



Deliverable

D4.5 DUET standard reports and data analysis tools

Project Acronym:	DUET	
Project title:	Digital Urban European Twins	
Grant Agreement No.	870697	
Website:	www.digitalurbantwins.eu	
Version:	1.0	
Date:	08/06/2021	
Responsible Partner:	TNO	
Contributing Partners:	AIV, IMEC, KUL, AEG, VCS, P4ALL	
Reviewers:	Internal Leonidas Kallipolitis (AEG) Thomas Adolphi (VCS) Gert Vervaet (AIV) External Yannis Charalabidis Michiel Van Peteghem Andrew Stott	
Dissemination Level:	Public	X
	Confidential – only consortium members and European Commission	

Revision History

Revision	Date	Author	Organization	Description
0.1	17.03.2021	Max Schreuder	TNO	Initial structure
0.2	23.04.2021	Max Schreuder	TNO	TOC
0.3	21.05.2021	Philippe Michiels	imec	Completed section 2
0.4	22.05.201	Leonidas Kallipolitis Jurgen Silence Lieven Raes	AEG AIV	Chapter 3
0.5	02.06.2021	Max Schreuder	TNO	executive summary added
0.6	04.06.2021	Andrew Stott, Yannis Charalabidis, Christophe Stroobants		ready for review
1.0	7.06.2021	Max Schreuder	TNO	Final version

Table of Contents

1. Introduction	8
2. Data flow	9
2.1. Data Architecture in DUET	9
2.2. Data Lakes	10
2.3. Data Analysis Tools	10
3. Digital Twin related reports and tools	13
3.1. Introduction	13
3.2. Related user roles	13
3.3. Reporting tools	15
3.3.1. DUET 2D/3D base map	16
Goal	16
Target groups & Relevant Epics	16
Types	19
Functionalities	20
3.3.2. DUET Dashboards	29
Goal	29
Target groups & Relevant Epics	29
Types	31
Public dashboard	31
Expert dashboard	31
Examples	32
Functionalities	35
3.3.3. DUET Storytelling	38
Goal	38
Target groups & Relevant Epics	38
Types	41
Examples	41
Functionalities	43
3.3.4. DUET Gamification	44
Goal	44
Target groups & Relevant Epics	44

Techniques	45
Examples	45
Functionalities	48
3.4. Data Management and monitoring tools	50
3.4.1. Data catalog	50
Goal	50
Target groups & Relevant Epics	50
Types	51
Public Catalog of Datasources	51
Datasource Management	51
Examples	51
Functionalities	51
3.4.2. Infrastructure monitoring	52
Goal	52
Target groups & Relevant Epics	52
Types	52
Application Monitoring	52
Resource Monitoring	52
Examples	53
Functionalities	55
4. Conclusion	57

Overview of figures

Figure 1: DUET components are shown mapped to the smart data platform. Data is sourced from outside the system, transformed, aggregated, ... and finally mapped onto desired schemas and formats for use in models and reporting tools. For more details about Smart Data Management and SDP, we refer to Deliverable D3.2.	9
Figure 2: the integration of reporting tools (3D map, dashboard, storytelling) into a case presentation on the DUET landing pages.	15
Figure 3: Virtual City Systems viewer software.	20
Figure 4: Virtual City Systems map viewer details.	21
Figure 5: OpenStreetMap layer and terrain information (Flanders) as a basis for the VCS map viewer. Source: alpha & closed beta versions DUET.	22
Figure 6: LOD1 (Athens), LOD2 (Ghent, Flanders) and LOD3 (Pilsen) visualisations. Source: alpha & closed beta versions DUET.	24
Figure 7: integration of tree data and bus station data in Athens.	25
Figure 8: visualisation of traffic in Ghent and Antwerp (Flanders).	26
Figure 9: visualisation of NO ₂ -levels in Pilsen.	27
Figure 10: visualisation of noise pollution in Pilsen.	28
Figure 11: air quality dashboard.	32
Figure 12: night (A) and day (B) view on noise pollution in Europe, detailed view on road noise pollution (C) and basic information on exposure to noise for a city.	33
Figure 13: PoliVisu Schoolstraten dashboard, Mechelen (Flanders).	34
Figure 14: component of the general DUET dashboard structure.	35
Figure 15: component of the general DUET dashboard structure.	36
Figure 16: component of the general DUET dashboard structure.	36
Figure 17: example - storytelling European Council.	41
Figure 18: example - storytelling House of Commons Committees (UK).	42
Figure 19: example - storytelling Traffic Accidents Evolution in Flanders (BE).	42
Figure 20: BadgeOS gamification elements.	46
Figure 21: Former Klout ranking approach.	47
Figure 22: Example of Duolingo gamification elements.	48
Figure 23: visualising Kafka topics and clients.	53
Figure 24: web server access logs.	53
Figure 25: Kubernetes monitoring using external (top) or internal (bottom) dashboard visualisations.	54
Figure 26: monitoring of resources and deployed services via the cloud provider (Azure) monitoring dashboard.	55

Overview of tables

Table 1: some of the most used free open source Big Data tools.	12
Table 2: user roles and involved epics and user groups.	14
Table 3: DUET 2D/3D base map - involved user roles and epics.	18
Table 4: DUET 2D/3D base map - user stories.	28
Table 5: DUET dashboards - involved user roles and epics.	31
Table 6: DUET dashboards - user stories.	37
Table 7: DUET storytelling - involved user roles and epics.	40
Table 8: DUET storytelling - user stories.	43
Table 9: DUET gamification - involved user roles and epics.	45
Table 10: DUET data catalog - involved user roles and epics.	50
Table 11: DUET data catalog - user stories.	52
Table 12: DUET infrastructure monitoring - involved user roles and epics.	52
Table 13: DUET infrastructure monitoring - user stories	56

Executive Summary

DUET aims to support expert users (data analysts, policymakers, IT specialists) and citizens that wish to be involved in a co-creation process of policy-making and address their specific needs. To achieve this, DUET offers a set of technologies and expert tools of variable complexity. In this deliverable, we present the DUET features that enable the realisation of a multipurpose platform that addresses the needs of both expert users and citizens relating to reporting and analysis needs.

First, we describe how DUET supports the data processing needed for reporting and analyses purposes. Secondly, we present an overview of the identified user groups and list the available tools and components that fulfil the associated functional requirements. This is not a strict list and may be extended or updated depending on, e.g. new technical insights. Various reporting techniques and components are currently used in the closed beta version. Others we want to deploy soon.

The key to a successful big data strategy is smart data management. The DUET architecture facilitates any big data analytics supplier for the simple reason that data can always be delivered in any desired format and schema but, most of all, that the meaning of the data is well understood. Although the DUET project considers data lakes primarily out of scope, we point out that the concept of replicating or storing data nearby algorithms, processing systems, or reporting tools is very much compatible with the DUET architecture and fits well into the “storage to scale” approach. The DUET architecture can support different tools to process and handle data, information, and knowledge.

The different reports and tools we will test and use in DUET are described from the user roles and perspectives, Citizen, Policymaker, Urban planner, Entrepreneur and DUET administrator;

- 2D/3D maps to visualise cases, describing the use of software, base maps, 3D-building and POI views, and visualisations of traffic, air and noise data.
- Public and expert dashboards as a supporting reporting tool.
- Storytelling; we studied and selected existing tools we can use to integrate into cases presented in the DUET solution.
- Gamification elements which can be interesting to use in the DUET solution.

The data architecture, tools and associated reporting capabilities of DUET described in this deliverable will cover the needs of the different user groups. DUET’s data architecture is compatible with the ‘Data Lake’ concept.

However, refinement of user stories and emerging functional requirements has led to the current DUET approach. A data broker is responsible for handling data exchange among the simulation models and visualisations tools without storing it. This approach enables us to provide better and more complex simulation workflows, which will be realised in the upcoming versions of the platform while allowing more specialised data analysis tools to be employed for further data-oriented analysis of outcomes.

A set of examples and functionalities of the possible solutions has been presented and will be used as the basis to actually implement the reporting functionalities in the final version of the platform.

1. Introduction

This deliverable presents the DUET features that enable the realisation of a multipurpose platform which addresses the needs of both expert users (data analysts, policy makers, IT specialists) and citizens that wish to be involved in a co-creation process of policy-making. To achieve this, DUET offers a set of technologies and expert tools of variable complexity addressing different user needs.

Section 2 shows how DUET supports the data processing needed for reporting and analysis purposes. It maps the DUET onto the Smart Data Management Architecture (discussed in more detail in Deliverable D3.2) and explains how data lakes, that are often involved in heavy-duty analytics, fit into the architecture.

Section 3 presents an overview of the identified user groups, as detailed in D2.3, D6.1, and lists the available tools and components that fulfill the associated functional requirements. It must be noted that DUET's well-defined data access procedure, governed by an authentication and authorisation mechanism (D3.10) is the main way to ensure the differentiation of user roles and their access level to DUET components.

That being said, all DUET dashboards and interfaces offer a public facing version of visualisations and relevant customisation tools and reports to foster citizen inclusion in the decision making process via an engaging and meaningful manner.

On the other hand, most of the backend technologies mostly refer to users with a strong IT background and domain expertise in the Digital Twin domain who are looking to see how DUET addresses issues like interoperability, standardisation and data management in a smart city real-time digital representation.

Chapter 3 discusses the various reporting techniques and components we are currently using in the closed beta version, or we want to deploy in the near future. This is not a strict list and may be extended or updated depending on various factors such as new technical insights.

- The use of 2D/3D maps to visualise cases is explained. We describe the use of public and expert maps, and we look into more detail to the functionalities of this tool, defining finer-grained user stories describing the used software, base maps, 3D-building and POI views, and visualisations of traffic, air and noise data.
- We explain our plan to use public and expert dashboards as a supporting reporting tool using examples (visualisation of traffic, air and noise data) and by analysing the components of a generic dashboard model.
- Storytelling is another potent tool we plan to introduce in the DUET solution. Rather than developing our own tools, we studied and selected existing tools we can use to integrate into cases presented in the DUET solution.
- Gamification elements can be interesting to use in the DUET solution. These components can be combined with other tools. We go into more detail on the functionalities we have in scope for the DUET solution.

2. Data flow

2.1. Data Architecture in DUET

In DUET, data is accessed through a data broker that includes a data catalog where data publishers can register data sets or data services. Although this does not rule out that data sources reside locally to models and/or clients, it is not assumed that this is the case. Data from remote IoT stacks can be relayed to models that are part of yet another deployment.

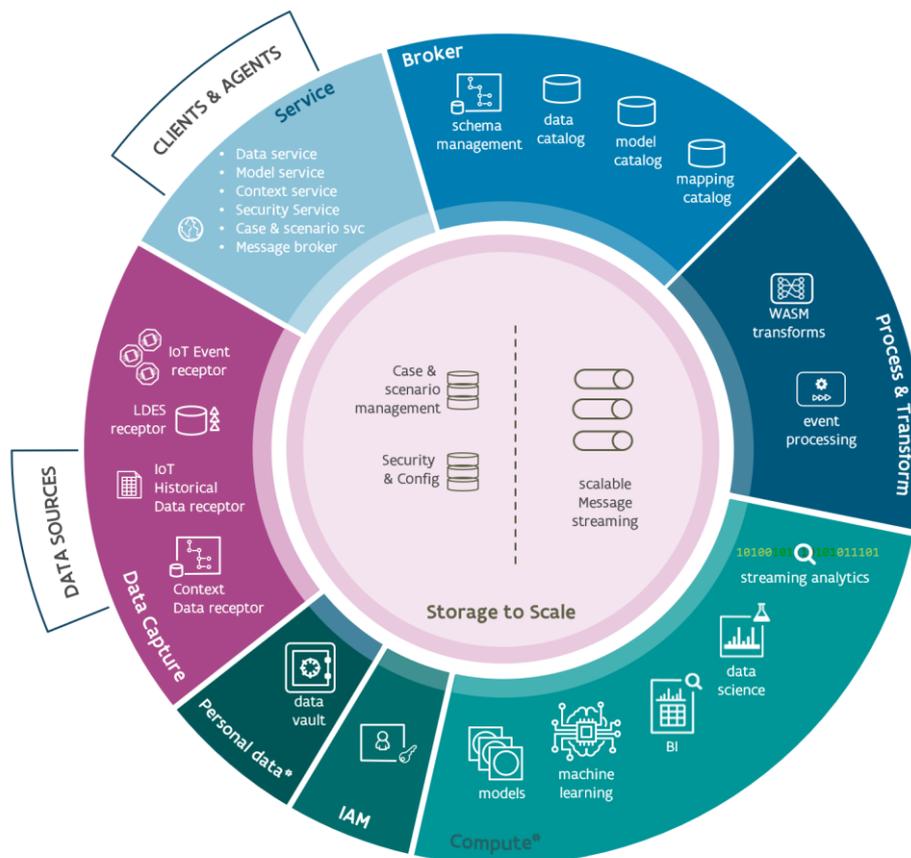


Figure 1: DUET components are shown mapped to the smart data platform. Data is sourced from outside the system, transformed, aggregated, ... and finally mapped onto desired schemas and formats for use in models and reporting tools. For more details about Smart Data Management and SDP, we refer to Deliverable D3.2.

The figure above shows how DUET components can be mapped onto the Smart Data Management reference architecture. Data flows across the components in the different domains as follows:

1. Data sources are discovered through the broker (Broker Domain)
2. Data is onboarded through components in the Capture Domain. This can be done in many ways ranging from IoT stack subscriptions to parsing CSV files.
3. The data is processed in smaller chunks typically as (bursts of) sensor measurements, geographical tiles, ... These messages are streamed to their respective consumers.
4. Depending on their needs, consumers can use tools and services in the Process and Transform Domain to make sure the data is in a usable form, i.e., in the correct format and compliant with a certain schema.
5. Using models, algorithms, data science tools and services, etc. the data is processed to produce other, more insightful data that can be used in graphs, reports, dashboards, or 2D/3D visualizations in the Compute Domain.

2.2. Data Lakes

Data can be stored in different ways. In some cases mostly for performance reasons, having data in proximity is a necessity. This can concern raw data (such as raw sensor streams or even video feeds) or data that is the result of applying processing to input streams. When the latency induced by having to fetch data just-in-time from remote systems is unacceptable, a data storage system capable of handling data sources of different origins and nature that runs close to the algorithms and/or reporting tools is needed. Such a system is called a data lake.

Although the DUET project does not discuss data lakes in much detail and considers it largely out of scope, we point out that the concept of replicating or storing data nearby algorithms, processing systems, or reporting tools is very much compatible with the DUET architecture. Datalakes fit well into the “storage to scale” approach as visualized in the centre of figure 1.

A data lake system can be for instance deployed on the same infrastructure where a simulation model is running. Instead of fetching the data just-in-time, subscriptions on one or more input sources aggregate data onto the local infrastructure in a way that allows the model to deal with it efficiently.

In the same way, the model may store its output on that local infrastructure. This data can easily be published as a data source on the digital twin as well by exposing it through a proper API that can connect with a DUET data receptor.

2.3. Data Analysis Tools

Data lakes are at the centre of big data processing tools. They provide storage for data and allow it to be prepared for further use by algorithms and analysis tools. There are many tools available for this purpose. Some are open source and free, some are commercial. We briefly discuss some of the most used free open-source products¹:

¹ Source: [Top 15 Big Data Tools \(Big Data Analytics Tools\) in 2021 \(softwaretestinghelp.com\)](https://www.softwaretestinghelp.com/top-15-big-data-tools-big-data-analytics-tools-in-2021/)

Tool	Description
Apache Hadoop	<p>Apache Hadoop is a software framework employed for clustered file systems and handling of (heterogenous) big data. It processes datasets of big data by means of the MapReduce programming model.</p> <p>Hadoop is an open-source framework that is written in Java and it provides cross-platform support. It is a typical weapon of choice for building data lakes.</p> <p>See Apache Hadoop website</p>
KNime	<p>KNIME stands for Konstanz Information Miner which is an open-source tool that is used for Enterprise reporting, integration, research, CRM, data mining, data analytics, text mining, and business intelligence. It supports Linux, OS X, and Windows operating systems.</p> <p>More info on the KNIME Software Overview KNIME website</p>
HPCC	<p>HPCC stands for High-Performance Computing Cluster. This is a complete big data solution over a highly scalable supercomputing platform. HPCC is also referred to as DAS (Data Analytics Supercomputer). This tool was developed by LexisNexis Risk Solutions.</p> <p>This tool is written in C++ and a data-centric programming language known as ECL(Enterprise Control Language). It is based on a Thor architecture that supports data parallelism, pipeline parallelism, and system parallelism. It is an open-source tool and is a good substitute for Hadoop and some other Big data platforms.</p> <p>See Home Page HPCC Systems website</p>
Apache Storm	<p>Apache Storm is a cross-platform, distributed stream processing, and fault-tolerant real-time computational framework. It is free and open-source. The developers of the storm include Backtype and Twitter. It is written in Clojure and Java.</p> <p>Its architecture is based on customized spouts and bolts to describe sources of information and manipulations in order to permit batch, distributed processing of unbounded streams of data.</p> <p>See the Apache Storm website</p>
Apache SAMOA	<p>SAMOA stands for Scalable Advanced Massive Online Analysis. It is an open-source platform for big data stream mining and machine learning.</p> <p>It allows you to create distributed streaming machine learning (ML) algorithms and</p>

	<p>run them on multiple DSPEs (distributed stream processing engines). Apache SAMOA’s closest alternative is BigML tool.</p> <p>See the SAMOA web site</p>
Apache Spark	<p>Apache Spark is an open-source framework for data analytics, machine learning algorithms, and fast cluster computing. This is written in Scala, Java, Python, and R.</p> <p>See the Apache Spark website</p>
Python	<p>Although not a big data framework by itself, Python is a very accessible environment and its libraries include many interesting free and non-free big data processing and machine learning tools making it a very popular programming language among data scientists.</p>
Lumify	<p>Lumify is a free and open-source tool for big data fusion/integration, analytics, and visualization.</p> <p>Its primary features include full-text search, 2D and 3D graph visualizations, automatic layouts, link analysis between graph entities, integration with mapping systems, geospatial analysis, multimedia analysis, real-time collaboration through a set of projects or workspaces.</p>

Table 1: some of the most used free open source Big Data tools.

Other popular (non-free or non-oss) tools include Tableau, Talend, Rapidminer, R, Cognos, PowerBI, etc. The list of tools and environments is endless. As we point out in deliverable D3.2, the key to a successful big data strategy is smart data management. From there the DUET architecture facilitates any big data analytics supplier for the simple reason that data can always be delivered in any desired format and schema but most of all, that the meaning of the data is well understood.

3. Digital Twin related reports and tools

3.1. Introduction

The Open Digital Twin architecture can support different tools to process and handle data, information, and knowledge. We dive deeper into the different reports and tools we will test and use in DUET from the user roles and perspectives. The following paragraphs start with an overview of the user roles and the various user groups that can undertake them and present the reports and tools that DUET has to offer in order to cover their needs.

3.2. Related user roles

Going further than a citizen/policy maker separation of users, WP2 work has delivered a fine-grained analysis of user groups and their role in the DUET environment. The following table summarises the identified user roles who were used to formulate the epics driving the implementation of the project. These roles will then serve as a reference for reports and tools mentioned in the next paragraph.

User Role/epics	Involved user groups
Citizen G4 - G14, G17	Pro-environment citizens: users who would like to become familiarized with the use of public means of transport in everyday life, to use less private vehicles, discover pedestrian areas in the city, adopt environmental consciousness and contribute to the air pollution reduction.
	3D data enthusiasts: users who will be able to access the 3D data of the city (open data, web service, API), with the goal to import it into other applications, play with the data, enrich it, create their own 3D visualizations of selected areas/buildings and share their work with the community.
	Students and policy-advocacy groups (e.g. NGOs): users who want to act like data contributors, evaluators, testers of proposed changes in the city (e.g. new green routes)
Policy maker G1 - G3, A1, P6, P8	City officials: users who would like to take initiatives and proceed with strategic activities to reduce noise, air pollution and traffic issues in their city. They need to have access to historical data of the city on mobility, parking and environmental measurements and tools to simulate proposed policies.
	City Domain Experts: users who want to know the impact of road closures, road redirections in the city and more specifically in neighbourhoods, to have insights into the mobility flows and on how changes in the traffic flow influence mobility and also to know the level and impact of air and noise pollution, the reasons and the impact

	<p>on citizens well-being in the city. They can then use their knowledge to propose new policies to city officials and policy makers.</p>
<p>Urban planner P1 - P5, P9</p>	<p>Urban planners: users who will understand trends in the historical noise/air pollution levels (at various spatiotemporal resolutions) and predict/model future scenarios, with the goal to propose measures to reduce noise levels (such as sound walls, rerouting traffic, green space, physical interventions, noise absorption materials) and to improve air quality. Their goal is also trying to achieve a higher quality of the public space by using tools that allow to better simulate, plan in scenarios (e.g. related to the urban planning) and regulate the future development of the city</p>
	<p>City 3D experts: users who will create high-res 3D models of selected public buildings or areas (e.g. the cathedral or football stadium) with the goal to stimulate the further use of the 3D data (both commercial and non-commercial) by the data enthusiasts, students and professionals.</p>
<p>Entrepreneur P7</p>	<p>Investors: users who will provide 3D data (as well as BIM data) of his envisaged major construction projects to the city, thus allowing the city administration to assess their project in 3D, with the goal to inform citizens about the project in the official digital twin of the city (under the 'future' view).</p>
	<p>Entrepreneurs/Local businesses: users who will use the city's 3D data for their business, with the goal to deliver better services to their customers.</p>
<p>DUET Admin G15 - G16</p>	<p>Administrators: users who are responsible to set up, operate and monitor the DUET platform from a technical perspective. They need to ensure adequacy of resources, enforcement of security policies and overall monitoring of the running system.</p>
	<p>Data Analysts: users that are responsible to manage models and assess resulting outputs so that on one hand digital twins realistically represent reality and on the other hand simulations produce reliable projections of future urban changes.</p>

Table 2: user roles and involved epics and user groups.

3.3. Reporting tools

In this paragraph, we follow a structured approach to present the reports and tools required to generate them. For every tool we present its goal, the target user roles, the different available types and examples of the produced outputs. We also specialise in the generic epics associated with every tool by describing more detailed user stories that present the requirements to be satisfied. Following the development progress, a number of detailed user stories has been already put in the development roadmap, whereas functionalities to be developed at the future releases are described with examples and toolsets that provide the envisioned implementation and are subject to adjustments according to the continuous assessment of users during the agile development process.

The integration of reporting tools into the case presentation on the DUET landing pages was explained and demonstrated to the pilots in the month of April 2021. The following figure shows a case detail page on the landing pages. Depending on the case specifications, more in-depth insights can be gained by clicking hyperlinks, pointing to various reporting tools (2D/3D-Map visualisations, dashboards, storytelling and gamification). This will be described in detail in this chapter.



Figure 2: the integration of reporting tools (3D map, dashboard, storytelling) into a case presentation on the DUET landing pages.

3.3.1. DUET 2D/3D base map

Goal

2D and 3D map visualisations will be used to visualise various aspects of **cases**.

A **case** can best be described as an entry into the platform part of the DUET, which requires a set of visualisations that are suitable for a certain analysis, discussion, policy action/decision and so on. Depending on the case, datasets will be selected, settings filled in, models will be chosen for data analysis, dashboards created, a location and zoom level is chosen, ...

Target groups & Relevant Epics

2D and 3D map visualisations will be used by all user roles mentioned in the list of epics (public servants, citizens, city officials, urban planners, investors and policymakers) for a vast majority of all epics.

User Role	Epic No	Epic description
Public servant	G1	<p>As a public servant of a relevant department (mobility, spatial planning and environmental department,...)</p> <p>I want to see the difference in density of traffic in the area of interest of a scenario where I closed traffic in a set of roads versus the base density,</p> <p>so I can assess the impact of changes to the local situation on the traffic in my area of interest</p>
	G2	<p>As a public servant of the mobility or environmental protection department,</p> <p>I want to know the level and impact on air pollution when certain roads would be closed</p> <p>so I can discover causes of air pollution and the impact on citizens well-being in the city</p>
	G3	<p>As a public servant of the mobility or environmental protection department,</p> <p>I want to know the level and impact of noise pollution when certain roads would be closed,</p> <p>so I can discover causes of noise pollution and the impact on citizens well-being in the city</p>
Citizen	G4	<p>As a citizen,</p> <p>I want to understand the predicted impact of scenarios related to new city developments, calculated using functionality used for what-if analysis,</p>

		so I can give feedback about scenarios
	G5	As a citizen, I want to be able to vote and give feedback about scenarios related to new city developments,calculated using functionality based on other epics, so I can participate in those designs
	G6	As a citizen, I want to see the current traffic flow in the city based on the model and available sensors so I can inspect the current traffic density
	G7	As a citizen, I want to see the current noise pollution in the city based on the model and available sensors so I can inspect the current level of noise pollution
	G8	As a citizen, I want to see the current air pollution in the city based on the model and available sensors so I can inspect the current level of air pollution
	G9	As a citizen, I want to see the historic traffic flow in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G10	As a citizen, I want to see the historic noise pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G11	As a citizen, I want to see the historic air pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G12	As a citizen, I want to see the predicted air pollution based on the model, sensors and predicted weather in the city based on the model and available sensors so I can inspect the near future situation of air pollution
City official	A1	As a city official,

		<p>I want to see the public transport in the city based on static datasets (Urban transport datasets includes timetables, routes and locations of stations) so I can assess the situation and elaborate on new strategic plans for interconnecting public transport</p>
Urban planner	P1	<p>As an urban planner I want to see all existing attributes for buildings and objects in 3D representation of the city so I can work with different data sources in a single environment</p>
	P2	<p>As an urban planner I want to see all existing attributes for public space such as surfaces, public green, tree informations (tree type, height, diameter of trunk, diameter of treetop) so I can work with different data sources in a single environment</p>
	P3	<p>As an urban planner I want to see Z dimension for all objects and surfaces (streets, pavements etc.) so I can work with the z dimension as it is not supported by current GIS solution used by city.</p>
	P9	<p>As an urban planner or 3D expert I want to import/export the 3D buildings or objects (incl. high-resolution 3D models of selected public buildings or areas, e.g. the cathedral or football stadium) from/to the digital twin so I can further enrich and keep the digital twin up to date</p>
Investor	P7	<p>As an investor, I want to provide 3D data (as well as BIM data) of my envisaged major construction project to the city, thus allowing the city administration to assess my project in 3D, so I can inform citizens about my project in the official digital twin of the city (under the 'future' view).</p>
Policy maker	P8	<p>As a policy maker, I want to make the 3D data of the city available as open data (see data section for already opened data), so I can engage the techie community and students to enrich the data and develop new services with the data. The city balances the relevance of opening the data with policy objectives, the price, the relevant level of granularity and so on.</p>

Table 3: DUET 2D/3D base map - involved user roles and epics.

Types

Public maps and datasets

Public map visualisations and datasets are available for all citizens.

Via the DUET landing pages, **cases** are presented in detail to the visitors. On the case detail pages, visitors can click hyperlinks to access map visualisations, dashboards, stories and gamification elements. The presented map views are focused on the public interest. The DUET pilots will be able to make and publish such visuals.

Expert maps and datasets

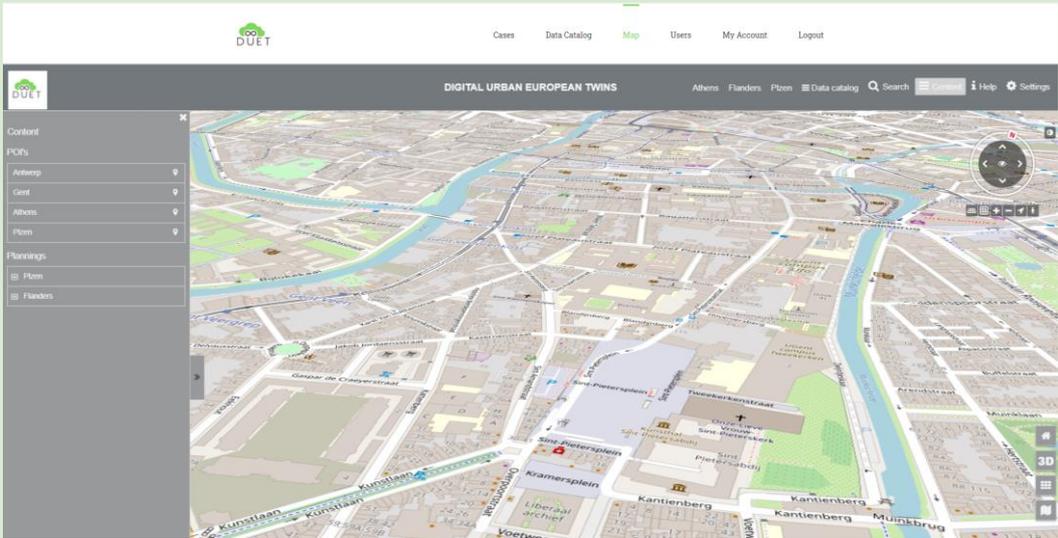
Experts can request a password, enabling them to make visualisations themselves. Also in this password-protected environment, admin users have access to standard maps and datasets. By combining maps and data layers and by adjusting the settings (location, zoom level, orientation/tilt level, dataset specification, ...) custom visualisations can be created.

Experts can further:

- upload their own datasets (in different file-formats) to be included into the map visualisation toolbox;
- access datasets/layers/models that are not available for other expert groups (or pilots). These datasets can be combined with the publicly available datasets;
- access to extra data within the same dataset (for example fine-grained or historic data);
- access more functionalities/technologies (such as HPC) to develop more accurate state-of-the-art visualisations;

Functionalities

The user story provides more detail on the Epics listed in the Ambitions² document. This description is translated into JIRA tasks, handled by the technical team.

User story	Epic nrs.
<p>User story As a DUET user (public servant, citizen, city official, urban planner, investor, policy maker), I want to have handy viewer software available, so I can visualise DUET case aspects.</p> <p>Our solution We will use the viewer software of Virtual City Systems. More details about the different components and how the package works can be found in Deliverable 4.4, DUET visualization Components v1.</p>  <p>Figure 3: Virtual City Systems viewer software.</p>	<p>G1-G12, A1, P1-P3, P7-P9</p>

² https://docs.google.com/spreadsheets/d/1L9o91u0_dBgCVOlesBwN1tsJmpMtssbQjd_XXmJdEc/edit#gid=0

 <p style="text-align: center;">Figure 4: Virtual City Systems map viewer details.</p>	
<p>User story As a DUET user (public servant, citizen, city official, urban planner, investor, policy maker), I want to have base 2D/3D maps available, so I can add interesting data layers and models on top of it.</p> <p>Our solution At this stage of the DUET project, we have a few data layers available that can serve as a basis to map datasets and models. Examples are: the OpenStreetMap, the GRB basemap and a layer of orthophotos for Flanders and the terrain model for Pilsen and Athens.</p>	<p>G1-G12, A1, P1-P3, P7-P9</p>

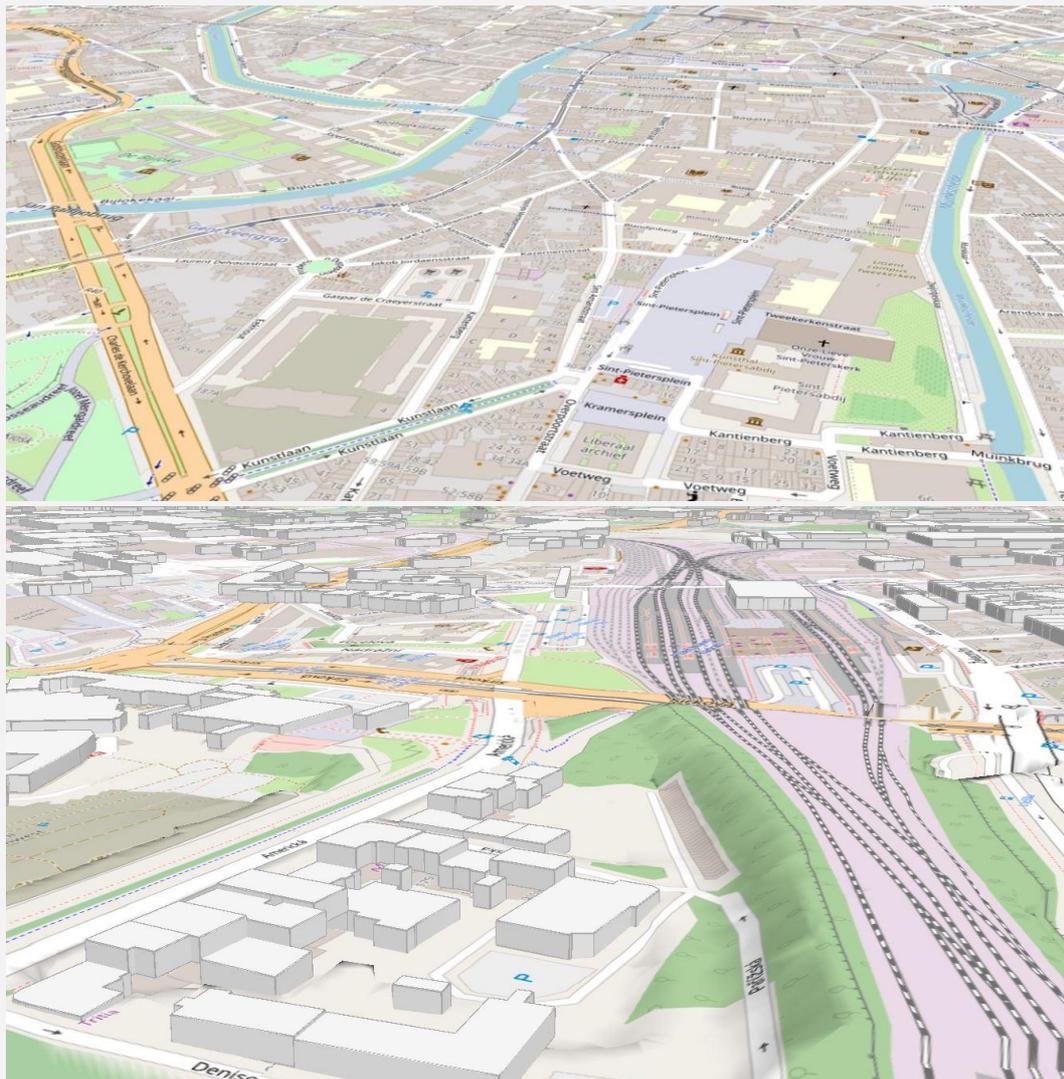


Figure 5: OpenStreetMap layer and terrain information (Flanders) as a basis for the VCS map viewer. Source: alpha & closed beta versions DUET.

Uses story

As an urban planner, 3D-expert or investor,
I want to see, import, export 3D-buildings in the digital twin
so I can integrate the buildings in my view.

Our solution

We plan to support integration of buildings with LoD 1, 2 and 3:

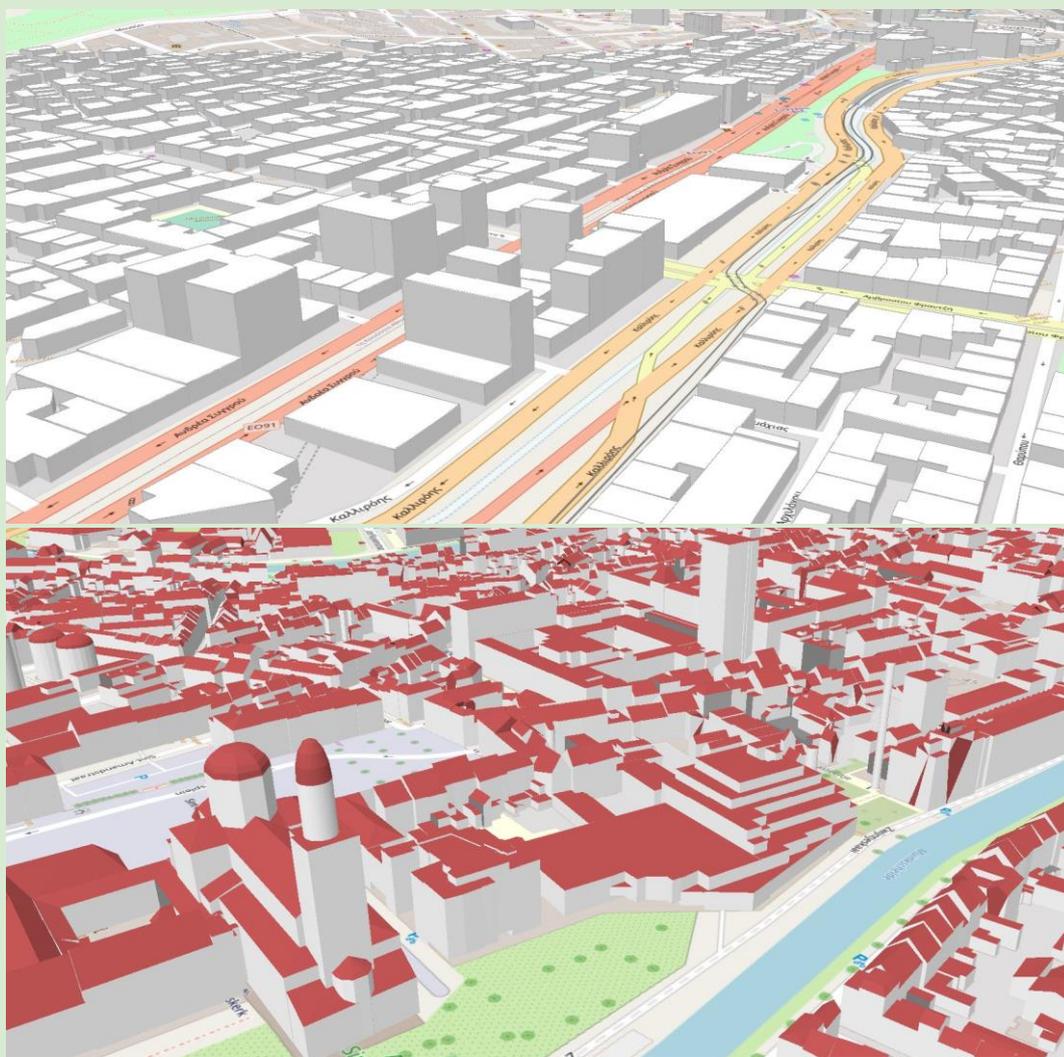
- **LoD1:** for every building or building part the generalized outer shell is represented by exactly one prismatic extrusion solid. Ground, floor, and roof surfaces must be horizontal, lateral boundary surfaces must be vertical.
- **LoD2:** for every building or building part the geometrically simplified outer shell is represented by horizontal resp. vertical outer surfaces and simplified roof shapes. All kinds of surfaces (e.g. ground surfaces, wall surfaces, roof surfaces, outer

P1, P3, P7,
P9

ceiling surfaces, outer floor surfaces, virtual closure surfaces) and additional building elements (e.g. building installations like balconies, dormers and chimneys) may be represented as semantic objects.

- **LoD3:** for every building or building part the geometrically detailed outer shell is represented by detailed outer surfaces and detailed roof shapes. All kinds of surfaces (e.g. ground surfaces, wall surfaces, roof surfaces, outer ceiling surfaces, outer floor surfaces, virtual closure surfaces) and additional building elements (e.g. building installations like balconies, dormers and chimneys) may be more detaily represented as semantic objects. In respect to LoD2 doors and windows can be modeled as planar thematic objects.

Some examples from the DUET alpha and closed beta versions:



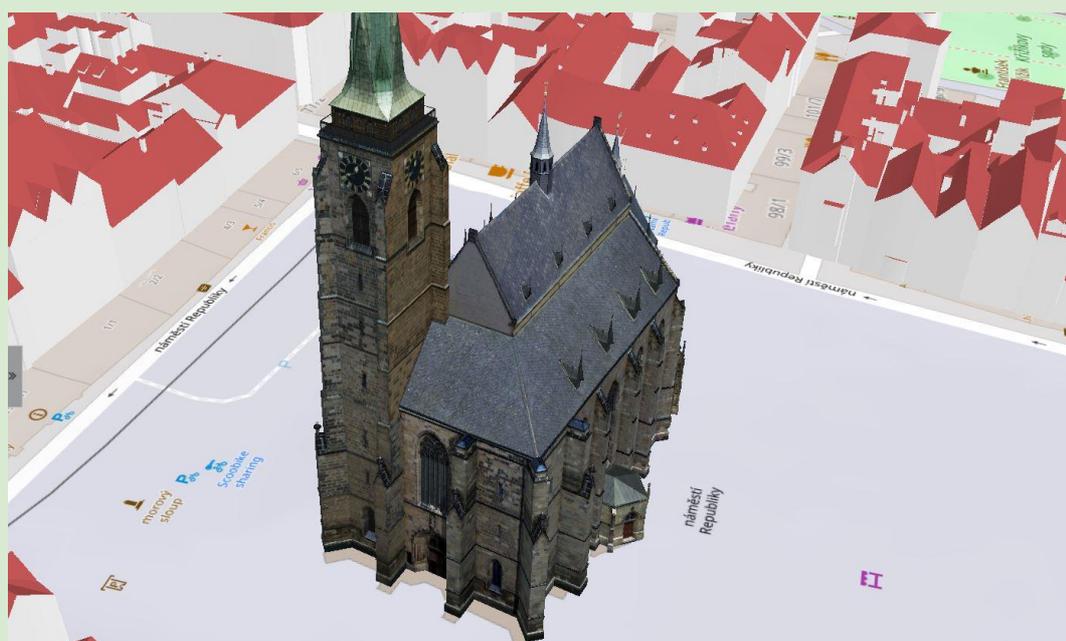


Figure 6: LOD1 (Athens), LOD2 (Ghent, Flanders) and LOD3 (Pilsen) visualisations. Source: alpha & closed beta versions DUET.

User story

As an urban planner, 3D-expert or investor,
I want to see, import, export POI and public domain elements (e.g. trees) in the digital twin
so I can integrate the POIs in my view.

Our solution

We plan to support the integration of POIs and public domain elements. Clicking a POI or public domain element will open a pop-up window showing detailed information about the POI or public domain element (if available).

Some examples from the DUET alpha and closed beta versions:

A1, P1, P9



Figure 7: integration of tree data and bus station data in Athens.

User story

As a public servant or citizen,

I want to see the historic, current and/or predictive traffic density and speed in the city based on the model and available sensors,

so I can inspect the current, historic and/or future situation and evaluate the impact of past/upcoming measures.

Our solution

Motorised traffic intensity and speed will be visualised using colour codes and varying height of the various road segments. Clicking on a road segment will trigger a pop-up window, showing detailed information as demonstrated by the image below.

Another way of visualising traffic was tested for a restricted area in Antwerp (Flanders). The use of various modes of transport (pedestrians, bicycles, cars, vans and trucks) in time is visualised by dynamic graphs. Historic and real-time data are shown.

G1, G6, G9

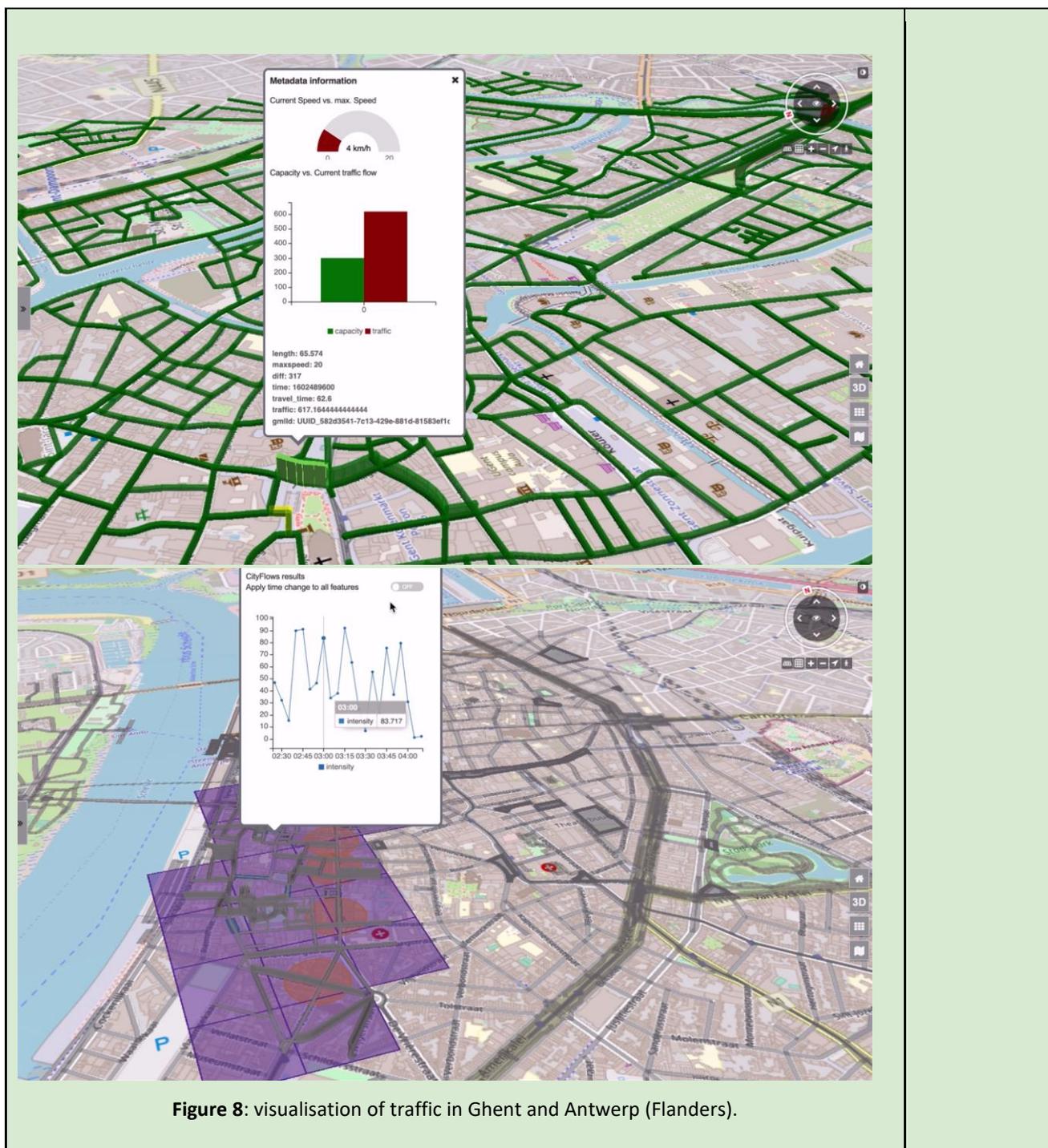


Figure 8: visualisation of traffic in Ghent and Antwerp (Flanders).

User story

As a public servant or citizen,

I want to see the historic, current and/or predictive air pollution in the city based on the model and available sensors, so I can inspect the current, historic and/or future situation and evaluate the impact of past/upcoming measures.

Our solution

Air quality sensor data will be visualised by using bars with varying z-components and

G2, G8, G11, G12

colours (related to the concentration of the pollutants). When clicked, detailed sensor information will be shown in a pop-up window as shown below.

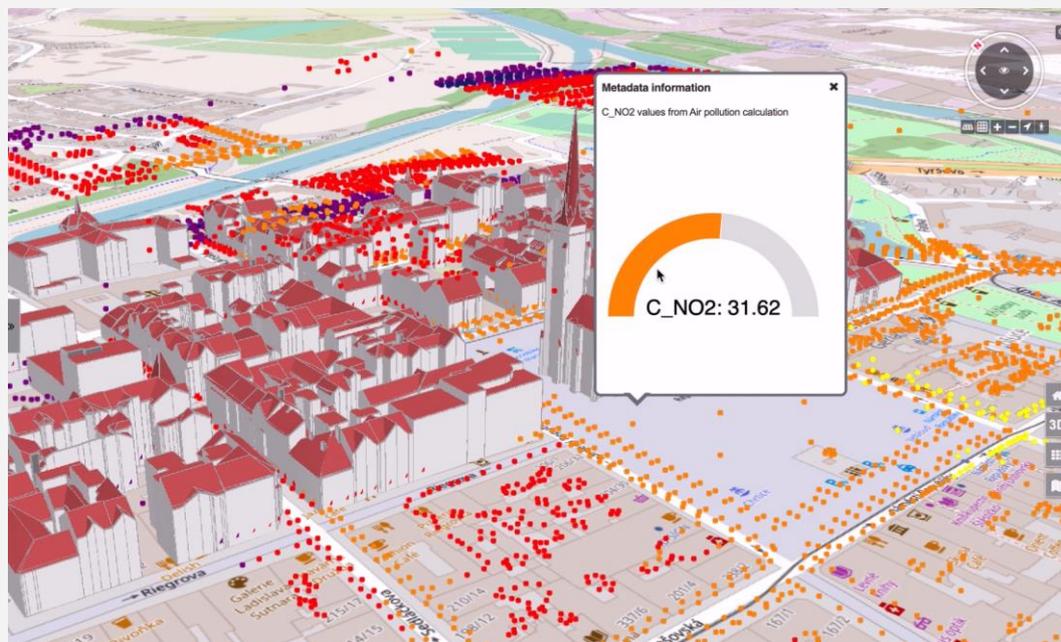


Figure 9: visualisation of NO2-levels in Pilsen.

User story

As a public servant or citizen,
 I want to see the historic, current and/or predictive noise pollution in the city based on the model and available sensors,
 so I can inspect the current, historic and/or future situation and evaluate the impact of past/upcoming measures.

Our solution

The different aspects of noise pollution can be visualised in a grid model or by a fluent 3D graph. Clicking grid points or graph segments result in a pop-up window with detailed information. Colour codes and bar heights are used to distinguish measured values. Various aspects of noise pollution are measured, as seen on the graph below.

G3, G7, G10



Table 4: DUET 2D/3D base map - user stories.

3.3.2. DUET Dashboards

Goal

A dashboard is a tool that provides visual representation of key performance indicators (KPIs) and other metrics. The information can be in the form of graphs, charts, or maps and with options for users to further drill down the data.

Data dashboards provide an objective view of performance metrics and serve as an effective foundation for further dialogue. A dashboard is a business intelligence tool used to display data visualisations in a way that is immediately understood.

Target groups & Relevant Epics

The epics below reflect those epics where a dashboard could give added value. During the next iterations, a more concrete choice will be made based on the input of the pilots. A dashboard can combine multiple epics in a single dashboard to pinpoint and emphasize the relation between the outcomes of multiple epics.

User Role	Epic No	Epic description
Public servant	G1	As a public servant of a relevant department (mobility, spatial planning and environmental department,...) I want to see the difference in density of traffic in the area of interest of a scenario where I closed traffic in a set of roads versus the base density, so I can assess the impact of changes to the local situation on the traffic in my area of interest
	G2	As a public servant of the mobility or environmental protection department, I want to know the level and impact on air pollution when certain roads would be closed so I can discover causes of air pollution and the impact on citizens well-being in the city
	G3	As a public servant of the mobility or environmental protection department, I want to know the level and impact of noise pollution when certain roads would be closed, so I can discover causes of noise pollution and the impact on citizens well-being in the city
Citizen	G4	As a citizen, I want to understand the predicted impact of scenarios related to new city developments, calculated using functionality used for what-if analysis,

		so I can give feedback about scenarios
	G6	As a citizen, I want to see the current traffic flow in the city based on the model and available sensors so I can inspect the current traffic density
	G7	As a citizen, I want to see the current noise pollution in the city based on the model and available sensors so I can inspect the current level of noise pollution
	G8	As a citizen, I want to see the current air pollution in the city based on the model and available sensors so I can inspect the current level of air pollution
	G9	As a citizen, I want to see the historic traffic flow in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G10	As a citizen, I want to see the historic noise pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G11	As a citizen, I want to see the historic air pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G12	As a citizen, I want to see the predicted air pollution based on the model, sensors and predicted weather in the city based on the model and available sensors so I can inspect the near future situation of air pollution
	G14	As a citizen, I want to have the possibility to contribute with data I can collect, so I can provide more data sources
City official	A1	As a city official, I want to see the public transport in the city based on static datasets (Urban transport datasets includes timetables, routes and locations of stations) so I can assess the situation and elaborate on new strategic plans for interconnecting public transport

Urban planner	P4	As an urban planner I want to style object based on available attributes so I can make custom analysis and visualisations
Policy maker	P6	As a policy maker, I want to motivate investors of major development projects to provide 3D data during the building planning and permission process, so I can (i) inform citizens of the future evolution of the city and (ii) to achieve a higher architectural quality of the urban space.

Table 5: DUET dashboards - involved user roles and epics.

Types

Public dashboard

For the public dashboards, we will focus on citizens. We will offer them low level, AS IS information of general public interest, presented in a comprehensible and well-arranged manner. To do so, we use various representation techniques (graphs, bar charts, pie charts, tables, icons, data grids, ...) and styling (use of colour codes, text styling, ...).

Expert dashboard

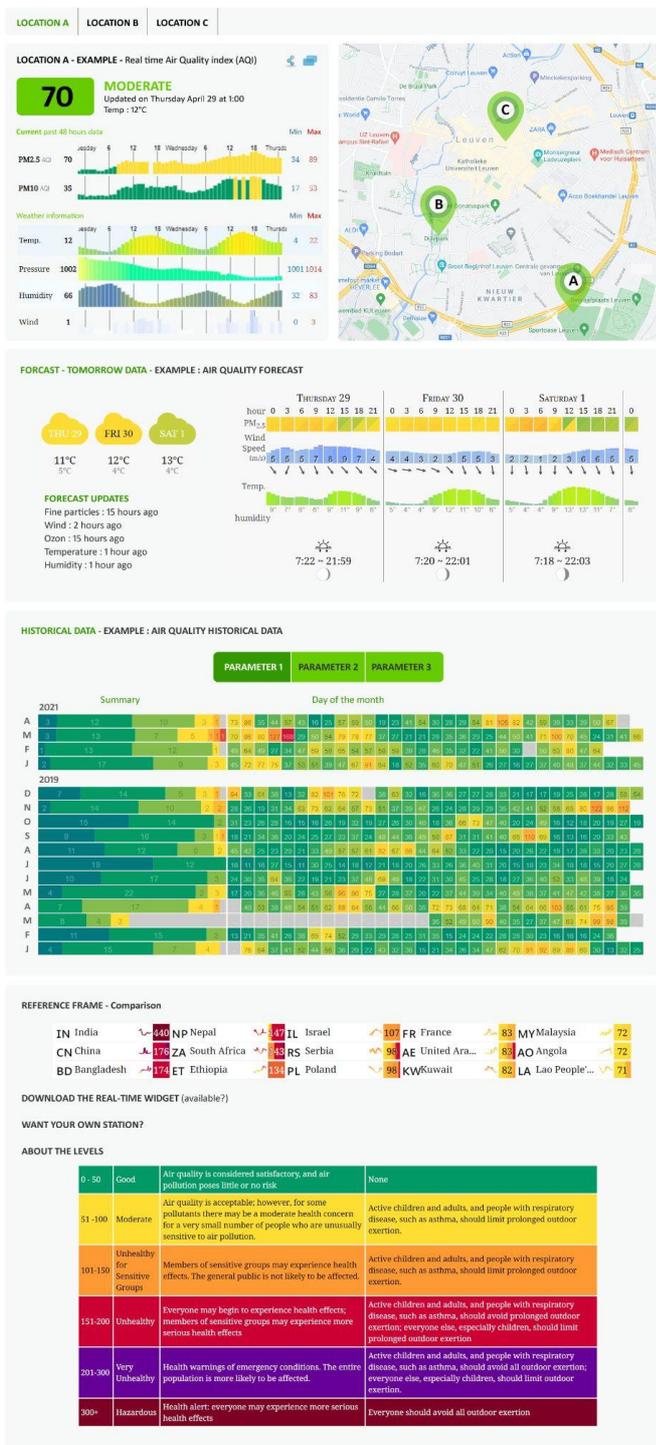
Expert dashboards are available to policymakers, urban planners and city officials. Extra elements are available on top of the public dashboards.

- Access to extra datasets/models set available to a limited target group. These datasets can be uploaded and combined with the generally available DUET datasets.
- Access to more data inside a dataset. For example, more historical data, going further back into time.
- Access to restricted (highly demanding) technologies (such as HPC and complex simulations), resulting in more accurate datasets and model outcomes;
- Access to extra visualisation options by connecting external visualisation tools to the DUET core.

Examples

For the 3 pilots, we focus on dashboards visualising traffic, air quality and noise.

AIR



- A good example is the World Air Quality Index project, <https://aqicn.org>.
- A first mock-up translation to the DUET environment is shown in image x.
- The mock-up contains real time information (top), predictions and historic data interpretations.

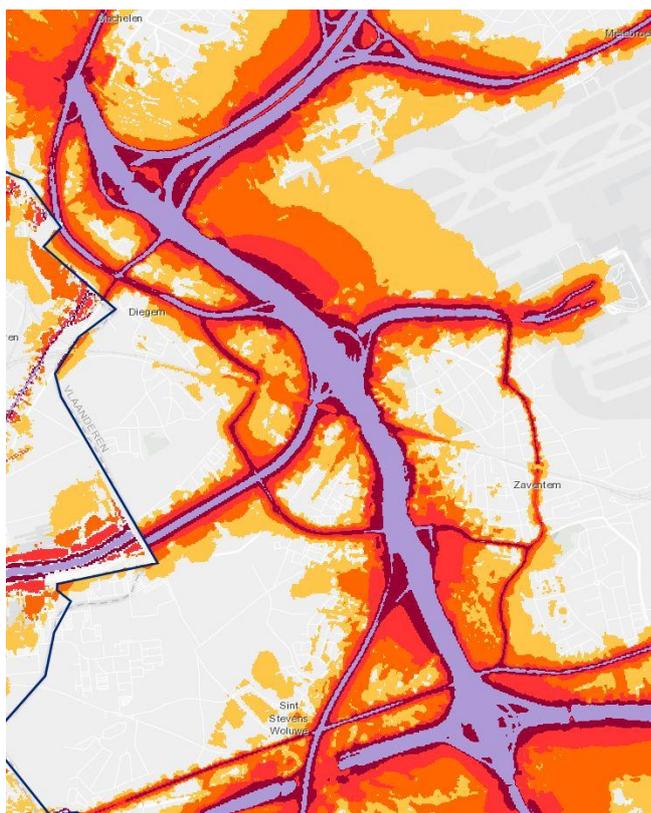
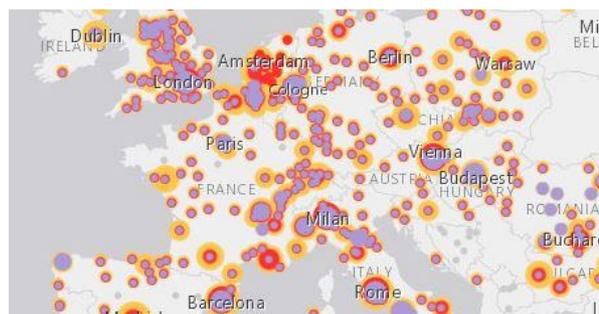
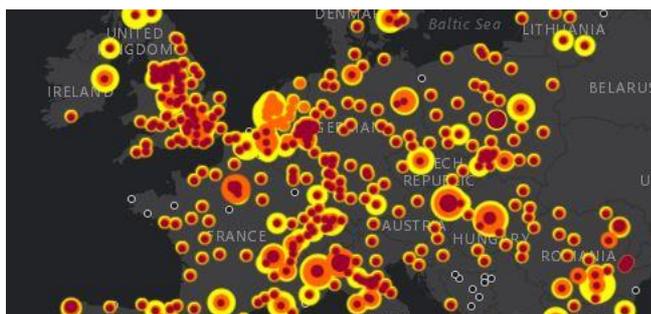
Figure 11: air quality dashboard.

NOISE

EU indicators for noise pollution (European Environment Agency)

<https://noise.eea.europa.eu/>

Different sources of noise pollution are taken into account: roads, railways, airports and industry. For each source of data, a distinction is made between data gathered during the day or during nighttime. Specific information about the exposure to noise pollution at city-level is shown when clicking a city with data available.



Madrid

In Madrid, a total of **1.124.300** people are exposed to night-time average sound levels of **50 dB** or higher from **road traffic**.

Number of people exposed to high levels of **road traffic noise in Spain (L_{night} ≥ 50dB)**

Spain	8.569.100
Inside urban areas	8.297.500
Outside urban areas	271.600

Madrid

Total number of people exposed per each noise band for **Roads-L_{night}**.

Figure 12: night (A) and day (B) view on noise pollution in Europe, detailed view on road noise pollution (C) and basic information on exposure to noise for a city.

TRAFFIC

Schoolstraten dashboard (H2020 PoliVisu project)

<https://schoolstraten.polivisu.eu/#/projects>

The Schoolstraten dashboard was designed to support an evaluation report investigating the impact of the policy to introduce schoolstreets in Mechelen, Flanders.

- Goal: display the difference in distribution over the different traffic modes before and after the introduction of a schoolstreet, in the street of the school as well as in the neighbouring streets.
- Data: count of cars, bicycles, trucks, and pedestrians per hour as measured in a street.
- Visualisation: A set of graphs connected to a time window selected by the end-user. The graphs show the number of people travelling using a specific mode of traffic. When a second time window is selected, the delta between the periods is shown as well.

To make the dashboard really drive the policy-making, a KPI was defined, measuring the number of bicycles in the street of the school. The agreed target for this school is 100 bicycles. As the weather has a potentially significant impact on the number of cyclists, this is shown in the dashboard as well.

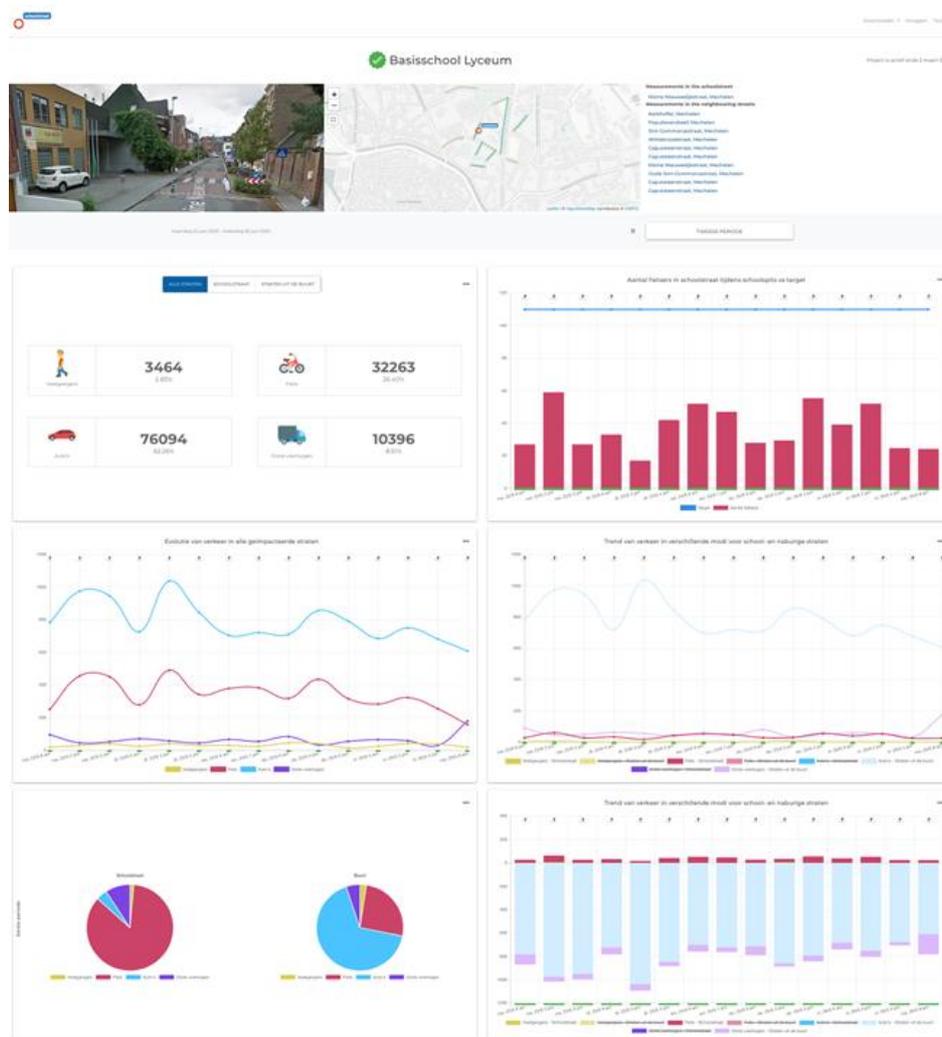


Figure 13: PoliVisu Schoolstraten dashboard, Mechelen (Flanders).

Functionalities

We see the following components to be part of the DUET dashboard:

Current information (YTT - Today)

- Selection of the area of interest on a scalable map with indication of the measurement locations. Easily switch location by clicking map or tabs. Use of colours for different types of measurement stations.
- Past 48 hours graph data. Graphs in function of time, if applicable, put graphs measuring different aspects under each other on the same scale so they can be compared easily. Example: PM2.5, PM10 (air quality) graphs and weather information (like temperature, humidity, wind) all under each other. Option to switch on/off graphs.
- Option to share this dashboard via different channels, option to see aspects full screen.

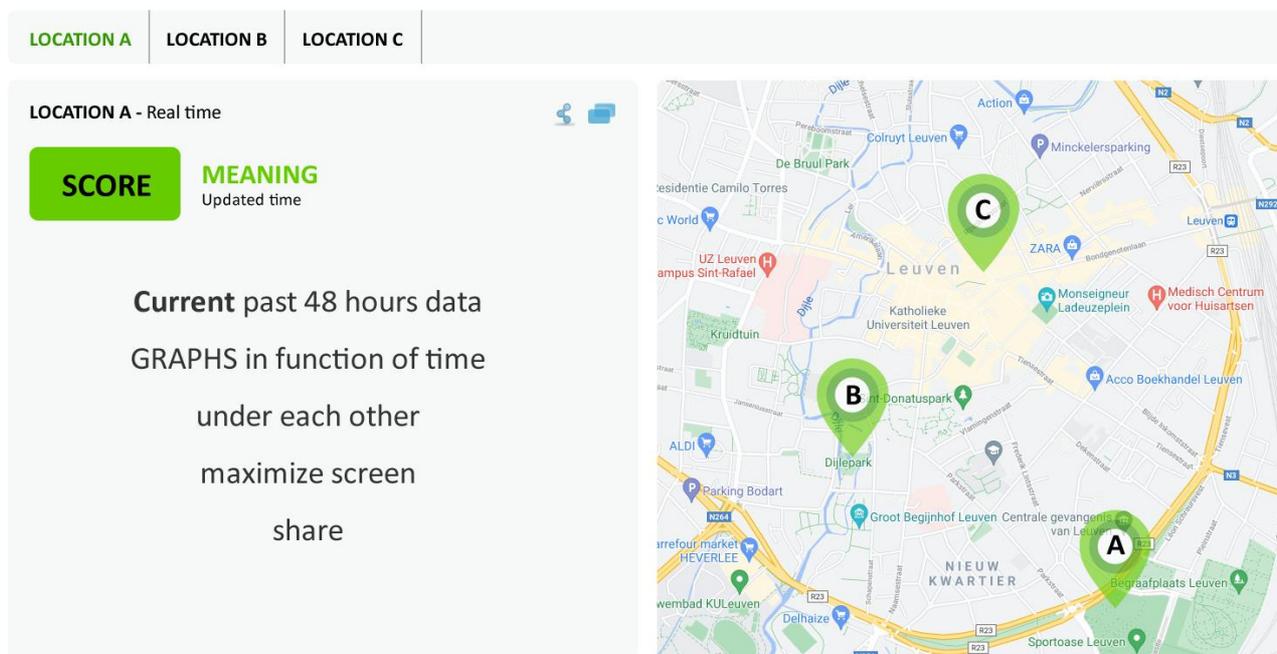


Figure 14: component of the general DUET dashboard structure.

Forecast data (YTT - Tomorrow) - if available

- Model-based prediction
- Example 3 days forward
- Graphs handling aspects in time, under each other, option to toggle layers on/off
- The set of graphs are repeated for the 3 days. The graphs are shown next to each other, so a visual comparison is immediate
- Basic information used to make the prediction + indication of the time that the last measurement was performed



Figure 15: component of the general DUET dashboard structure.

Historical data (Y - Yesterday) - if available

- Showing the evolution/behaviour of a parameter over time.
- Time = days, months, years. Example: horizontal - days, vertical - months & years
- Option to evaluate all parameters separately
- Use of colours helps to efficiently pick up trends

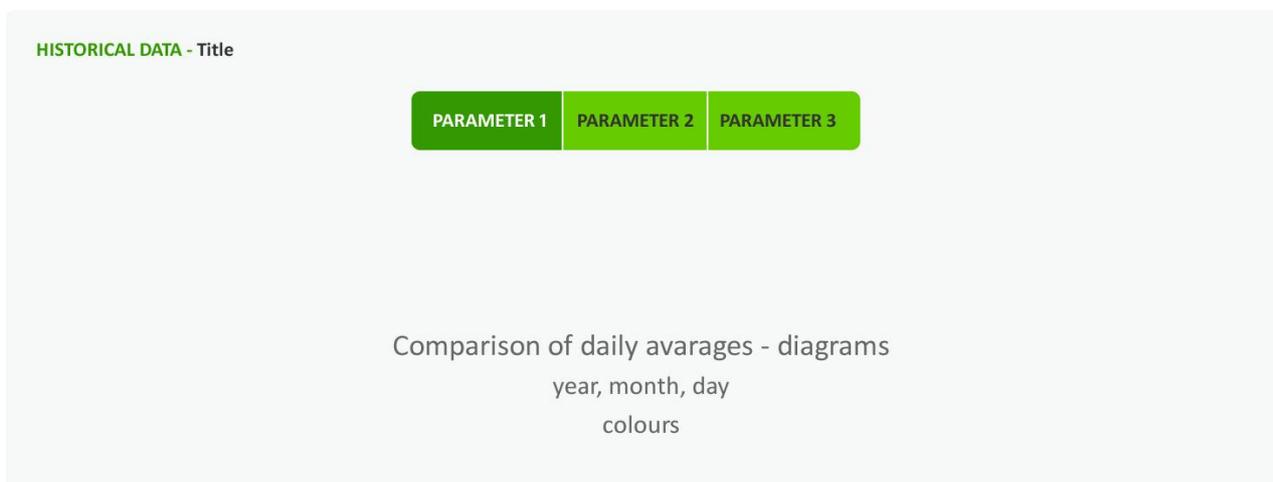


Figure 16: component of the general DUET dashboard structure.

The user stories underneath provide more detail on the Epics listed in the Ambitions³ document. This description is translated into JIRA tasks, handled by the technical team.

User story	Epic nrs.
As a citizen, I want to select an area, street segment, measuring station or sensor, so I can consult the dashboard.	G1-G4, G6-G12, G14, A1, P4, P6
As a citizen, I want to know which dataset and models are integrated into the dashboard, the timestamp of the included measurements and the meaning of the used color codes / symbols, ... so I can correctly interpret the dashboard.	G1-G4, G6-G12, G14, A1, P4, P6
As a citizen, I want to know the individual impact of different parameters that are measured into the dashboard, so I can investigate the importance of each parameter mentioned in the dashboard.	G1-G4, G6-G12, G14, A1, P4, P6
As a citizen, I want to browse the real time data in the dashboard, so I can understand the actual situation.	G1-G4, G12, G14, A1, P4, P6
As a citizen, I want to browse the historic data in the dashboard, so I can understand the historic situation and make a comparison with the actual situation.	G6-G8, G14, A1, P4, P6
As a citizen, I want to browse the predictive data in the dashboard, so I can understand the future impact of model simulation scenarios.	G1-G4, G12, A1, P4, P6
As a citizen, I want to share the dashboard, so I can disseminate this specific type of data presentation.	G1-G4, G6-G12, G14, A1, P4, P6

Table 6: DUET dashboards - user stories.

³ https://docs.google.com/spreadsheets/d/1L9o91u0_dBgCVOlesBwN1tsJmpMtssbQjd_XXmJDdEc/edit#gid=0

3.3.3. DUET Storytelling

Wikipedia⁴ describes storytelling as the social and cultural activity of sharing stories, sometimes with improvisation, theatrics, or embellishment. Every culture has its own stories or narratives, which are shared as means of entertainment, education, cultural preservations or instilling moral values.

The term “storytelling” can refer in a narrow sense specifically to oral storytelling and also in a looser sense to techniques used in other media to unfold or disclose the narrative of a story.

Goal

The goal of storytelling in a Digital Twin is to explain complex policy-related outcomes to target groups like citizens and local businesses. A story can emphasize the results of a policy decision, the process towards a policy (proposal/decision), the reasoning, the context and can explain potential alternatives. A story can also enlighten the different perspectives (for example, from the viewpoint of different personas).

Target groups & Relevant Epics

The target groups will depend on the use case. But in general, the target groups are:

- **Citizens** are probably the largest target groups that can be further split up depending on the needs. Citizens can be considered as non-expert users with limited data literacy. Sketching the context in a neutral way, giving insights based on evidence are cornerstones together with using neutral and insightful graphics. The focus is often on the societal impact of smart city measures. An important specific group in terms of language are young people.
- **Local businesses** and economic actors are an important group of non-government related professional actors with specific needs. The stories towards this group are more oriented to the economic impact compared to citizens.
- **Policymakers** are a large group representing public servants and politicians. Storytelling can be an instrument for a large organisation to share policy outcomes and results with experts working in other policy domains or managers/politicians with a broader overview of city processes.

⁴ <https://en.wikipedia.org/wiki/Storytelling> (10/5/2021)

Relevant epics:

The epics below reflect those epics where a dashboard could give added value. During the next iterations, a more concrete choice will be made based on the input of the pilots. It is to be expected that many of the stories will overarch multiple epics. This is for example the case when historical data and predictions (results of what if analysis) will be combined.

User Role	Epic No	Epic description
Citizen	G4	As a citizen, I want to understand the predicted impact of scenarios related to new city developments, calculated using functionality used for what-if analysis, so I can give feedback about scenarios
	G5	As a citizen, I want to be able to vote and give feedback about scenarios related to new city developments,calculated using functionality based on other epics, so I can participate in those designs
	G6	As a citizen, I want to see the current traffic flow in the city based on the model and available sensors so I can inspect the current traffic density
	G7	As a citizen, I want to see the current noise pollution in the city based on the model and available sensors so I can inspect the current level of noise pollution
	G8	As a citizen, I want to see the current air pollution in the city based on the model and available sensors so I can inspect the current level of air pollution
	G9	As a citizen, I want to see the historic traffic flow in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G10	As a citizen, I want to see the historic noise pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
	G11	As a citizen, I want to see the historic air pollution in the city based on the model and

		<p>available sensors</p> <p>so I can inspect the historic situation and evaluate the impact of past measures</p>
	G12	<p>As a citizen,</p> <p>I want to see the predicted air pollution based on the model, sensors and predicted weather in the city based on the model and available sensors</p> <p>so I can inspect the near future situation of air pollution</p>
	G13	<p>As a citizen,</p> <p>I want to express interest as a volunteer tester of green routes proposed by the city</p> <p>so I can validate the expected results and contribute prior to the actual implementation.</p>
	G14	<p>As a citizen,</p> <p>I want to have the possibility to contribute with data I can collect,</p> <p>so I can provide more data sources</p>
Policy maker	P6	<p>As a policy maker,</p> <p>I want to motivate investors of major development projects to provide 3D data during the building planning and permission process,</p> <p>so I can (i) inform citizens of the future evolution of the city and (ii) to achieve a higher architectural quality of the urban space.</p>
	P8	<p>As a policy maker,</p> <p>I want to make the 3D data of the city available as open data (see data section for already opened data),</p> <p>so I can engage the techie community and students to enrich the data and develop new services with the data. The city balances the relevance of opening the data with policy objectives, the price, the relevant level of granularity and so on.</p>
Investor	P7	<p>As an investor,</p> <p>I want to provide 3D data (as well as BIM data) of my envisaged major construction project to the city, thus allowing the city administration to assess my project in 3D,</p> <p>so I can inform citizens about my project in the official digital twin of the city (under the 'future' view).</p>

Table 7: DUET storytelling - involved user roles and epics.

Types

There are several storytelling products on the market delivering comparable features. There are noticeable difference between the products in terms of:

- Interaction (especially regarding non-linear interaction)
- interactive maps availability
- media integration

Examples

European Council (EU)⁵ - Explaining the facts about global warming

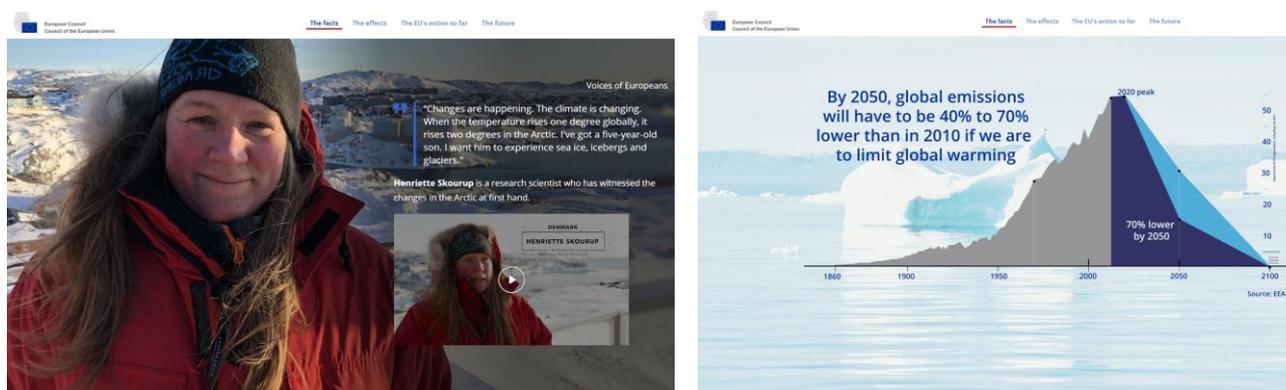


Figure 17: example - storytelling European Council.

The EU Council climate story “Taking the lead on climate change” is a good example of a linear story combining interactive graphs with interviews to support a climate-neutral future. The story also combines insights into the current emission situation based on scientific results and long-term goals to reduce global warming.

⁵ <https://www.consilium.europa.eu/en/eu-climate-change/>

House of Commons Committees (UK)⁶

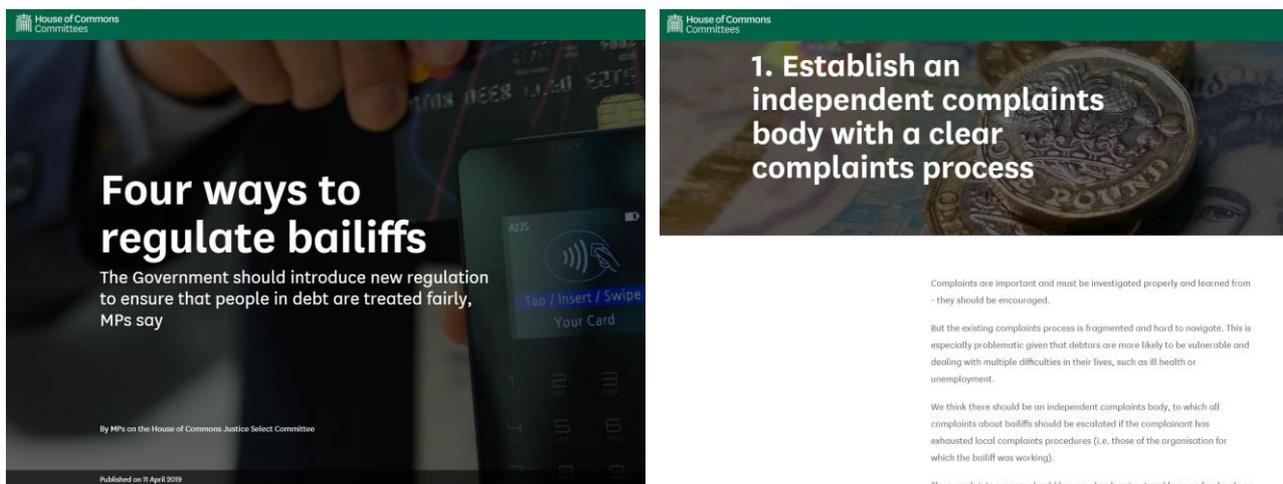


Figure 18: example - storytelling House of Commons Committees (UK).

The UK house of commons "Four ways to regulate bailiffs" is a straightforward example of how regulation can be presented clearly and comprehensively. The linear story draws attention by using a simple structure and providing the basic information needed. The story is a perfect replacement for a 4-page leaflet.

Traffic Accidents Evolution in Flanders (BE)⁷

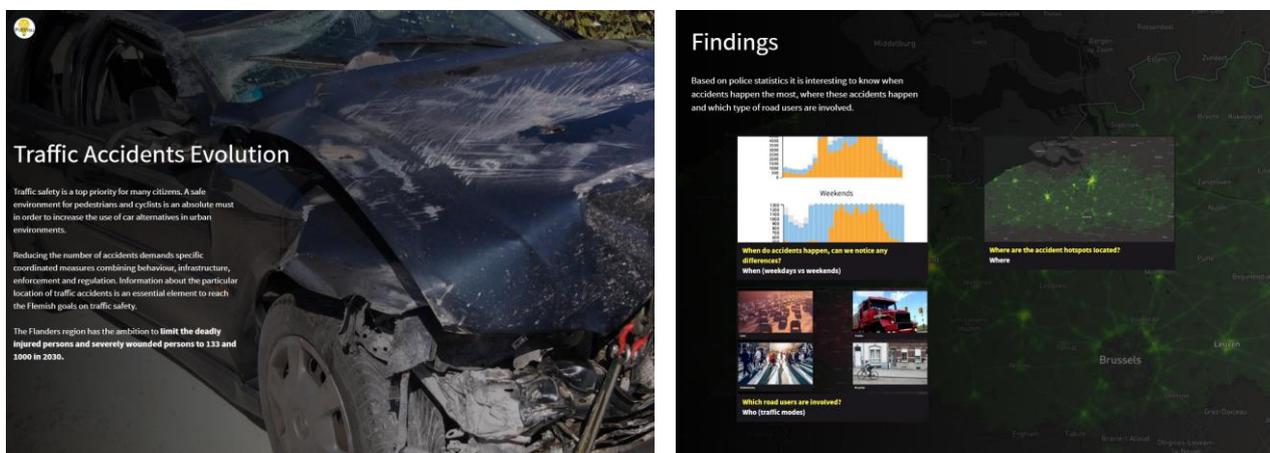


Figure 19: example - storytelling Traffic Accidents Evolution in Flanders (BE).

The Flanders Interactive Accident map created during the PoliVisu H2020 project provides in-depth insights into the accident's moment, place, and severity. An interactive story was created to lower the interactive map threshold and to highlight relevant conclusions in a non-linear narrative. As a user, you can shift between different locations and traffic modes to get better and more detailed insights.

⁶ <https://houseofcommons.shorthandstories.com/justice-committee-bailiffs/index.html>

⁷ <https://polivisu.pageflow.io/flanders-accident-map#215197>

Functionalities

The user stories underneath provide more detail on the Epics listed in the Ambitions⁸ document. This description is translated into JIRA tasks handled by the technical team.

User stories

User story	Epic nrs.
As a DUET user, I want to login into the open source storytelling tool, so I can create/modify/delete/save a story.	G4-G14, P6-P8
As a DUET user, I want to add text (WYSIWYG-editor), images, videos, dynamic map compositions, ... in a user friendly and intuitive way, so I can share my story with others.	G4-G14, P6-P8
As a DUET user, I want to customize my story (subdivisions/steps, pagination/navigation, styling ...) so I can make it more attractive.	G4-G14, P6-P8
As a DUET user, I want to make stories in different languages and I want to have a unique and user friendly URL, so I can maximally disseminate my story.	G4-G14, P6-P8

Table 8: DUET storytelling - user stories.

⁸ https://docs.google.com/spreadsheets/d/1L9o91u0_dBgCVOlesBwN1tsJmpMtssbQjd_XXmJDdEc/edit#gid=0

3.3.4. DUET Gamification

Goal

Gamification can be described as the addition of game mechanics into the nongame Duet environments. The goal of gamification is to engage visitors to inspire, collaborate, share and interact.

Target groups & Relevant Epics

The epics below reflect those epics where a dashboard could give added value. During the subsequent iterations, a more concrete choice will be made based on the input of the pilots. Similar to, e.g. storytelling, multiple epics can be combined for gamification.

User Role	Epic No	Epic description
Citizen	G4	As a citizen, I want to understand the predicted impact of scenarios related to new city developments, calculated using functionality used for what-if analysis, so I can give feedback about scenarios
Citizen	G5	As a citizen, I want to be able to vote and give feedback about scenarios related to new city developments, calculated using functionality based on other epics, so I can participate in those designs
Citizen	G9	As a citizen, I want to see the historic traffic flow in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
Citizen	G10	As a citizen, I want to see the historic noise pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
Citizen	G11	As a citizen, I want to see the historic air pollution in the city based on the model and available sensors so I can inspect the historic situation and evaluate the impact of past measures
Citizen	G12	As a citizen,

		<p>I want to see the predicted air pollution based on the model, sensors and predicted weather in the city based on the model and available sensors</p> <p>so I can inspect the near future situation of air pollution</p>
Citizen	G13	<p>As a citizen,</p> <p>I want to express interest as a volunteer tester of green routes proposed by the city</p> <p>so I can validate the expected results and contribute prior to the actual implementation.</p>

Table 9: DUET gamification - involved user roles and epics.

Techniques

In the framework of the DUET project, we think of a few techniques enhancing the interaction with citizens. These techniques can be perfectly combined with other reporting tools.

Example/showcase - comparison of multiple scenarios

The introduction of a green zone can be investigated/simulated in two different locations. The effects on air quality and traffic are taken into account as well.

- Both scenarios can be documented by map visuals and dashboards.
- All information can be presented in a comprehensive and well-arranged way using a storytelling tool.
- As icing on the cake, gamification elements can be introduced, triggering citizens to give feedback on the scenarios. What is the best scenario? What is missing? Is there another alternative scenario? What are your suggestions, remarks or questions?

Examples

Gamification⁹ is a means of influencing behaviour, promoting learning and even problem solving by using the theory and principles of game mechanics¹⁰. At its simplest, it is the act of taking an existing process such as completing a survey or filling in a user profile and adding game elements to make it more fun and attractive to users. On the other end of the spectrum is serious games¹¹ which mainly applies to educational video gaming and simulations.

⁹ [The Ultimate Definition of Gamification \(With 6 Real World Examples\) \(growthengineering.co.uk\)](https://growthengineering.co.uk)

¹⁰ [Game mechanics - Wikipedia](https://en.wikipedia.org/wiki/Game_mechanics)

¹¹ [Serious game - Wikipedia](https://en.wikipedia.org/wiki/Serious_game)

DUET will tap into the potential of gamification to try and ‘hook’ users in positive forms of behaviour that others will be prompted to adopt and outdo via naturally competitive instincts. By introducing gamification into Smart City thinking, DUET aims to transcend the current limitations of bottom-up innovation in a manner that ultimately results in a growing number of new users for the pilots as well as encouraging a new number of Urban Digital Twins for collaborative policy decisions within cities across Europe.

Using fundamental psychology to understand and connect the mission of the DUET’s cities with the motivations of the user means gamification can be a complex task for web portals and software solutions and should always be considered at the start of the design process. Consideration needs to be given to the desired outcome, i.e., does the public sector want quality or quantity of outcomes; how much time does the Digital Twin manager want to spend on managing interactions; how often would a user realistically need to use the service?

To keep things simple for users DUET will start off with gamification measures based on proven popular tactics adopted by other solutions. At this stage a ‘one-size fits all’ approach will be adopted which can be enhanced in the future. It’s important to note that not all users like game elements so it’s good practice to offer users the choice to ‘opt-out’ of gamification. Methodologies for consideration include:

- **Points based achievements** – leverages positive reinforcement that allows users to set goals, earn badges, and gain some form of higher status, e.g., Fitbit badges and trophies¹² for walking a certain distance.

As DUET presents a new way of collaborating and working with data for many users badges can be awarded as they progress from "rookie" to "expert" depending on how many actions a user performs e.g. 0-5 rookie | 6-12 expert | 13-25 moderator. Funny names like “Social Butterfly” to "Good Samaritan" can be adopted for people who answer a specific number of questions in forums, or "Top Cartographer" for some who created over 10 maps, or "Data Supremo" for someone who uploaded over 20 datasets. BadgeOS¹³ is a WordPress plugin which can be used to design, create and manage a badge achievement strategy.



Figure 20: BadgeOS gamification elements.

¹² [Presenting the Official List of Fitbit Badges. How Many Do You Have?](#)

¹³ [Home - BadgeOS](#)

- **Competition** – competition between other users or to get a result (win a prize) or a personal high score, e.g. Klout¹⁴ used to provide a number that measured and ranked your impact on social media, Twitter¹⁵ shows how many followers each user has to imply popularity and many commercial websites run competitions to encourage users to return.

This approach can be combined with the points-based achievement approach above or be adopted by itself. For DUET a leaders table or score could be given for neighbourhood klout or ‘missions’ set to find things hidden in the maps around a specific social challenge, to encourage data uploads, provide feedback or encourage other desired behaviours.



Figure 21: Former Klout ranking approach.

- **Rules of Play** – guide user through what to do in a short period of time (2 to 5 mins) combined with fast feedback when a user does something correctly, e.g. woo-hoo achievements such as those used on Duolingo who uses an avatar to build a teacher/student relationship with the users.

Elements of this approach could be useful for users who are unfamiliar with map-based data. An animated star, congratulations yes you’ve done it message with positive words of encouragement popping up on the screen when a user does something correctly on the Digital Twin e.g. Create a new map composition, or add new contextual information to a map (upload photo or written observation) gives the user an immediate sense of success and confidence to explore/work further.

¹⁴ [Wanna' Know How Your Klout Score is Really Calculated? | Social Media Today](#)

¹⁵ [You're Being Played By Twitter - Associate's Mind \(associatesmind.com\)](#)



Figure 22: Example of Duolingo gamification elements.

This approach could be useful for users who are unfamiliar working with map-based data. An animated star, congratulations, yes you've done it message with positive words of encouragement could pop up on the screen when a user does something correctly on the Digital Twin e.g. Create a new map composition, or add new contextual information to a map (upload photo or written observation). This approach gives the user an immediate sense of success and confidence to explore/work further.

- **Self expression** – stimulating collaboration such as answering questions on a message board, liking the comments or maps of others, sharing content such as on Twitter or Facebook.

Making it easy to respond to the content and ideas of others, to build and share content around a social (policy) need/goal/objective/challenge can be combined with other elements described above. For message boards it's important to ensure responses are engaged with quickly, that the user is notified by email when there is a response to their message/thread to keep dialogue open and encourage others to join the conversation.

Functionalities

We think that the following gamification techniques have strong potential to enhance interaction with citizens.

- **Voting** for the best scenario
- **Liking** scenarios, comparable to Facebook likes
- Option to **share** scenarios via various social media channels
- **Rating the scenarios - rating scale**
<https://www.questionpro.com/blog/rating-scale/>

A rating scale can be defined as a closed-ended survey question used to represent respondent feedback in a comparative form for specific particular features/products/services/scenarios. The rating scale is a variant of the popular multiple-choice question, which is widely used to gather information that provides relative information about a specific topic. There are four primary types of rating scales that can be suitably used in DUET online surveys:

- **Graphic rating scale** indicates the answer options on a scale of 1-3, 1-5, etc. Likert scale is a popular graphic rating scale example. Respondents can select a particular option on a line or scale to depict rating.
 - **Numerical rating scale** has numbers as answer options. Not each number corresponds to a characteristic or meaning.
 - In a **descriptive rating scale**, each answer option is elaborately explained to the respondents. A numerical value is not always related to the answer options in the descriptive rating scale.
 - **Comparative rating scale**, as the name suggests, expects respondents to answer a particular question in terms of comparison, i.e. on the basis of relative measurements or keeping other organizations/products/features/scenarios as a reference.
- **Feedback form.** Give written comments/opinions, ask questions, suggest ideas to improve the scenarios.
 - **Questionnaire / survey / quiz / poll**
Various aspects of scenarios (with various approaches) can be investigated by asking specific questions to the citizens.
 - **Participation / cocreation initiatives**
Using a platform/forum, a community of interested citizens can be created. Together they can create new scenarios.
 - The Introduction of **challenges**
By clearly presenting a policy question and providing the necessary tools, individual citizens may be triggered to create their own DUET solution as a possible scenario to meet the question.

3.4. Data Management and monitoring tools

3.4.1. Data catalog

Goal

The goal of data management tools is to provide both expert and non-expert groups of DUET users the ability to use data sources that are either already offered in the platform or can be added by them by using the available processes.

Target groups & Relevant Epics

User Role	Epic No	Epic description
Citizen Citizen	G14	As a citizen, I want to have the possibility to contribute with data I can collect, so I can provide more data sources for my city.
	G17	As a citizen, I want to see only the datasources that are relevant so I don't see confidential information
Urban Planner	P9	As an urban planner or 3D expert I want to import/export the 3D buildings or objects (incl. high-resolution 3D models of selected public buildings or areas, e.g. the cathedral or football stadium) from/to the digital twin so I can further enrich and keep the digital twin up to date
DUET Admin	G15	As a DUET admin, I want to be able to connect datasources so I can be sure that the necessary data and information is available
	G16	As a DUET admin, I want to be able to restrict the access to datasources so I can be sure confidential data is not made publicly available

Table 10: DUET data catalog - involved user roles and epics.

Types

Public Catalog of Datasources

The publicly facing datasource catalogue gives the non-expert user groups the possibility to search for available datasources via the 2D/3D Map interfaces and quickly add them to their current visualisations.

Datasource Management

DUET's data catalogue services and accompanying ontology and data models allow experts to register their datasources, restrict access to them and use them for calibrating simulation models so as to support complex simulation scenarios.

Examples

Detailed description of the Data Catalog and relevant data management capabilities are given in D3.8.

Functionalities

The user story provides more detail on the Epics listed in the Ambitions¹⁶ document. This description is translated into JIRA tasks, handled by the technical team.

Detailed User Story	Epic nrs.
As a DUET citizen, I want to be able to have a list of all available resources and their metadata so I can search for one of my interest to view it on a map	G17
As a DUET citizen/urban planner, I want to be able to manage (add, edit, delete) my data resource so I can contribute to community and use it for a new map	G14, G15, P9
As a DUET admin/urban planner, I want to be able to set licensing and access rights to datasources so I can ensure confidentiality and privacy of data	G16
As a DUET admin, I want to be able to have a list of all available resources and their metadata (region, license, category, format, etc)	G15, G16

¹⁶ https://docs.google.com/spreadsheets/d/1L9o91u0_dBgCV0lesBwN1tsJmpMtssbQjd_XXmJDdEc/edit#gid=0

so I can be aware of data catalogue status	
As an urban planner/ DUET ADMIN I want to be able to request data access for registered data sources / models	G16, P9

Table 11: DUET data catalog - user stories.

3.4.2. Infrastructure monitoring

Goal

The goal of infrastructure monitoring is to provide an overview of the status of DUET resources, services and processes in order to ensure uninterrupted operation or, when this is not possible, foster root cause analysis of malfunctions, performance degradations or other operation affecting incidents.

Target groups & Relevant Epics

User Role	Epic No	Epic description
DUET Admin	G18	As a DUET admin, I want to be able to monitor platform status so I can adjust resource allocation and investigate logged errors or misuse

Table 12: DUET infrastructure monitoring - involved user roles and epics.

Types

Application Monitoring

Tools to monitor DUET at application level may include monitoring of the Message Broker (Kafka status), the web servers (access/error logs) and the DUET APIs(health status). Informative error logging is a best practice followed during DUET’s software development lifecycle (D3.10), therefore application errors will be collected and presented to administrators who will then assess them and proceed with corrective actions.

Resource Monitoring

DUET’s cloud infrastructure as well as HPC facilities will be monitored to check resources like CPU utilisation, memory consumption, kubernetes pods, etc.

Examples

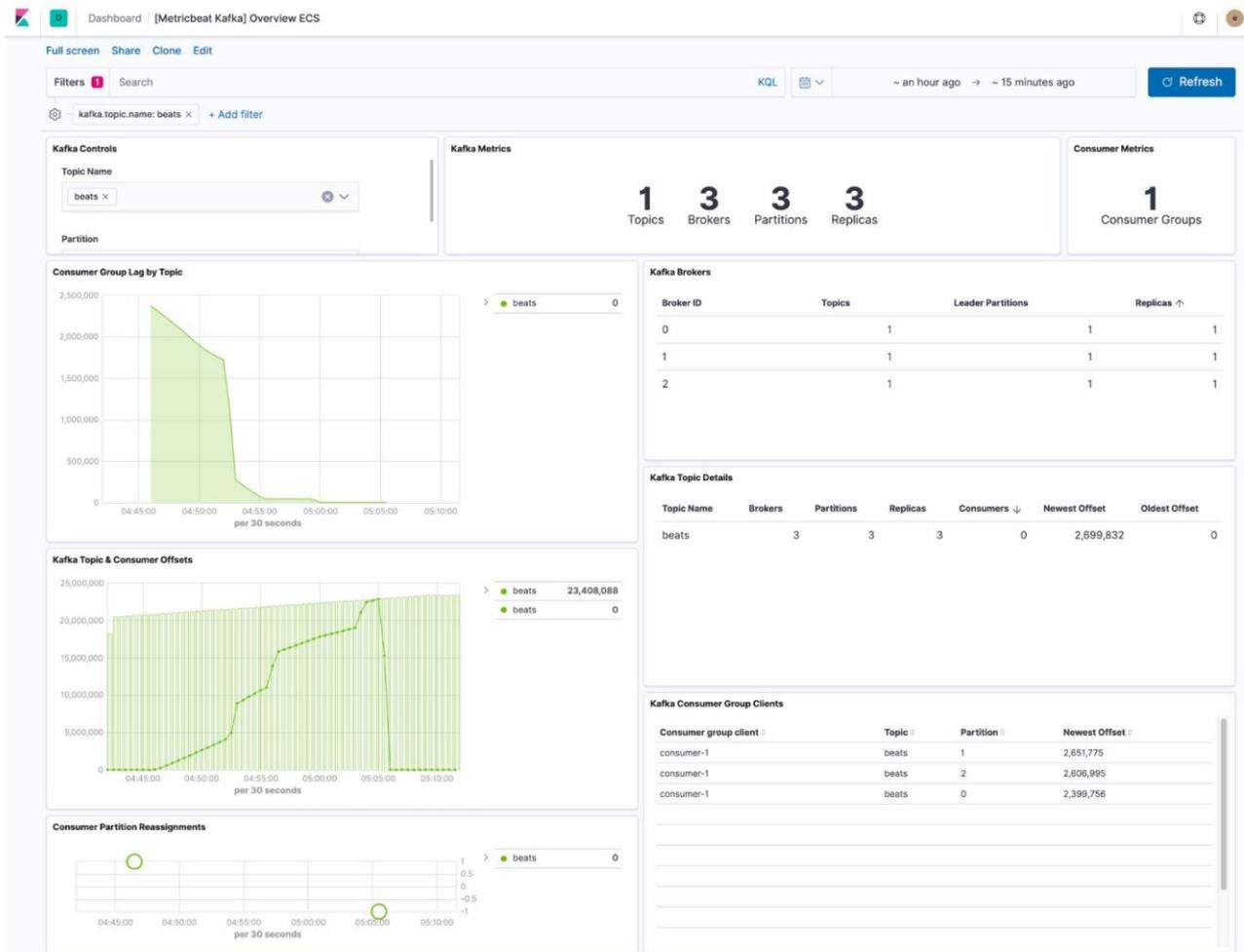


Figure 23: visualising Kafka topics and clients.

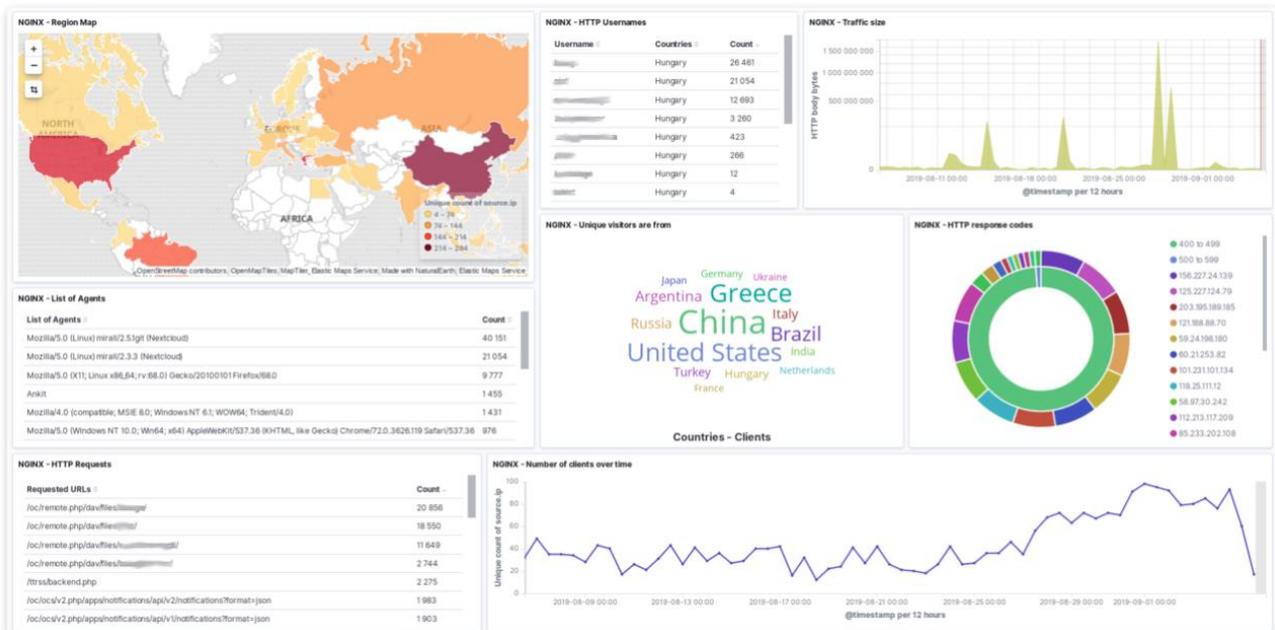


Figure 24: web server access logs.

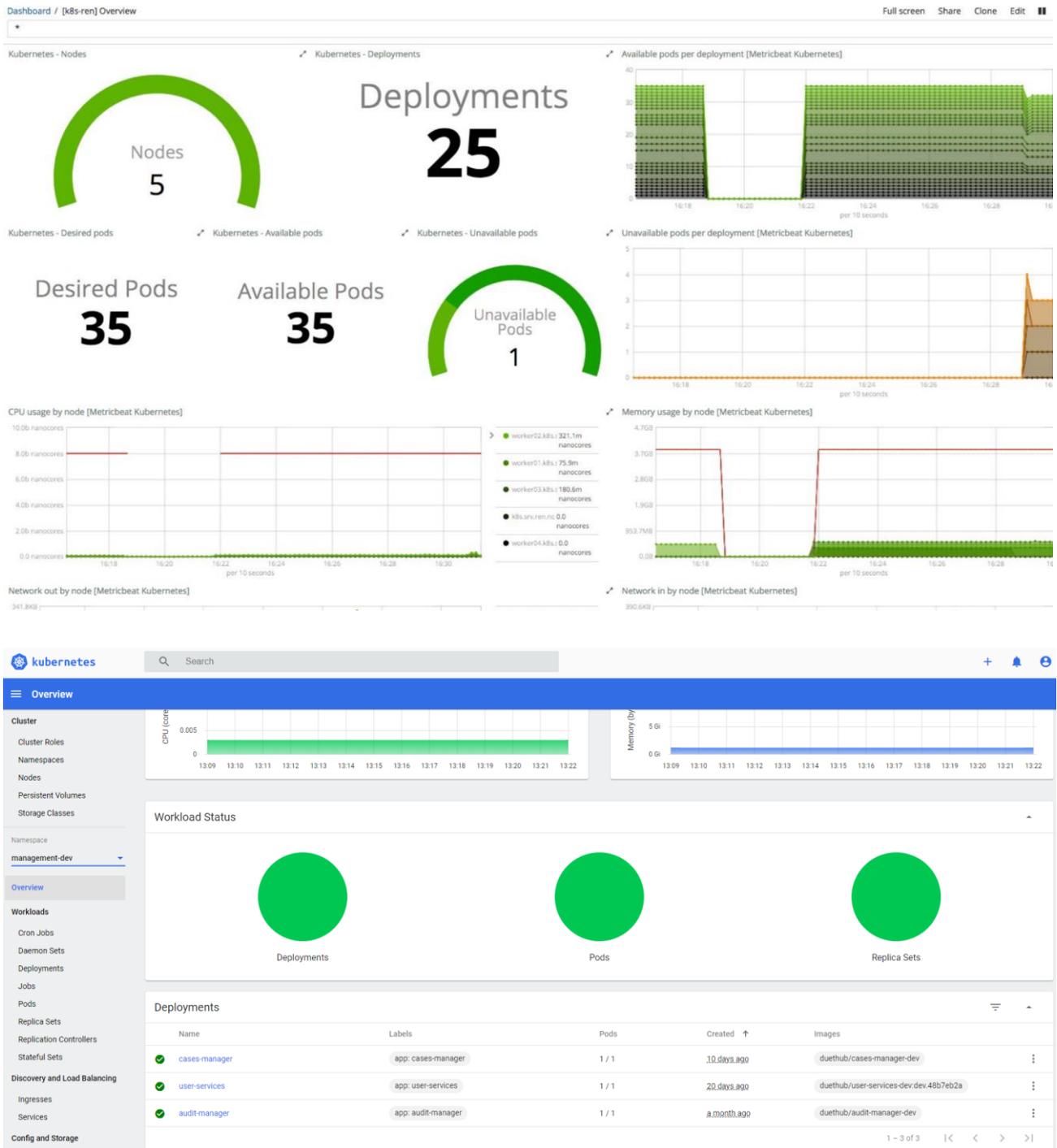


Figure 25: Kubernetes monitoring using external (top) or internal (bottom) dashboard visualisations.

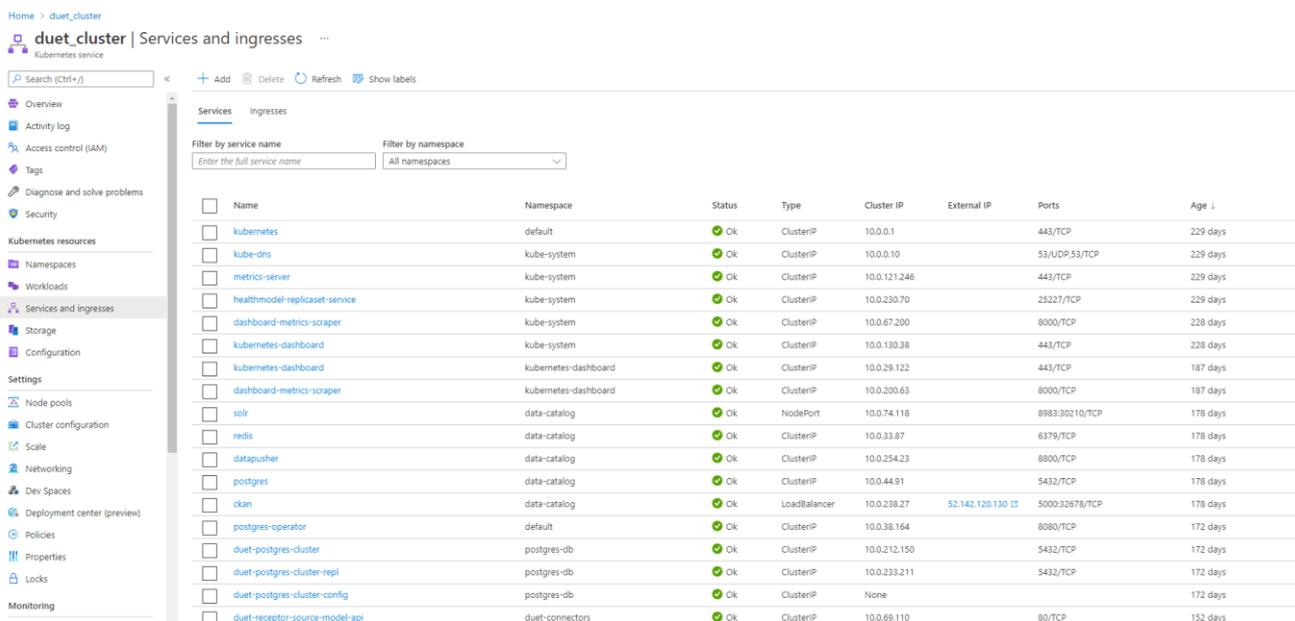


Figure 26: monitoring of resources and deployed services via the cloud provider (Azure) monitoring dashboard.

Functionalities

The user story provides more detail on the Epics listed in the Ambitions¹⁷ document. This description is translated into JIRA tasks, handled by the technical team.

Detailed User Story	EPIC
<p>As a DUET admin I want to be able to view monitoring information in a visual way (i.e. dashboards) so that I can quickly become aware of any important anomalies</p>	G18
<p>As a DUET admin I want to have as few as possible monitoring tools so that I don't need to switch between multiple tools to get the information</p>	G18
<p>As a DUET admin I want to monitor cloud resources so that I keep a track of costs and health status</p>	G18
<p>As a DUET admin I want to monitor web servers and applications so that I can get access statistics and any errors</p>	G18

¹⁷ https://docs.google.com/spreadsheets/d/1L9o91u0_dBgCVOlesBwN1tsImpMtssbQjd_XXmJDdEc/edit#gid=0

As a DUET admin I want to monitor the message broker (Kafka) so that I can be aware of usage statistics, any errors and message delays	G18
As a DUET admin I want to monitor HPC so that I can optimise execution times of simulation models	G18

Table 13: DUET infrastructure monitoring - user stories

4. Conclusion

This deliverable exhibits the data architecture, the tools and associated reporting capabilities of DUET that will cover the needs of the different user groups using the platform. The first question (chapter 2) is on how the data flow in the platform and the developed data management functionalities allow for a well-structured collection, access and storage of data going through the platform. DUET achieved in designing a data architecture that is compatible with the 'Data Lake' concept. The concept is characterised by keeping the data close or inside the model simulation infrastructure so that the models can effectively fetch them.

However, the refinement of user stories and emerging functional requirements has led to the current DUET approach. A data broker is responsible for handling data exchange among the simulation models and visualisations tools without storing it. Following this approach enables us to provide better and more complex simulation workflows, which will be realised in the upcoming versions of the platform while allowing more specialised data analysis tools to be employed for further data-oriented analysis of outcomes.

The various components covering the needs of the different stakeholder groups are using and taking advantage of the visualised information and received reports. Based on a specialisation of the generic user epics into more detailed user stories, DUET has described how components' output can be customised. This serves the purposes of publicly-facing, non-IT specific reports and those of the reports targeted at more advanced, technically oriented experts. A set of examples and functionalities of the possible solutions is described and will be used as the basis for the actual implementation of the reporting functionalities in the final version of the DUET Digital City Twin.