# URBANITE

## Supporting the decision-making in urban transformation with the use of disruptive technologies



## Deliverable D3.3

## Data Harvesting Module and Connectors Implementation v2

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|---|---|
| **Abstract:** | This deliverable is an update of the deliverable D3.2. It presents the final version of the software implementation of the data harvesting module accompanied with the design specification and documentation. This deliverable is the result of Task 3.1. |
| **Keyword List:** | Harvester, Data Management, Piveau, Pipe, Software |
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# Document Description

## Document Revision History

| Version | Date | Modifications Introduced | |
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| | | Modification Reason | Modified by |
| v0.1 | 24/06/2022 | Section updates assignment | FhG |
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| v0.4 | 30/09/2022 | Address the comment of internal review | FhG |
| V1.0 | 30/09/2022 | Final version for submission | TEC |

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# Terms and abbreviations

| | |
|---|---|
| API | Application Programming Interface |
| EC | European Commission |
| CC | Creative Commons |
| CSV | Comma Separated Values |
| DCAT | Data Catalogue Vocabulary |
| DCAT-AP | DCAT Application Profile |
| HTML | HyperText Markup Language |
| HTTP | HyperText Transport Protocol |
| HTTPS | Hypertext Transfer Protocol Secure |
| JDBC | Java Database Connectivity |
| JSON | JavaScript Object Notation |
| JSON-LD | JavaScript Object Notation Linked Data |
| JVM | Java Virtual Machine |
| MIF/MID | MapInfo Interchange Format |
| NGSI | Next Generation Service Interface |
| NGSI-LD | Next Generation Service Interface Linked Data |
| O/D | Origin/Destination |
| POI | Point of Interest |
| RDW | Specific Open Data Portal of Amsterdam |
| REST | Representational State Transfer |
| SOAP | Simple Object Access Protocol |
| SPDP | Standard for Publishing Dynamic Parking Data |
| URL | Uniform Resource Locator |
| XML | eXtensible Markup Language |
| XSD | XML Schema Definition |

# Executive Summary

This deliverable contains an overview over the software components that are related to the tasks of data harvesting. This refers to the process of downloading data for further processing, albeit without making substantial changes to the data itself. While minor adjustments or filtering is part of this step, thorough data preparation, transformation and curation are covered in deliverable D3.6. Due to the heterogeneous nature of the data present in the URBANITE context, the connector modules typically require specific tailoring to the respective methods of access. As such, the components that have been developed for performing this task are described in this deliverable.

As shown in deliverable D5.4, the Data Management Platform follows a microservice architecture. Of course, all components involved in the steps of fetching to storing data and metadata must integrate into this architecture. In order to achieve this goal, the Piveau Pipe Concept is employed, a design approach aimed at high flexibility and loose coupling when orchestrating software services. The Piveau Pipe Concept is covered in detail in this deliverable, but also applies to the aforementioned components described in D3.6. One key service in this architecture is a dedicated scheduling component that is responsible for ensuring that data is fetched in regular intervals. For each existing module described in this deliverable, an overview along with a description is given. Where applicable, details on configuration and usage are provided. Finally, a description is given of the Messina Edge Components, used for the collection and processing of a large amount of context data. This processing is performed at the edge.

# 1 Introduction

The term Data Management Platform stands for a variety of distinct software components that work together to deliver the key functionalities, that are data harvesting, data preparation/transformation/curation/anonymisation, and data aggregation and storage. The deliverables D3.2, D3.5, and D3.7, together with their updated versions D3.3, D3.6 and D3.8, focus on these core features respectively. Due to the interaction between these modules, the aforementioned deliverables should be understood as a collection of documents related to the same overarching concept that is the Data Management Platform.

## 1.1 About this deliverable

Within the Data Management Platform, this deliverable focuses on the data harvesting and the software components involved in this task, i.e. connectors, importers, and the Scheduler. It presents the challenges involved in harvesting, the proposed solution, and their implementation. Also, it features a section that describes the Piveau Pipe concept, an architecture and software design that is used for implementing all harvesting related components. Developers can get started by reading the relevant sections on how to write Piveau pipe compliant modules. Additionally, a section presents how the collection and processing of a large amount of context data can be performed at the edge, over a distributed and heterogeneous infrastructure; dedicated management of time series data in an optimized way is also presented.

## 1.2 Document structure

Section 2.1 covers the functionalities provided by the harvesting components as well as how they fit into the general URBANITE architecture. This is followed by a description of the Piveau Pipe concept, which is the overarching design into which the individual harvesting related components are integrated. These are listed in section 2.2.2, along with technical specifications and explanations on how to develop connectors and how to configure the scheduler. The specific edge time series data management techniques used in the Messina pilot are described in 2.3. Next, section 3 contains instructions on how to build, configure, and run the application(s). The document wraps up with some conclusions and references.

## 1.3 Updates with respect to version 1

The main updates of this document with respect to version 1 consist of added harvesters, new sources that these harvesters support, and updates to the functionality of these harvesters. Additionally, a description of the Messina Edge Component was added.

# 2 Implementation

## 2.1 Functional description

The harvesting modules and connectors need to provide a number of functionalities. First and foremost, they need to implement ways to import (i.e. download) data and metadata from endpoints on the web. These endpoints can come in all shapes and forms, for example, simple public REST APIs, restricted SQL dumps, simple file downloads, or geodata streams. All these different kinds of data and metadata then need to be checked, cleaned and harmonised for further processing, which is covered in D3.6 [1]. This is achieved by data preparation and subsequent transformation steps, as well as curation. Once the data and metadata are brought into a common format (i.e. URBANITE Data Model, which is an extension of FIWARE Smart Data Model [2]), they need to be stored in dedicated databases (covered in D3.8 [3]).

Additionally, the (meta-)data needs to be downloaded in regular intervals to account for changes thereof. Managing these intervals is the responsibility of the Scheduler. Unlike the other components described in this deliverable, it does not download data itself, but triggers the other data importers, which in turn download the data.

In summary, this deliverable, therefore, covers harvesting and scheduling. For completeness' sake, the exporting component, which is responsible for pushing arbitrary data to the applicable API endpoints of the data storage, is also featured in this deliverable. Once harvested, data could be stored directly through the exporter into the database repositories if no preparation or data transformation is necessary, or it can be pushed to the next step of the pipeline for data quality checks and transformations. Note that neither the Scheduler nor exporting component are shown as dedicated modules in Figure 1.

The functional requirements for harvesting and scheduling were listed in deliverable D5.1 and a detailed design was provided in deliverable D5.4 [4]. Table 1 shows a short summary of the development status. All the requirements applicable to the data models and datasets have been fulfilled.

*Table 1: Status of Harvester requirements from D5.1*

| Requirements in D5.1 | Current Status |
|---|---|
| Data Harvesting from heterogeneous data sources | Fulfilled: a variety of data is supported |
| Pagination | Fulfilled: specific harvesters support pagination where needed, e.g. the Messina commune harvester. |
| Data Harvesting extensibility | Fulfilled: the pipeline design is flexible and extensible |
| Data Harvesting supported protocols | Fulfilled: although for the moment, all harvesters use HTTP(S) |
| Scheduled data fetching | Fulfilled: Cron triggers can be set up for pipelines |

### 2.1.1 Fitting into overall URBANITE Architecture

In general, the harvesting modules and connectors are part of the backend services of the URBANITE architecture. They are managed by the scheduling component mentioned in the previous section. Since all related components follow a microservice approach, they fit well with the docker-based architecture designed in WP5. As such, they also scale well, which is considered a key requirement when frequently downloading potentially large amounts of data and preparing/transforming them. The components that are described in this deliverable are highlighted in green in the architecture diagram (Figure 1) from deliverable D5.8.

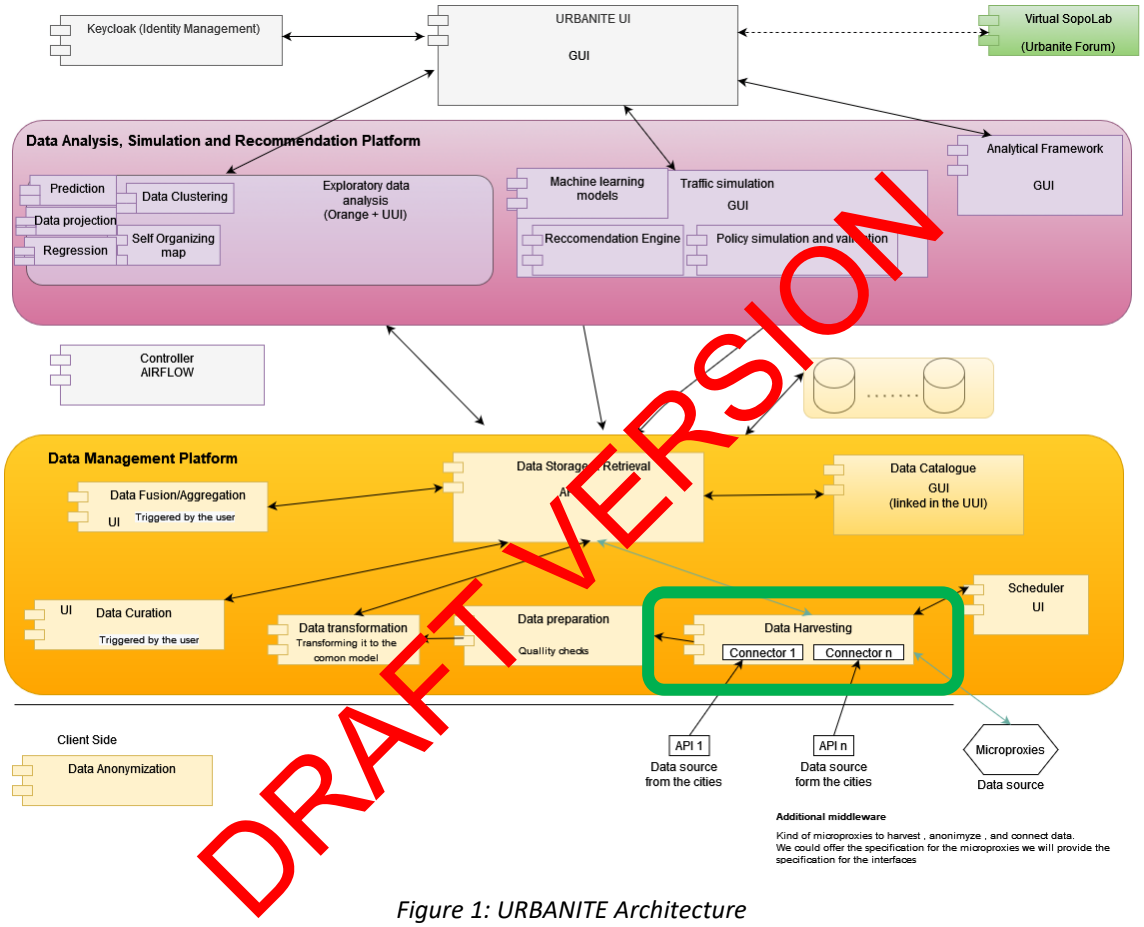



*Figure 1: URBANITE Architecture*

## 2.2 Technical description

This section describes the technical details of the implemented software. Data management is the process of fetching, anonymising, preparing, transforming, storing, organising and maintaining the data created and collected by an organisation. Harvesting refers to the subset of steps from the import of data to the export into a data store. In URBANITE, this harvesting process has been implemented using a pipeline, i.e. a chain of processing components arranged so that the output of each component is the input of the next. The pipeline has been developed using the open source solution named Piveau Pipe Concept, which is explained in detail in section 2.2.1. This is followed by an overview of the components that have been developed thus far in section 2.2.2. Examples of how to write a compatible connector and how to schedule pipes are also included.

### 2.2.1 Piveau Pipe Concept

The components involved in the steps from data fetching until storage are orchestrated by the Piveau Pipe concept [5] outlined in this section. A high-level overview of how components interact in this processing chain is shown in Figure 2.

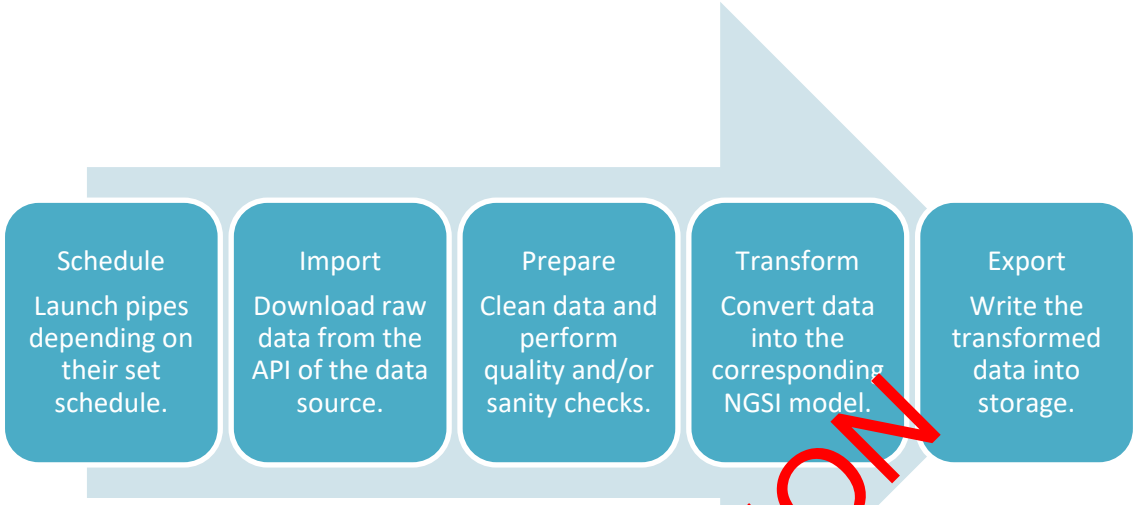
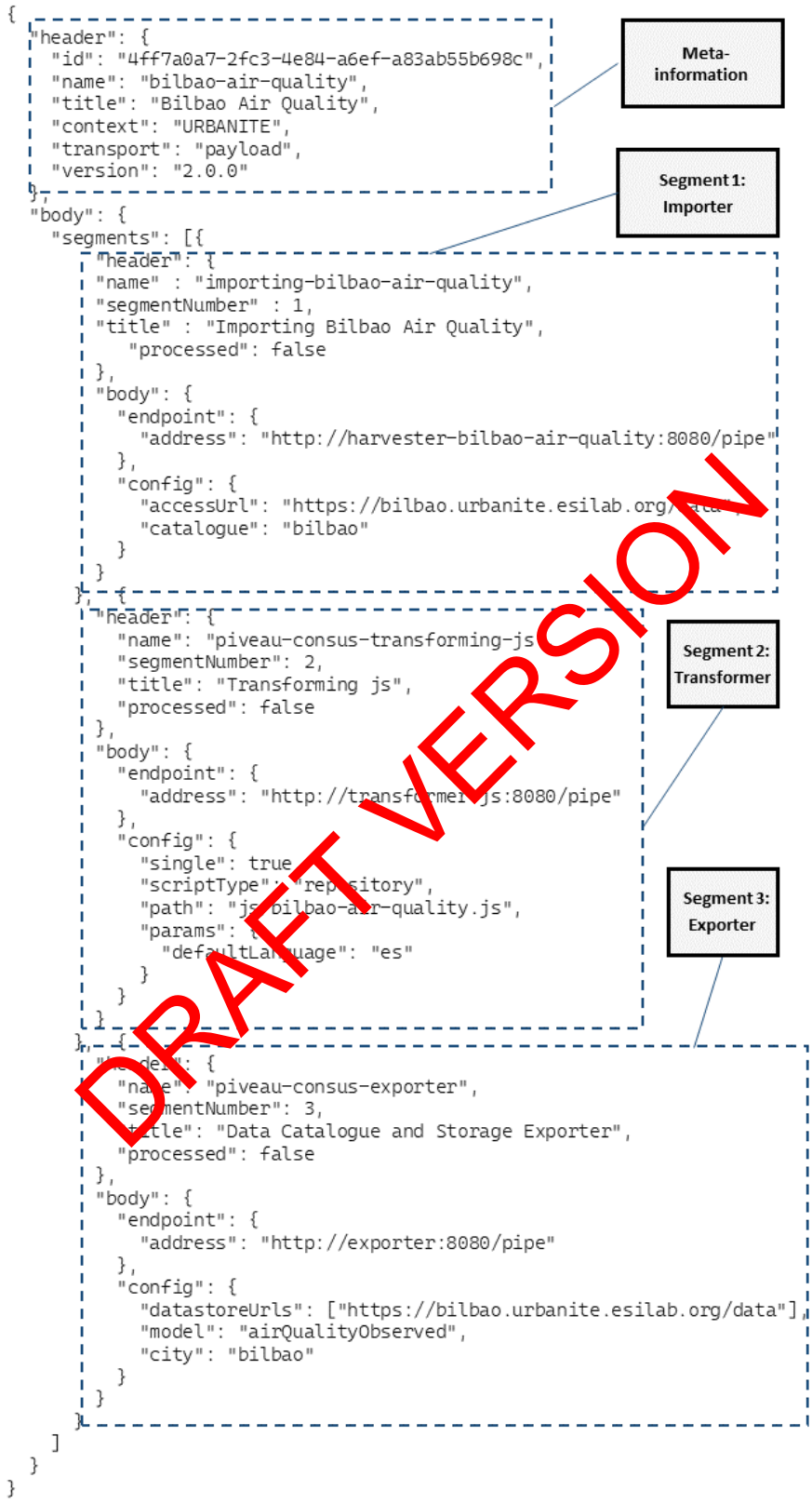



*Figure 2: URBANITE data harvesting implemented using the Piveau Pipeline concept*



On an architectural level, the Piveau Pipe allows the collection of data from heterogeneous data sources and the orchestration of a multitude of subsequent services. In order for a component to cohere to the Piveau Pipe concept, it needs to be developed as a web service that exposes a common RESTful interface, which is explained in detail in section 2.2.2.1. This means that the services can be connected in a generic fashion to implement specific data processing chains. No central instance is responsible for orchestrating the services. This is achieved by so-called pipe descriptors, a JSON file that contains a definition of components (endpoints, chronological order, specific configurations) that makeup one processing sequence. Each processing chain is defined in one of these files (see Figure 3).

The Scheduler is the component responsible of managing and launching all the pipelines. To do so, the Scheduler either reads these files from disk or polls a Git repository to become aware of which pipes are available. These can then be assigned to a periodic trigger for recurring execution. When such a trigger fires, a copy of the contents of the according to pipe descriptor is sent to the first component in line, i.e. the one identified in the segment with segment number 1. During processing, the pipe descriptor is augmented. Data that needs to be passed along the processing chain is written into a payload field of the next component in line. For smaller amounts of data, this can happen directly; for larger amounts of data, a pointer to an external datastore can be used. Figure 3 shows an example of a pipe descriptor for downloading Bilbao air quality data, transforming it, and writing the transformed data to an instance of the data storage.




```
{
  "header": {
    "id": "4ff7a0a7-2fc3-4e84-a6ef-a83ab55b698c",
    "name": "bilbao-air-quality",
    "title": "Bilbao Air Quality",
    "context": "URBANITE",
    "transport": "payload",
    "version": "2.0.0"
  },
  "body": {
    "segments": [{
      "header": {
        "name" : "importing-bilbao-air-quality",
        "segmentNumber" : 1,
        "title" : "Importing Bilbao Air Quality",
          "processed": false
      },
      "body": {
        "endpoint": {
          "address": "http://harvester-bilbao-air-quality:8080/pipe"
        },
        "config": {
          "accessUrl": "https://bilbao.urbanite.esilab.org/
          "catalogue": "bilbao"
        }
      }
    }, {
      "header": {
        "name": "piveau-consus-transforming-js
        "segmentNumber": 2,
        "title": "Transforming js",
        "processed": false
      },
      "body": {
        "endpoint": {
          "address": "http://transformer-js:8080/pipe"
        },
        "config": {
          "single": true
          "scriptType": "repository",
          "path": "js/bilbao-air-quality.js",
          "params": {
            "defaultLanguage": "es"
          }
        }
      }
    }, {
      "header": {
        "name": "piveau-consus-exporter",
        "segmentNumber": 3,
        "title": "Data Catalogue and Storage Exporter",
        "processed": false
      },
      "body": {
        "endpoint": {
          "address": "http://exporter:8080/pipe"
        },
        "config": {
          "datastoreUrls": ["https://bilbao.urbanite.esilab.org/data"],
          "model": "airQualityObserved",
          "city": "bilbao"
        }
      }
    }
  ]
  }
}
```

*Figure 3: Example of a Piveau Pipe Descriptor*

As can be seen, each segment contains a header with metadata and a body with component-specific configurations, for example, relevant URLs. As stated earlier, this resembles the pipe's descriptor. Whenever the Scheduler triggers a pipe, this descriptor is sent to the first component in line, in this case, the `importing-bilbao-air-quality` module. Each dataset is immediately sent to the next component, in this case, the `transforming-js` module. Once the datasets have been transformed to the desired output format, in this case, the FIWARE `airQualityObserved` SmartData model, the result is sent to the Exporter, an adapter that is capable of uploading data and metadata to the data storage. The process of how the conversion of data between import and export is accomplished is explained in detail in deliverable D3.6 [1].

It is important to note that all this happens on a per-dataset basis; that is, the Importer does not wait for all datasets to download and send the payload in bulk, but each dataset is handled individually. This ensures flexibility, as no component needs to keep a state or track how much data has been received. Also, each component can be scaled individually depending on the respective workloads.

The way this works is that payloads are injected into the descriptor as it is passed along the pipeline. The descriptor is, therefore, not a static, immutable object but changes over time. This also makes debugging easier, as the evolution of the payload can be tracked. The Scheduler does not provide a payload, so the descriptor is sent as is. The Importer, however, creates a copy of the descriptor for each dataset it downloads and injects said dataset into this copy. Of course, each component is also capable of extracting its respective payloads. The Transformer works in the same way; it takes the payload sent by the Importer, processes it, and injects the result as a payload for the Exporter.



### 2.2.2 Components overview

The following harvesting related components shown in Table 2 have been developed. Some of these components are suitable for the continuous fetching of data in regular intervals. In contrast, historic data or data sources such as public holidays/calendar data or points of interest (POI), by nature aren't prone to frequent changes and/or updates. For simplicities sake, this kind of data that can be considered as almost static, has been loaded into the data storage using connectors developed in Java code but have not been included in the Piveau pipeline. However, using the file importer, this could have been accomplished in coherence with the Piveau pipeline. Table 3 shows all data sets that are currently in the data storage and the source URL where available. Besides, dump files provided by the cities have been used to complete the historical data.

*Table 2: Component Overview*

| Type | Name | Description |
|---|---|---|
| Importer/ Connector | OpenWeatherMap | Downloads weather data from the OpenWeatherMap provider. Requires an account with a valid API key. |
| | OpenStreetMap | Downloads data from OpenStreetMap. The query must be configured into the respective pipe descriptor. |
| | File | Generic importer for downloading files from URLs. The file is Base64 encoded prior to forwarding. The importer ships with a Python script that can be used to spin up a simple webserver that serves a file from local storage over HTTP. |
| | XML | Downloads XML documents and extracts data before forwarding. Optionally, if the file is gzip compressed, it will be uncompressed before handling the data itself. |
| | Web wrappers | Web page wrappers to extract information from an unstructured web page. They are used to a) harvest the schedule of football matches in Bilbao and b) the schedule of ferry arrivals and departures in the Port of Hesinki. |
| | Bilbao Air Quality | Downloads air quality data from Euskadi Open Data Portal. |
| | Bilbao Traffic Flow | Downloads traffic data from Euskadi Open Data Portal. |
| | Helsinki Traffic Flow | Downloads traffic data in the city of Helsinki. |
| | Helsinki Harbour Traffic Flow | Downloads traffic flow from ferries in the Port of Helsinki. |
| | Messina Commune | Downloads various data from the Messina Commune Edge Components API, like population statistics, bus stops and points of interest. As well as timeseries data like air quality, noise or traffic data. |
| | Amsterdam OIS | Downloads data from Amsterdam OIS Portal |
| | Amsterdam Air Quality | Downloads air quality data from Amsterdam |
| | Amsterdam Telraam | Imports traffic data from the Telraam API. This data includes car, bike and pedestrian traffic. |
| Misc. | Scheduler | Keeps track of existing pipe descriptors and manages triggers. The former are polled from a Git repository, the latter can be created/updated/deleted via a REST API. The service exposes a shell accessible by HTTP or Telnet that allows basic interaction, like viewing existing pipe descriptors and launching them manually. |
| | Data Storage Exporter | Pushes incoming data and metadata to the data storage. Allows the specification of multiple storages, which is required for data that is relevant to multiple environments. |
| | Historic data wrappers | Manage the files with historical data (air quality, traffic) provided by the cities. |
| Library | Piveau Pipe Model | Container for storing information encoded in a pipe descriptor. Offers a selection of related methods, like (de-) serialising and setting certain fields. |

| | | |
|---|---|---|
| | Piveau Pipe Connector | Handles communication between pipe components. Should be used when implementing pipe compliant services. |
| | Piveau Pipe Launcher | Is used by the Scheduler for initiating the execution of existing pipes. |

*Table 3: Existing data sets*

| Name | Added in Version 1/2 | Description | Model |
|---|---|---|---|
| OpenWeatherMap | 1 | Weather data from the OpenWeatherMap provider including precipitation, relative humidity, temperature, wind direction, wind speed and atmospheric pressure. Source: https://openweathermap.org | WeatherObserved |
| Calendar | 1 | Calendar data for the four cities since 2015. It includes information about the day of the week, whether it is a public holiday or not, a working day or not and a school day or not. Due to its complexity, the information has been manually merged from different websites. E.g. https://www.unime.it/it/ateneo/amministrazione/calendario-accademico, https://www.calendarioslaborales.com/calendario-laboral-vizcaya-2022.htm | Calendar |
| Amsterdam Air Quality | 1 | Amsterdam Air Quality Data (no, no2, pm10). Source: https://api.luchtmeetnet.nl/open_api | AirQualityObserved |
| Amsterdam Ring Ring Districts | 2 | Amsterdam Zones used by Ring-Ring bike data Source: provided by Ring-Ring https://ring-ring.nu/ | GtfsShape |
| Amsterdam Bike O/D | 2 | Amsterdam O/D Matrix from Ring Ring bikes data. Source: Created by WP4 algorithms. | OriginDestinationMatrix |
| Amsterdam Schools | 2 | Primary and secondary schools in Amsterdam. Source: https://schoolwijzer.amsterdam.nl/nl/api/v1/lijst/po/format/geojson and https://schoolwijzer.amsterdam.nl/nl/api/v1/lijst/vo/format/geojson | PointOfInterest |
| Amsterdam Sports | 2 | Sport offer in Amsterdam. Source: https://data.amsterdam.nl/datasets/a6WW_Ay-oeY_dQ/sportaanbieders-in-amsterdam/ | PointOfInterest |
| Amsterdam Telraam | 2 | Data from the Telraam Traffic platform. Telraam devices count road users passing in front of them. Traffic modes (heavy vehicles, cars, two-wheelers, pedestrians). Source: https://telraam-api.net/ | TrafficFlowObserved |
| Amsterdam Transport Stations | | Tram and metro stations in Amsterdam. Source: https://data.amsterdam.nl/datasets/zoek/ | TransportStation |
| Bilbao Air Quality | 1 | Air quality data (no, no2, nox, pm10 and so2) in Bilbao since 2019. Source: | AirQualityObserved |

| Name | Added in Version 1/2 | Description | Model |
|---|---|---|---|
| | | https://www.ingurumena.ejgv.euskadi.eus/aa17aCalidadAireWar/estacion/geojson | |
| Bilbao Traffic Flow | 1 | Traffic status in Bilbao since 2017. Source: https://www.geobilbao.eus/geobilbao/Main | TrafficFlowObserved |
| Bilbao Football Matches | 1 | Schedule of matches from the Athletic Bilbao Team for seasons from 2014-2015 until 2021-2022. Source: https://www.livefutbol.com/equipos/athletic-bilbao/ | Event |
| Bilbao Bikes | 1 | Bike rental's locations. Source: https://api.citybik.es/v2/networks/bilbon-bizi | PointOfInterest and TransportStation |
| Bilbao Districts | 1 | Bilbao districts. Source: data provided by the city | GtfsShape |
| Bilbao Bike OD matrix | 1 | OD matrices based on bike trips data. Source: created by WP4 algorithms. | OriginDestinationMatrix |
| Bilbao Wifi Zones | 1 | Areas that define the Wi-Fi zones in Bilbao. Source: data provided by the city. | GtfsShape |
| Bilbao Wifi O/D | 1 | OD Matrices for all travel modes based on Wi-Fi data. Source: created by WP4 algorithms. | OriginDestinationMatrix |
| Bilbao Bike Trips | 2 | Itineraries (only start and end location) followed by public bikes in Bilbao. Source: provided by the city from the Bilbaobizi service. | TouristTrip |
| Helsinki Bike Stations | 1 | Location of the bike stations in Helsinki. Source: https://api.citybik.es/v2/networks/citybikes-helsinki | TransportStation |
| Helsinki Bike Trips | 2 | Helsinki bike trips (only start and end location) from 2017-2021:<br>2017 ->May to October<br>2018 -2019 -> April to October<br>2020 --> March to October<br>2021 -> April to October<br><br>Source: data provided by the city in files. | TouristTrip |
| Helsinki Traffic | 1 | Traffic Flow in the city of Helsinki since 2019. Source: https://lamapi.azurewebsites.net/api/Public | TrafficFlowObserved |
| Helsinki Harbour Traffic | 1 | Traffic Flow from ferries in the Port of Helsinki. It includes heavy traffic (lorry) and car traffic. Source: https://lamapi.azurewebsites.net/api/Public | TrafficFlowObserved |
| Hensinki Ferries | 2 | Schedule of ferry arrivals and departures in the Port of Helsinki since 8th November 2021. Source: | Event |

| Name | Added in Version 1/2 | Description | Model |
|---|---|---|---|
| | | https://www.portofhelsinki.fi/en/passengers/arrivals-and-departures | |
| Messina Districts | 2 | GtfsShapes of Messina Districts. Source: https://urbanite-node1.comune.messina.it/ | GtfsShape |
| Messina Bus and Tram Stops | 2 | Collection of bus and tram stops. Source: https://urbanite-node1.comune.messina.it/ | TransportStation |
| Messina POIs | 2 | Collection of Points of Interest. Source: https://urbanite-node1.comune.messina.it/ | PointOfInterest |
| Messina Air Quality | 1 | Messina Air Quality Data (no, no2, pm10, c6h6, co). Source: https://urbanite-node1.comune.messina.it/ | AirQualityObserved |
| Messina Cameras | 2 | Collection of cameras in Messina. Source: https://urbanite-node1.comune.messina.it/ | PointOfInterest |
| Messina Noise pollution | 2 | Noise pollution measurements. Source: https://urbanite-node1.comune.messina.it/ | NoiseLevelObserved |
| Messina Electromagnetic Noise | 2 | Electromagnetic noise pollution measurements. Source: https://urbanite-node1.comune.messina.it/ | ElectroMagneticObserved |
| Messina Vehicle Counts | 2 | Messina traffic flow observations. Source: https://urbanite-node1.comune.messina.it/ | TrafficFlowObserved |
| Messina Population | 2 | Statistics about Messina population. Source: https://urbanite-node1.comune.messina.it/ | PopulationObserved |



### *2.2.2.1 Writing an importer/connector*

In this section, we provide a detailed explanation of how to create an importer/connector to easily integrate it into the pipeline. The connector or importer in segment 1 will download the data, make a first validation of it, create the necessary metadata and redirect to the next process in the pipeline. Harvesting related components are based on Vert.X[1] framework. Therefore, in order to be integrable into the pipeline, the connector/importer should be an instance of the Verticle class.

[1] https://vertx.io/

```
public class ImportingBilbaoAirQualityVerticle extends AbstractVerticle
```

*Figure 4. Importer for air quality data in Bilbao*

When this Verticle is launched for the first time, the handler for processing pipe messages is registered with the eventbus. The MainVerticle, which is responsible for spawning the Pipe API and content-negotiation, sends incoming requests along the eventbus. This is then consumed by the aforementioned handler. This is shown in Figure 5.

```
@Override
public void start(Promise<Void> startPromise) {
    vertx.eventBus().consumer("bilbao-importer", message -> {
        PipeContext pipeContext = message.body();
        pipeContext.log().info("Import started");
        accessUrl = pipeContext.getConfig().getString("accessUrl");

        ...
    });

    ...
}
```

*Figure 5: Registering a Pipe handler with the Vert.X Eventbus*

In the example in Figure 5, `accessUrl` is a parameter included in the pipe descriptor, as shown in Figure 6.

```
"config": {
  "accessUrl": "https://bilbao.urbanite.esilab.org:8443/data",
  "catalogue": "helsinki"
}
```

*Figure 6: Pipe descriptor with accessUrl*



Thanks to the pipe descriptor, the same importer can be used to harvest different data sources without modifying the component's code. To download the data, a web client can be used if the data source is available through HTTP, e.g. in the case of a web service API or a URL.

```
webClient.getAbs("https://bilbao.urbanite.esilab.org/data")
        .addQueryParam("R01HNoPortal", "true")
        .addQueryParam("tipoICa", "2")
        .addQueryParam("idContaminante", "8")
        .putHeader("Accept", "application/json")
        .expect(ResponsePredicate.SC_OK)
        .send()
```

*Figure 7: Web client to download air quality data from Bilbao's air quality service*

Once the data is downloaded, not all of it is forwarded to the next process in the pipeline. For example, the Basque Country's air quality service (see Figure 8) returns data about all the meteorological stations in the entire province. However, in URBANITE, we are only interested in the information coming from the stations in the municipality of Bilbao. The rest of the data is discarded. In addition, the metadata is created for the downloaded data and forwarded in the `metadata` field. The helper classes for constructing DCAT-AP metadata are included in the Piveau libraries.

```
DCATAPGraph dcatapGraph = new DCATAPGraph();
Dataset dataset = dcatapGraph.createDataset("sample_dataset")
    .setTitle("Bilbao Air Quality")
    .setDescription("Air Quality information for Bilbao")
    .addKeyword("Bilbao")
    .addKeyword("Air Quality")
    .setIssued(Instant.now())
    .setModified(Instant.now())
    .setAccessRights("public")
    .setTheme("http://publications.europa.eu/resource/authority/data-theme/REGI")
    .setTheme("http://publications.europa.eu/resource/authority/data-theme/TRAN")
    .setPublisher("URBANITE", "https://urbanite-project.eu/");

dataset.createDistribution("sample_distribution")
    .setAccessURL(accessUrl + "/getTDataRange/airQualityObserved/bilbao)
    .setFormat("http://publications.europa.eu/resource/authority/file-type/JSON")
    .setLicense("http://publications.europa.eu/resource/authority/licence/CC_BY")
    .setDescription("Air Quality information for Bilbao")
    .setTitle("Bilbao Air Quality)
    .build();
```

*Figure 8: Creation of the metadata for the downloaded dataset and distribution*

Finally, both the data and metadata are forwarded to the next process in the pipeline (see Figure 9). For all interactions between the Piveau Pipe services, the `pipe-connector`[2] library should be used. It provides an abstraction from the inner workings and communication protocols implemented. It also parses the incoming pipe descriptors and extracts the applicable segment info for a given service.

```
// pass dataset to next pipe module
private void forwardDataset(JsonObject dataset, PipeContext pipeContext, String identifier) {
    ObjectNode dataInfo = new ObjectMapper().createObjectNode()
            .put("identifier", identifier)
            .put("catalogue", pipeContext.getConfig().getString("catalogue"));

    pipeContext.log().info("Importer result:\n{}", dataset.encodePrettily());
    pipeContext.setResult(dataset.encodePrettily(), "application/json", dataInfo).forward();
}
```

*Figure 9: Forwarding both the data and the metadata to the next process in the pipeline.*



[2] https://github.com/piveau-data/piveau-pipe-connector

#### *2.2.2.2 Scheduling the data fetching*

Depending on the data source, the update frequency changes. For example, traffic flow data is updated every 5 minutes whereas air quality data is updated every hour. For this reason, each pipeline needs to be triggered with a different frequency. As explained before, the Scheduler is the component responsible of managing these triggers. To configure the Scheduler, triggers can be set using the provided REST API. It supports one-time ("immediate") and Cron[3] triggers. For example, to trigger the harvesting pipeline for the air quality data every hour we would send the request shown in Figure 10 via PUT method to `triggers/bilbao-air-quality`. Note the `pipeId` in the payload (`bilbao-air-quality`).

### 2.2.3 Technical specifications

```
[
  {
    "id": "BilbaoAirQuality",
    "status": "enabled",
    "cron": "0 0 0/1 ? * * *",
    "next": "2021-07-23T10:45:00Z"
  }
]
```

*Figure 10: Triggering the harvesting pipeline every hour*

All harvesting related components are written in Java and are based on the Vert.X[4] framework developed by the Eclipse Foundation. Vert.X proposes and supports an asynchronous programming paradigm which aims to improve performance and responsiveness by ensuring that a thread is never blocked by long-running tasks. The basis of this is the Netty[5] project.

The pipe functionality (parsing and manipulating the pipe descriptor) is provided by the Piveau Pipe Model library. The common endpoint each component exposes is implemented by the Piveau Pipe Connector library.

All pipe components except the Scheduler are stateless. As such, only the Scheduler requires a database and for this purpose, relies on the embedded version of the Open-Source relational database H2[6], accessible via JDBC. The component uses the database to store pipeline triggers.

With all services being JVM based, the software stack runs on any machine that is supported by the JVM. Depending on the number of instances running and the kind of data that is processed, a sufficient amount of memory should be available.



## 2.3 Messina Edge Components

In order to be able to efficiently collect a huge and heterogeneous amount of information and data by acquiring real-time vehicle locations, weather data, air quality measurements or GPS position of electric vehicles in the city centre, innovative techniques, trying to improve existing methods, have been explored. The decision to attempt to improve some known data acquisition techniques together with technologies already designed for this purpose, such as time-series databases, emerged from real problems encountered directly in the field.

[3] http://www.nncron.ru/help/EN/working/cron-format.htm
[4] https://vertx.io/
[5] https://netty.io/
[6] https://h2database.com

The schema below presents the role that the Messina Edge components represent into the general URBANITE architecture. They are considered as connectors to external data processing them to be harvested by the system.

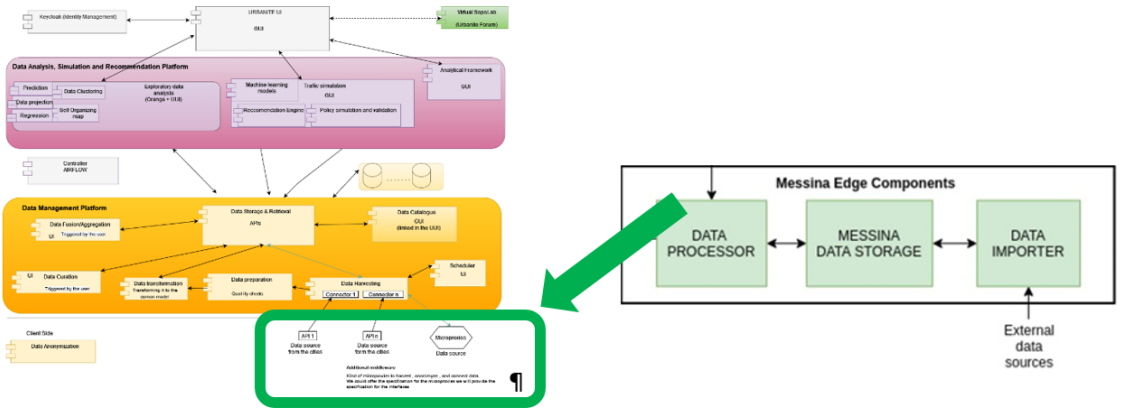



*Figure 11: Messina Edge components as external data process*

Some of the critical issues encountered were the size of the datasets to be stored (especially in the case of timeseries data) and the difficulty of existing technologies to return the results of quite complex queries in an agreeable time frame. The existing system, in some cases, could not respond without crashing, probably also due to problems with the scalability of the system itself. The main scope of processing this information is to provide both administrators and citizens with real-time information or digital services that can improve their quality of life.

The large amount of data exchanged between IoT acquisition tools (such as sensors and cameras) and databases, but also the need to make this information immediately available, makes central the creation of increasingly efficient data models, both in the process of writing data into the selected database and in the reading phase, when the access time by users becomes extremely important to increase the quality of the service.

The study focused on the optimisation of data acquisition and their query in the case of using MongoDB. The organisation of the collected data and their structure is fundamental. In general, the data relating to this technological field are series of historical measurements acquired by the sensors, hence the reference to time-series data.

The approach used is the one related to the bucket structure, generally used in the field of time series data and document-oriented databases. The proposed solution can be used in the context of urban mobility, but it has a general value.

Here, with the used “buckets approach”, documents are grouped with predetermined criteria into container documents. Consequently, the single collection contains buckets that consist of an array of documents, which represent the real measures, as well as contain the metadata that remains constant over time. The bucket length can be fixed if there is a set maximum number of measurements, or dynamic if the insertion of a measurement within it depends on other factors.

This approach exploits as much as possible the use of buckets, a well-known pattern that is used to improve the management of time series data, using methodologies in order to optimise performances and functionalities to the maximum.

It is based on five main pillars:

1) Bucket

2) Total count

3) Aggregation

4) Range pagination

5) Query pipeline

The most convenient bucket structure for the purposes is a dynamic one, in which a single bucket contains the measurements coming from a specific data source in a given time interval because this will allow us to use specific algorithms for data retrieval.

Further information about methodologies and implementation are available in the published paper "Time Series Data Management Optimized for Smart City Policy Decision" (doi: 10.1109/CCGrid54584.2022.00068), in which there is also a comparison between the proposed solution and the native time series data management features offered by the new version of MongoDB.

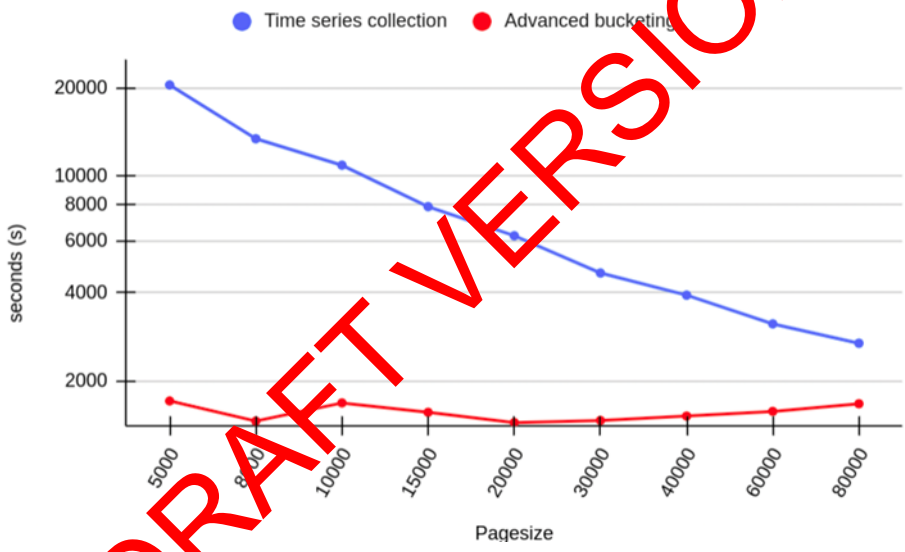





*Figure 12: Comparison of data retrieval considering an interval containing 15,000,000 measurements: the Time series collection approach improves by increasing the dimension of the page, through the Advanced Bucketing, the behaviour remains more or less constant*

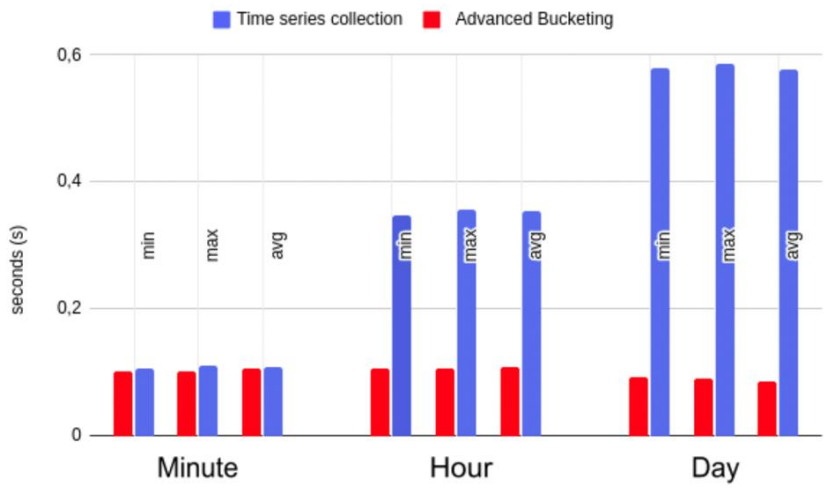



*Figure 13: Comparison between different data formats in the response result. The Time series collection approach behaves slightly better with ungrouped and grouped by id data, however, the Advanced Bucketing prevails with grouping by timestamps.*

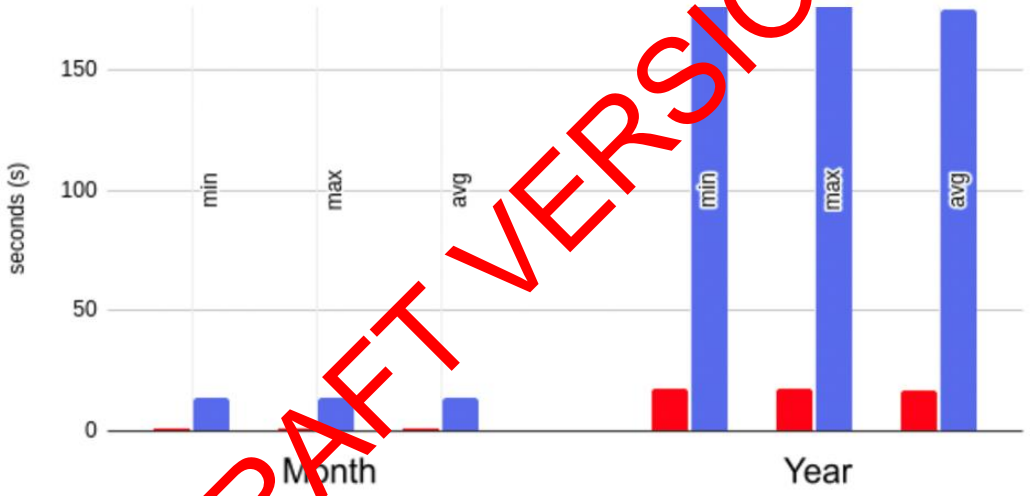



*Figure 14: Comparison of data aggregation considering different granularities (minute, hour, day, month, year). Time intervals are chosen according to the specific granularity.*

# 3 Delivery and usage [Harvesting modules]

## 3.1 Package information

All components are Java applications that are built using Maven[7]. As such they cohere to the default standardized folder structure for source files (`/src/main/java/io/piveau/{componentName}`) and resource files (`/src/main/resources`). The latter contains files like the OpenAPI specification (`webroot/openapi.yaml`) when applicable and logging configuration (`logback.xml`).

## 3.2 Installation instructions

In order to integrate well into the URBANITE platform, all components are available as Docker images. However, before building the Docker images, the corresponding JAR file needs to be created. A JAR file is an executable that runs on the JVM. The harvesting components rely on a build tool called Maven for dependency management and generation of the JARs. As such, the deployment of a service can be achieved using the three commands below. Note that curly brackets indicate that applicable values need to be substituted.

```
$> mvn clean package

$> docker build -t urbanite/{component-name} .

$> docker run -p {PORT}:8080 urbanite/{component-name}
```

Depending on the respective component, a certain configuration may need to be applied, for example, an API key. This can be achieved using environment variables, which can be passed to Docker containers like so:

```
$> docker run -e {ENV_VAR}={value} urbanite/{component-name}
```

## 3.3 User Manual

In general, each component provides a human-readable form of its OpenAPI specification at `{hostname:port}/index.html`. The corresponding file is stored at `src/main/resources/webroot/openapi.yaml`. However, this does not apply to those components that spawn their endpoints based on a library. This is specifically the case for all pipe components that rely on the Piveau Pipe Connector library. These expose the common endpoint at `{hostname:port}/pipe`, which accepts compliant pipe descriptors via the HTTP POST method.

Aside from this, most of the components require very little configuration and work out of the box. The specific environment variables that need to be set for each service are listed in the respective `README.md` file in the root directory.



[7] https://maven.apache.org/

### 3.3.1 Scheduler

A special case however is the Scheduler, which requires a little more setup and also exposes more endpoints than the other pipe components. As described previously, the Scheduler serves two main purposes: keeping track of existing pipe descriptors and managing triggers for these pipes. In order to fulfil the former task, the pipe descriptors can either be copied to the `src/main/resources/pipes` directory before compilation. Alternatively, the descriptors can be managed using a GitLab repository. For this, a so-called cluster-config akin to the snippet shown in Figure 15 must be set.

```
PIVEAU_CLUSTER_CONFIG:

{
   "pipeRepositories": {
     "system": {
       "uri":
"https://gitlab.com/urbanite/harvesting-
pipes.git",
       "username": "gitlab-user",
       "token": "gitlab-token”,
       "branch": "master"
     }
  }
}
```

*Figure 15: PIVEAU_CLUSTER_CONFIG variable*

The Scheduler frequently polls this repository, thereby detecting changes to the pipe descriptors at runtime. In order to monitor pipe descriptors registered with the Scheduler, view their contents or launch them manually the component exposes a shell, accessible either via HTTP or Telnet. To enable this, a shell config like the one in Figure 16 must be set.

This exposes HTTP access at `{hostname}:8085/shell.html` and Telnet access on port 5000. The available shell commands are shown in Table 4.

```
PIVEAU_SHELL_CONFIG:

{
  "http": {
     "host": "0.0.0.0",
     "port": 8085
  }, "telnet": {
       "host": "0.0.0.0",
       "port": 5000
   }
}
```

*Figure 16: PIVEAU_SHELL_CONFIG variable*

*Table 4: Scheduler Shell Commands*

| Command | Description |
|---|---|
| pipes | List available pipes. |
| show {pipeId} | View contents specific pipe descriptor. |
| trigger {pipeId} | List triggers of specific pipe. |
| launch {pipeId} | Start specific pipe immediately. |

Management of triggers is made possible via an exposed RESTful API. The available paths and corresponding methods are listed in Table 5.

*Table 5: Scheduler API*

| Path | Method | Description |
|---|---|---|
| /triggers | GET | Get a list of pipe IDs and scheduled triggers. |
| | PUT | Bulk update of all triggers. |
| /triggers/{pipeId} | GET | Returns all triggers for the pipe with the specified pipeId. |
| | PUT | Create or update triggers for pipe with pipeId. |
| | DELETE | Delete previously created triggers. |

## 3.4 Licensing information

*Piveau consus* is published under Apache 2.0.

The software developed in the project is licensed under Affero General Public License (AGPL) version 3[8].

## 3.5 Download

All source code resides in the GitLab maintained by Tecnalia[9]. There, pilot specific components (i.e. data source adapters) are grouped in dedicated subgroups. Generic harvesters and components resign in the root.



[8] https://www.gnu.org/licenses/agpl-3.0.en.html
[9] https://git.code.tecnalia.com/urbanite/public/-/tree/main/data_management_platform/harvester

# 4 Delivery and usage [MESSINA Edge Component]

## 4.1 Package information

The Messina Edge Component comprehends different applications which allow to harvest and import data into a database and expose them via REST-API.

The architecture developed is composed of different parts: the internal GUI (Graphical User Interface) is realized in ReactJS; the parts of the Data-Importer and the Data-Processor are developed using Python and finally, the database is a NoSQL storage: MongoDB.

## 4.2 Installation instructions

In order to ease the deployment, all components are available as Docker images, for each of which a Dockerfile to build is provided.

The entire package is managed through a single *docker-compose* in which the services that can be deployed in the realised *edge* architecture are defined.

As a result, deployment can be performed by simply typing the command below from within the folder where the ***docker-compose.yml*** file is located:

```
$> docker compose up -d
```

If services need to be publicly exposed, the ports must be set appropriately. By default, the ports binded to the host are:

- port:8000 (GUI)
- port:8001 (Data-Processor)

It is recommended to use the volumes specified in the docker-compose configuration in order to have adequate data persistence.

## 4.3 User Manual

### 1.2.1 Data-Importer

In order to import data via the Data-Importer, it is necessary to write a python script for each data source to be placed in the following folder within the Data-Importer volume:

```
- importer/app/importers/<dataset_to_import>/
```

The script can be launched manually when needed, or in an automated manner in case the import needs to be cyclically repeated.

Once the script has been created, it can be executed by simply typing:

```
- docker exec urbanite-messina-importer python3
/app/importers/<dataset_to_import>/<script_name>.py
```

To import *Static* or *TimeSeries* data, the methods defined in the ***/app/db/mongo.py*** module should be used.

### 1.2.2 Configuration: Data-Processor

The Data-Processor configurations are located within the folder:

- /app/server/conf

There are three kinds of configuration:

1) **Data models**: the names of collections containing *static data* must be specified within the *StaticData class* in the ***models.py*** file. The names of the collections containing *TimeSeries data* within the *TimeSeriesCollection class*.

2) **Bucket structure for time-series data**: the bucket configuration of the specific collection must be entered into the collections key, indicating the appropriate values in the ***bucketconf.json*** file (as in the example below):

```
"rebuildCache": true,
"expandProperties": [true, false],
"matchFields": "path,road,QD",
"availabilityGranularity": "month",
"bucketGranularity": "day",
"bucketDateField": "date",
"bucketDataField": "data",
"bucketDateTimeField": "datetime",
"bucketProperties": ["len", "roadShape"],
"dataId": ["path", "road", "QD"],
"dataFields": ["JF", "SP", "SU", "FF", "CN"],
"aggregationAvailableOps": ["avg", "min", "max"],
"aggregationDataFields": ["JF", "SP", "SU", "FF", "CN"],
"bucketElementsName": "roads",
"groupByDatetime": {
  "groupResultsByDataField": "datetime",
  "entryKey": "roadKey"
},
"groupById": {
  "groupResultsByDataField": "k",
  "entryKey": "datetime"
}
```



3) **Tokens enabled for using the authenticated API**: the creation of tokens to access the realised API is done within the ***users.py*** file by specifying the token, the name and role of the user.

4) **Metadata**: they are defined in the file `/app/server/metadata/metadata.json` and, for each data source static or timeseries, a title, a description, a link, the list of formats, and the source have to be indicated. Other fields can be added optionally if needed.

# 5 Conclusions

Overall, this document describes the technical details of the components involved in the harvesting process. This includes the custom adapters for data sources, both generic and pilot specific as well as common components like the Scheduler. It is shown how these modules integrate into the general URBANITE data management platform architecture and the Piveau Pipe concept. The latter describes a mechanism of loose component coupling by standardising exposed APIs, thereby fostering the reuse of existing services. For developers, the deliverable contains instructions on how to develop Piveau pipe compliant services.

Additionally, noteworthy components like the Scheduler and the Messina Edge Components are described in detail with respect to implementation and configuration. A more general rundown of the other components is also provided. In conclusion, this deliverable allows the reader to get an understanding of the technical solution(s) employed for the continuous harvesting of data sources.



# 6 References

[1] FhG, TEC and ENG, “Data curation module implementation-v2,” 2022.

[2] TEC, C. Messina, ENG, BIL, MLC and FhG, “URBANITE Mobility Data Sources Analysis,” European Commission, 2020.

[3] FhG, TEC and ENG, “Data aggregation and storage module implementation-v2,” 2022.

[4] TEC, FhG, ENG and JSI, “URBANITE architecture,” 2021.

[5] F. Kirstein, K. Stefanidis, B. Dittwald, S. Dutkowski, S. Urbanek and M. Hauswirth, “Piveau: A Large-Scale Open Data Management Platform Based on Semantic Web Technologies,” 2020.

[6] FhG, TEC and ENG, “Data harvesting module and connectors implementation-v1,” 2021.

[7] FhG, TEC and ENG, “URBANITE data structure and semantic model specification,” 2020.

[8] TEC, FhG, ENG and JSI, “Detailed requirements specification,” 2020.