finally an implementation model describes the data used by one implementation. In the OSLO methodology, all reuse levels coexist, each with distinct life cycles, but together form one distributed connected knowledge graph. To establish that, the data technology cornerstone of OSLO data standards are persistent, dereferenceable URIs for all terms and documents. This approach builds a coherent Semantic Web where users (developers, business analysts) can find the semantics of the data by dereferencing the URI as a URL. Making the publishing coherent with browsing the Web increases the adoption.

The OSLO reuse first approach is powerful, but it still faces the usual data interoperability challenges when connecting with other data ecosystems that are not an intrinsic part of the OSLO knowledge graph. Then mapping approaches are to be applied.

In the case of FIWARE and OSLO a smart data model that is aligned with the vocabulary used in OSLO will be created. A smart data model JSON-LD context can be created using the "create external referenced context" service, which can refer to OSLO context files. Also, a specification needs to be created for an OSLO Application Profile, similar to the DCAT-AP data model. This approach makes a lossless data conversion possible between the OSLO and NGSI-LD ecosystems. The vocabulary terms are being reused and the rules of the application profile are still respected. With the smart data model specification, developers have better guidelines how to let OSLO data flow through the NGSI-LD ecosystem.

Applied OSLO vocabularies and application profiles

Following OSLO vocabularies and application profiles are re-used and contextualised for GreenMov:

- Hoppin points[20]: a place where you can easily transfer between one means of transport to another. Depending on the location, you will find bicycle parking spaces, tram and bus stops, shared vehicles, a Park & Ride[21].
- Application Profile Mobility: Trips and Offers[22].
- Vocabulary Mobility: Trips and Offers[23].
- Application Profiles Mobility: Timetable and Scheduling[24].
- Vocabulary : Timetable and Scheduling[25].

Within this project, the Hoppin points vocabulary and application profile were translated into English together with some extensions (e.g. accessibility for people with a disability and a more efficient way to report real time availability of shared bikes). The co-creation approach, as mentioned in 2.4.1, was applied and documented in deliverable D2.3. All project partners and other stakeholders had the opportunity to join the workshops.

3 Datasets identified in European open data portals

This section identifies the different datasets across European open data portal and specifically in the European Data Portal[26] and in other European data portals to make the defined data models the more similar to existing ones, and eventually completely compatible.

3.1 In the European Data Portal

Data published through the official European Data Portal[26], managed by the Publication Office of the European Union.

3.1.1 Murcia/Molina Use Case

Datasets for the use case were found at the European data portals (August 2022) as a federation of other data portals (see section 3.2.1).

3.1.2 Nice Use Case

Nice's data sets aim to assess the air quality at specific location, but also to assess noise pollution, traffic activity, and finally to assess the available alternative transportation solutions in real time. Some datasets will be filled from existing European data sets such as those described in the next subsection (3.2.2).

3.1.3 Flanders Use Case

- Data about the real-time availability of Blue Bikes. Currently, only data in the greater city area of Ghent is documented. This is done for each train station, with one or more Blue Bike facilities.
  - Blue Bike sharing bikes Ghent Sint-Pieters (M. Hendrikaplein)[27]
  - Blue Bike sharing bikes Ghent Sint-Pieters (St. Denijslaan)[28]
  - Blue Bike sharing bikes Ghent Dampoort[29]
  - Blue Bike sharing bikes Merelbeke — Drongen — Wondelgem[30]
- Data about the planned and actual timetable of trains:
  - SNCB GFTS - scheduled timetable and real-time data[31]

3.2 In other European data portals

3.2.1 Murcia/Molina Use Case

- European Air Quality Portal[32]: is an open source dedicated to the Air Quality e-Reporting system established by the European Commission (EC)[33] and run by the European Environmental Agency (EEA). It contains technical details and services that facilitate the reporting of official air quality data from EU Member States and other EEA member and co-operating countries. It also provides access to different tools which allow to visualize the collected data and statistics as well as to download them.
- AEMET: that is the meteorological data reported by the Spanish "Agencia Estatal de Meteorología", This data is pulled into the European Open Data Portal. Aemet Open Data portal[34].

3.2.2 Nice Use Case

For the Nice Use case, some of the datasets to be used are available on other European data portals:

- European Data Portal for air quality measurement: The European Union's services package to promote the reuse of open data from its institutions and EU Members.
    - Among others, the air quality data from Nice will be used for environment data such as PM10, PM2.5, O3, CO, NO2 and SO2.
    - ATMOSUD[35] for air quality measurement: The Air quality monitoring French association, approved by the Ministry of the Environment, data is standardized in formats that meet international standards through REST APIs or CSV files.
- MNCA API's[36] for weather, traffic measurement and public transport: The Nice Metropolis web platform dedicated for retrieving NGSI standardised data via a list of APIs. It can be used for traffic flow observation, air quality monitoring, noise pollution and public transportation availability.
- Historical weather data from the Open Weather Map[37] and Meteo France platform[38].
- Historical Noise data from European Environment Agency[39].

3.2.3 Flanders Use Case

All source datasets that are needed were identified through the official European Data Portal.

3.3 Not present in any European Data Portal

3.3.1 Murcia/Molina Use Case

- Molina Smart City: data generated by IoT devices belonging to Molina Town Council, related to air quality and noise monitoring.
- Murcia Bike Stations: data about bike availability in the different stations in Murcia.
- HOPU Parking Sensors: data collected by sensors produced by HOPU, that are installed in electric car parking places, and measure if the place is free or not.
- Traffic Cameras: data about vehicle count and traffic intensity collected by the cameras installed by Murcia and Molina municipalities.

3.3.2 Nice Use Case

- Real time and historical traffic data collected by the different sensors in the city of Nice will be collected within the GreenMov project.
- Real time and historical detailed noise pollution data: Lden, Lnight, LMax, LAaeq... available on an internal platform (AGORA) as well as on the API's of the Metropolitan area of Nice.
- GTFS data about the public transportation stops, routes, timetable[40].
- Other external data sources: Web services such as the use of Velo Bleu[41] open data will complete the European data sets used in this use case.

3.3.3 Flanders Use Case

All source datasets that are needed were identified through the official European Data Portal.

4 Existing Data Models used in GreenMov

4.1 Shared attributes for data models at the Smart Data Models Program

From the outcomes derived from the methodology described in section 2 and applied to the scenarios in Murcia and Molina de Segura, Flanders and City of Nice pilots, this subsection lists the updated versions of the data models identified (compatible with those in the Smart Data Models Program) and the attributes used to map the provided data. For all these data models, there exist a set of common attributes that must be present to guarantee Smart Data Models and FIWARE compliance. These are listed in Table 1.

Table 1. Common attributes for all Smart Data Models

Attribute Name	Data type	NGSI type	Description
id	id	Property	UNIQUE identifier of the entity (same attribute for all entities' models).
type	string	Property	TYPE of the reporting entity (AirQualityObserved, NoiseLevelObserved …).
address	object	Property	The mailing address
location	Geopoint	Geoproperty	Location (Lat/Long) of the sensor reporting data (Location of the measurement).
dateModified	date	Property	Date of the last entity modification (timestamp).
dateObserved	date	Property	Date of the observation (timestamp).
alternateName	string	Property	An alternative name for this item

4.2 Data models used without any changes

When necessary a column indicating the recommended units is included into the tables

4.2.1 AirQualityMonitoring

Air Quality Monitoring (AQM) Data Model. Subject Environment[42]. 2 new attributes will be used within GreenMov, and thus have been proposed to expand the Smart Data Model.

Table 2. Attributes of Air Quality Monitoring

Attribute Name	Data type	NGSI type	Description
airQualityIndex	number	Property	Overall Air Quality Index (AQI) for the observed air quality.
airQualityLevel	string	Property	Air Quality Category Indication. Qualitative level defined according to the local health agencies. For example, 'GOOD', 'MODERATE', 'POOR', 'UNHEALTHY', 'SEVERE', 'HAZARDOUS' etc.

4.2.2 GTFSStopTime

A description of the arrival and departure times of public transportation lines from a specific station. Subject Transportation[43]. Not all available attributes are used.

Table 3. Attributes of 4.2.2 GTFSStopTime

Attribute Name	Data type	NGSI type	Description
arrivalTime	number	Property	Same as GTFS arrival_time
departureTime	number	Property	Same as GTFS departure_time
hasStop	string	Property	Same as GTFS stop_id. It shall point to an Entity of type GtfsStop
hasTrip	string	Property	Trip associated to this Entity. It shall point to an Entity of Type GtfsTrip
data.operator	string	Property	Name of the operator (inside of attribute data which is an object)
data.lat	number	Property	The latitude of the station
data.lon	number	Property	The longitude of the station
data.web	string	Property	URL that can be used by a web browser to show more information about renting a vehicle at this station (added in v1.1).

Attribute Name	Data type	NGSI type	Description
data.web	string	Property	URL that can be used by a web browser to show more information about renting a vehicle at this station (added in v1.1).

4.2.3 WeatherObserved

An observation of weather conditions at a certain place and time. This data model has been developed in cooperation with mobile operators and the GSMA. Subject Weather[44].

Table 4. Attributes of WeatherObserved

Attribute Name	Data type	NGSI type	Description
temperature	number	Property	Instantaneous temperature of the measured air.
referenceTemperature	number	Property	Reference temperature of the measured air.
atmosphericPressure	number	Property	Observed atmospheric pressure (hP).
relativeHumidity	number	Property	Humidity in the air. Observed instantaneous relative humidity (water vapour in the air).
windSpeed	number	Property	Wind intensity.
windDirection	number	Property	Wind direction.
precipitation	number	Property	Amount of rainwater measured.
solarRadiation	number	Property	Observed solar radiation measured in Watts per square meter..

4.2.4 WeatherForecast

A forecast of weather conditions for a certain place and time. Subject Weather[44]

Table 5. Attributes of WeatherObserved

Attribute Name	Data type	NGSI type	Description
temperature	number	Property	Instantaneous temperature of the measured air.
referenceTemperature	number	Property	Reference temperature of the measured air.

Attribute Name	Data type	NGSI type	Description
atmosphericPressure	number	Property	Observed atmospheric pressure (hP).
relativeHumidity	number	Property	Humidity in the air. Observed instantaneous relative humidity (water vapour in the air).
windSpeed	number	Property	Wind intensity.
windDirection	number	Property	Wind direction.
precipitation	number	Property	Amount of rainwater measured.
solarRadiation	number	Property	Observed solar radiation measured in Watts per square meter..
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: \`validFrom\`, \`validTo\`.

4.3 Existing data models extended in Greenmov project

4.3.1 AirQualityObserved

An observation of air quality conditions at a certain place and time. Subject Environment.

Table 6. Attributes of Air Quality Observed

Attribute Name	Data type	NGSI type	Description
temperature	number	Property	temperature of the item.
relativeHumidity	number	Property	Relative Humidity of the air (a number between 0 and 1 representing the range of 0% to 100%).

Attribute Name	Data type	NGSI type	Description
windSpeed	number	Property	Intensity of the wind.
windDirection	number	Property	Direction of the weathervane.
precipitation	number	Property	Amount of rainwater recorded.
co	number	Property	Carbon Monoxide detected.
co_2	number	Property	Carbon Dioxide detected.
no	number	Property	Nitrogen monoxide detected.
no2	number	Property	Nitrogen dioxide detected.
o3	number	Property	Ozone detected.
nox	number	Property	Other Nitrogen oxides detected.
so2	number	Property	Sulphur dioxide detected.
pm10	number	Property	Particulate matter 10 micrometres or less in diameter.
pm25	number	Property	Particulate matter 2.5 micrometres or less in diameter.
volatileOrganicCompoundsTotal	string	Property	Alkanes <C10, ketones <C6, aldehydes <C10, carboxylic acids <C5, aspirits<C7, Alkenes <C8, Aromatics.

New attributes identified to complement AirQualityObserved Smart Data Model.

Table 7. New Attributes of Air Quality Observed

Attribute Name	Data type	NGSI type	Description
pm1	number	Property	Particulate matter 1 micrometres or less in diameter.

4.3.2 NoiseLevelObserved

An observation of those acoustic parameters that estimate noise pressure levels at a certain place and time. Subject Environment.

Table 8. Attributes identified to complement NoiseLevelObserved

Attribute Name	Data type	NGSI type	Description
dataProvider	property	Property	A sequence of characters identifying the provider of the data entity.
dateObservedFrom	value	Property	Observation period start date and time.
dateObservedTo	value	Property	End date and time of the observation period.
LAeq_d	number	Property	Average sound level during the day (8h).
Lamax	number	Property	Maximum sound level recorded during the measuring time.

New attributes identified to complement NoiseLevelObserved Smart Data Model.

Table 9. New attributes identified to complement NoiseLevelObserved

Attribute Name	Data type	NGSI type	Description
noiseFrequency	number	Property	Measurement frequency of the used sensor.
heightAverage	number	Property	Sensor height above ground.
distanceAverage	number	Property	Average distance between sensor and potential noise sources.
obstacles	string	Property	Type of potential obstacles between the sensor and the noise source.

4.4 TrafficFlowObserved

An observation of traffic flow conditions at a certain place and time. Subject Transportation[45].

Table 10. Attributes of TrafficFlowObserved

Attribute Name	Data type	NGSI type	Description
intensity	number	Property	Total number of vehicles detected during this observation period.
occupancy	number	Property	Fraction of the observation time where a vehicle has been occupying the observed lane.
averageVehicleSpeed	number	Property	The mean speed of the vehicles.

New attributes identified to complement TrafficFlowObserved Smart Data Model.

Table 11. New attributes for TrafficFlowObserved model

Attribute Name	Data type	NGSI type	Description
Fluency	string	Property	A string describing the fluency of the traffic.

5 New Data Models

This section presents the new data models within the Smart Data Models framework identified in the analysis for the three use cases. Although these models should be final, minor issues (slight changes) can happen during the next months during the execution of the project (June 2022).

5.1 NoisePollution

NoisePollution Smart Data Model proposal is intended to merge specific and punctual noise measurements (coming, e.g. from NoiseLevelObservation entities) into average parameters referred to city areas, providing a more city-related data about noise pollution status and evolution.

Table 12. Attributes of new NoisePollution Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
noiseAnnoyanceIndex	number	Property	Health risk index (1 to 10) according to noise level.
Lanight	number	Property	Average sound level recorded during the night (8h)
noiseOrigin	string	Property	Main origin (source) of the recorded noise.
ExposureType	String	Property	Specifies the Exposure time: short term exposure, long term exposure
buildingsType	string	Property	Type of predominant buildings within the measurement area.
groundType	string	Property	Type of predominant ground in the measurement area.
wallsType	string	Property	Facade material types dominant in the measurement area.
Lamax2	number	Property	Maximum sound level recorded for 2 hours. (dB)
LAeq_2	number	Property	Average sound level during the day (2h). (dB)
dateObservedFrom	date-time	Property	Observation period start date and time
dateObservedTo	date-time	Property	Observation period end date and time

5.2 NoisePollutionForecast

NoisePollutionForecast Smart Data Model proposal corresponds to the results of a forecast of noise pollution.

It includes the specific attributes of NoisePollution data model, as well as the specificities of data models for forecasts.

Table 13. Attributes of new NoisePollutionForecast Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: `validFrom`, `validTo`.
noiseAnnoyanceIndex	number	Property	Health risk index (1 to 10) according to noise level.
Lanight	number	Property	Average sound level recorded during the night (8h)
noiseOrigin	string	Property	Main origin (source) of the recorded noise.
ExposureType	String	Property	Specifies the Exposure time: short term exposure, long term exposure
buildingsType	string	Property	Type of predominant buildings within the measurement area.
groundType	string	Property	Type of predominant ground in the measurement area.
wallsType	string	Property	Facade material types dominant in the measurement area.
Lamax2	number	Property	Maximum sound level recorded for 2 hours. (dB)
LAeq_2	number	Property	Average sound level during the day (2h). (dB)
dateObservedFrom	date-time	Property	Observation period start date and time
dateObservedTo	date-time	Property	Observation period end date and time

5.3 BicycleParkingStationPTH-AP

This data model is intended to bridge Fiware Smart data models with OSLO data models for bike stations.

Table 14. Attributes of new BicycleParkingStation Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
ParkingFacility.capacity	integer	Property	Bikes capacity of a civic structure
InfrastructureElement.geometry	string	Property	The geometry corresponding to the infrastructure element

5.4 BicycleParkingStationPTH-AP-Forecast

Table 15. Attributes of new BicycleParkingStationPTH-AP-Forecast Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: \`validFrom\`, \`validTo\`.
ParkingFacility.capacity	integer	Property	Bikes capacity of a civic structure.
InfrastructureElement.geometry	string	Property	The geometry corresponding to the infrastructure element.

5.5 ResourceReportPTH-AP

This data model is intended to bridge FIWARE Smart data models with OSLO data models for bike stations.

Table 16. Attributes of new BicycleParkingStation Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
ResourceReport.actuator	string	Relationship	Engine of the means of transport.
ResourceReport.location	object	Property	Location of the Resource. This could be a bike parking station or the real-time location of the vehicle, e.g. in free-floating part transport.
ResourceReport.meansOfTransport	string	Property	The type of means of transport of the Resource.
ResourceReport.number	integer	Property	Point in time for which the report is valid.
ResourceReport.reportTime	date-time	Property	Point in time for which the report is valid.
ResourceReport.service	object	Property	The MobilityService used within the ResourceReport.
ResourceReport.status	object	Property	State of a Resource. E.g. reserved, inactive, available. Determines whether a resource can be used.
ResourceReport.type	object	Property	Nature of the Resource.
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: `validFrom`, `validTo`.

5.6 ResourceReportPTH-AP-Forecast

Table 17. Attributes of new ResourceReportPTH-AP-Forecast Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
ResourceReport.actuator	string	Relationship	Engine of the means of transport.
ResourceReport.location	object	Property	Location of the Resource. This could be a bike parking station or the real-time location of the vehicle, e.g. in free-floating part transport.
ResourceReport.meansOfTransport	string	Property	The type of means of transport of the Resource.
ResourceReport.number	integer	Property	Point in time for which the report is valid.
ResourceReport.reportTime	date-time	Property	Point in time for which the report is valid.
ResourceReport.service	object	Property	The MobilityService used within the ResourceReport.
ResourceReport.status	object	Property	State of a Resource. E.g. reserved, inactive, available. Determines whether a resource can be used.
ResourceReport.type	object	Property	Nature of the Resource.

5.7 AirQualityForecast

Table 18. Attributes of new AirQualityForecast Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.

Attribute Name	Data type	NGSI type	Description
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: `validFrom`, `validTo`.
airQualityIndex	integer	Property	Number used to report air quality
airQualityLevel	string	Property	Overall qualitative level of health concern corresponding to the observed air quality
co_2	number	Property	Carbon Dioxide detected
no2	number	Property	Nitrogen dioxide detected
o3	number	Property	Ozone detected
nox	number	Property	Other Nitrogen oxides detected
so2	number	Property	Sulfur dioxide detected
pm10	number	Property	Particulate matter 10 micrometers or less in diameter
pm25	number	Property	Particulate matter 2.5 micrometers or less in diameter
temperature	number	Property	Instantaneous temperature of the measured air
relativeHumidity	number	Property	Relative Humidity of the air (a number between 0 and 1 representing the range of 0% to 100%)
windSpeed	number	Property	Intensity of the wind
precipitation	number	Property	Amount of rainwater recorded

5.8 TrafficEnvironmentImpact

This data model is part of the environment subject and aims to calculate the environmental impact of the current traffic flow observed at a given location. The vehicles identified in a traffic flow are categorized by emission categories (i.e. vehicleType). An average of their characteristics is then computed to fill the

TrafficFlowObserved data that corresponds to the considered VehicleType. A link to this vehicletype's TrafficFlowObserved data is added in this datamodel.

Table 19. Attributes of new TrafficEnvironmentImpact Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
Co2emissions	Number	Property	CO_2 emissions calculated from the current Traffic Flow Observed in the area (gCO_2/km)
traffic	Array	Property	Array of objects containing the different types of vehicles and its relations with the object of the traffic flow observations
VehicleType	String	Property	Part of traffic array (see above), this attributes corresponds to the name of the category of vehicles that have been identified in the current traffic observed
TrafficFlowObservedLink	String	Property	Link to the trafficFlowOserved entry corresponding to the average of the vehicles of a given category

5.9 TrafficEnvironmentImpactForecast

This data model is part of the environment subject and aims to calculate what will be the environmental impact of the current traffic observed at a given time and location.

Table 20. Attributes of new TrafficEnvironmentImpactForecast Smart Data Model proposal

Attribute Name	Data type	NGSI type	Description
dateCreated	date-time	Property	Entity creation timestamp. This will usually be allocated by the storage platform.
validFrom	date-time	Property	Validity period start date and time.
validTo	date-time	Property	Validity period end date and time.
validity	date-time	Property	Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: `validFrom`, `validTo`.

Attribute Name	Data type	NGSI type	Description
Co2emissions	Number	Property	CO_2 emissions calculated from the current Traffic Flow Observed in the area. (gCO_2/km)
traffic	Array	Property	Array of objects containing the different types of vehicles and its relations with the object of the traffic flow observations
VehicleType	String	Property	Part of traffic array (see above), this attributes corresponds to the name of the category of vehicles that have been identified in the current traffic observed
TrafficFlowObservedLink	String	Property	Link to the trafficFlowOserved entry corresponding to the average of the vehicles of a given category

5.10 Data models finally not used in the different pilots

These data model were initially selected during the first designs of the pilots. However when refining and understanding better the contents of the data sources and the requirements of the use cases they were either rejected or replaced by others. some of them were already identified in the first version of this document.

ParkingSpot: Initially a ParkingSpot was meant to be used but the final version of the pilots no longer requires this data model.

VehicleEmissionsLabel: This data model proposal characterises the road traffic within the city (or a given area) by enabling the calculation of gases emissions due to vehicles. It has been replaced by the TrafficEnvironmentImpact

PublicTransportation: PublicTransportation proposal provided information about the public transport service of the city, to support the applications that requires inter-modal and commuting functionalities. It was replaced by GBFS data models.

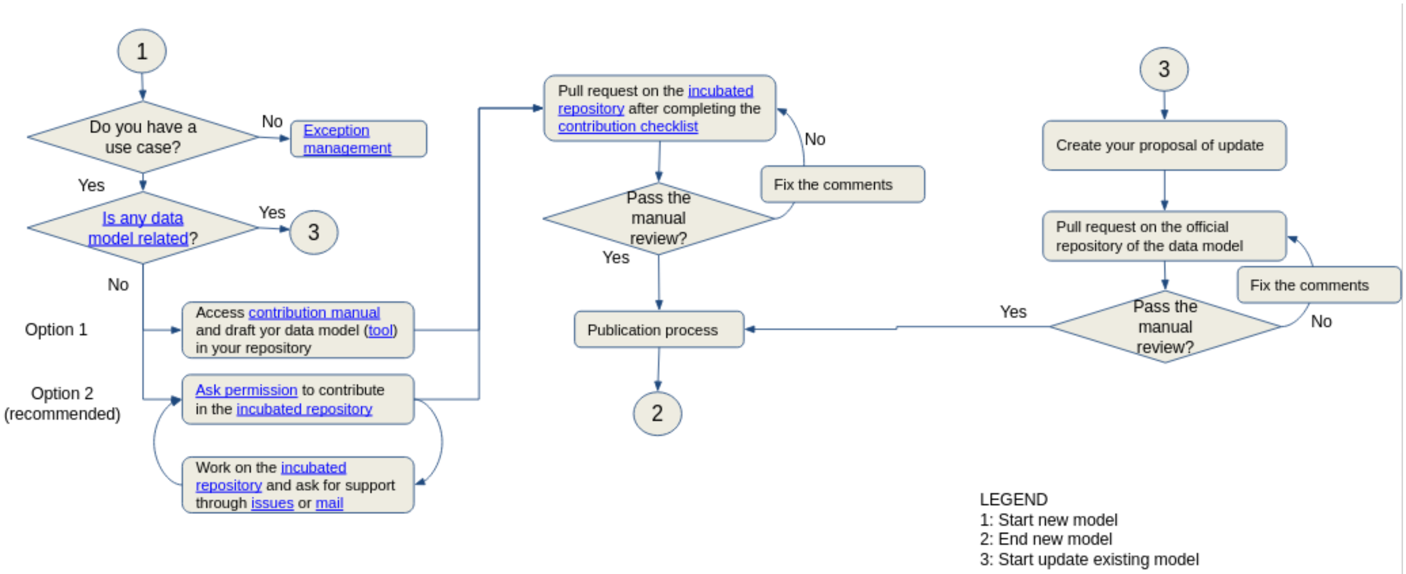
GBFS station_status: Describes the capacity and rental availability of the station According to the Standard GBFS 2.2

GBFS station_information. Details including system operator, system location, year implemented, URL, contact info, time zone. According to the Standard GBFS 2.2. Mapping of the Standard GBFS 2.2.

6 Contribution Procedure of data models to SDM

The procedure to contribute to the Smart Data Models Program[46] is quite straight forward. Initially depends on whether the contribution is a new data model (1) or a modification to an existing one (3). The end is the same (2) the official publication of the data model.

This is the workflow diagram



First requirement is to have an actual use case, demonstrating the validity of the data model in practical situations. If there is not a use case usually the request is rejected

After that, SDM checks if the request is related to any existing data model. This was the case then it is send back the information about the existing data model and it is suggested to extend it.

If the data model is really new, then the user can work in their local repository or in the incubated one (this second is recommended). The contribution only requires 2 mandatory files (json schema containing the definitions and the data types of the different elements, and the example which meet the submitted schema). The json schema contains the descriptions for the first level attributes. The grammar for this description is defined in the contribution manual[47]. And other 3 yaml files with optional content (ADOPTER, CONTRIBUTORS and notes), ADOPTERS provide contact details where this data model is actually being used, CONTRIBUTORS provides credit to the authors of the data model. And notes allow to customize with additional content the specification.The specifications are translated into 5 additional languages besides the English original, German, French, Spanish, Italian and Japanese.

The contribution is made by making a PR on the incubated repository (new data model) or on the specific repository (extension of existing data model).

The PR are reviewed and comments send to contributor if necessary. Once approved an automatic process is launched. This process publish the data model in the right repository, generate the examples (csv, yaml, DTDL, geojson features, json, jsonld, etc) populate the database of attributes to be searchable and generate the documentation in 6 languages (EN, FR, ES, DE, JA, IT) generates the README.md files.

Finally once everything is published a post is included in the main site of SDM and disseminated in the @smartdatamodels twitter account and in the LinkedIn group.

7 Conclusions

A common data models' set to capture and share the information supplied by the heterogeneous IoT infrastructures (and information sources) available in the cities, constitutes the first (and relevant) step in the design of any interoperable city service. With this in mind, current text summarises both: the steps done within GreenMov to identify the sources and required models that support the final cities' use cases; and the definition of each of their structures, by reusing existing Smart Data Models and creating new ones based on the available information.

Aligned with this idea, this deliverable represents the second version of the data models that feed the services developed within the Activity 3 which, in turn, enable the scenario to build the final cities' uses cases in Activity 5. These services are intended to be portable and independent of the cities' scenarios, relying only on the availability (or not) of required information. In this sense, the here defined data models present the first integration's key component, as they design the data injection layer: any city or new adopter that wills to deploy the GreenMov's services must start by adopting and fulfilling each required data model.

These data models have been proposed in close collaboration with the service development (GreenMov's activity 3) and the use cases definition (GreenMov's activity 5), progressing with the methodology already introduced in the first version. This ensures the coverage of the use cases' initial features and the requirements of the current planned services, but, as these two lines within GreenMov are still evolving at the time of writing this document, some expansions may appear within the final deployments that complement the use cases functionalities.

As an evolution of the models described in D2.1, task 2.2 analysed the different sources available on each scenario according to the requirements of the services. These sources, as targets of GreenMov, included the IoT infrastructures deployed on each city, the European Data Portal and the OSLO framework. Activity 2 works with the use cases' providers (the cities) to build the models' structure and attributes whilst these providers (within Activity 5) explore the mentioned sources to fill the required datasets. As the correlation of these data models with the European open data portal remains limited (few of them are available there), other portals are under analysis to complete the information sets.

The data homogenisation process within GreenMov has provided new general Smart Data Models to capture noise extra information (**NoisePollution**), bikes availability (**BicycleParkingStation** from the OSLO PassengerTransportHub) and the traffic impact on the environment (**TrafficEnvironmentImpact**). It has also proposed some expansions to existing **NoiseLevelObserved** and **AirQualityMonitoring** models.

The focus on forecasting of the activity GreenMov services also produced new related Smart Data Models: **NoisePollutionForecast**, **AirQualityForecast**, **BicycleParkingStationForecast** and **TrafficEnvironmentImpactForecasting**.

All the models here reported will become part of the Smart Data Models framework. This will enrich the FIWARE ecosystem and will foster the GreenMov's outcomes within a growing platform for city services. The process to include the new data models and to expand existing ones with new features is also reported here, so new expansions beyond GreenMov can be easily adopted and shared by existing and new participants.

8 References

[1] https://joinup.ec.europa.eu/collection/oslo-open-standards-local-administrations-flanders/about

[2] https://www.werkenaandering.be/en/working-on/hoppin-points

[3] https://www.blue-bike.be/en

[4] Buyle, R. (2021). Raising semantic and technical interoperability in the public sector. Ghent University. Faculty of Engineering and Architecture, Ghent, Belgium.

[5] https://joinup.ec.europa.eu/collection/interoperable-europe/interoperable-europe

[6] http://inspire.ec.europa.eu/

[7] Buyle, R., De Vocht, L., Van Compernolle, M., De Paepe, D., Verborgh, R., Vanlishout, Z., De Vidts, B., Mechant, P., Mannens, E. (2016). OSLO: Open Standards for Linked Organizations. In Proceedings of the International Conference on Electronic Governance and Open Society: Challenges in Eurasia (pp. 126-134). ACM.

[8] http://data.vlaanderen.be/ns/

[9] https://purl.eu/

[10] Buyle, R., Van Compernolle, M., De Paepe, D., Scheerlinck, J., Mechant, P., Mannens, E., & Vanlishout, Z. (2018). Semantics in the wild : a digital assistant for Flemish citizens. In PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE ON THEORY AND PRACTICE OF ELECTRONIC GOVERNANCE (ICEGOV2018) (pp. 1–6). Galway, IRELAND. https://doi.org/10.1145/3209415.3209421.

[11] Buyle, R., Van de Vyvere, B., Rojas Melendez, J. A., Van Lancker, D., Vlassenroot, E., Van Compernolle, M., … Mannens, E. (2021). A sustainable method for publishing interoperable open data on the web. DATA, 6(8). https://doi.org/10.3390/data6080093

[12] https://data.vlaanderen.be/standaarden/erkende-standaarden/proces-methode-ontwikkeling-standaarden/proces-methode-ontwikkeling.html (Dutch)

[13] https://github.com/belgif/review/blob/master/Process/201906-ICEG%20-%20process%20and%20method.docx (English)

[14] https://data.vlaanderen.be/standaarden/erkende-standaarden/proces-methode-ontwikkeling-standaarden/proces-methode-ontwikkeling.html (Dutch)

[15] https://github.com/belgif/review/blob/master/Process/201906-ICEG%20-%20process%20and%20method.docx (English)

[16] ETSI NGSI-LD: Context Information Management (CIM) and Application Programming Interface (API); 2019. https://www.etsi.org/

[17] Abbas, A.; Privat, G. Bridging Property Graphs and RDF for IoT Information Management. In Proceedings of the SSWS@ ISWC; 2018; pp. 77–92.

[18] https://github.com/FIWARE/data-models/blob/master/specs/ngsi-ld_howto.md

[19] https://www.fiware.org/smart-data-models/

[20] https://www.werkenaandering.be/en/working-on/hoppin-points

[21] https://data.vlaanderen.be/standaarden/standaard-in-ontwikkeling/vocabularia-en-applicatieprofielen-hoppinpunten.html

[22] https://data.vlaanderen.be/standaarden/erkende-standaard/applicatieprofiel-mobiliteit-trips-en-aanbod.html

[23] https://data.vlaanderen.be/standaarden/erkende-standaard/vocabularium-mobiliteit-trips-en-aanbod.html
[24] https://data.vlaanderen.be/standaarden/standaard-in-ontwikkeling/applicatieprofielen-mobiliteit-dienstregeling-en-planning.html
[25] https://data.vlaanderen.be/standaarden/standaard-in-ontwikkeling/vocabularium-mobiliteit-dienstregeling-en-planning.html
[26] https://data.europa.eu
[27] https://data.europa.eu/data/datasets/1cff1bfd-7c47-38ab-a4d2-5ca9aa753d0c?locale=en
[28] https://data.europa.eu/data/datasets/blue-bike-deelfietsen-gent-sint-pieters-st-denijslaan?locale=nl
[29] https://data.europa.eu/data/datasets/blue-bike-deelfietsen-gent-dampoort?locale=nl
[30] https://data.europa.eu/data/datasets/34da56c8-80ad-3d12-9e5c-1d24391775d2?locale=nl
[31] https://data.europa.eu/data/datasets/ef98f1a2-4a77-4327-bc5a-99a3c66bed80?locale=en
[32] https://aqportal.discomap.eea.europa.eu/
[33] https://www.eea.europa.eu/themes/air
[34] https://opendata.aemet.es/
[35] https://opendata.atmosud.org
[36] https://iot.nicecotedazur.org/
[37] https://openweathermap.org/
[38] https://meteofrance.fr/
[39] https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-8
[40] http://opendata.nicecotedazur.org/site/
[41] https://www.velobleu.org/en/nos-stations
[42] https://github.com/smart-data-models/dataModel.Environment
[43] https://github.com/smart-data-models/dataModel.Transportation/
[44] https://github.com/smart-data-models/dataModel.Weather/
[45] https://github.com/smart-data-models/dataModel.Transportation/
[46] https://smartdatamodels.org
[47] https://bit.ly/contribution_manual