Deliverable

D7.7 Business & Exploitation Scenarios (final)

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Executive Summary

This deliverable is a continuation of D7.6 (Business and exploitation scenarios v1) where an exploitation roadmap was created by identifying different building blocks such as data governance, open data and so on.

The goal of this deliverable, however, is to provide an overview on the different exploitation possibilities based on the feedback of the consortium members. The consortium consists of both commercial and non-commercial partners, and therefore each partner may have other goals and objectives. In order to identify the different exploitation possibilities, input was gathered from previous deliverables and consortium partners. This information was summarised, consolidated and discussed with the different consortium partners during personal interviews and collective workshops. Also, a survey was sent to request the final input on the individual components and their exploitation potential.

Based on the partner's feedback, four criteria (objects of exploitation, target group, further R&D to be done, business model) were identified that determine the different exploitation possibilities. These criteria generated six possible exploitation scenarios:

1. The components developed in DUET are being exploited as stand-alone or combined elements in future digital twin solutions
2. The Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites
3. The platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers (cities, governments,...)
4. The Digital Twin platform and pilot cases remain active 'as is' as a demo environment
5. The Digital Twin platform is further developed in a subsequent research project
6. The lessons learned from the DUET project are being exploited beyond the project as 'knowledge'

Before discussing each of these scenarios, a chapter is spent on the different objects of exploitation. As discussed in D7.6, DUET also contains objects that are of non-technical nature such as a starter kit, e-book and so on.

Next, each scenario is discussed more in detail and we emphasised that some scenarios can co-exist and that some scenarios can be regarded as building further upon each other.

The main conclusion was that some of the scenarios (1,4,5 and 6) are already taking place or will happen in the near future. It was also clear that the nowadays provided solution is not mature enough to be actively used by the pilot cities (scenario 2), but each of the pilot cities expressed their enthusiasm about DUET by joining the European follow up proposal of DUET (DUETTE). We also learned that in order to make DUET as a platform usable for external parties (scenario 3), concepts such as data spaces and international IT standards need to be set up, however these were out of scope of this project. To end, much value was created in terms of awareness on digital twins, reusable software, knowhow and learnings. These knowhow and lessons will be exploited by objects such as an e-book, starter kit and policy brief (scenario 6).

1.   Introduction

This deliverable describes different exploitation scenarios that are possible with DUET after the project ends and is a continuation of D7.6 "Business and Exploitation Scenarios''. This deliverable is structured as follows:

- **Aims & approach - exploitation: the goal to transcend DUET beyond the project lifetime**

In this chapter we describe the aims of this deliverable, which in essence boils down to transcending the lifetime of this EU-project and making a lasting impact in terms of exploitation of the results and lessons learned. We also introduce our approach and the frameworks and terminology used in this deliverable.

- **DUET's potential objects of exploitation**

Before talking about exploitation, we first define what exactly can be exploited since DUET compromises not only the DUET platform, but also many technical components that potentially are also exploitable. In addition, other outputs such as the DUET book, the policy brief and the starter kit contain relevant knowhow, lessons learned and recommendations for LDT adopters that are also exploitable.

- **Exploitation scenarios & business models**

In this chapter, a brief overview is given of the possible exploitation scenarios and business models, indicating the probability of them and the degree of transformation. We define six scenarios that are possible with DUET after the project ends and a distinction is made between commercial and non-commercial scenarios:

1.   the components developed in DUET are being exploited as stand-alone or combined elements in future digital twin solutions (commercial)
2.   the Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites (commercial)
3.   the platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers (cities, governments,...) (commercial)
4.   the Digital Twin platform and pilot cases remain active 'as is' as a demo environment (non-commercial)
5.   the Digital Twin platform is further developed in a subsequent research project (non-commercial)
6.   the lessons learned from the DUET project are being exploited beyond the project as 'knowledge' (non-commercial)

Next, each scenario is discussed whereby we assess the viability based on feedback of the consortium partners and of stakeholders that have been in contact with the tangible outcomes of the DUET project. We also consider the related intellectual property rights and the required actions for fulfilling each scenario. In addition we mention potential barriers that some scenarios could face to succeed.

In the final conclusion we summarise the conclusions for each individual scenario. There we learn that some scenarios are already taking place while others need a lot of further development and research. In addition

we address the importance of data spaces and international IT standards which are out of DUET's scope but are needed to create an operational Digital Twin.

In the ideal innovation process, we must consider three criteria: A desirable solution (one that the customer needs), a feasible solution (built on the strengths of the current operational capabilities) and a profitable solution (with a sustainable business model). These criteria are presented as the three IDEO circles (https://www.ideou.com/blogs/inspiration/how-to-prototype-a-new-business). The IDEO circles are presented in the figure below.

As input to this deliverable, we used a.o. the architectural deliverables of WP3 and WP5 to list the developed individual and joint components of the overall DUET Digital Twin platform, which relate to the technical FEASIBILITY of the developed solution within DUET, the user feedback and testing deliverables led by OASC are used as input on the DESIRABILITY of the developed solution, whereas the initial exploitation deliverable 7.6 and this deliverable mainly deal with the VIABILITY of the developed solution.
Therefore, this deliverable can be regarded as a reality check of the delivered solutions, solution components and non-technical elements in terms of their exploitation potential beyond the lifetime of the DUET project.

In terms of the development of innovations and their related business models, as proposed by IDEO, DUET has focused mainly on the FEASIBILITY of a Local Digital Twin solution. This was also apparent in the scoping of the three LDT pilots, as the epics were mainly aggregated based on the availability of current datasets and models (FEASIBILITY), rather starting from in-depth investigations into concrete needs and wants of the eventual end-users of the LDT solution.
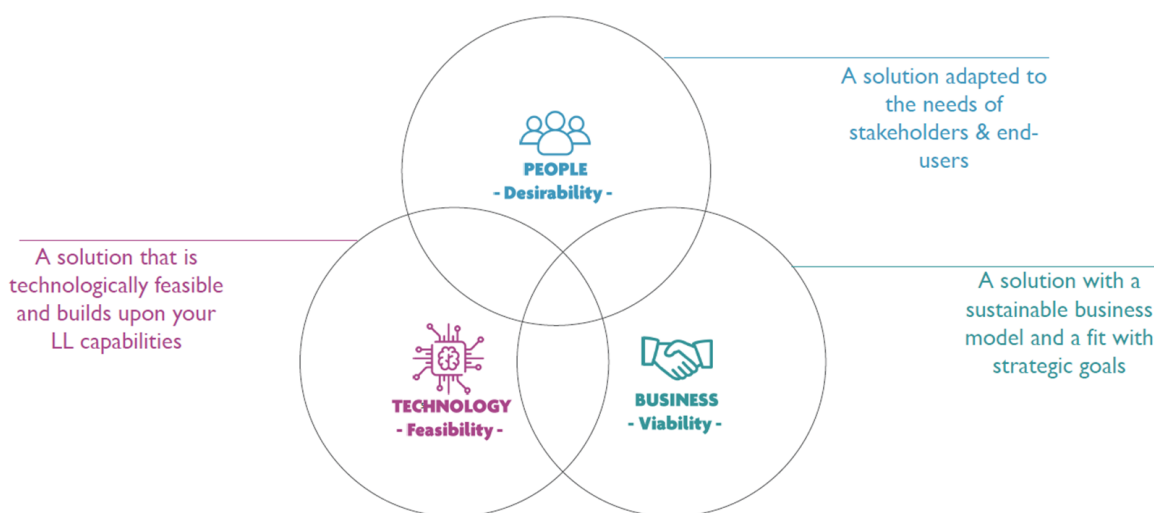
This has of course severe repercussions on the potential VIABILITY of the resulting solutions and on the probability of the exploitation and business model scenarios. Therefore, commercial exploitation scenarios at this moment are less likely, but the pioneering learnings in terms of (technological) FEASIBILITY will have a large impact on the potential future VIABILITY of LDT solutions. The lessons learned from the DUET project also put the consortium members in an ideal position to use these lessons learned in future joint efforts to focus more on the DESIRABILITY of LDT which will enable more concrete and realistic VIABILITY scenarios.

2. Aims & approach - exploitation: the goal to transcend DUET beyond the project lifetime

Within this deliverable, we tackle the important question: what will become of DUET after the project ends? Will it gradually wither away, or can it actually become an authority on digital twins that is recognised by industry, policy, tech and research communities? Or will it be something in the middle of that spectrum? If DUET continues to live on in some form, will project partners and existing pilot cities remain its only users, or can we expect to see new cities adopting DUET to achieve their development and policy goals?

Before these questions can be answered, we should first define what it means to be sustainable. Existence post-project can happen in different ways.

2.1. Scenarios

In order to investigate the different exploitation possibilities of DUET, input was gathered from previous deliverables and consortium partners. This information was summarised and consolidated in a MIRO-board, which was then discussed with the different consortium partners during personal interviews (with TNO, VCS, ATC and imec) and collective workshops. Also, a survey was sent to request the final input on the individual components and their exploitation potential. Based on this feedback, we identified four criteria that determine the different exploitation possibilities:

- What is exploited exactly? As discussed in D7.6 (Business and exploitation scenarios v1), DUET compromises not only the platform and the individual components, but also contains non-technical material such as an e-book, starter kit and so on. Chapter 3 will discuss the potential objects of exploitation.
- Who is the target group? The users of the starter kit might be a different group than the users of the platform.
- Is further R&D required? Depending on the direction the consortium wants to go, further R&D might be necessary.
- Will DUET be exploited in a commercial or non-commercial way?

Based on these four questions, we identified six possible scenarios that could happen with DUET after the lifetime of the project. These scenarios are presented in the table below and will be discussed and examined in the following chapters.

Scenario	What is exploited	to who	Further R&D required?	Business Model
1. The components developed in DUET are being exploited as stand-alone or combined elements in future digital twin solutions	Stand-alone components (or a combination of some components)	The consortium	NO	Commercial
2. The Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites	The integrated solution (LDT)	The three pilot cities	YES	Commercial
3. The platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers (cities, governments,...)	The integrated solution (LDT)	External customers	YES	Commercial
4. The Digital Twin platform and pilot cases remain active 'as is' as a demo environment	The integrated solution (LDT)	anyone interested in LDT's	NO	Non-Commercial
5. The Digital Twin platform is further developed in a subsequent research project	The components and/or The integrated solution (LDT)	(new) consortium members	YES	Non-Commercial
The lessons learned from the DUET project are	knowhow/lessons	policy and smart city researchers, policymakers,	YES	Non-Commercial

being exploited beyond the project as 'knowledge'		smart city project managers, data experts, ICT architects and managers, smart city developers and urban information experts		

2.2.   Methodology

In order to structure the discussion on the different exploitation objects and scenarios we will use an innovation framework named Innovatrix and its related (business model) elements (Schuurman et al., 2019). Innovatrix was developed by Imec and is an alternative to Osterwalder's Business Model canvas (Osterwalder et al., 2011).

The framework helps in structuring the different aspects of a business model in a more complex ecosystem and consists of 8 key innovation criteria. In the other chapters of this deliverable we use these criteria to describe the different (business model) elements of the resulting DUET components and solutions.

Innovatrix was developed within imec.livinglabs (https://www.imec-int.com/en/livinglabs - previously iLab.o and iMinds.livinglabs), one of ENoLL's (the European Network of Living Labs - https://enoll.org/) founding members and a forerunner in the network in terms of business orientation within Living Labs. As Living Labs are public-people-private partnerships that facilitate multi-stakeholder innovation rooted in co-creation and real-life testing, this kind of innovation is also in line with Open Innovation and User Innovation approaches (Schuurman, 2015). At first, when still operating under the banner of iLab.o, the innovation projects followed a rather linear innovation methodology, quite similar to other known Open Innovation organisations such as Testbed Botnia (FormIT) (Almirall et al., 2012). However, as the number of projects and the organisation itself started to grow, the need was felt to adopt a less linear approach that was more in line with the concrete issues the living lab customers experienced. To this end, in 2014, the Lean Validation Board was used in the projects to map and validate assumptions during the project as suggested by one of the new team members who had used the Lean Validation Board in her previous working experience. However, soon it became apparent that the validation board did not work optimally in a living lab setting, as the different elements are not really linked and there is less process involved, which made its use limited to the start of the project. Therefore, it was decided to start creating a custom-made innovation management canvas to map and validate assumptions and containing the most critical elements of a living lab innovation (see D'Hauwers et al., 2015 for a more thorough discussion on these development steps). Eventually, Innovatrix was born, consisting of eight elements informed by what we deemed from our practical experiences are most crucial for living lab innovation. To this day, more than 100 innovation projects have been carried out within imec.livinglabs and more than 50 have used Innovatrix, whereas the other either used no (business model) canvas, used the lean validation board, or used a premature version of Innovatrix (see D'Hauwers et al., 2015). By having multiple customer segments, each with their own needs, etc., this canvas appeared to be more process-oriented, which made it easier to use as an innovation management tool. We see this as the biggest differentiation from the other business model canvasses, as Innovatrix starts from the user (customer segments) and assumes that different user or customer groups each have their own distinctive needs, current practices, etc. In short, it allows practitioners to link and differentiate the different elements with and for different user groups, which also allows them to capture the outcomes of living lab activities, such as co-creation activities with different users.

We now briefly introduce and discuss the criteria that compose the Innovatrix: Customer Segment, Current Practices, Needs, Value Proposition, Solution, Barriers, Value Capture, and Key Partners (Figure 1). Below, each of these eight components is discussed in detail. We also indicate whether these elements belong to the "current state" or appear "as is" without the innovation, or if they are related to the "future state" or are yet "to be" with the innovation. For each of the criteria, we also introduce "checks" or questions that can be used to fill out the different criteria.

2.2.1.   Customer segment - current state

As used in the Validation Board (Ries, 2011) and the Business Model Canvas, Innovatrix starts from customer segments. However, there is room for multiple customer segments. Also, the other elements are all linked to customer segments and do not necessarily apply for all segments. This approach enables more fine-grained assumption development. In the Innovatrix framework, there is room for three customer segments (the grey areas in the framework) to cater to the need for clear focus through limited scope. The first column is used as

an overarching column to map similarities between defined segments. Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Customer Segment criteria: What customer segments should be focused on? What are the key characteristics? What is the usage context?

2.2.2. Needs - current state

Osterwalder (et al., 2015) includes customer jobs, pains, and gains in the Value Proposition Design canvas, which is the basis for the needs identification in the Innovatrix framework. Furthermore, Ries (2011) links customer segments – customer problems and the fit with the potential solution or value proposition. Following the application of Innovatrix, checks can be used to gauge the need for relevant input into the Needs criteria: What are the needs of the customer segment? How do we prioritize these needs?

2.2.3. Current practices - current state

One missing pillar in Ries (2011), Osterwalder et al. (2011), and in Ballon (2007), is the competition and the differentiation of an SME/startup/innovator. Competition refers to the Five Market Forces of Porter (1985), which draws from the five forces model. The five forces make up the attractiveness of a market. The five forces can be defined as: 1) the degree of rivalry within the industry, 2) the threat of new entrants, 3) the threat of substitutes, 4) the bargaining power of suppliers, and 5) the bargaining power of buyers. Assessing rivalries within the industry can help identify the difficulties of entering the market. If, for example, the market consists of multiple strong players (i.e., an oligopoly market), the need to diversify can lead to high barriers to entry. On the other hand, if several new entrants enter the market (i.e., monopolistic competition), it could indicate that it is an attractive market with lower barriers of entry. For some products or services, one can find possible substitutes that can serve as an alternative to the specific service or product. Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Current Practices criteria: Who are competitors, alternatives, and customers, and what is their behaviour? What are the pains and gains of these current practices?

2.2.4. Value propositions - current and future state

The value proposition is covered by the Lean Matrix of Ries (2011), the Value Proposition and the Business Model Canvas of Osterwalder (et al., 2011; et al., 2015), and by the Business Model Matrix of Ballon (2007). The value proposition is the match between the needs of customer segments and how this can be solved with the solution provided by the innovator. Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Value Proposition criteria: What (measurable) impact will we create for this customer segment?

2.2.5. Solution - future state

The solution refers to "the functional architecture" of Ballon (2007) in the Business Model Matrix. The functional architecture comprises the technical systems, which are composed of at least one building block (or module) governed by specific rules (or intelligence) that interwork (or not) with other technical systems through predetermined interfaces. The composition of the solution in the key modules and technical systems enables the researcher and the innovator to identify the unique selling point of the innovation compared to the competition. This division is less explicitly included in Osterwalder (et al., 2011), even though the difference can be significant in certain innovations. Following the application of Innovatrix, checks can be

used to gauge the need for relevant input to the Solution criteria: What are the components of our (digital) solution? How do these components differ for the different customer segments?

2.2.6. Value capture - go-to-market

Ballon (2007) included the financial model in the Business Model Matrix, which described the revenue model and the revenue-sharing model. Osterwalder (et al., 2011) also takes into account the revenue model, where the pricing level and the pricing model are mentioned. Therefore, we opted to utilise the definition of "value capture", which comprises the pricing model and the pricing level, and in cases where revenue sharing is applicable, this section can be utilised. The application of the Innovatrix framework in different projects shows that partners can face difficulties identifying their pricing model and pricing level, and thus this needs to be included in the framework. Value capturing has an important link with how pressing the customer need is and to the associated value the partner promises to deliver. Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Value Capture criteria: What value (monetary and non-monetary) do we receive in return? What price should we set (and how)?

2.2.7. Key partners - go-to-market

The value network definition is an alternative to the broad, market-based approach of the Business Model Matrix of Ballon (2007). In the value network analysis, however, the applicability is more adapted to innovations in the form of partnerships required to deliver the innovation to the customers and with whom do innovators need to collaborate. Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Key Partners criteria: Who are our key partners? How should we interact with stakeholders?

2.2.8. Barriers

According to Steinkühler and colleagues (2014), self-justification is the most empirically supported explanation for escalation of commitment, the "...tendency to become locked-in to a course of action, throwing good money after bad or committing new resources to a losing course of action" (Staw, 1981). Therefore, Steinkühler and colleagues (2014) argue that self-justification cannot be totally avoided but for de-escalation of the commitments, the search for disconfirming evidence can help. Therefore, it was decided to explicitly include "barriers" as an element to look for this disconfirming evidence. This forces the practitioner to play the role of "devil's advocate". Following the application of Innovatrix, checks can be used to gauge the need for relevant input to the Barriers criteria: What are the barriers to adoption, usage, and/or market entry?

Downloads of the 'physical' canvas:
https://timreview.ca/sites/default/files/IMEC_innovatrix2019_A0_FINAL.pdf
https://timreview.ca/sites/default/files/IMEC_innovatrix2019_B0_FINAL.pdf

3. DUET's potential objects of exploitation

In this chapter, we will identify the different objects from the DUET project that can be the object of exploitation or valorisation. These objects are all results of the DUET project, by which we mean all the foreground IP, which is all the knowledge and IP produced collaboratively during the project. The table below summarises and groups these objects. If we want to explore the different exploitation scenarios of DUET, we should first define what exactly can be exploited. We therefore introduce the different exploitation objects: these are all the different elements of DUET that have an exploitation potential. First, we can distinguish between exploiting DUET as a technological solution or by transferring the knowhow gained during the project. Furthermore, some of the individual components of the tool may also bring value to a specific customer segment. In this chapter, we will discuss all the different exploitation objects. An overview is given in the table below:

	Category	Exploitation object
Technological solution (3.1)	The Main Digital Twin solution	Local Digital Twin / City Twin platform
	Decomposed main solution	Standalone Value Objects
Knowhow (3.2)	Research Findings, Recommendations & Capacity Building	Project Website & Starter Kit
		Deliverables
		Publications
		Videos
		Use cases
		Awards

In the following paragraphs, we discuss these elements in more detail.

3.1. Technological solutions

3.1.1. DUET Platform framework

The DUET platform assists in making data driven decisions regarding urban planning. As discussed in D5.1 in paragraph 4 the platform integrates different data sources, models and visualisation clients.
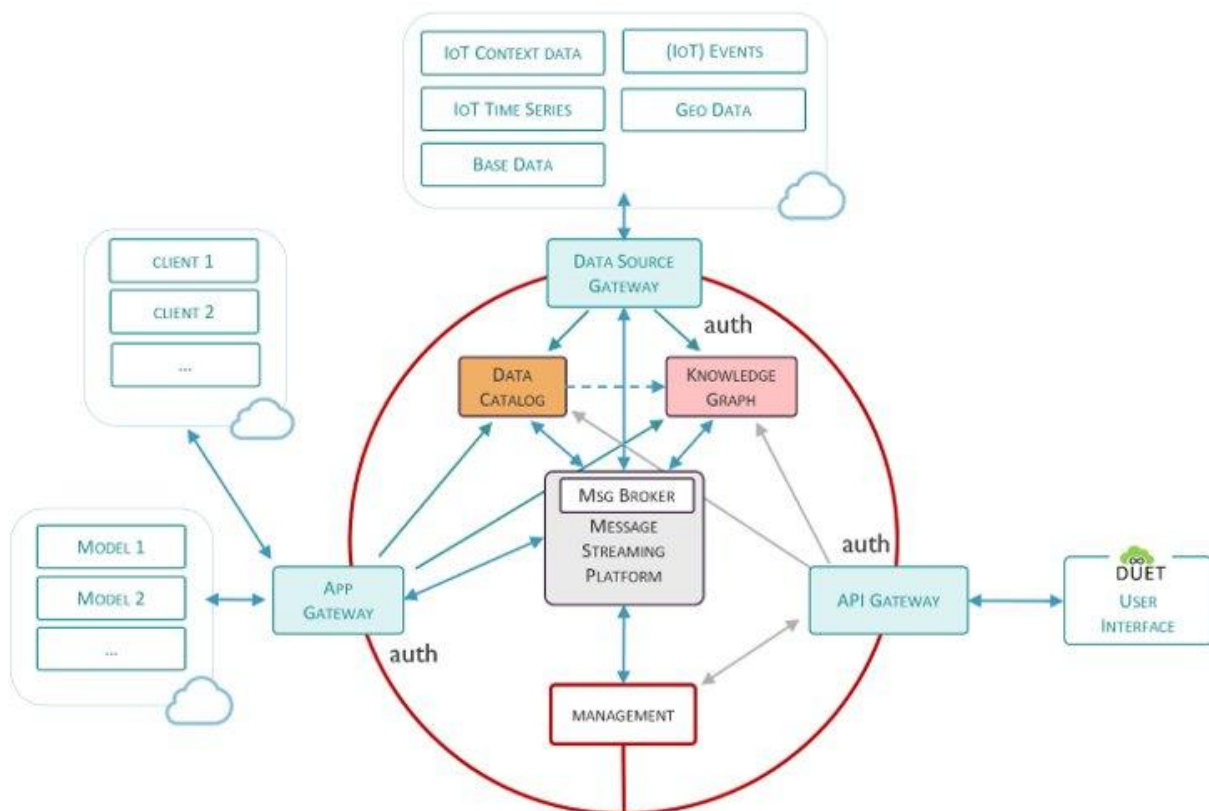
The main interactions can be summarised in the following list:

- The App Gateway exchanges data with models and external applications over secure protocols. Similarly, the Data Sources Gateway interacts with the IoT sources and the API Gateway with other external applications like visualisations.
- The DUET UI interacts with the users over HTTPS. In order to communicate with the internal APIs of the cell, the DUET UI communicates only with the API Gateway that provides a single point of access.
- The App Gateway, with every message that arrives, performs user authentication and authorization with the help of the Management component and data validation with the help of the Data catalogue. The same applies for the Data Sources Gateway. The API Gateway only performs user authentication and authorisation.
- The App Gateway performs data mapping on the messages to the applications out of the cell with the help of the Data Catalogue.

- The Data catalogue communicates with the Knowledge Graph during the registration of a new data source, for retrieval of the available ontologies and storage of the semantic representation of the datasource.
- All components besides the API Gateway send events to the Message Streaming Platform during their operations.

3.1.2. DUET standalone components

Component		Function	Provider
Message Broker		Intervenes between the registered models and other external systems like visualisations, controlling the data flow from/to them and the Message Streaming Platform.	ATC
Data Catalog		Allows to manage and publish data sources for use in DUET. Stores metadata in DCAT format.	Imec
Model Catalog		Allows to manage and publish models for use in DUET. Captures all relevant details of models in relation to inputs and outputs.	Imec
Message Streaming Platform (Kafka)		The Message Streaming Platform allows the different DUET components to communicate and exchange data in an asynchronous way. Apache Kafka is used for this purpose, which provides features like stream processing, highly scalable architecture, high availability and throughput.	ATC
Connectors	IoT Data connector	(Federated API and REST API receptor) Provides a uniform way of connecting to IoT data for other DT components.	Imec
	Subscription Service	Allows a user/client of the system, e.g., a model, to subscribe to specific events/data sources of the platform, e.g., the results of another model, to receive the relevant messages through the Message Broker.	Imec
	Subscription Service	Allows a user/client of the system, e.g., a model, to subscribe to specific events/data sources of the platform, e.g., the results of another model, to receive the relevant messages through the Message Broker.	ATC
	Interaction Service	Orchestrates the different components involved when running experiments.	Imec

Visualisation	VC MAP API	Framework for 3D & 2D visualisation on the web, based on CESIUM JS and OpenLayers JS.	VCS
	VCS Viewer	Plugin for VC MAP developed within DUET project for displaying 2D / 3D data in web, based on VC Map API	VCS
	GLayer	Analytical maps platform that allows exploratory analysis of big spatio-temporal data relying on GPU accelerated database engine focused on fast data aggregation, filtering and visualisation through maps, charts and dashboards.	P4ALL / InnoConnect
	Dashboard	Interactive dashboards visualising and contextualising IoT sensor data, map and graph functionalities	ATC
	Landing Pages	A website built on Wordpress that provides an entry point for the DUET visitors. It acts as a dissemination portal where DUET city admins can publish their most interesting cases providing information like the challenges and the approach, images and videos related etc	ATC
UI	Asset Mgmnt	Management of the simulation models and the data sources	ATC
	Management Component	It is responsible for the initialisation of the DUET cell and the management of key entities of the system like users, roles and access rights.	ATC
	Scenario Manager	Does not really exist yet - will probably be included in the VCS VIEWER)	VCS
Models	Traffic Modeller	Calculates traffic density in the city for each day/hour. It also allows recalculating traffic density based on added events or changes in the road network.	P4ALL
	Noise Modeller	Calculates noise caused by traffic in the city. Recalculates the noise on-demand (typically by changed traffic situation)	P4ALL
	Noise Model Flanders / Athens	Calculates noise caused by traffic. Traffic noise emissions are calculated and form point sources. Accumulated noise energy is calculated for calculation points. Surface and Shielding and reflection is taken into account. Model uses GPU and HPC for acceptable calculation times	TNO

	Air Quality Model	Calculates air concentration levels of several agents (NOx, NO2, PM10, PM2.5, EC...). Traffic emissions are calculated, and their dispersion is combined with other (background) emission sources. The model relies heavily on parallel GPUs and HPC for acceptable calculation times.	TNO
	Air Quality Model	Fast calculation of yearly averages of PM10, PM2.5 fine dust particles based on emissions by traffic and spatial elements like elements and spatial morphology.	VITO
	Air Quality Model	Fast calculation of yearly averages of NO2 emissions by traffic and spatial elements and spatial morphology.	VITO
	Traffic Model (static)	Software component (part of KUL's dyntapy toolkit) that assigns traffic flows to regional or city traffic networks for a given time period (e.g., 1 AM peak hour). It produces time-averaged flows and delays for each network link. (interfaced with DUET platform)	KUL
	Traffic Model (Dynamic)	Software component (part of KUL's dyntapy toolkit) that assigns traffic flows to regional traffic networks, taking into account queue dynamics. It produces time-dependent flows, queues and delays for each network link. (interfaced with DUET platform)	KUL
	Tile Service	The tile service is used to generate interpolated calculation results of TNO Air and Noise Pollution models. It also generates different maps to show the difference between other calculations. The resulting images (PNG) prevent the exchange of large amounts of data resulting from the calculation	TNO
	Poidpy	Tool to generate origin destination matrix as part of the configuration of any traffic model (stand-alone software module supporting city-specific configuration of DUET-interfaced traffic models)	KUL

Some of the standalone components can also bring value to a specific stakeholder segment as a stand alone component which means that one component can function without the other components whilst being integrated in another solution or platform.

3.2. Knowledge & lessons learned that could bring value to a stakeholder segment

Over the course of the project, the consortium has produced many outputs that are non-technological in nature. By non-technological we mean they are not software or hardware components such as those used in citytwin.eu. Although not part of the platform, these "soft" outputs support exploitation in different ways, for instance by spreading the word about DUET, by showcasing its benefits to different audiences, by explaining how the platform works and the kind of use cases it supports—all with the aim of making DUET more appealing to potential adopters and raising awareness regarding the potential, opportunities and possible use cases of local digital twins.

There are six non-technical exploitation objects. Some focus on the project as a whole, some exclusively on the platform, its features, functionalities, added value, current and future potential. The six elements are:

- Project website and the Starter Kit
- Project deliverables
- Publications, including a forthcoming Springer book, peer-reviewed journals, and conference proceedings
- Videos that explain the project and its benefits to different audiences
- Use cases published on cititwin.eu
- Awards, such as SCEWC 2021 award for the Best Enabling Technology

Details on how these elements will be exploited and sustained are provided in Scenario 6.

4. Exploitation scenarios & business models

As discussed in chapter 2, six scenarios were identified:

1. the components developed in DUET are being exploited as stand-alone or combined elements in future digital twin solutions (commercial or non-commercial)
2. the Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites (commercial)
3. the platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers (cities, governments,...) (commercial)
4. the Digital Twin platform and pilot cases remain active 'as is' as a demo environment (non-commercial)
5. the Digital Twin platform is further developed in a subsequent research project (non-commercial)
6. the lessons learned from the DUET project are being exploited beyond the project as 'knowledge' (non-commercial)

Each of these scenarios will be discussed in the coming paragraphs. The figure below gives an overview of the 6 scenarios whereby a distinction is made between 'city twin exploitation' (the original purpose of DUET) and an alternative exploitation model. The horizontal axis represents the amount of necessary development for each scenario. In addition, a distinction is made between commercial and non-commercial scenarios. We also emphasise that scenarios are not mutually exclusive, some can co-exist.
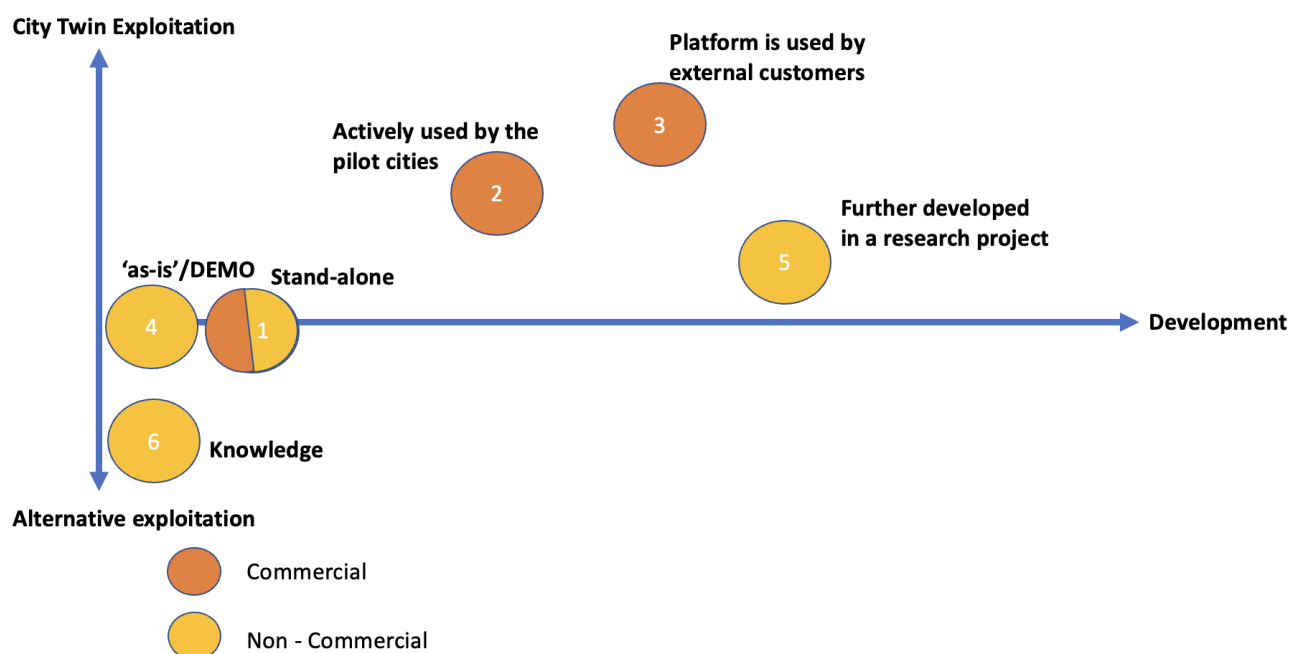
4.1. Scenario 1: The components developed in DUET are being exploited as stand-alone or combined elements in future digital twin solutions

As mentioned in the introduction, some (or a combination) of the components can bring value to one specific customer segment. For example a component, built for DUET, could also be used in other initiatives or for other purposes. This section compromises 4 parts:

- The first part discusses the **exploitation possibilities and technological maturity** for each component
- The second part describes the outcome of interviews with the consortium members whereby each member was asked about the **intentions to commercially exploit one or more components**
- The third part addresses the component's **intellectual property regulations** for exploitation.
- The last part contains a small note that exploitation of the stand-alone or combined elements is also **possible in a non-commercial way**.

In addition we also consider the partners' interests to exploit the components they have built for DUET and the related Intellectual Property (IP) rights for exploitation.

4.1.1. Component maturity and exploitation possibility

In chapter 3, an overview was given of the DUET standalone components. Some components, however, still need further development before exploitation is possible. The table below compromises all components as well as the related maturity level and the usability as stand-alone.

In order to define the technological maturity for each component, we used the Technological Readiness Level (TRL) standard from the H2020 programme (source). The TRL levels are divided over 4 phases: discovery phase, development phase, demonstration phase and deployment phase. The TRL levels are:

Discovery phase
 TRL 1: Fundamental research
 TRL 2: Applied research
 TRL 3: Proof-Of-Concept
Development phase
 TRL 4: Implementation & testing prototype
 TRL 5: Validation of the prototype
Demonstration phase
 TRL 6: Demonstration prototype in a testing environment
 TRL 7: Demonstration prototype in an operational environment
 TRL 8: Product is complete and operational
Deployment phase
 TRL 9: Product is market ready

Only components that reached a TRL of 9 (deployment phase) can be considered ready for commercialisation.

Component		Function	Provider	TRL	Usable as a stand alone component?
Message Broker		Intervenes between the registered models and other external systems like visualisations, controlling the data flow from/to them and the Message Streaming Platform.	ATC	7	Yes
Data Catalog		Allows to manage and publish data sources for use in DUET. Stores metadata in DCAT format.	Imec	6	yes
Model Catalog		Allows to manage and publish models for use in DUET. Captures all relevant details of models in relation to inputs and outputs.	Imec	2	Yes
Message Streaming Platform (Kafka)		The Message Streaming Platform allows the different DUET components to communicate and exchange data in an asynchronous way. Apache Kafka is used for this purpose, which provides features like stream processing, highly scalable architecture, high availability and throughput.	ATC	7	Yes
Connectors	IoT Data connector	(Federated API and REST API receptor) Provides a uniform way of connecting to IoT data for other DT components.	Imec	6	Yes
	Subscription Service	Allows a user/client of the system, e.g., a model, to subscribe to specific events/data sources of the platform, e.g., the results of another model, to receive the relevant messages through the Message Broker.	Imec	7	Yes, although this would be considered as part of the Message Broker
	Subscription Service	Allows a user/client of the system, e.g., a model, to subscribe to specific events/data sources of the platform, e.g., the results of another model, to receive the relevant messages through the Message Broker.	ATC	7	Yes

	Interaction Service	Orchestrates the different components involved when running experiments.	Imec	6	yes
Visualisation	VC MAP API	Framework for 3D & 2D visualisation on the web, based on CESIUM JS and OpenLayers JS.	VCS	8	Yes
	VCS Viewer	Plugin for VC MAP developed within DUET project for displaying 2D / 3D data in web, based on VC Map API	VCS	4	Yes
	GLayer	Analytical maps platform that allows exploratory analysis of big spatio-temporal data relying on GPU accelerated database engine focused on fast data aggregation, filtering and visualisation through maps, charts and dashboards.	P4ALL / InnoConnect	9	Yes
	Dashboard	Interactive dashboards visualising and contextualising IoT sensor data, map and graph functionalities	ATC	7	Yes
	Landing Pages	A website built on Wordpress that provides an entry point for the DUET visitors. It acts as a dissemination portal where DUET city admins can publish their most interesting cases providing information like the challenges and the approach, images and videos related etc	ATC	/	/
UI	Asset Mgmnt	Management of the simulation models and the data sources	ATC	8	Yes
	Management Component	It is responsible for the initialisation of the DUET cell and the management of key entities of the system like users, roles and access rights.	ATC	7	Yes
	Scenario Manager	Does not really exist yet - will probably be included in the VCS VIEWER)	VCS	3	NO
Models	Traffic Modeller	Calculates traffic density in the city for each day/hour. It also allows recalculating traffic density based on added events or changes in the road network.	P4ALL	9	Yes
	Noise	Calculates noise caused by traffic in	P4ALL	7	Yes

	Modeller	the city. Recalculates the noise on-demand (typically by changed traffic situation)			
	Noise Model Flanders / Athens	Calculates noise caused by traffic. Traffic noise emissions are calculated and form point sources. Accumulated noise energy is calculated for calculation points. Surface and Shielding and reflection is taken into account. Model uses GPU and HPC for acceptable calculation times	TNO	8/9	Yes
	Air Quality Model	Calculates air concentration levels of several agents (NOx, NO2, PM10, PM2.5, EC...). Traffic emissions are calculated, and their dispersion is combined with other (background) emission sources. The model relies heavily on parallel GPUs and HPC for acceptable calculation times.	TNO	8/9	Yes
	Air Quality Model	Fast calculation of yearly averages of PM10, PM2.5 fine dust particles based on emissions by traffic and spatial elements like elements and spatial morphology.	VITO	9	Yes
	Air Quality Model	Fast calculation of yearly averages of NO2 emissions by traffic and spatial elements and spatial morphology.	VITO	9	Yes
	Traffic Model (static)	Software component (part of KUL's dyntapy toolkit) that assigns traffic flows to regional or city traffic networks for a given time period (e.g., 1 AM peak hour). It produces time-averaged flows and delays for each network link. (interfaced with DUET platform)	KUL	7	Yes
	Traffic Model (Dynamic)	Software component (part of KUL's dyntapy toolkit) that assigns traffic flows to regional traffic networks, taking into account queue dynamics. It produces time-dependent flows, queues and delays for each network link. (interfaced with DUET platform)	KUL	7	Yes
	Tile Service	The tile service is used to generate interpolated calculation results of TNO Air and Noise Pollution models. It also	TNO	7	Yes

		generates different maps to show the difference between other calculations. The resulting images (PNG) prevent the exchange of large amounts of data resulting from the calculation			
	Poidpy	Tool to generate origin destination matrix as part of the configuration of any traffic model (stand-alone software module supporting city-specific configuration of DUET-interfaced traffic models)	KUL	6	Yes

Based on the Technology Readiness Level of the components, we can conclude that the majority of the components has not reached a TRL level of 8 or 9 and are not ready for commercialization yet. This also has a severe impact on the possible commercialization of the platform as a whole (cf. infra). However, all components are potentially reusable in a future platform or other setting, which opens perspectives for follow-up projects (cf. infra).

4.1.2.   Partner interests to commercially exploit a component (or a combination)

Once the development of the components and the integrations with the DUET platform were done, the partners were interviewed about their intentions and the required actions to commercially exploit one or more components. The table below summarises the gathered feedback.

Partner	intention to commercially exploit one or a combination of components	Required actions
ATC	ATC will exploit the DUET results mainly to improve its current offerings dedicated to PAs (Public Administration), citizens and public and private service providers. ATC envisions in the DUET project a relevant opportunity to enhance its knowledge concerning needs, barriers, opportunities and lessons learned related to digital twin technologies, by exploiting mainly the technological solutions build in the context of DUET to strengthen its capabilities of providing innovative and	- Share DUET results, competence and experiences with ATC Business Units, strengthening the company's capabilities of providing innovative services to its public administration customers, accelerating their strategies for the digitalisation of procedures and improving citizen/customer experience. - Support cooperation with other European projects and initiatives working towards similar objectives and where ATC has a predominant or contributing role. - ATC will contribute to the project visibility through its networks. ATC will use its internal communication and dissemination channels (i.e. its company website, active social media presence

	citizen-centric technological solutions to its customers, both public and private.	and online magazines) to create a wide awareness on the project activities, progress and its results. - Collaboration with the technical partners that would like to continue with the technical and commercial development of the DUET solution.
P4ALL + InnoConnect	Want to commercially exploit both models (via SaaS or pay/request) and GLayer (SaaS), however the noise modeller still needs to be further developed and therefore extra funding is required.	Actions to exploit GLayer are already taken: InnoConnect has built a software platform for interactive data visualisation (through map, charts, dashboards). Exploitation of TraMod: the core traffic modelling algorithms are made open source. However the integration within the operational TraMod tool is a complex process. This deployment service is what P4ALL sells. However, the main action would be to find suitable use cases.
VITO	Models are already commercially exploited for particular use cases. The model runs on VITO's infrastructure.	Models need to be trained continuously Currently VITO's assistance is still required to configure the model for each use case and to help interpret the results.
KUL	Models will be commercialised via commercial players (for example TML, a KUL spin off).	Static traffic model & poidpy: TML (spin off) will further develop & commercialise the model. To achieve this, they will further integrate various data sources, refine granularity, refine traffic process models on intersections, and add other transport modes (cycling, public transport). Dynamic traffic model in dyntapy needs further development for more computational efficiency and progress towards (semi –) automated configuration of the traffic network, dynamic demand, and of the calibration/fine-tuning. NB: these models are open source, so any other developer or consultant can further develop them (respecting licence conditions).
VCS	The components that were built for DUET are hard to exploit since several plugins and extensions needed to be 'hacked' to make VC's framework connect to the DUET platform. However, we will stay active in this field and rebuild most of the	In parallel to DUET project VCS has started to work on a new VC Map framework and have made the development open source. Basically all that was developed in DUET is hard to exploit as it has not been nicely integrated into our VC Map nor will it work 1:1 in the new framework. However, some ideas and concepts will make it into the new

	components/connectors within follow-up projects (commercial and funded).	framework. For example a VC Map in the past was more or less a static application and now we will make it possible to easily add dynamically content. Also a catalog connector will be added to our new map and rework the user management. So many positive ideas and developments but not directly commercially exploitable.
TNO	The models used in DUET are already used in other initiatives (even DT) as well.	There is an expert needed to configure the model and during the acquisition phase of the data.
Imec	Imec has no intention to commercially exploit the components since it is an open knowledge institute. Our aim is to do research so others can commercial exploit.	Additional research on the reference architecture, its components and formalisation of standards regarding data exchange and model orchestration.

We can conclude that not all partners have the intention to commercially exploit the components they have built. Only P4ALL / Innoconect, VITO and KUL are planning to exploit or are already exploiting components from the DUET project. VCS and ATC state that the learning from DUET will help them in the exploitation of their current offerings or in future offerings.

4.1.3. Intellectual Property

When exploring the exploitation possibilities for DUET's components, the related Intellectual Property (IP) rights should also be considered. Therefore the partners were asked to define their IP regulations of the components. A distinction was made between the background IP (the knowledge that was supplied by the partners at the start of the project) and the foreground IP (the knowledge that was produced within DUET's project activities). Background inventory describes the background IP for each partner. Furthermore, DUET's foreground IP comprises different kinds of results that broadly fall into two categories:

- The technical solution, which consists of the LDT platform and know-how and the different components where the platform is made of: Here, the main result is obviously the platform (https://citytwin.eu/), also the practical knowledge gained during the development process, and the TRL increase in background IP attributable to DUET. Also, all the separate components of the LDT platform that were developed, on which the practical knowledge was increased and that gained an TRL increase fall under this first category.

- Knowhow or knowledge that was generated during the DUET project, which consist of research findings and recommendations, and training and capacity building: This category includes mostly written outputs e.g. official deliverables, peer-reviewed papers, the Springer book. By serving as a vehicle for dissemination, these outputs support the exploitation of results from the first category.

Some research outputs will only become available after the project e.g. Springer book. In terms of training and capacity building, these results will be produced in the near future - that is, once we start imparting knowledge on how to use the platform and embark on a digital twin journey. Key outputs here will be the starter kit (D7.8), the how-to videos for the platform, webinars (some co-organised with sister projects) and maybe even an online course (still under consideration). To an extent, there is some overlap between results in category two and three as they both leverage research findings and issue some kind of recommendations. What makes cat 3 results different, however, is a more pronounced focus on the hands-on implementation, as well as the means of delivery i.e. video, toolkit, e-learning platform as opposed to report.

As we can see in the background IP inventory, there is a clear difference in IP regulations between commercial and non-commercial partners. The commercial partners that exploit a DUET component (or the related software) make use of software licences or/and paid implementation services, while the research institutes have other IP regulations. Some of these research institutes offer the open-source code via a licence, others grant access rights without any restriction depending on the project.

However, with these many different IP regulations, the commercialisation of the DUET platform (scenario 3) will be a big challenge. This aspect will be further elaborated in section 4.3.1 (potential value propositions and barriers for adoption).

4.1.4. Non-commercial exploitation of (a combination of) the standalone components

The continuation of the DUET combined components is also possible in a non-commercial way. A non-commercial entity (for example a government agency) could exploit a combination of the DUET components, governed by a business model covering only actual costs. This exploitation could avoid potential vendor lock-ins.

4.2. Scenario 2: The Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites

The second scenario states that the pilot cities will continue to use the DUET platform. Therefore some technical adjustments and further development might be required. Besides the technical aspect, it is crucial to understand the end user's needs and current practices to ensure the product-market fit and the adaption of the DT by the pilot cities.

For each use case we will look at the difference between the current realised output and the use case user requirements. We will use the Innovatrix framework to structure this. Upfront, an important remark should be made regarding the possible exploitation of the pilot use cases. The majority of the use cases have been scoped based on the current availability of data sources and the technical objectives that were set in the DUET project. In other words, emphasis was put on the FEASIBILITY of the pilot use cases, rather than on the DESIRABILITY. The potential users of the Digital Twin pilot case were less involved in the scoping stages, which had an impact on the potential commercial exploitation of the use cases itself.

Pilsen

CUSTOMER SEGMENT	Policy maker: elected representatives or high-level managers of the city who decide on policies:	Urban Planner urban planners who work primarily with, city basic structure, urban planners who work with 3D model of the city within their urban planning competence	Public Servant of a relevant department (mobility, spatial planning and environmental department,...)	Citizen to be informed about the smart city policies
NEEDS	°Is interested in the effects of policy making decisions °They need a tool to create appropriate visualisations that they can then use to communicate with the public and stakeholders	°they are interested in the possibility of inserting new studies/projects into the existing 3D model of the city °Need to know how a new urban design project will impact traffic, environment, etc. (i.e., solve the problem in context)	°Need cross domain data and insights on the data ° Needs simulations of the impact of measures on other domains.	° Need information regarding policy making (preparations) ° Want to know the impact of policy measures (for example the effects of selected architecture proposal on a 3D map).
CURRENT PRACTICES	°Individual desktop GIS applications usable only by professional users °Static web sites and presentations	°Robust desktop GIS and CAD tools °Visualization and sharing of data/maps/visualizations to third party cloud (ArcGIS online)	° Tools that are focussed on one domain (traffic models ° Using single GIS tools without modelling option.	° Static web site or articles in media. ° Presentations at meetings.
VALUE PROPOSITION	° Overview of the cities' different policy domains in one simpler and	°simpler and more accessible applications for more users	°Connect/deploy different models (traffic, 3D, noise,...) ° Single web	° Better overview of proposed solutions. ° Increase citizen involvement. ° Option to

	more accessible application ° Single web tool to present the effects of policy making ° Communication tool	° new tools for data analysis and visualisation	tool to show the cross-domain effects to policy makers. ° Big data based decisions.	comment or vote for a solution. ° Possibility of own comparisons and basic measurements.
BARRIERS	° making the tools available to a wider audience can lead to misinterpretation of data and analysis results (Lack of ICT and data literacy)	°Non-unified style of communication with designers and architects. °Data compatibility (using different BIM and 3D formats across different systems). °Risk of different analysis results in different systems (applications) ° use of other software tools (such ESRI ArcGIS) for which data exchange and interoperability with DUE needs to be ensured	° Fragmentation of data formats and software solutions. ° Need to switch systems ° Lack of qualitative data ° High investment costs ° Lack of relevant knowhow and competences	° Lack of ICT and data literacy ° No simplicity and ease of use of the presented outputs.

Flanders

CUSTOMER SEGMENT	Policy makers/ Urban Planners *representatives or high-level managers of the city who decide on policies*	Public Servants *of a relevant department (mobility, spatial planning and environmental department,...)*	Citizens *to be informed about smart city policies*
NEEDS	°Need an overview on the cities' different policy domains, seen from different points of view °Is interested in the effects of policy making on different policy domains °Communication to internal and external stakeholders	°Need cross domain data and insights on the data ° Needs simulations of the impact of domain specific measures on other domains. ° Needs to simulate the effects of other domains' measures on their domain.	° Need information regarding policy making (preparations) ° Want to be involved in the policy making of their neighbourhood ° Want to know the impact of policy measures (for example the effects of the closure of a road represented on a 3D map).
CURRENT PRACTICES	Tools that are focussed on one domain (traffic models, own GIS systems,…)	An external research/engineering company is used to perform different studies. These, however, are often focussed on one single domain.	Static communication: brochures, website, info sessions, presentations, …
VALUE PROPOSITION	° Overview of the cities' different policy domains in one application ° Single tool to show the cross-domain effects of policy making ° Communication tool	° Single tool to show the cross-domain effects of policy making	° Increase citizen involvement °better understanding of the policy measures. ° Possibilities to evaluate different measure scenarios.
BARRIERS	° Lack of (relevant) data ° High investment costs ° Lack of relevant knowhow and competences ° Limited collaborations between different departments	° Lack of qualitative data ° High investment costs ° Lack of relevant knowhow and competences ° Limited collaborations ° Need to switch systems	° Lack of ICT and data literacy

Athens

CUSTOMER SEGMENT	Policy maker: elected representatives or high-level managers of the city who decide on policies:	Urban Planner urban planners who work primarily with, city basic structure, urban planners who work with 3D model of the city within their urban planning competence	Citizen to be informed about the smart city policies	Public Servant of a relevant department (mobility, spatial planning and environmental department,…)
NEEDS	Tool to design policies and monitor impact Take decisions according to foreseen impact Advance the city processes technologically	Need to have a tool unified for urban planning overview in order to organize and launch new activities/projects A technology that is cross-sectoral and correlates processes from different domains	Be informed and involved on policy making process	High usability of a tool that can reduce bureaucracy. Integrated sources of datasets Helpful visualization of the city/3D interactive map
CURRENT PRACTICES	Traditional decision-making based on municipal strategic plan	Planners follow the decisions of the city council Their role is consulting only	Individual initiatives from citizens not taken into account by the city Initiatives by the city with citizens not properly diffused	Traditional practises of city planning Old data sources
VALUE PROPOSITION	Liaison with citizens on policy making Tool that concentrates sources of data Monitoring on the correlation	Active role in the city planning Tool that enables their expertise to be taken into account	Increase citizens' engagement Enhancement of being part of city decisions Citizen are acting as testers / 'sensors"	Technological advancement In line with EU cities processes

	of different domains			
BARRIERS	Investment on resources (human, financial) Investment on sensors, sustainability Lack of openness in datasets	Lack of openness in datasets Provision on sustainability Lack of communication among city departments	DTs require some basic level of IT literacy Lack of interest of city matters Low trust in public administration	Literacy on Digital Twin concept and on ICT Integration of DT in the daily work Datasets in non-compatible formats Lack of communication among city departments

We can conclude that there are a lot of similarities between the cities' needs and current practices, however, the city of Pilsen is the only city that is demanding for compatibility with ESRI software, which was not implemented in DUET. We also detected lots of barriers that could prevent DUET to be adopted by the cities. The main barriers are that the end users might lack the necessary (ICT) skills to use a LDT, low level UX, the limited collaborations between different departments, the lack of qualitative data and the risk of the misinterpretations of data. These barriers should be taken seriously and be further investigated.

As discussed in the previous scenario, the current DUET's technical solution is not mature enough to match the defined value propositions for the corresponding cities yet, and further research and development is necessary. However many lessons were learned, awareness was created on the added value of LDTs, and new digital twin projects are coming up. We asked each city what the experience was with DUET and which next steps will be taken.

Since Pilsen participated already in European digital twin projects such as Polivisu there was already an interest in data-supported policymaking. In addition, the city had some concrete use cases that could be implemented in DUET such as the impact of traffic of the closure of the General Patton Bridge, and impact on noise and pollution of the construction of a new Western Ring. In general, the city was enthusiastic about the DUET simulations. However, the solution as it is now, lacks many features (such as the Integration with ESRI software, in which the city invested), which are crucial to be adopted in commercial terms. These missing features can be developed in future projects and therefore Pilsen is also interested in participating in follow up projects (such as DUETTE).

DUET was Athens' first experience with LDT's and the result was very positive. One of the city's main challenges is to structure within the city green routing policies and to encourage citizens to provide feedback on the proposed decisions and also to be familiarised with alternative mobility. In order to reduce traffic and pollution, the policy makers and urban planners are examining the effect of closing streets and creating more pedestrian streets. DUET's value propositions match therefore perfectly to the city's needs. In addition, initiatives such as "The Great Walk of Athens" are currently being implemented whereby streets are

temporarily closed to increase public space and promote public transport. The city decided to continue with DUET by joining the consortium for DUETTE and COMPAIR (these projects will be discussed in scenario 5). We can conclude that there is a high willingness to continue with the project after the lifetime.

Some cities in Flanders, such as Antwerp, were also already involved in LDT projects and therefore Flanders wanted to be involved in DUET as well. The city of Ghent wanted to test the impact of the closure of a bridge on the traffic and three scenarios were defined (the closure in both individual directions and the closure of just one direction). This use case was simulated in DUET and the city was very enthusiastic about the outcome. Flanders wants to participate in future international funding initiatives such as DUETTE and will assist in keeping DUET as-is (DEMO), which is scenario 4 in this deliverable.

A final remark is that the pilot cities should be aware that if they want to continue using the DUET platform, costs of triggering models outside of DUET (for example VITO AQ model) will be involved.

City	Willingness to continue with DUET after the project's lifetime
Athens	YES
Flanders	YES
Pilsen	YES, under certain conditions (ESRI compatibility)

4.3. Scenario 3: The platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers (cities, governments,...)

The third commercial exploitation scenario consists of a commercial offering of the DUET-platform to external customers such as cities and governments. This scenario, however, would imply that DUET has reached a more mature level. To do so, as discussed in chapter 5 of *The State Of The Art Deliverable*, many technical actions should be taken to reach that maturity level. In parallel, it is crucial to identify these external customers' needs and current practices for offering the matching value propositions but also to detect potential barriers. This section compromises 3 parts:

- The first part discusses the **potential value propositions and barriers**, according to the partners
- The second part describes the **actions** that the DUET partners would take to bring DUET to a more mature level
- The third part addresses the **partners' willingness** to bring DUET to a more mature level

4.3.1. Potential value propositions and barriers for adoption

In order to assess the potential value propositions and adoption potential of a commercial roll-out of the DUET-platform, a survey was sent to all DUET project partners to assess whether they see potential in a commercial valorization of the platform. The main questions were what they saw as reasons of why the platform CAN be commercialised (value proposition) and reasons of why the platform CANNOT be commercialised (barriers). The outcome is presented in the table below:

Platform *can be* commercialized	Platform *cannot be* commercialized (Barriers)
- Data driven collaborative decision making is needed - There is a clear demand for an open architecture for Digital Twins based on open standards and principles. The technology we are using (e.g. to connect simulation models) is innovative in how it combines and connects different vendor simulation models (open source and closed source) - Many cities are interested in "buying" a digital twin - There is a great momentum now and interest in the digital twins in the market - The platform offers the presentation of its own data for each city. The map project can be customised for each city (customer) - It is a universal solution applicable to other cities - It can be used for urban planning - If the cost effectiveness of DUET DT and dashboards is proven in terms of market analysis, then the platform is entitled to be commercialised - This is so innovative in the market and we feel a need from cities to have this. - Helping city officials check impact on city planning decisions and citizens to view status of their city in terms of traffic, air and noise levels	- The solution is not mature enough (TRL), is too complex, and has too many stakeholders. Cities need deeper integration with their existing IT solutions. If we are able to sell something, it will be parts connectable to existing city solutions. There is an opportunity to hook up on an existing strong GIS software vendor and offer analytical modules connectable to it's GUI - In the current state, the maturity level is insufficient. Not just in technology, but also at the level of the much needed smart data management principles that can provide reliable sovereign data that is a hard requirement for policy support systems - There are still many weak spots especially in the viewer development (many things are more or less hacked but not production ready) as well as in the backend services and simulation integration. Before it can be used commercially, additional 2-3 man years of development are needed - Before it can be used commercially, a few things need to happen: 1) components and code need to be licensed and versioned, 2) short cuts made during development need to be hardened and polished, 3) TRL level of components need to be uplifted, 4) a support and maintenance processes needs to be set up, 5) partner agreements need to be set up between the consortium partners to share the value, 6) non functional requirements need to be defined and developed - Each city has is bit different situation, handling their own problems → each customer has unique needs → limited scalability - Apps need a trained user → we need to educate our consumers - Acceptance of the solution from the market it is targeting since it will be putting the bar quite high in terms of end users and industry

	awareness levels for eventual operational deployment. In order to approach and make a positive impact, a large number of potential clients will need to be exposed to the DUET Offer.
	- Lack of clear buy-in amongst end users (relatively) Low maturity level of the platform - Complex web of IP arrangements (recurring barriers to exploitation already warned upfront by Europe) - Inadequate financing - skills shortages - regulation that hinders innovation - intellectual property right issues - traditional value chains that are less keen to innovate - incompatibility between parts of systems (lack of standards - mismatch between market needs and the solution

Based on feedback of the partners we can conclude that many different arguments were formulated for which DUET can/cannot be commercialised. However, it is clear that the partners agree that the awareness of the importance of LDT's for cities and governments is growing. In contrast, it is also clear that the current solution does not meet the market needs since the current TRL level is too low. There is a need for smart data and processes, and various types of agreements should be set up and clarified. Only then a commercial exploitation of the platform would become possible. Therefore scenario 5 seems the next step in order to enable this commercial exploitation scenario.

As discussed in section 4.1.3 (The IP regulations for exploitation of the standalone components) and as mentioned in the table above, there are many different IP agreements involved in DUET since each partner uses its own agreements. This complex web of IP arrangements is an enormous barrier to exploit DUET as a platform.

4.3.2.   Partners' required technical actions to bring DUET to a more mature level

As mentioned in this section's introduction and chapter 5 in *the State of The Art deliverable*, various technical actions should be taken to bring DUET to a more mature level.

The main conclusions are that new components need to be added, functionalities of existing components should be extended and internationally recognized IT standards are needed. In addition, there is a need to integrate data spaces into LDT's to source the required data from a multitude of organisations and to prevent the LDT from storing the data. By this integration, the LDT solution remains scalable and uses federated data storage solutions. However, the concept of data spaces is out of DUET's scope, but elaborated in initiatives such as Gaia-X, IDSA (International Data Spaces) and VSDS (Vlaamse Smart Data Space).

In this part, we asked the DUET partners which actions they would take to bring DUET to a more mature level. The results are presented in the table below.

Partner	required actions to bring DUET to a more mature level
P4ALL / InnoConnect	**GLayer** - further develop project configuration options so that data analysts have more choices to configure maps according to their needs (new chart types, data comparison tools, new map layer types etc.) - develop additional database connectors that allow import of data to the GLayer platform, to support more data sources/formats - develop new functionalities to support more types of data sources next to the current traffic related data (e.g. air quality data, statistics data) - implementing new tools such as configurable dashboards
P4ALL	**Traffic Modeller** - further development of the Traffic Modeller towards dynamic traffic modelling - development of periodic automatic calibration using real time sensor data - allow to develop basic traffic model 'from scratch' just with publicly available (open) data (such as OpenStreetMap)
ATC	- Develop services to integrate large amounts of data from different data sources enabling the user to access easily data on-demand; - Further develop visualisation, drill-down, visual exploration and combination of data into meaningful outcomes, rather than try to do everything. - Focus on building image and awareness.
VITO	- Investigate on how the models can be created interchangeably and make the data formats generic. - Handover the hosting of the mapserver for visualisation of the results to the Citytwin platform. - Discuss with the consortium members how a data warehouse can be foreseen where the results can be pushed and remain available. - Improve the results of the AQ model.
KUL	- A traffic expert would be needed to calibrate the traffic models and make them valid. - develop additional software, depending on the use cases
VS	- Rebuild the technology stack to better fulfil the requirements of the t-cell design and ease the reuse of components. - Make the switch from static 3D map deployment to more dynamic applications
imec	- Increase the model and data interoperability - Align components and data models with data space initiatives (generic tools for ecosystem data sharing) - Define a model processing pipeline

| TNO | - Create a solution to store the results and make the UI responsible for the display of these results. |
| | - Create a GPU infrastructure for calculations. |

We can conclude that a lot of actions for each partner would be required to bring DUET to a more mature level. Next to that, a connection to a data space initiative seems necessary to fully enable the potential of the DUET platform.

4.3.3.   Partners' willingness to bring DUET to a more mature level

Partners, such as TNO and Imec are already participating in other digital twin initiatives and are motivated to participate with the DUET initiative to contribute and create a European standard for digital twins. This allows them to easily connect their components or software to other systems and would enable them to facilitate local National Digital Twin initiatives aligned with the European initiatives. For other partners such as ATC it was the first time to participate in a project regarding digital twins. Many of these partners expressed their willingness to bring DUET to a more mature level and are currently writing a proposal for a follow up project based on the lessons learned in DUET (DUETTE).

Indirectly, the internal survey showed that a partner's organisation type largely determines its exploitation objectives. Public authorities are more interested in having a stable and sufficiently advanced platform that can support the work of their policy departments. Tech partners in commercial opportunities that offer them a chance to leverage project experience to create LDTs for prospective customers. Research bodies in technical insights and improved background IP that can be used in an educational setting, for exercises, and research projects.

Whatever strategy we put in place, it's clear that it should be multi-pronged to accommodate diverse exploitation ambitions that exist within the consortium. Perhaps one avenue that should get increased attention is commercialisation, an area that is often overlooked or underdeveloped in EU projects. Given all the hype surrounding urban digital twins, or local digital twins, it would be a shame if we didn't seriously explore DUET's commercialisation potential.

There are different ways in which to approach this. One is to exploit DUET as a blueprint for new LDT creation, another is to exploit the current platform as a data space. When used as a blueprint, DUET may deliver financial gains to partners that leverage project experience (e.g. know-how, improved tools) to offer product and services (e.g. consultancy) to customers looking for a LDT solution. When used as a data space, the current platform may be developed into a marketplace that connects buyers and sellers, enabling them to create new value offerings and information services based on interoperable and secure data streams. This idea is being seriously considered in Rotterdam. The plan there is that the digital twin will "have customers who sell information services, such as real-time parking management, but also based on artificial intelligence to analyse trends."

4.4. Scenario 4: Keep the DUET platform and pilot cases as is - demo platform / showcase

One of the most obvious scenarios is to keep DUET 'alive' as is, this could be considered as 'no exploitation' of DUET at all. This scenario provides an opportunity to stress the benefits of what DUET achieved, i.e. a very open and interoperable architecture. One of our concerns in private/commercial DT development is the emergence of closed DT's with exclusive use of certain models and/or datasets.

This implies that the platform, components and infrastructure need to be kept operational on a daily basis. Therefore a maintenance plan was set up and a forecast on the expected costs was made.

4.4.1. Maintenance plan

Deliverable D5.3 describes the intentions of the partners for sustaining and keeping the DUET platform operationally for one year after the end of the project. The document describes the software maintenance tasks for DUET's components and the user support tasks within the project. Component maintenance is necessary to ensure stability in terms of interface and behaviour. The DUET team will also deliver technical support to end users when encountering technical issues. D5.3 defines three levels of support, depending on the effect on the proper function of the platform. This subdivision will be evaluated by ATC and is aimed to provide the best possible service in the most efficient manner.

4.4.2. Cost Forecast

On top of the maintenance plan, a forecast was set up representing the estimated costs that are related to the tasks and efforts mentioned in the maintenance plan. This aims to meet the interest of the Commission to keep the DUET platform alive for one more year for demo purposes and is to be agreed on with the Commission.

We can conclude that this scenario is likely to take place, since the partners expressed their intention to keep DUET operational for one more year. Therefore the aim is to keep the DUET platform active and available as a demo platform for at least one year after the project officially ends.

4.5. Scenario 5: The digital twin platform is further developed in a subsequent research project

Since further development and research need to be done before we can speak about an operational LDT, an obvious scenario would be to link DUET to another research project where it can be further developed. We detected several projects where DUET could potentially be further developed and listed these below. In these initiatives, the concept and architecture of the components will be used and/or further developed. Many of the consortium members are also participating in these initiatives. Below is a short description of the projects where the concepts of DUET will be explored and matured:

CITCOM.AI is a testing and experimentation facility for AI and robotics in EU27 smart cities and communities.

EU Mission: Climate Neutral Smart Cities: Deliver 100 climate neutral smart cities with experimental innovation hubs delivering concrete solutions.

H2020: URBANAGE: RIA using digital tools to support urban planners in making cities more inclusive and age friendly.

Horizon Europe: COMPAIR is a European project consisting of 15 partners that will empower citizen scientists with digital sensors to easily measure, monitor and act on local air quality data.

Horizon Europe: DUETTE proposal was submitted where the components and architecture will be further developed. The proposal is still in review.

4.6. Scenario 6: The lessons learned from DUET are being exploited beyond the project as 'knowledge'

As discussed in chapter 3, the consortium has also created outputs that are non-technical in nature, but can offer value in different ways. The six objects are :

- Project website with Starter Kit
- Project deliverables
- Publications
- Videos
- Use cases
- Awards

4.6.1. Project website with Starter Kit

The website is the main knowledge repository of the project. It's been organised to cater to different interests based on four results types: policy making, research, tech, and comms. The Starter Kit falls under the policy making category as the intention is to offer a maturity model that cities can use to build a Local Digital Twin (LDT) that is right for them. The main idea behind the Starter Kit is to package its learnings into a useful and easily digestive format to help future potential digital twin adopters and suppliers.

The starter kit compromises 3 parts:

- Provide fundamentals via the **DUET book**: This will be a digital twin textbook containing the outcomes and results of the DUET project supplemented by findings from other digital twin implementations in order to support other early adopters. This book is aimed at a broad range of readers who have some technology knowledge but are not necessarily domain experts such as policy and smart city researchers, policymakers, smart city project managers, data experts, ICT architects and managers, smart city developers and urban information experts. The writers of the book decided that it will be published with Springer publishing on an open access book.
- Provide inspiration via the **CityTwin portal (www.citytwin.eu):** The gateway to the DUET digital twins through the landing pages. It delivers inspiration through the case studies and users can access the digital twins themselves. In addition, the portal is enriched by user stories.
- Support implementation via the **project website (www.digitalurbantwins.com)**: The website already was the storage place for DUET's official deliverables and outputs and also communicates DUET's value propositions to different stakeholders. An updated version will also contain the *Digital Twin Maturity Model* which helps determine where a city is in their digital twin journey. It is a high level diagnostic tool that defines 4 stages (Awareness, Exploratory, Predictive and Future-Ready) and contains questions to identify the current stage a city is in. Subsequently, the tool helps cities plan and prepare on how to formulate their vision and create their strategy and roadmap for the change. The four stage model is outlined below.

DUET Digital Twin Maturity Model
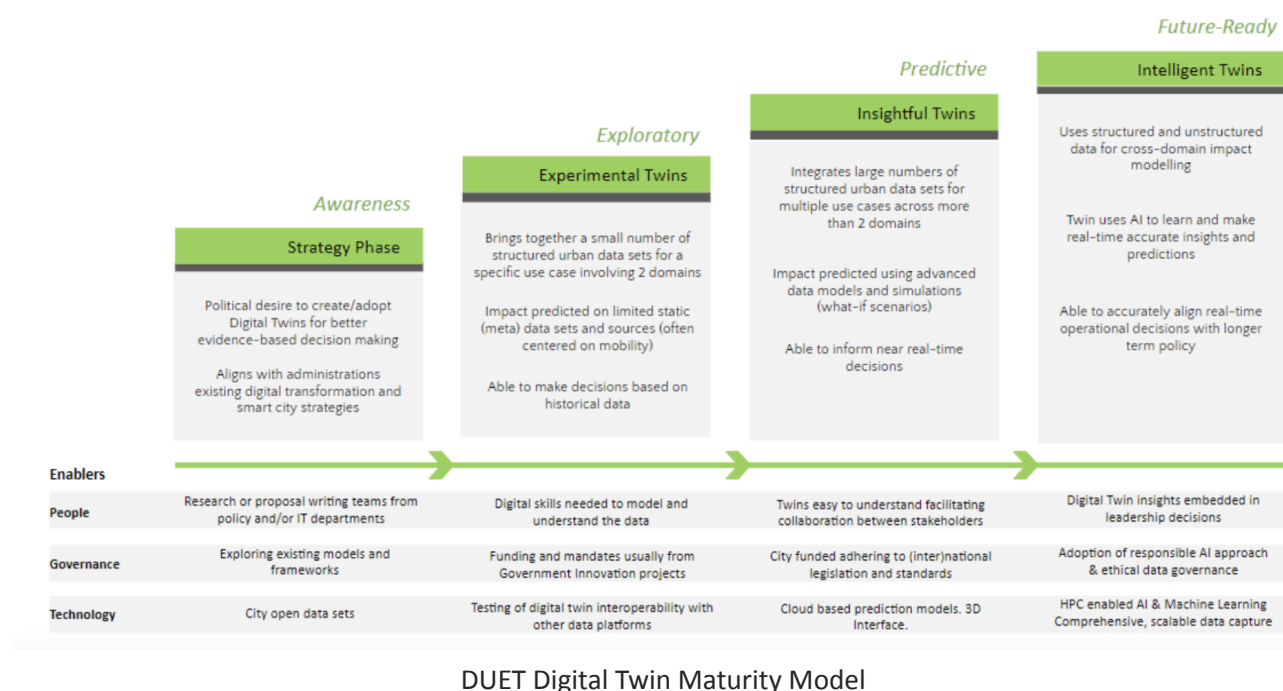
The website will remain live for at least two years after the project, and will be maintained for as long as necessary thereafter if it proves to be a popular resource, as evidenced by traffic to and user interactions with the site and its contents.

4.6.2. Project deliverables

These are written reports that document all the ideas, steps, processes and tools used in the creation of the DUET brand. DUET is mainly known for its LDT platform, but the brand is actually more than that. It includes new ways of thinking about digits twins for the public sector, new approaches to data governance and interoperability, new ethical and legal considerations, and new business models for sustaining LDTs commercially. All these are captured in several dozen deliverables so that others can easily learn from DUET to create their own LDTs. Given their immense value, project deliverables must remain available for as long as possible, not just on the project website but other channels too. To that end, we will publish all public deliverables on Cordis and Zenodo after receiving approval from the European Commission and make them available on the DUET deliverable overview page of the website.

4.6.3. Publications

By the end of the project, DUET will have produced 12 publications: two white papers, two conference papers, two peer-reviewed papers, five policy briefs, and one book. Some were prepared by members of the consortium, some in cooperation with external stakeholders. Most publications reuse content from deliverables, while a few are based on the outcome of past events. The collection is hosted on the DUET website, with links to the publisher's channel available for each paper. DUET's presence on external sites (e.g. Springer, IEEE, ERCIM) means we can amplify our key messages more easily, spreading the word about the project further and faster.

While all publications have their merits, the most important one is arguably the open-access Springer book that is due for submission in October 2022. The editorial team includes DV, OASC, imec, 21c and some

external experts. Titled **'Decide Better. Local and Interoperable Digital Twins'** the book contains 12 chapters that introduce the reader to LDTs (part one), explains how to implement them (part two) and how to unlock maximum value from their (re)use (part three). The book will be announced at DUET's final event in Barcelona in November 2022 during the Smart City Expo World Congress. Although the book will be published in Spring 2023 at the earliest, parts of the manuscript can and will be shared sooner via DUET's channels as part of the open access arrangement with the publisher.

4.6.4. Videos

DUET has a small but diverse collection of videos on its YouTube Channel. There are animated project videos, videos where project partners explain DUET and its benefits, and videos with testimonials from Flemish policy makers that were recorded for the TechForGovernment competition in which DUET was a finalist. By the end of the project, a new set of videos will be added to explain how to use the platform. These will be 1-2 minute videos where we explore our digital twins from the point of view of different stakeholders e.g. a traffic analyst, an environment officer, a citizen. Based on the persona, a short how-to video will be recorded to explain how a particular stakeholder can use the platform to carry out a specific task e.g. compare traffic scenarios in response to different road measures. The videos will be embedded into citytwin.eu and will remain on YouTube indefinitely.

4.6.5. Use case

Use cases are captured in the form of scenarios that address real policy needs and/or urban challenges faced by DUET's pilot cities. There are currently 13 use cases on citytwin.eu: five Czech use cases, five Greek ones, and three for Flanders. Each scenario is set in context. This allows the user to better understand the challenge, how best to address it, and what the expected outcome should be. The use cases come complete with a guide that walks the user through the steps needed to simulate a scenario in a digital twin environment. Use cases provide a template for how-to videos described earlier, and are going to be sustained in their current form on the platform and as videos on YouTube.

4.6.6. Awards

DUET was named the best Enabling Technology at the World Smart City Awards 2021, a prestigious international competition that seeks to recognise pioneering projects, ideas and strategies making cities around the world more livable, sustainable, and economically viable. The Enabling Technologies Award is given to the most innovative and successful projects being implemented and developed in the fields of data and technology. After a highly competitive selection process, DUET was invited to the awards ceremony in Barcelona, where it was placed in the spotlight on a recognised international platform and in front of a large, diverse audience. The Enabling Technology Winner badge is now proudly displayed on the project's website. In addition, DUET was a finalist in the Tech for Government Pitch competition sponsored by the French National Institute of Public Service in celebration of France's take-over of the EU Presidency. In March 2022, Digital Flanders travelled to Strasbourg to present DUET in front of 27 EU ministers responsible for digital transformation. Both of these achievements are a testament to the wider recognition of the pioneering work DUET is doing to evolve policy making through LDTs. Given their intangible nature, there is no easy way to sustain these results. Possible options include adding the 'award winning' label to DUET in future dissemination material, including videos, and project description on platforms life Living-In.EU, of which DUET is a member.

5. Conclusions & wrap-up

This deliverable described different possible scenarios that could happen with DUET after the lifetime of the project. Some scenarios require additional development work, others can be executed already. We also emphasised that some scenarios can co-exist and that some scenarios can be regarded as building further upon each other.

Scenario 1 (**The components developed in DUET are being exploited as stand-alone or combined elements in future digital solutions**) is already taking place since some of the partners are already commercially exploiting the components they built for DUET. In this scenario we also learned that other components still require lots of development work and some of the components are not even exploitable, since these were built to make DUET as a Proof Of Concept.

Scenario 2 (**The Digital Twin instantiations in the three pilot sites remain active after the DUET-project, actively being used by the pilot sites**) was defined since three regions/cities (Flanders, Pilsen and Athens) decided to test the current solution and there is a possibility that one or more of these cities will actively use the LDT after the project. However, we learned that the current solution is not mature enough to be actively used by the different cities. In addition some barriers were detected why a digital twin solution could potentially not be adopted by the pilot cities. The main barriers are that the end users might lack the necessary (ICT) skills to use a LDT, the limited collaborations between different departments, the lack of qualitative data and the risk of the misinterpretations of data. These barriers should be taken seriously and be further investigated. Further development and research of the platform and the use cases is needed to realise this scenario, e.g. via scenario 5. The three pilot cities are willing to participate in follow up projects (such as DUETTE).

Scenario 3 (**The platform (citytwin.eu) developed within DUET is being exploited beyond the lifetime of the project by external customers**) described which actions would be necessary to bring DUET to a more mature level so that external parties can use the LDT. We learned that not only new components and functionalities should be added, but integrations with data spaces should be set up as well. The concept of data spaces still needs a lot of research and development and was out of DUET's scope. In addition, we learned that DUET consists of a complex web of IP agreements, which results in a big barrier to commercially exploit DUET as a platform. This means that scenario 3 is unlikely to happen in the near future, possibly after a successful accomplishment of scenario 5.

Scenario 4 (**Keep the DUET platform and pilot cases as is - demo platform / showcase**) is a non commercial scenario whereby DUET is kept alive as a DEMO (e.g. design freeze) to demonstrate the POC of a LDT and create awareness to cities. Although no further development is necessary, the platform, components and infrastructure need to be kept operational. Therefore a software maintenance plan was set up and an overview was created on the corresponding costs. This scenario will become reality as there are plans to keep DUET on air for at least one year after the project officially ends.

Scenario 5 (**The digital twin platform is further developed in a subsequent research project**) addressed the further development of DUET in subsequent research projects. At the moment, at least three EU projects will use (parts of) DUET to further develop and integrate them in these projects' ambitions and solutions.

The final scenario, 6 (**The lessons learned from DUET are being exploited beyond the project as 'knowledge'**), described how the lessons learned from DUET (as knowhow) can be exploited through different channels and tactics e.g. Starter Kit, deliverables, publications, awards.

We can summarise that most of these scenarios are already executed or will be executed in the near future. For example some of the partners are already exploiting the components they have built for DUET (scenario 1). Also, many partners expressed their willingness to keep DUET operational as a DEMO (scenario 4) and are even willing to bring DUET to a more mature level, for example by submitting a proposal for a follow up project DUETTE (scenario 5). Currently some of the consortium partners are creating outputs that are non technical in nature such as the starter kit, e-book and policy brief.

In order to bring DUET to a more mature level so that the pilot cities can actively use the platform (scenario 2), or external parties can use it (scenario 3), concepts such as data spaces and international IT standards need to be set up. However, these are out of scope of this project.

Even if it wasn't possible to create a LDT that is instantly deployable in cities and governments, all partners agree that lots of value was created in terms of reusable software, knowhow and learnings. Today, DUET offers a unique scalable and open digital twin architecture that functions well as a proof of concept and is able to cooperate with a variety of external systems of different maturity levels. Some (parts of) components and knowhow will be reused in further projects and initiatives. In addition, DUET generated awareness of the benefits of a LDT at the pilot cities. The stakeholders of these cities learned that an LDT will assist them in the transition towards data driven governments and also gained insights in which tools and ICT systems can help them during this transition.

References

Almirall, E., Lee, M., & Wareham, J. 2012. Mapping Living Labs in the Landscape of Innovation Methodologies. Technology Innovation Management Review, 2(9): 12–18. http://doi.org/10.22215/timreview/603

Ballon, P. 2007. Business Modelling Revisited: The Configuration of Control and Value. info, 9(5): 6–19. https://doi.org/10.1108/14636690710816417

D'Hauwers, R., Rits, O., & Schuurman, D. 2015. A Hypothesis Driven Tool to Structurally Embed User and Business Model Research within Living Lab Innovation Tracks. Paper presented at the 2015 European Network of Living Labs (ENoLL) Open Living Lab Days.

Osterwalder, A., Pigneur, Y., Oliveira, M. A. Y., & Ferreira, J. J. P. (2011). Business Model Generation: A handbook for visionaries, game changers and challengers. African journal of business management, 5(7), 22-30.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. 2015. Value Proposition Design: How to Create Products and Services Customers Want. Chichester, UK: John Wiley & Sons.

Porter, M. E. (1985). Technology and competitive advantage. Journal of business strategy.

Ries, E. 2011. The Lean Startup: How Constant Innovation Creates Radically Successful Businesses. New York: Crown Business.

Schuurman, D. 2015. Bridging the Gap between Open and User Innovation? Exploring the Value of Living Labs as a Means to Structure User Contribution and Manage Distributed Innovation. Doctoral dissertation. Ghent University and Vrije Universiteit Brussel VUB. https://biblio.ugent.be/publication/5931264/file/5931265.pdf

Schuurman, D., Herregodts, A. - L., Georges, A., & Rits, O. 2019. Innovation Management in Living Lab Projects: The Innovatrix Framework. Technology Innovation Management Review, 9(3): 63-73. http://doi.org/10.22215/timreview/1225

Staw, B. M. 1981. The Escalation of Commitment to a Course of Action. Academy of Management Review, 6(4): 577–587. https://doi.org/10.5465/amr.1981.4285694

Steinkühler, D., Mahlendorf, M. D., & Brettel, M. 2014. How Self-justification Indirectly Drives Escalation of Commitment – A Motivational Perspective. Schmalenbach Business Review, 66(2): 191–222.

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Almirall, E., & Wareham, J. 2008. Living Labs and Open Innovation: Roles and Applicability. The Electronic Journal for Virtual Organizations and Networks, 10(3): 21–46.

Almirall, E., & Wareham, J. 2011. Living Labs: Arbiters of Mid- and Ground-Level Innovation. Technology Analysis & Strategic Management, 23(1): 87–102.

https://doi.org/10.1080/09537325.2011.537110

Äyväri, A., & Jyrämä, A. 2017. Rethinking Value Proposition Tools for Living Labs. Journal of Service Theory and Practice, 27(5): 1024–1039.
https://doi.org/10.1108/JSTP-09-2015-0205

Baccarne, B., Logghe, S., Veeckman, C., & Schuurman, D. 2013. Why Collaborate in Long-Term Innovation Research? An Exploration of User Motivations in Living Labs. Paper presented at the 4th European Network of Living Labs (ENoLL) Living Lab Summer School 2013.

Ballon, P., Van Hoed, M., & Schuurman, D. 2018. The Effectiveness of Involving Users in Digital Innovation: Measuring the Impact of Living Labs. Telematics and Informatics, 35(5): 1201–1214.
https://doi.org/10.1016/j.tele.2018.02.003

Bergvall-Kåreborn, B., Ihlström Eriksson, C. Ståhlbröst, A., & Svensson, J. 2009. A Milieu for Innovation: Defining Living Labs. In Proceedings of the 2nd ISPIM Innovation Symposium, New York, December 6–9.

Bergvall-Kåreborn, B., Howcroft, D., Ståhlbröst, A., & Wikman, A. M. 2010. Participation in Living Lab: Designing Systems with Users. In J. Pries-Heje, J. Venable, D. Bunker, N. L. Russo, & J. I. DeGross (Eds), Human Benefit through the Diffusion of Information Systems Design Science Research. TDIT 2010. IFIP Advances in Information and Communication Technology, 318. Berlin: Springer.
https://doi.org/10.1007/978-3-642-12113-5_19

Blank, S. 2006. The Four Steps to the Epiphany. Foster City, CA: Cafepress.com.

Blank, S. 2013. Why the Lean Start-Up Changes Everything. Harvard Business Review, 91(5): 63–72.

CB Insights. 2018. 253 Startup Failure Post-Mortems. CB Insights. Accessed July 1, 2018:
https://www.cbinsights.com/research/startup-failure-post-mortem/

Coorevits, L., & Schuurman, D. 2014. Hypothesis Driven Innovation: Lean, Live and Validate. In Proceedings of the XXV International Society for Professional Innovation Management (ISPIM) Innovation Conference.

Gage, D. 2012. The Venture Capital Secret: 3 Out of 4 Start-Ups Fail. The Wall Street Journal, September 29, 2012. Accessed March 1, 2019:
https://www.wsj.com/articles/SB10000872396390443720204578004980476429190

Gourville, J. T. 2005. The Curse of Innovation: A Theory of Why Innovative New Products Fail in the Marketplace. HBS Marketing Research Paper No. 05-06. Boston, MA: Harvard Business School (HBS).
https://dx.doi.org/10.2139/ssrn.777644

Herregodts, A. L., Baccarne, B., Conradie, P., & Schuurman, D. 2017. Managing Innovation Uncertainties: A User-Oriented Knowledge Typology. In Proceedings of the 2017 International Society for Professional Innovation Management (ISPIM) Innovation Symposium.

Jyrämä, A., & Äyväri, A. 2015. Art Encountering Society; Identifying the Skills. Paper presented at the 13th International Conference on Arts and Cultural Management (AIMAC), Aix-en-Provence and Marseille, France, June 28 – July 2, 2015.

Katzy, B. 2012. Designing Viable Business Models for Living Labs. Technology Innovation Management Review, 2(9): 19–24.
http://doi.org/10.22215/timreview/604

Kristensson, P., Matthing, J., & Johansson, N. 2008. Key Strategies for the Successful Involvement of Customers in the Co-Creation of New Technology-Based Services. International Journal of Service Industry Management, 19(4): 474–491.
http://dx.doi.org/10.1108/09564230810891914

Leminen, S., Westerlund, M., & Nyström, A.-G. 2014. On Becoming Creative Consumers – User Roles in Living Labs Networks. International Journal of Technology Marketing, 9(1): 33–52.
http://dx.doi.org/10.1504/IJTMKT.2014.058082

Leminen, S. 2015. Living Labs as Open Innovation Networks – Networks, Roles and Innovation Outcomes. Doctoral dissertation. Helsinki, Finland: Aalto University.

Leminen, S., & Westerlund, M. 2017. Categorization of Innovation Tools in Living Labs. Technology Innovation Management Review, 7(1): 15–25.
http://doi.org/10.22215/timreview/1046

Lovallo, D., & Kahneman, D. 2003. Delusions of Success. Harvard Business Review, 81(7): 56–63.

Maurya, A. 2012. Running Lean: Iterate from Plan A to a Plan That Works. Sebastopol, CA: O'Reilly

Osterwalder, A. & Pigneur, Y. 2013. Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. Chichester, UK: John Wiley & Sons.

Rits, O., Schuurman, D., & Ballon, P. 2015. Exploring the Benefits of Integrating Business Model Research within Living Lab Projects. Technology Innovation Management Review, 5(12): 19–27.
https://timreview.ca/article/949

Schaffers, H., Cordoba, M. C., Hongisto, P., Kallai, T., Merz C., & van Rensburg, J. 2007. Exploring Business Models for Open Innovation in Rural Living Labs. Paper presented at the 13th International Conference on Concurrent Enterprising (ICE), Sophia-Antipolis, France.

Schuurman, D., & De Marez, L. 2012. Structuring User Involvement in Panel-Based Living Labs. Technology Innovation Management Review, 2(9): 31–38.
http://doi.org/10.22215/timreview/606

Schuurman, D., De Marez, L., & Ballon, P. 2013. Open Innovation Processes in Living Lab Innovation Systems: Insights from the LeYLab. Technology Innovation Management Review, 3(11): 28–36.

http://doi.org/10.22215/timreview/743

Schuurman, D., & Protic, S. M. 2018. Living Labs versus Lean Startups: An Empirical Investigation. Technology Innovation Management Review, 8(12): 7–16. http://doi.org/10.22215/timreview/1201

Ståhlbröst, A. 2013. A Living Lab as a Service: Creating Value for Micro-enterprises through Collaboration and Innovation. Technology Innovation Management Review, 3(11): 37–42. http://doi.org/10.22215/timreview/744

Wildevuur, S., van Dijk, D., Hammer-Jacobsen, T., Bjerre, M., Äyväri, A., & Lund, J. 2013. Connect – Design for an Empathic Society. Amsterdam: BIS Publishers.

Yin, R. K. 2009. Case Study Research: Design and Methods. Thousand Oaks, California: SAGE Publications, Inc.