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Designing smart, resilient cities for all

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Executive summary

This guide Smart City Design and Decision Platforms (Urban Data Platforms or UDPs) highlights the role and use of emerging UDPs in the context of the RUGGEDISED lighthouse cities. RUGGEDISED fellow cities, as well as any other city in Europe, can draw inspiration and guidance from this guide for the development of an UDP. The guide is based on lessons learned from the RUGGEDISED Liaison Group meetings. Together with D1.4 “Guide for setting up and sustaining Local Innovation Platforms”, D1.5 “Prototype Smart Energy District Planner” and D1.8 “Guide on ruggedized implementation and innovation of smart solutions” this guide on Urban Data Platforms synthesises the lessons learned from the implementation phase of the RUGGEDISED project.

City data has immense potential to improve the quality of life, business and governance in smart cities. Urban Data Platforms (UDPs) are addressed in this guide as the bridging infrastructure between the city data that can be of public or private nature. The lighthouse cities in the RUGGEDISED project, the cities of Glasgow, Umea and Rotterdam, are all engaged in the development of UDPs. UDPs differ in shape and process, but have the same goal: to process and use data for a resilient city that can cope with grand challenges such as climate change and rapid urbanization. This guide provides guidance for developing a city data strategy and an UDP for cities.

From realising UDPs in the RUGGEDISED lighthouses, the following can be concluded:

- UDPs are an essential means in the journey towards smart cities. Due to their novelty it is common that UDP projects start off as an innovation project. However, for support of the UDP and the desired impact in the smart city, thorough embeddedness of the UDP over the entire local government and alignment with the needs and resources of the stakeholders in the ecosystem is essential. This entails that organizational change could be required, and that a government wide strategy on city data (availability, processing, and use) should be developed.
- Stakeholders should have sufficient trust in the UDP for sharing data and using the UDP to create new use cases. Creating an environment in which involved stakholders have trust in each other and in the UDP software, hardware and governance, is therefore of utmost importance. Thorough stakeholder engagement strategies, as well as a charter that sets the governance rules of collaboration in the ecosystem of the UDP aid this trust.
- Data management challenges, e.g. availability, quality, interoperability, ownership/governance, privacy, valuation and monetization are essential elements of a city data strategy and influence the design of the UDP. This should be acknowledged by new UDP projects for the design and governance of the UDP and the city data.
- UDPs should be developed in a demand-driven manner, as value creation in a user-centric business-model is essential. However, it is recommended to incorporate sufficient room in the platform design to cater in the unkown or future demands as demands could change and are currently not fully articulated. In addition to economic aspects, the business model should also account for the environmental and social aspects. In order to have a city wide impact, the UDP should address needs of the politicians, planners, businesses and citizens. Already in the development process, clear value cases should be defined together with the potential users. The added value of the UDP should be evidenced by means of functional prototypes to convince the potential users and data providers of its added value, also known as the “show, don’t tell” strategy
- In line with a demand-driven strategy, the UDP should be visually appealing and convenient to use by the target groups. This entails convenient APIs, user friendly interface, open source development, cost efficient, and innovative visualization (3D, VR/AR).
- The UDPs in the three lighthouses go beyond data sharing and create opportunities for decision-making support for first of all the government, and to a varying extent, for citizens and businesses in the city. Moreover, the UDPs enable the co-creation of digital products and services by the various stakeholders.

- Depending on resources and expertise available, the municipality needs to make an important decision whether or not to develop, host and maintain the UDP in-house, or partly or completely outsource the development, hosting or maintenance of the UDP. This process is critical for the success of the UDP and needs to be done at all times with an agile and user-centric philosophy with room for innovation (due to the rapidly evolving technological change in this field), while preventing vendor lock-ins.

These conclusions are captured in an UDP development process consisting of 5 main phases. This process is summarized in Figure 1 and combines state-of-the-art knowledge about developing UDPs, for instance coming from the European Innovation Partnership for Smart Cities & Communities, with the lessons learned from the UDPs in the RUGGEDISED lighthouse cities. The depicted development process provides guidance for cities that want to start with development of a UDP, leads them through the different phases, and provides an overview of the aspects to take into account in each phase.

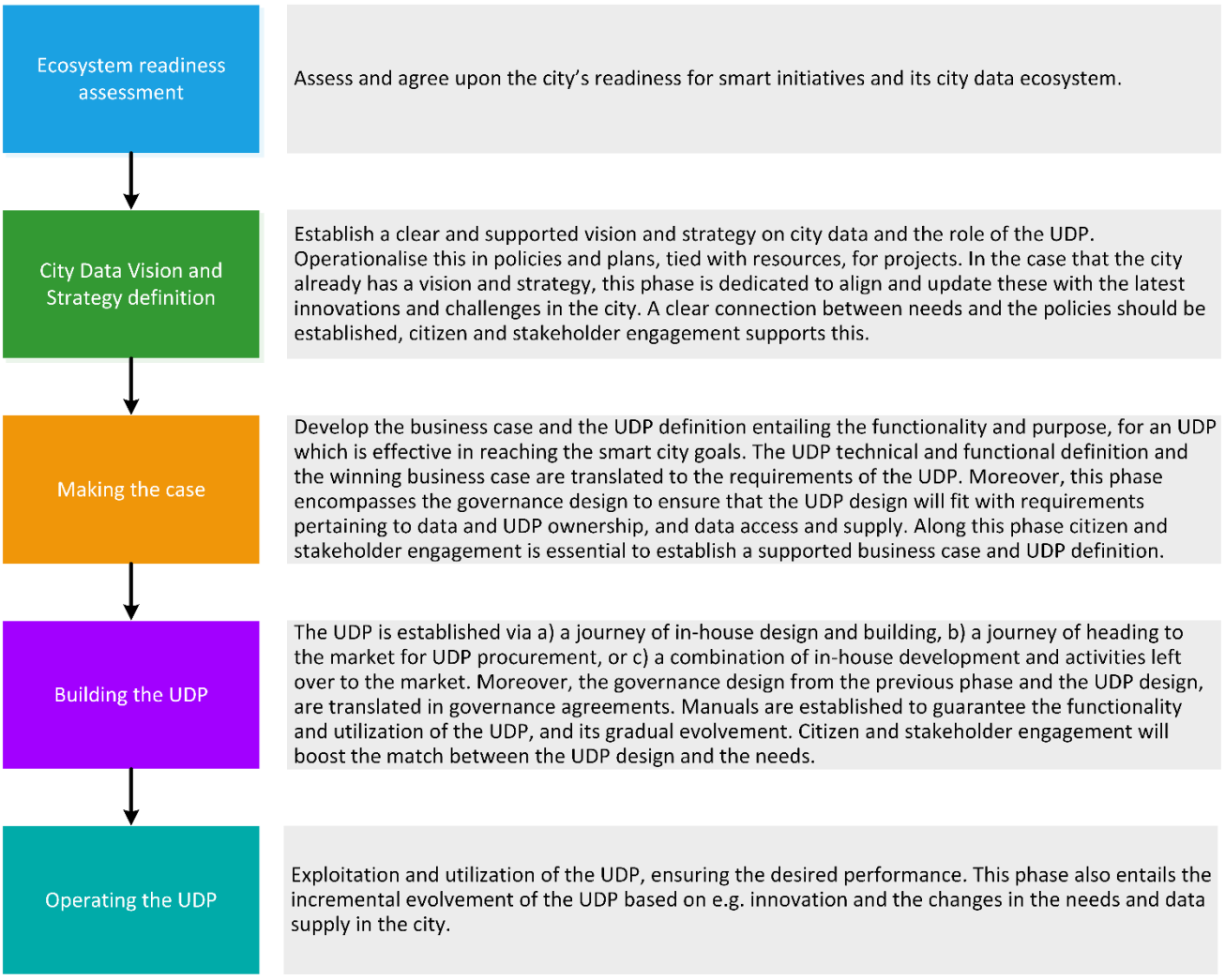

Figure 1: A 5 step guide for developing an UDP in cities

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1. Introduction

This guide is based on the lessons that has been learned and discussed by the Lighthouse Cities in the RUGGEDISED Liaison Group meetings. Together with D1.4 “Guide for setting up and sustaining Local Innovation Platforms”, D1.5 “Prototype Smart Energy District Planner” and D1.8 “Guide on ruggedized implementation and innovation of smart solutions” this guide on Urban Data Platforms synthesis the lessons learned from the implementation phase of the RUGGEDISED project. The RUGGEDISED Fellow Cities will test the collaborative smart city guides. Eventual changes will be taken up in final versions of the guides at the end of the running periode of the RUGGEDISED project (Autumn 2021).

1.1 Smart cities in the age of global grand challenges

Today over 50% of the world’s population lives in cities. Due to rapid urbanization this number will continue to rise with people moving to cities as places of opportunity and creativity. However, cities are also facing continuous stress in coping with these numbers which have adverse effects like pollution, crime, and alienation. Along these are regional and local issues, cities are also challenging by Global phenomena which manifest on the city level. Among these grand challenges, climate change, digitilisation, globalization is commonly addressed as the most impactful. The smart city of the future will use digital technologies to improve efficiency, inclusion, sustainability, and prosperity. Digital technologies create a hyper-connected and hyper-intelligent world, where the dividing line between virtual and physical worlds disappear (Sheombar, van Oosterhout, Larsen, Kotterink, & Dittrich, 2019).

1.2 The emergence of data and urban data platforms in the smart cities

Within smart cities novel digital services such as smart grids, on-demand mobility, smart water management, intelligent infrastructure e.g. lighting and bridges are reinventing the public service models and processes. These smart city activities are increasing the data generation and flows in today’s cities at an unprecedented rate (Schieferdecker, Tcholtchev, & Lämmel, 2016; Barns, 2018). Previously, digitilisation is mentioned as one of the grand challenges for cities. On the same note, this digitilisation is of increasing value for policy makers, urban planners, businesses and citizens via the endless opportunities for decision-making and processes in the cities to be improved in terms of efficacy and reach.

With efforts and investments in smart cities are now wide spreading over the world, so is the emergence of data-driven platforms and tools to foster the efficacy and upscaling of smart city activities. The data being generated within this context can be defined as city data. In the memorandum of understanding towards Open Urban platforms for Smart Cities and Communities, city data is defined as data held by organisations, public, private or not-for-profit, which is providing a service or product, or is occupying part of a city with a significant impact on the population or the functioning of the city (Schieferdecker et al., 2016). This data can be static and descriptive, and in the future the role of real-time, operational data will increase. Moreover, this data can be sourced from public parties, e.g. on traffic infrastructure, or private parties, e.g. the energy consumption, and in the future more data can be generated by citizens. Subsequently privacy and trust will become of increasing importance.

For this city data to be put to effective use in optimizing the activities and use of resources in the city, Open Urban Platforms or Urban Data Platforms (UDP), form the necessary infrastructure. The terms Open Urban Platforms and Urban Data Platforms are used interchangeably among literature and smart city projects, and to a large extent they entail the same. In this guide the term Urban Data Platforms will be used. According to the European Innovation Partnership for Smart Cities & Communities, these UDPs are defined as “a logical city data architecture that brings together and integrates data flows within and across city systems in a way that exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc).” An UDP contains building blocks for the city to adapt data-driven effective operations and new ways of conveying public services to city stakeholders, while engaging them in that process.

An UDP, defined and designed for utilization and impact, fosters the connectivity and intelligence between the different actors in cities’ ecosystem. Intelligence can emerge via the interactions which are captured and visualised on the platform. The open nature of an UDP and the transparency about its rules and

regulations will benefit a democratic society and spur innovation (Sheombar, van Oosterhout, Larsen, Kotterink, & Dittrich, 2019).

The development of UDPs has evolved over time and is driven by the emerging governance challenges and opportunities pertaining to the rise of the data assets in the cities, but also the open government agenda with the “government as a platform”, the rise of the smart cities emphasizing data-driven methods to solve the challenges in cities, and the increasing role of real-time data-driven performance monitoring and control of activities in the cities (Barns, 2018).

1.3 A guide for Urban Data Platforms

UDPs have the objective to foster a new way of governing our cities., However, the development and utilization of UDPs is not yet part of the existing processes in local governments. Due to the novelty, UDPs are treated as innovation projects within governments. However, for these UDPs to be effective, embeddedness within the activities and processes of government, citizens and other urban stakeholders is essential. Hence, this guide aims to provide insights in possibilities to embed the UDP within the local government and the city, hence let it be more than an innovation project.

1.4 Reading guide

In the proceeding chapter 2, light will be shed on the concept of Urban Data Platforms from a literature overview. This is followed by the presentation of the UDPs established in the three RUGGEDISED lighthouses in chapter 3. Together, chapter 2 and chapter 3 result in a general development process, as a starting point to develop a UDP. This is presented in chapter 4. Chapter 5 presents recommendations to promote the utilization of the UDP. Chapter 6 provides some essential remarks to conclude.

2. State of the art on Urban Data Platforms

2.1 What is an Urban Data Platform?

2.1.1 Urban Data Platform definition and conceptualization

One of the aims of is to advance the understanding of Urban Data Platforms (UDPs) and to contribute to the development of more and improved UDPs throughout Europe. The terms Open Urban Platforms and Urban Data Platforms are used interchangeably in literature and smart city projects. To a large extent, they entail the same. NEN, the Dutch Standardization Institute, applies the term Open Urban Platforms and developed standards for such an Open Urban Platform. These standards, on design, development and procurement, improve the availability of open data and interoperability (NEN, 2019). This guide uses the term Urban Data Platforms (UDPs).

UDPs can be conceptualized in different ways.

Figure 2 displays the UDP, as conceptualized in RUGGEDISED. UDPs consist of two main levels, namely a supply layer, consisting of various data sources and a demand layer, consisting of the possible applications of data. The UDP is located between these two levels and functions as the linking bridge.

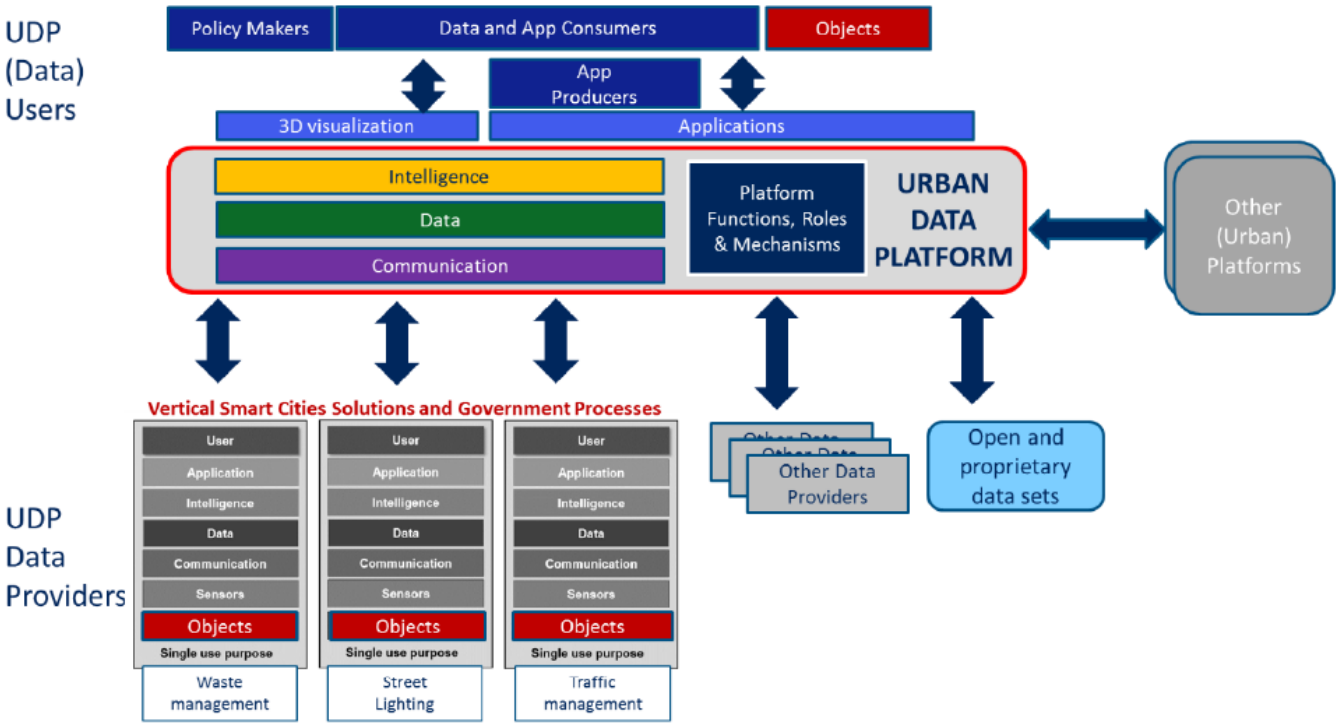


Figure 2: UDP conceptualization, adapted from (Sheombar et al., 2019)

In Figure 3 the ecosystem of a UDP is displayed, capturing the stakeholders involved in more detail.

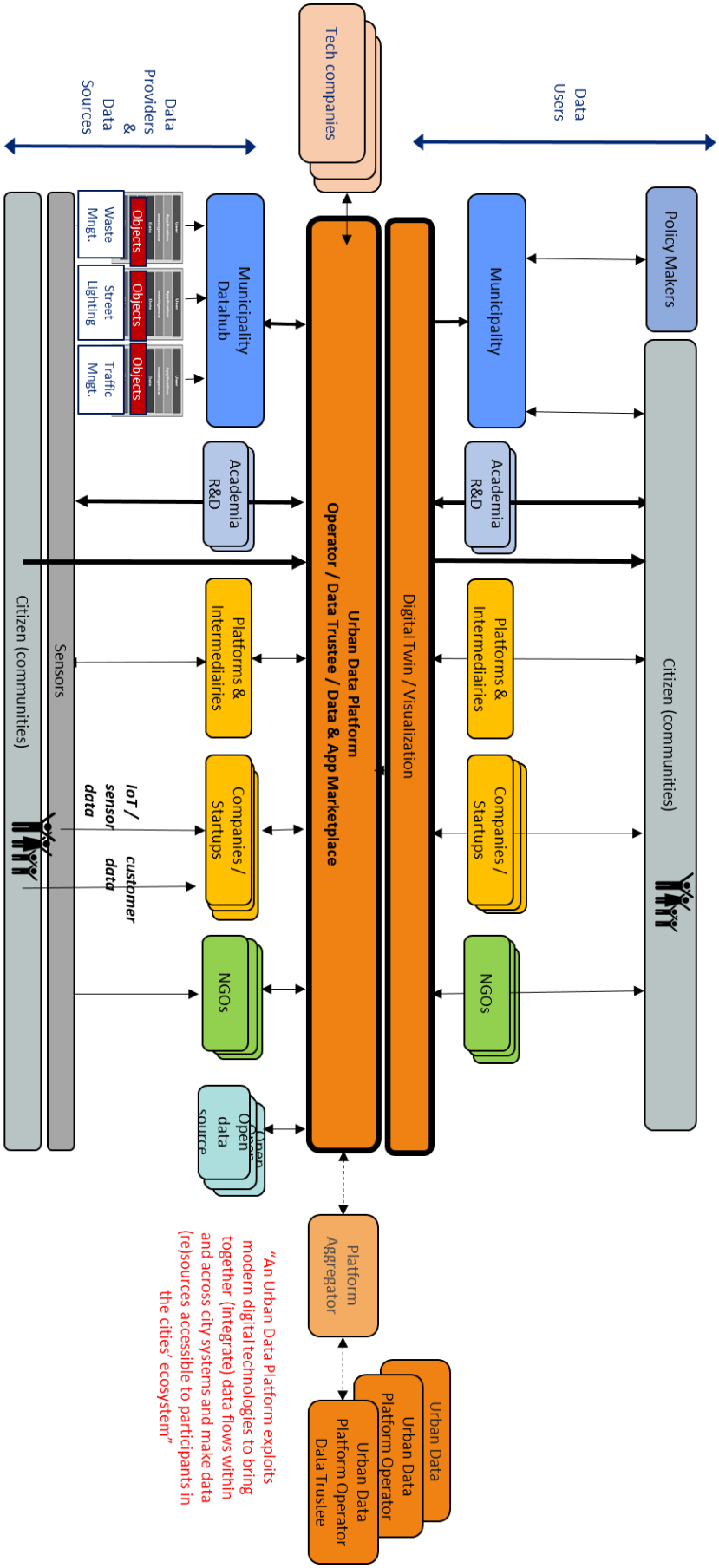

Tech companies
Data Users
Data Providers & Data Sources
Policy Makers
Municipality
Municipality Datahub
Waste Mngt.
Street Lighting
Traffic Mngt.
Objects
Academia R&D
Urban Data Platform
Operator / Data Trustee / Data & App Marketplace
Digital Twin / Visualization
Platforms & Intermediairies
Companies / Startups
NGOs
Open data source
Citizen (communities)
Sensors
IoT / sensor data
customer data
Platform Aggregator
Urban Data Platform Operator
Urban Data Platform Operator Data Trustee
Urban Data
"An Urban Data Platform exploits modern digital technologies to bring together (integrate) data flows within and across city systems and make data (re)sources accessible to participants in the cities' ecosystem"

Figure 3: Conceptualization of a UDP ecosystem, adapted from (Sheombar et al., 2019)

2.1.2. UDP functionality

The UDP functions as the enabling infrastructure that will attract an ecosystem of users, developers, citizens, and government. Together they create both private (e.g. innovation, profit) and public value (e.g. political, social, environmental) by developing and using digital products and services. They feed the providers and users of these products and services with data (Sheombar et al., 2019). Most UDPs are subsequently developed to collect, process, integrate, store, share, (3D) visualize and analyse data from smart city solutions, and enrich these data with other open and closed data (van Oosterhout, Sheombar, van Heck, Kuper, & Ros, 2018).

One of the main functional aims of UDPs is to derive inisghts on the current functioning of the city. Those insights are input to support decision making over various domains. According to Schieferdecker, Tcholtchev, and Lämmel (2016) four types of insights can be drawn from city data through UDPs:

1. *Operational insights* to understand the properties and characteristics of urban objects and activities, and to derive opportunities for improvement of e.g. public real-estate and public services to citizens.
2. *Critical insights* to monitor and derive recommendations of reactions to incidents or crises.
3. *Analytical insights* to identify and assess patterns and correlations to subsequently derive forecasts on urban innovation. Additionally, for impact assessment of urban innovation measures and the derivation of evidence on challenges and opportunities in the urban environment.
4. *Strategic insights* to facilitate overarching strategies among goals, plans and decisions in the urban environment

2.1.3. UDP framework for effective data processing and publishing

The challenges for data collection, processing and publishing are significant. City data come from a variety of heterogeneous sources. They are generated, stored and exchanged using different technologies and methods. Research on UDPs is actively developing comprehensive frameworks to tackle these challenges. For instance, Liu et al. (2017) propose a framework to effectively process and publish city data on a UDP, see Figure 4. In this framework, data is assessed and categorized based on its *sensitivity* regarding privacy. Accordingly, an anonymization method is proposed to ensure that the data on the platform is complying with the privacy rules and regulation.

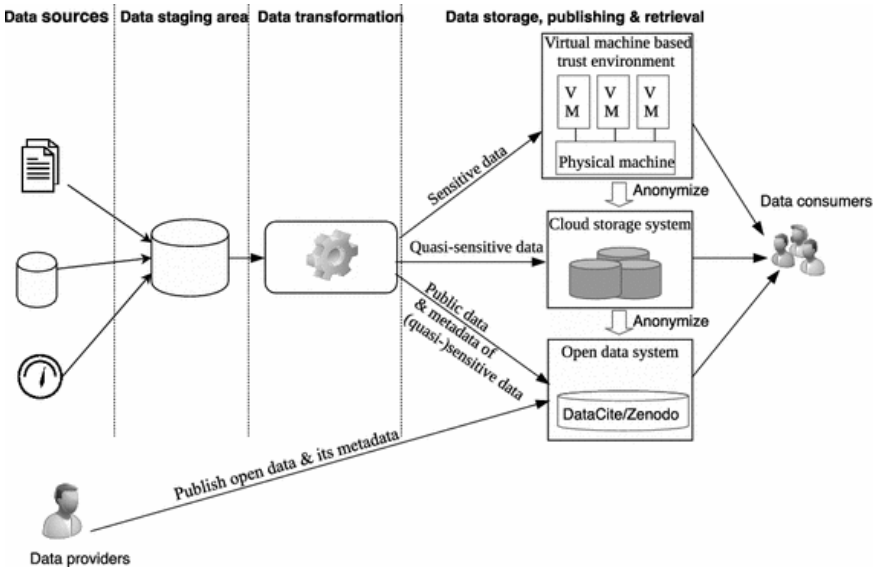


Figure 4: A framework for effective data handling and publishing, adapted from (Liu, Heller, & Nielsen, 2017)

2.1.4. UDP types

Different types of UDPs developed over time. They differ in terms of their functionality, architecture etc. In a review on UDPs by Barns (2019), four types of UDPs are distinguished. Table 1 provides an overview of the various types and their characteristics.

Table 1: UDP typology as defined by Barns (2018)

	objective	functionality	Ownership/initiative
Data repositories or portals	• Data services innovation • Transparency • Create opportunities for an active role by the government in the management of city data assets	• Provide access to government data • Data in machine readable formats • Data not necessarily linked to policies or performance monitoring	Created by local governments
Data showcases	• Data visibility • Transparency • Create opportunities for an active role by the government in the management of city data assets	• Promote access to data visualisations based on urban policies • Underlying data not always available for download or not in machine readable format	Developed by local governments often in collaboration education institutes
City Scores	• Performance monitoring • Indicators can be based on ISO 37120:2018 Sustainable cities and communities — Indicators for city services and quality of life	• Integrating datasets to enable and support performance monitoring via predefined indicators and targets • Underlying data not always available	Created by local governments with less focus on collaboration and engagement
Datastores or Marketplaces	• Data service innovation • Create opportunities for an active role by the government in the management of city data assets	• Provide access to data in machine readable formats, to function as input or service in other digital tools or software • Data purchasing, access, use, and sales by external parties is promoted • Applications developed based on the data can address a myriad of purposes e.g. public performance monitoring or commercial marketing	Developed by local governments or the private sector

2.1.5. UDP stakeholder landscape

The last column in table 1 shows the various options of organisations taking a role in the initiation and ownership of the UDP. In a study on UDPs in Europe by van Oosterhout et al. (2018), see figure 4, it was argued that the public sector, by way of local, regional and national government, has a significant role to play in the phase of exploring and planning the UDP. This role becomes even more important (to over 70%), when it comes to investments in the actual development and exploitation of UDPs.

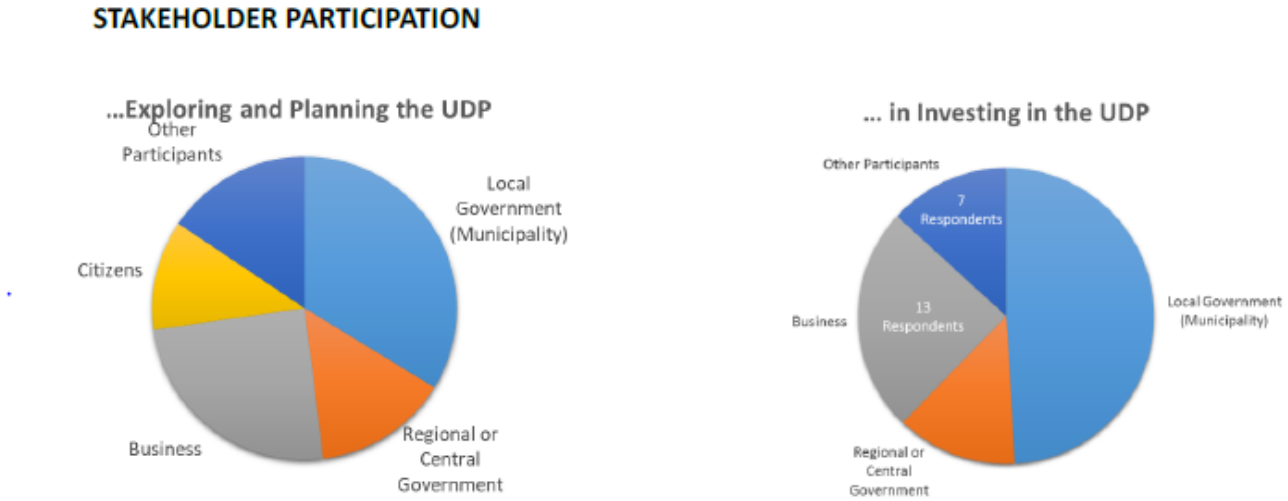


Figure 5: Findings on the UDP involvement of stakeholders in the European study by van Oosterhout et al. (2018)

2.1.6. An overview of Urban Data Platforms

The study by van Oosterhout et al. (2018) presented that an increasing amount of cities are establishing (a vision to develop) an UDP, however, still in the early stages. Where many UDPs are still in development, there are also examples of UDPs that have been operational for some time now and continue to set the example for the new UDPs to be developed. Table 2 presents a non-exhaustive selection of UDPs which have been operational for some time now.

Table 2: UDPs example cases

Platform name	Location	Initiative Owner	Type	Description
London Datastore	United Kingdom	Greater London Authority (GLA)	Data Marketplace	A free and open data-sharing platform, with around 700 datasets on the city accessible for everyone. The datastore website is equipped with visualizations of key city indicators, hence showing some features of a CityScore platform and including data analytics. Reports of the analysis are provided, including the data used. Moreover, various Data Showcase dashboards have built upon the London Datastore for the visualization of the 700 datasets, e.g. London - City Dashboard.
New York Citizen Dashboard	United States of America	The Mayor's Office of Data Analytics and the Department of Information Technology and Telecommunications	Data repository and dashboard	The New York Citizen Dashboard is built on top of the city's Open Data Repository which aims to make data available to all citizens and stakeholders. The dashboard aims to effectively gather and visualize data of a city with immense scale, in a manner which is understandable for all.
Boston CityScore	United States of America	The Boston Analytics Team	City Scores	A platform designed and developed to inform the Mayor and city managers about the health of the city, by combining KPI's into aggregated indicators.
Dublin Dashboard	Ireland	National Institute for Regional and Spatial Analysis	Data Showcase	Provides citizens, policymakers and other stakeholders with real-time information, time-series data and interactive maps on various aspects in the city.

				To this end, the dashboard aggregates data from various source. The underlying data is available to all parties to conduct their own analysis and build their own applications.
City Data Exchange	Copenhagen, Denmark	Copenhagen Municipality, the Capital Region, CLEAN (Danish clean-tech cluster) and Hitachi	Data Marketplace	A shared data hub examining the possibilities for private/public data exchange (purchasing, selling and sharing between citizens, public organisations and private parties). The aim is to improve the quality of life, support business, and contribute to achieve Copenhagen's goal to be carbon neutral by 2025.

2.2. Challenges faced by UDPs

From literature it can be derived that UDPs are still being confronted with significant challenges. In table 3 an overview of these challenges is presented, distinguished in technical challenges, organizational or governance challenges and challenges related to users and trust.

Table 3: An overview of challenges encountered by UDPs

Category	Challenge	Source
Technical design and data challenges	Develop and maintain a UDP which can adapt to the fast-paced development of new technologies, standards and services.	(Krylovskiy et al., 2015)
	Difficult interoperability between the mainframe and other specific systems. The lack of a common standard and not knowing how both systems are built, complicate their integration.	(Trilles et al., 2017)
	Build a data platform on top of existing and future platforms for all smart city activities to share and reuse data processing and analytics. This pertaining to both real-time and historical data: a) Efficient storage of unstructured and semi-structured data b) Efficiently process historical data and real-time data and keep aggregated results updated in a scalable and incremental manner. c) Efficiently share data processing and analytics across applications via flexible and open APIs. d) Efficient data collection from heterogenous data sources.	(Cheng et al., 2015)
	Data quality issues and data interoperability, integration and exchange	(Liu et al., 2017; Badidi & Maheswaran, 2018)
	Unpredictable data generation rates, data heterogeneity, different data access constraints, and technical requirement for real-time processing are challenges regarding social data mining based on different social media	(Giatsoglou et al., 2016)
	For IoT, there is minimal human intervention for data collection, aggregation and analysis. The machine-to-machine communications results in challenges on access control.	(Truong et al., 2016)
	Security and privacy challenges, e.g. personal data, cost intensive security applications, risk of hacking	(Badidi & Maheswaran, 2018; Liu et al., 2017)
Organizational and governance challenges	Organizational goals and priorities which are not aligned with the efforts and investments required for the UDP and its hardware, software and expertise.	(Badidi & Maheswaran, 2018)
	A lack of supported integration standards, establishing and getting standards approved and implemented take a long time	(Badidi & Maheswaran, 2018)
Trust and stakeholder challenges	Low willingness to share data or the lack of motivation to follow standards for convenient data integration and interoperability	(Badidi & Maheswaran, 2018)

2.3. Innovations in UDPs

2.3.1. Big Data and IoT

The digitilisation of the urban environment and the proliferation of smart devices in our life vastly increase the number and scope of human-to-human, human-to-machine, and machine-to-machine interactions. Smart cities represent dense systems-of-systems, generating huge quantities of data, or Big Data. Big Data is characterized by a complex mix (Variety) of data, which is not always trustworthy (Veracity), in immense (Volume) and rapidly growing datasets (Velocity), which require new computational resources and techniques and data management resources (Osman, 2019).

As part of the urban digitilisation the emergence of embedded devices is increasing, e.g. sensors and actuators in the form of smart phones and smart watches or a sensor network at a traffic intersection. This is in line with the decentralization by the development of computation in terms of its hardware, software and data (Batty, 2013). For instance, in 2020 about 50 billion “things” will be connected to the internet, connecting even more physical objects and people over a digital network. This introduces cities to the Internet of Things (IoT) era. IoT enables real-time decision-making with real-time data for energy management, traffic management, smart parking and security. In addition, urban planning can benefit from IoT by utilising historical data generated by an IoT network for decision-making on the future, e.g. changes to the public space by analysing changes in pedestrian patterns (Rathore, Ahmad, Paul, & Rho, 2016).

In an IoT enabled system, where an immense number of devices are connected to each other, massive amounts of data are generated. With an UDP anticipating on the increasing role of IoT significant hardware and software changes are required. These changes are related to the storage and processing of larger volumes of data, to incoming the real-time data, and to the increasing variety of data sources which challenges the interoperability of data (Rathore et al., 2016; Ahlgren, Hidell, & Ngai, 2016). Moreover, data management requires changes to cope with the increasing amount of data. A paradigm shift towards imprecise and imperfect data management of large amounts of data where imperfections are accepted, is preferred for big data rather than the precise management of smaller sets of perfect data (Moreno-Cano, Terroso-Saenz, & Skarmeta-Gomez, 2015).

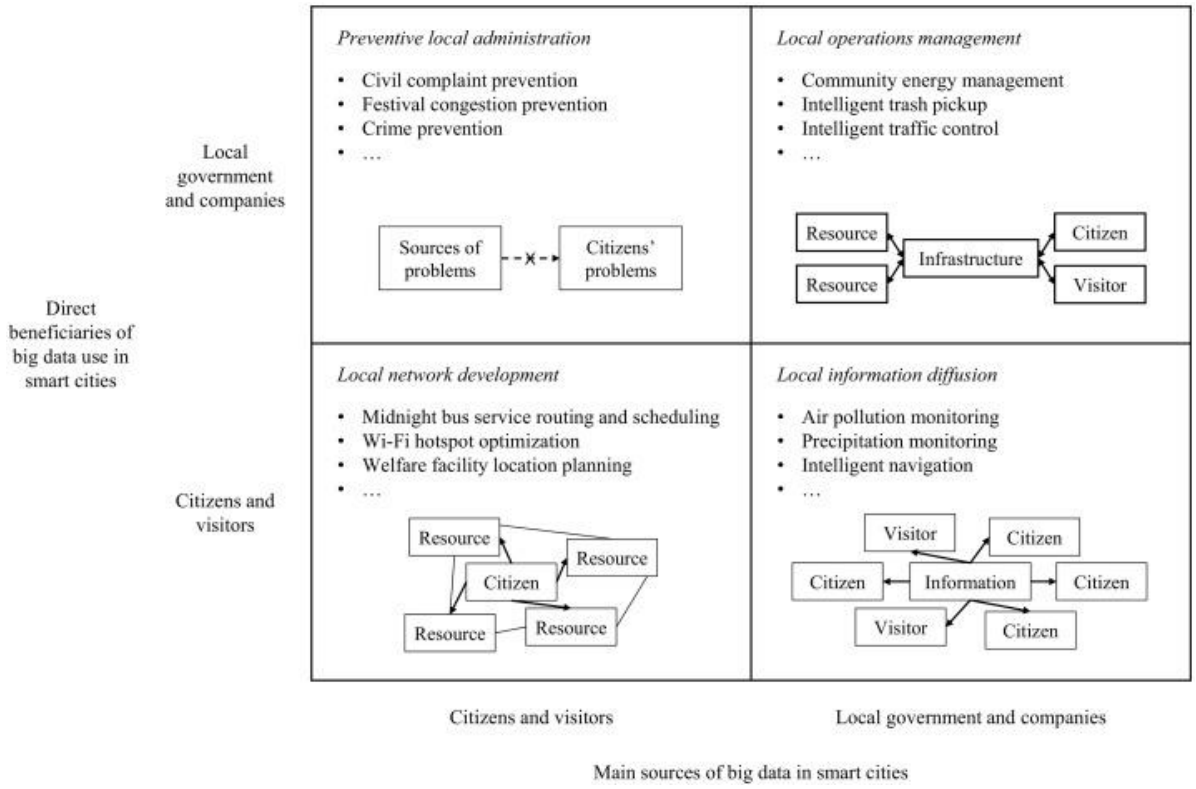


Figure 6: A framework to classify big data use in smart cities, from (Lim, Kim, & Maglio, 2018)

However, the potential for big data techniques is to advance decision-making in smart cities. A start for the inclusion of big data in UDPs can be to determine specific added value and stakeholder benefits. In Figure 6: A framework to classify big data use in smart cities, from (Lim, Kim, & Maglio, 2018)", a model is proposed by Lim, Kim and Maglio (2018). It classifies big data based on its sources and beneficiaries. This classification provides insights on how to design and develop the UDP accordingly.

With the IoT as source of machine-generated or sensed data in smart cities, crowd sourced data can be seen as data generated actively or passively by citizens. Social media, with geotagging functionality, is the dominant channel to leverage citizen input for urban policies and decision-making (Zook, 2017). Here, topics of interest and potential solutions can be glanced from citizens that are expressing their opinions on social media. The potential of crowdsourced data to improve urban policy and decision-making is well-known, as are its privacy implications. Giatsoglou, Chatzakou, Gkatziaki, Vakali, and Anthopoulos (2016) present work on use cases where social media data is used to infer knowledge on a city. They even propose a data analytics platform for social media data in a smart city.

Mirri, Prandi, Salomoni, Callegati and Campi (2014) present work where data on the urban accessibility is crowdsourced and sensed by citizens using mobile phones. This data can be linked with data from e.g. the public transport company and traffic sensors. Together they provide pedestrians, cyclists and road users with feedback on routes and departure times. In the context of UDPs the citizens would assume a role as data supplier by applying the techniques of crowdsourced and sensed data. By utilizing their mobile phones, and the sensors embedded in their phones, a network of dynamic sensors is created which negates the necessity for local governments or other parties to install dedicated sensors.

However, crowdsourced data remains challenging to incorporate in urban policy and decision-making. In addition to privacy concerns, there are concerns about data quality and trustworthiness depending on the accuracy of sensors used and the credibility of citizens involved in data gathering. Moreover, the high density and velocity of real-time data coming from citizens remains a challenge for data processing, in terms of hardware and software (Mirri et al., 2014).

2.3.2. 3D models and Digital Twins

Visual 3D models, and City Digital Twins become increasingly popular. They help to gain understanding of the city's spatial and temporal fluxes, and the human-infrastructure-technology interaction. In turn this understanding can be translated to insights on the city's reactive, recovery and adaptive abilities over time and space (Mohammadi & Taylor, 2017). Digital Twins are established and used as means of visualization and experimentation targeting policymakers, citizens and other stakeholders. With UDPs as the central hub for city data, Digital Twins can be build on top of the UDP. They can guide the development of the UDP and also influence the data collected and shared via the UDP. Digital Twins are fed by data coming from the datafication of infrastructure, buildings and public space. The interconnectivity provided by IoT is utilized (Mohammadi & Taylor, 2017). However, in many situations this data is lacking or insufficient and interoperability remains a challenge.

Mohamadi and Taylor (2017) and El Saddik (2018) also see opportunities for technologies such as Virtual Reality and Augmented Reality to visualise and simulate the contextual data and dynamic human-infrastructure-technology interactions in digital reality. In a digital environment, "what-if" simulations can be run. For instance, citizens can experiment with different sizes and locations for a new public playground and see how the interactions in the environment might be impacted (Ruohomäki, et al., 2018, Mohammadi & Taylor, 2017).

The combination of a UDP with 3D City Digital Twins creates a bases for more efficient and smarter (re)use of data. It also provides a commonly shared image of current reality to use in all kinds of applications and services. And therefore, it forms the centrepiece of an urban digital (community) ecosystem.

In this chapter the state-of-the art is presented on UDPs, in the following chapter the UDP developed in each of the three RUGGEDISED lighthouse cities will be presented.

3. Urban Data Platforms in the RUGGEDISED cities

This chapter addresses the UDPs as developed and deployed in the RUGGEDISED lighthouse cities. The chapter sheds light on the goals and the main characteristics of these UDP, and on the differences and similarities between the platforms.

3.1. Description of the UDPs

3.1.1. Rotterdam 3D City Model

In Rotterdam the UDP is shaped around the development of a 3D Digital Twin as a base for smart applications and services. Its main goal is the development of an innovative 3D information and communication platform. This platform is based on open data standards in which (near-) real-time physical and operational data of the city is projected on an accurate and smart 3D model of the city. This creates a digital twin of the physical city infrastructure and functions. Figure 6 indicates possible use-cases in the city, based on a Digital Twin. Commonly environmental aspects such as noise and pollution are measured in 2D. However, these aspects also manifest in vertical direction. By measuring these aspects in 3D and visualizing in 3D, the user gets a richer understanding of these multi-dimensional phenomena. 3D is a universal language that most people understand far better than 2D and thick textual reports.

The approach to create value with the UDP is to develop an innovative, municipality-led, open data and services ecosystem. The financing in the initiating phase of the development is led by the municipality. The value case for the operational phase is not yet clear. This will depend very much on the ownership and governance role the municipality sees for itself in that phase. Significant value of the platform (as being enabling infrastructure), in the form of Return on Investments, is expected in the mid to long term, while use cases and pilots are underway to elaborate their own value cases (on the short term). This creates the problem that financing the platform from the development of use cases in pretty complicated. The 3D model allows third parties to develop or augment services. They draw on the UDP data streams and functions through open APIs contributed by city actors, both public and private. The UDP includes a service-layer that enables citizens to access key city services as well as services provided by third parties. In Figure 7 the envisioned use-cases are presented, while in **Error! Reference source not found.** the UDP is presented as it is embedded in the ecosystem.

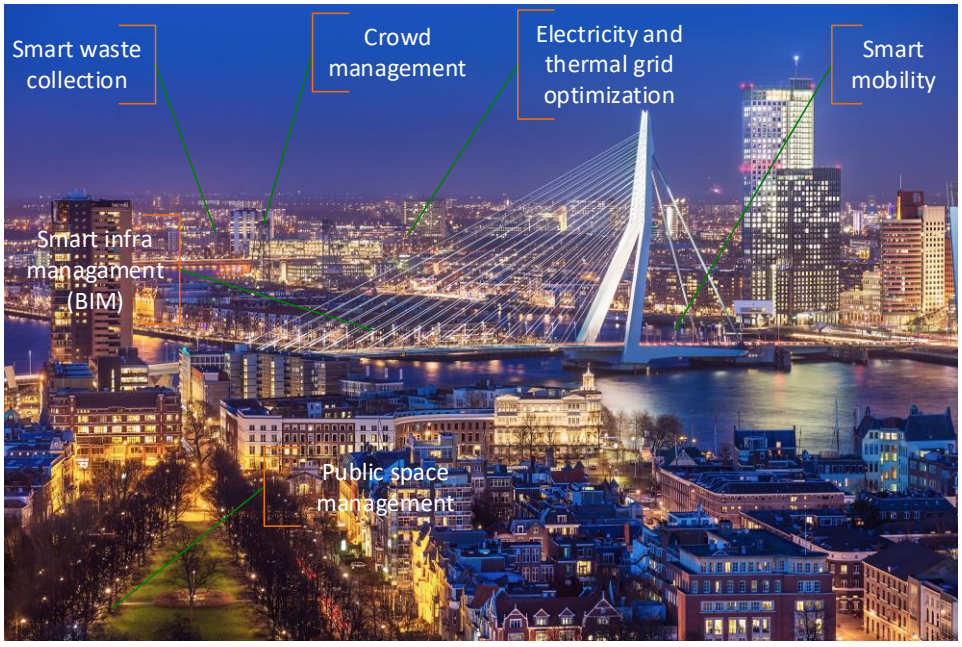


Figure 7: Overview of potential use-cases for the Rotterdam 3D model, build on a UDP

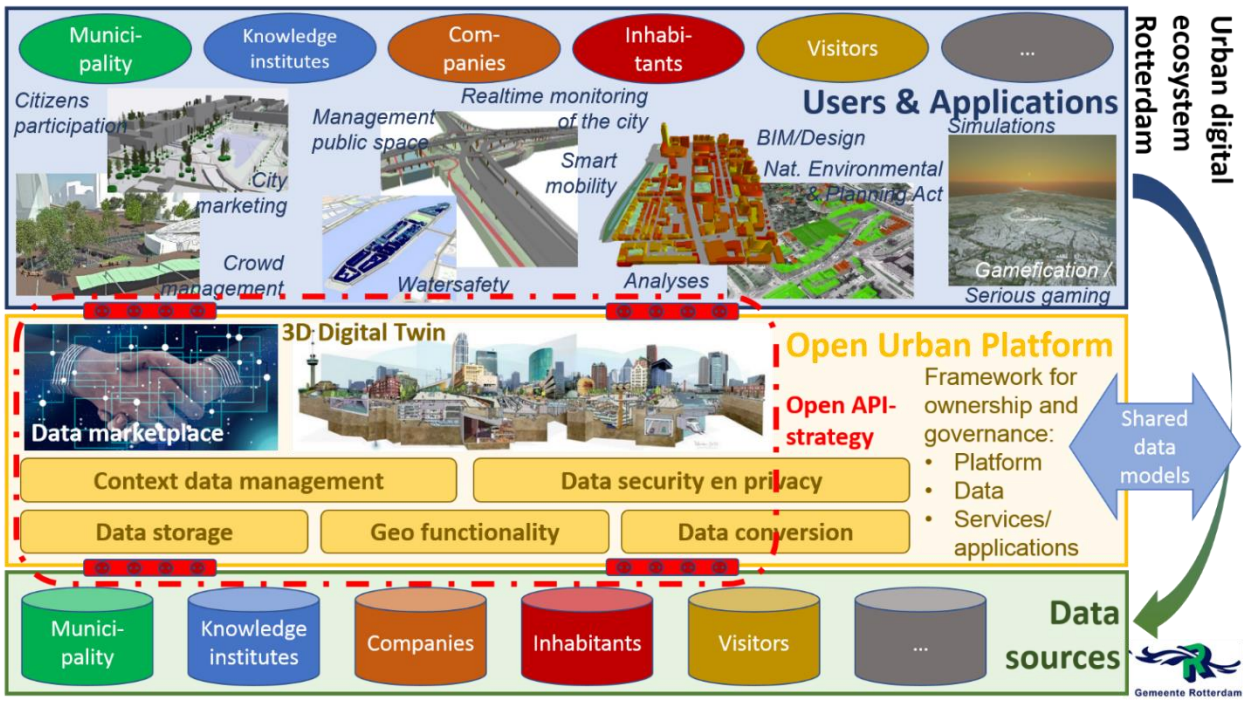


Figure 8: The UDP embedded in the Rotterdam ecosystem of stakeholders, data sources and functionality

For the development process and platform deployment, Rotterdam foresees a 3-year period to complete the platform and yield tangible results. In developing the platform Rotterdam builds on the modular design principles, the so called 'minimal interoperability mechanisms' (MIM's) conceived in the H2020 Smart City project Espresso. The core components of the platform architecture are meant to be the use of open data standards (pivotal points of interoperability, PPI's) to avoid vendor lock-in. The current Rotterdam UDP developed within RUGGEDISED is a partnership between the municipality, key companies such as telecommunications company KPN for data management and private utilities and operators such as Eneco.

3.1.2. Umeå Smart City Open-data Decision Support Platform

The Umeå UDP will support the citizens and planners in short- and long-term decision-making towards a fully sustainable and smart city. It will succeed in doing that by visualizing real-time data and static historic data to assess the impact of smart city interventions in a shared knowledge repository. In addition to

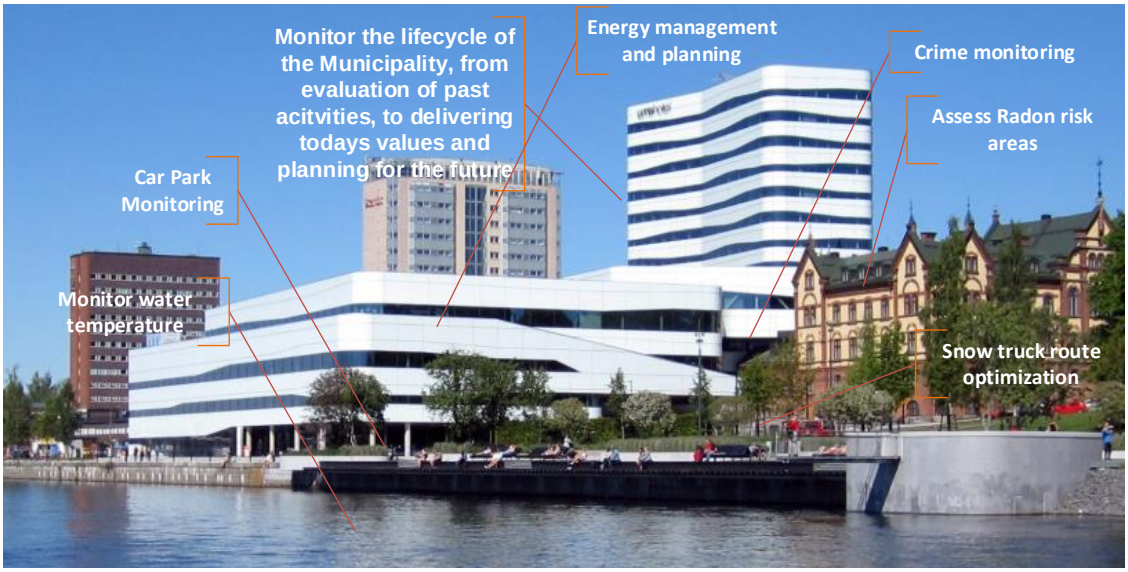


Figure 9: Potential use-cases for the UDP in Umea

visualizing the data, the UDP will provide means to combine data towards new knowledge. To this end the Umeå UDP is committed to sharing data to various target groups, with different right regarding data access, and envision a 3D interface to engage citizens.

Supporting the delivery of citizen services is the main value case of the UDP. The UDP aims to collect all the data available in Umeå and publish this towards interested parties in the city to function as input or service in applications and activities. Services that draw on data collected through the UDP include energy applications (based for example on block-energy consumption, AR feedback on buildings, PV potential maps, consumption vs CO2 emission), Radon risk areas, Car park monitoring, Crime heatmaps etc. These services focus on the (re-)use of Open Data on the UDP.

3.1.3. Glasgow Data-Based Decision Platform (DBDP)

The UDP in Glasgow is named the Data-Based Decision Platform (DBDP), and the main aim of the Glasgow DBDP is threefold: 1) Provide a means to understand the impact of smart city interventions through real-time visualisations, 2) Provide a means to combine data from RUGGEDISED smart city projects, other smart city interventions, and existing data within the council, and finally 3) Help non-data 'experts' explore the data – real time or otherwise – to help with city planning, stakeholder engagement, etc. To these ends, the UDP is enabled to 1) provide an interface, through which each user can customise their own dashboard, that enables query-based analysis of multiple datasets to support policy, strategy, investment, etc; 2) enable complex data analysis without the need for expensive resources and specific expertise, 3) utilise existing datasets and software applications; and finally, 4) minimise legacy costs. In figure 9 potential use-cases are presented.

The idea behind the system is to allow individual users to customise their own dashboard, which will allow them to view all the chosen data sets at once in order to ensure the most efficient use of time, planning and resources across the city. Moreover, the DBDP allows external and internal datasets to be brought together for analysis. This was previously not possible through corporate ICT platforms such as ESRI as it requires a translation step to bring the external data – in GeoJSON format, for example – in the corporate GIS system without the intervention of an expert user. The DBDP can ingest layers both externally and internally for immediate consumption and analysis, allow non-data experts to begin analysis immediately and with minimal training.

The UDP campaign reaches out to citizens, private companies, public agencies, and planners. Data is at the heart of the Glasgow RUGGEDISED solutions, and the UDP will be the central point for all data within the Council. For the UDP, Glasgow City Council will utilise the existing Open Data Platform and Urban 3D model and build the DBDP around existing ICT infrastructure. The data architecture comprises four pillars (see figure 8): 1) integration of data from many sources (sensors, SQL and api); 2) storing data, 3) analysing data and 4) presenting/reporting the results. The components include industry standard database solutions like Azure Cloud homegrown tools. Data is captured using APIs.

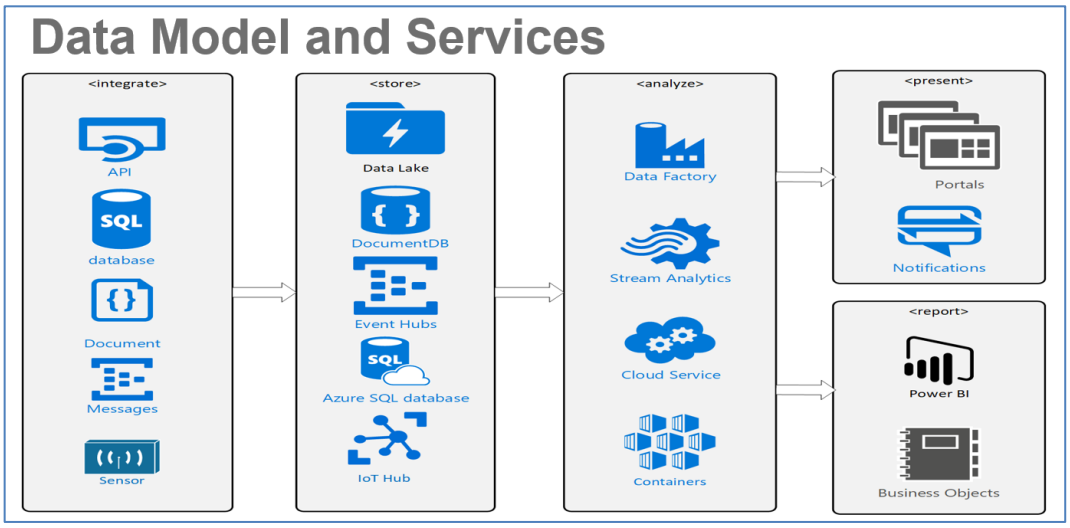


Figure 10: UDP architecture in Glasgow

Figure 11: Potential use-cases for the DBDP in Glasgow

The UDP/DBDP is designed to identify efficiencies in public service delivery, to identify new business models, to support SME's, and to foster new relationships. The financing of the DPDP is not factored. Financial benefits/impacts are expected to come from individual projects. Glasgow needs short term results due to financial austerity.

3.2. Challenges faced by the lighthouse UDPs

In the previous section we introduced the UDPs in the lighthouse cities, by means of their vision, aims and desired functionality. The lighthouse cities made great efforts to engange on the journey to establish UDPs in their city. However, this journey was not one without challenges, in Table 4 these challenges are presented.

Table 4: Challenges faced by UDP in the RUGGEDISED lighthouses

Category	Challenge	City
Technical design challenges	It remains a technical challenge to gather and publish real-time data sourced by municipal sensors, due to internal firewalls in the Municipal IT systems.	Umea

	Providing access to data and the means to analyse it by non-expert users was of paramount importance to Glasgow, and at the same time a challenge to enable. By design the DBDP turned out as an intuitive user-interface that guides the user easily through the import, visualisation and analysis steps, resulting in the creation of simple data dashboards.	Glasgow
	Data security and privacy is of primary importance. Glasgow dealt with the data security challenge by Linking the DBDP to the corporate GIS and data systems, to ensure that access to certain datasets is limited to those users that have access already within GCC. These datasets can then be compared with external datasets easily, such as governmental census statistics, all in the same interface. Rotterdam and Umea both introduced various levels of data access authorization for external users to ensure the data security and privacy of potentially sensitive data.	Glasgow, Rotterdam and Umea
	It can be a challenge to prioritise the functionality for which a UDP has to be designed due to the variety in stakeholders and unknowns about future users. The Digital twin concept helped Rotterdam to target the use of the UDP and provided a clear distinction of what the functionality of the platform should be and what can be developed in applications and services. Therefore, the platform itself contains a minimum of smart functionalities. This frame combined with the MIM approach has led to a small list of functionalities that the platform is expected to start with. From there functionalities can be added when needed.	Rotterdam
Governance or organizational challenges	Challenges pertaining to the internal data source owners and the process on how to engage these municipal data owners to share data on the UDP.	Rotterdam and Umea
	Companies who create data for commercial purposes are not accustomed to utilize open data standards, and they also lack incentive to do so. For Rotterdam it is important to enforce this when companies are building applications on the UDP. In the Rotterdam example of the smart waste collection at least three aspects were found for municipalities to take into account: a) Ensure that you have the full and free rights of using the source data, i.e. 'ownership' of the data. b) Ensure agreement upon creating a pro-active service on the company side to send the data to the municipality automatically, during the periods where the contract is active. c) Ensure that the data is delivered in an open data standard format that you can read and understand.	Rotterdam
	There is a municipal vision on city data, but without the necessary resources to execute this vision. On the other hand, there is the RUGGEDISED vision with resources. However, this RUGGEDISED vision is different from the municipal vision, and this mismatch is a challenge. Because the UDP is a RUGGEDISED project it is difficult to get commitment from the other departments to participate. Rotterdam tackled this challenge by embedding the RUGGEDISED UDP within the municipal vision and policies on city data.	Umea
	The IT department can be a limiting factor, they have significant concerns on the security of public platforms and the link to municipal databases. The IT-department of the council can impose barriers for in-house development related to the legacy software and hardware in use.	Umea and Glasgow

	Different fields of expertise are still not accustomed to communicate with each other. For example, the geo-field and the IoT-field are not used to work with each other. This complicated the integration of various technologies in a UDP.	Rotterdam
	Various cultural barriers within the organisation are in the way of successful pilots. Besides the difficulty of implementing innovation in general, the aim is to do this in a cross-siloed wat and by a new way of working (co-creation, partnerships, processes instead of smart projects etc.). All together this leads to the famous quote: implementing change is 25% technology and 75% cultural/organisational.	Rotterdam
	Open data standards are available, however, in a landscape of standards which is large and varied. Deciding on which standards to use is a challenge and depends on the current and future stakeholders.	Rotterdam
	Ensuring that the data on the platform is up to date is a challenge, in particular in the presence of a large field of heterogeneous data sources. In Glasgow, the direct link to external APIs ensures that each time a dashboard is uploaded, the data viewed is the most current and so real-time reports can be created to allow immediate decisions to be taken and subsequent actions enacted. This data can be conveyed easily to management, so that the data to back up decisions is available for all meetings in which decisions are to be made.	Glasgow
Stakeholder and trust related challenges	Stakeholders want to share data, but it is stored by a third party and the stakeholders have no access to the data, e.g. the parking garage operator wanting to share data, but the data is owned by the company operating the signals and displays in the parking garage.	Umea
	It is a challenge to populate the UDP with sufficient and relevant data from the various stakeholders in the city.	Umea
	It is a challenge to convince the citizens and stakeholders of the value of publishing data as open data on the platform.	Umea

From Table 4, it can be observed that most challenges faced by the lighthouse cities are within the category of organizational or governance challenges. Also, significant challenges relate to stakeholder involvement and trust. In particular Umea is struggeling with the stakeholder related challenges. Governance and organizational challenges, and the technical design challenges manifest over all three cities.

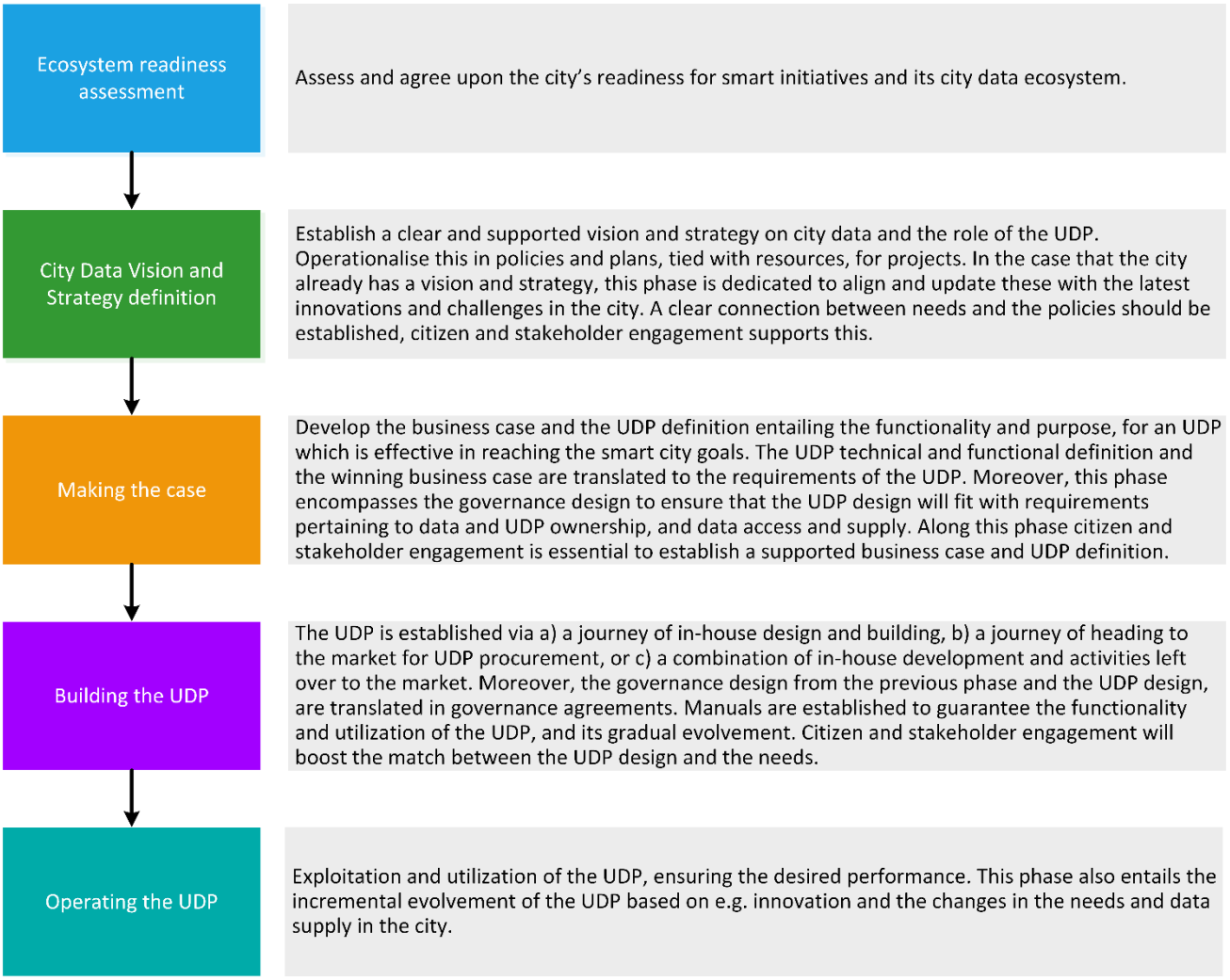
It is notable that the challenges experienced in the lighthouse cities show a different distribution over the three categories, compared to the overview of challenges as can be derived from literature and presented in Table 3. The challenges as found in literature were predominantly on the technical aspects. This calls for more research on the organizational and governance aspects of UDPs, but also on research on how to engage and manage the stakeholder ecosystem for an effective UDP. Moreover, it indicates that technical challenges may be experienced or interpreted as organizational or governance challenges, or that the technical challenges find their root causes in the organization and governance of UDPs and the associated stakeholder ecosystem.

With the understanding on UDPs provided in chapter 2, and the RUGGEDISED Lighthouse UDPs presented in chapter 3, the proceeding chapters will elaborate on a process guide to develop a UDP.Th lessons learned from each of the Lighthouse UDPs have been attached and haven been used as underpinnings.

4. Platform Design and Development process

In this chapter the content as discussed in the previous chapters, is utilized towards a process which can be followed in order to develop a UDP. A UDP that is innovative, supported, and that creates value for policy makers, citizens and stakeholders by matching the demand for city data with supply. In figure 10 the proposed process is presented by means of its main building blocks. The proceeding figures 11, 12, 13, 16 and 18, individually elaborate the building blocks.

Figure 10: A 5 step guide for developing an UDP in cities



4.1. Phase 1: Context definition

In the phase of "Ecosystem definition" the current situation is mapped to derive the contours of the ecosystem on city data. The questions leading this phase are:

1) What is the current vision or strategy? What policies are in place?
2) What are the running initiatives on city data sharing and utilization?
3) Which parties are behind these initiatives and in what role?
4) Which parties are the beneficiaries of these city data services and applications?
5) What technologies, standards etc. are utilized?
6) What does the demand and supply side consist of?
7) Which stakeholders, infrastructure, standards etc. are still missing or lacking in the ecosystem?

This phase results in comprehensive insights. By having a good overview of the existing strategies and plans for city data, the proceeding steps can ensure to draft missing elements. In this phase it is important to start involving and engaging the relevant stakeholders to determine what their ideas and interests are.

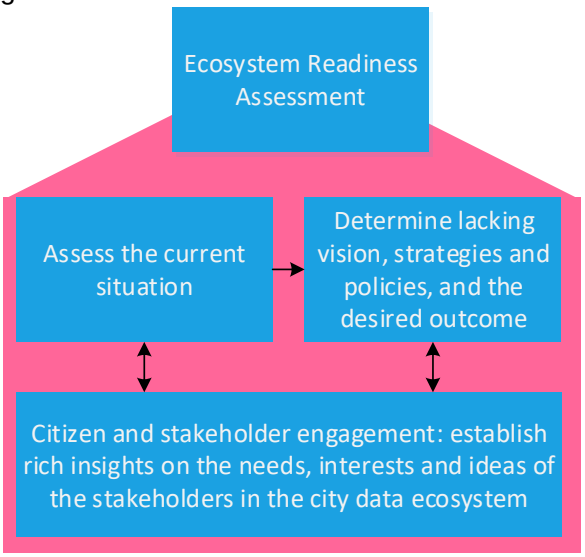


Figure 11: Phase 1 – context definition, for whom will a UDP be developed?

4.2. Phase 2: Vision and strategy

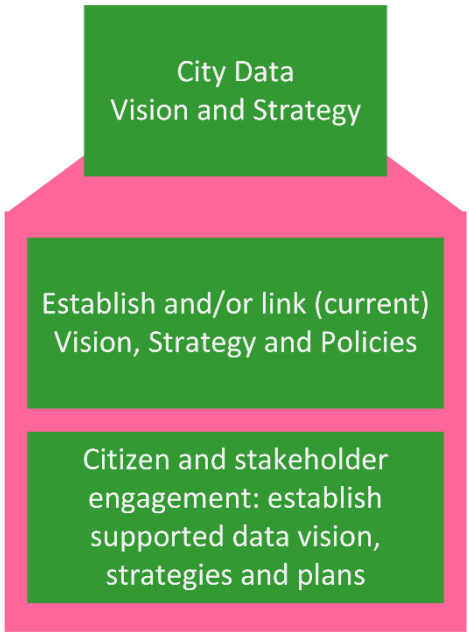


Figure 12: Phase 2 – Drafting a city data vision and strategy

With the existing ecosystem of city data strategies and initiatives mapped in the previous phase, phase 2 establishes a clear and supported vision and strategy on city data and the role of the UDP. Key is to also operationalise this in policies and plans for projects. In the case that the city already has a vision and strategy, this phase is dedicated to aligning and updating these documents with the latest innovations and challenges in the city. A clear connection between needs and the policies should be established. Stakeholder engagement might support this stap.

It is essential that in this phase the strategy for city data is embedded and supported by the municipal policy makers, to ensure that the UDP will be recognized, utilized and supplied with data by the entire organisation. This step is necessary to reduce the risk that different silos or departments within the municipality engage

on the development of their own UDP. They might not be aware of the city wide UDP or would like other functionalities to be included.

This phase results in a coherent, clear citizen-centric and ecosystem-wide supported vision, supported by a strategy and plans on city data. The plans on city data target: 1) the role in UDP and data ownership, 2) data access and sharing conditions, 3) UDP functionalities expressed as ambitions and goals, 3) contours for control mechanisms for data management, entailing data quality, interoperability and integrity.

4.3. Phase 3: Making the case

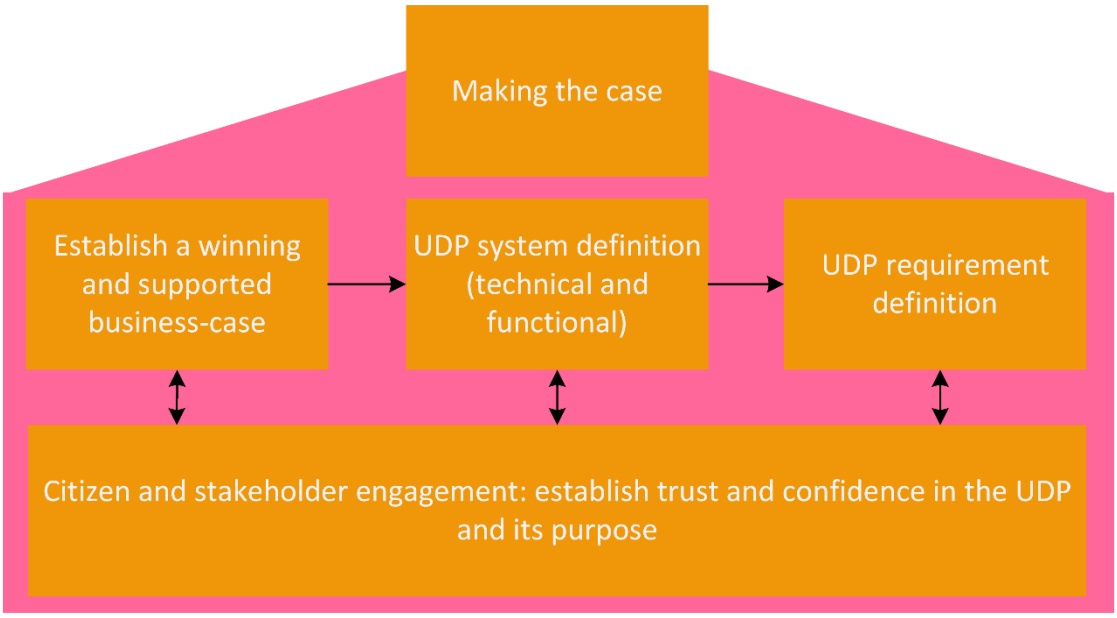


Figure 13: Phase 3 - "Making the case", starting with the winning business-case, followed by the UDP system definition and the UDP requirement definition.

Based on the assessment of the data needs and supply, and as captured in the data strategy and plans in the previous phases, this particular phase develops the business case and the UDP definition in terms of its functionality and purpose. The UDP's technical and functional definition and the winning business case are translated to the requirements of the UDP. Moreover, this phase entails the governance design to ensure that the UDP design will fit with the ambitions set in the city data strategy and plans. Along this phase, citizen and stakeholder engagement is essential to establish a supported business case and UDP definition.

This phase results in:

- A governance design on:
  - the public role in UDP and data ownership,
  - data access and sharing conditions,
  - UDP functionalities expressed as ambitions and goals,
  - contours for control mechanisms for data management, entailing data quality, interoperability and integrity.
- The winning business case, integrating the economic, environmental and social aspects.
- The UDP system definition (technical and functional), based on its needs and opportunities as set in the business-case.
- The requirement specification for the UDP, derived from the business-case and the UDP system definition.

4.3.1. A winning UDP business-model

To capture the complexity and variety of smart city initiatives, business models are required that also include the environmental and social aspects. This on the contrary to the traditional business models, focusing on

the economic aspects. Tradition models are deemed insufficient to capture the complexity and variety of smart cites. This resulted, among others, in the triple layered business model canvas by Joyce & Paquin (2016), which respectively entails an economic layer, an environmental layer and a social layer. For this model to be effective, a horizontal coherence (within the layer), as well as vertical coherence (between the layers) is essential.

In figure 14, a business model canvas is depicted, specifically designed for UDPs as produced within RUGGEDISED. This business model canvas is inspired by the business model canvas as filled in by Glasgow, the triple layered business model canvas by Joyce & Paquin (2016), and lessons learned in the other lighthouse cities. The model integrates the economic, social, and environmental aspects. It is

Mission Statement for Urban Data Platform: Create public and private value through Ecosystem Matchmaking

<table>
<tr><td rowspan="3"><u>Partners</u>

Investor / Owner

Governor vs Manager

Technology / (Social) Media Partner

Subcontractor</td><td><u>Platform Activities</u>
Tools & services, Matching, Audience building, Rules and standards, (Data) quality assurance</td><td rowspan="3"><u>Value Proposition</u>

“Place” for innovation, participation, collaboration, and public and private value creation</td><td><u>Guiding Public Values</u>

Platform purpose that engages all stakeholders</td><td rowspan="3"><u>Customers</u>

Citizens, Communities, Companies, Start-ups, Developers, Data providers and platforms, Government, NGOs</td></tr>
<tr><td><u>Platform Data & Data Assets</u>
Data types (domain, velocity, variety, domain) Data-acquisition, data gathering, exploitation/mining, data analytics, visualisation / 3D digital twin</td><td><u>Scope and Reach</u>

Open-closed, Local-global, Interoperability Access</td></tr>
<tr><td><u>Key Infrastructure & Resources</u>
Digital, Physical, Monetary, People, IP, Brand</td></tr>
<tr><td colspan="2"><u>Financial Cost</u>
E.g. investments, run costs</td><td colspan="3"><u>Financial Benefit</u>
E.g. ROI, revenue streams</td></tr>
<tr><td colspan="2"><u>Social Cost</u>
E.g. privacy, security, freedom</td><td colspan="3"><u>Social Benefit</u>
E.g. democratic participation, growth, improved living conditions</td></tr>
<tr><td colspan="2"><u>Environmental Cost</u>
E.g. carbon footprint platform ecosystem</td><td colspan="3"><u>Environmental Benefit</u>
E.g. sustainable innovation, reduced CO2 emissions</td></tr>
</table>

Figure 14: A Business case canvas for UDPs, (Sheombar et al., 2019)

equipped with a block for Platform Data Assets to emphasize the importance of data for UDPs. Moreover, the Public Values block signifies the government’s leading role in UDPs, and the Customers block represents the variety in involved actors.

4.3.2. Requirement specification

The platform should be conceptually decomposable into its major subsystems. Moreover, the platform’s functionality should be identifiable. Also, the interactions between the UDP and services, data providers and data users should be well defined and clear. These actions inhabit the step where the UDP system is defined technically and functionally and form input for the proceeding step where the UDP requirements are established. Requirements include functional and non-functional aspects. In order to prioritise requirements the distinction can be made between:

1) Constraints, these are requirements which the solution must comply with. The assessment whether solutions comply to these constraints can only have a binary outcome, yes or no. In other words, these constraints create the boundaries for the solution space.
2) Requirements which must be considered in the offer, but which can be complied with on a discrete scale, e.g. by being scored low-medium-high, or a score between 1 and 10. Additional direction requirements can be attached to these requirements, e.g. maximize require X1 and minimize requirement X2.
3) Requirements which are nice to have, these are the requirement which are not an absolute must from the perspective from the client, but where vendors or in-house developers can add functionality to distinguish their effort from the rest.

An elaborate guide on requirements specifications for software and systems in UDPs is published as part of EIP-SCC program on Integrated Infrastructure Action Cluster (EIP-SCC, 2016). The aim of the established requirements is that adoption of these requirements by cities will result in reduced pre-procurement times, increased confidence in platform designs, improved collaboration (particularly amongst smaller cities), innovation in business models, reduced costs, and a more secure basis for industry to apply its innovations.

***Box1.* Requirement specification in Umea**

Umea decided to completely outsource the development of the UDP to the market. Initial market consultation showed that in order to provide all desired functionality, there are no off the shelf solutions available. The functionality is based on questions such as: *what kind of data would we like to be able to link to and analyse?, How should data be visualised?, How much technical knowledge should be the minimum for the data provider in order to upload data? And for the potential users to utilize the UDP?, is the vendor required to host the portal?* Subsequently, the needs were translated into requirements divided over must-have and good-to-have requirements, in a manner which is as clear an unambiguous.

During this phase of establishing the system definition and specifying the requirements, it is important to take the stakeholder engagement process one step further. This entails cooperation with the stakeholders which will benefit or contribute in the UDP. A high-level overview of these parties, including the roles necessary within the city government, is presented in figure 15.

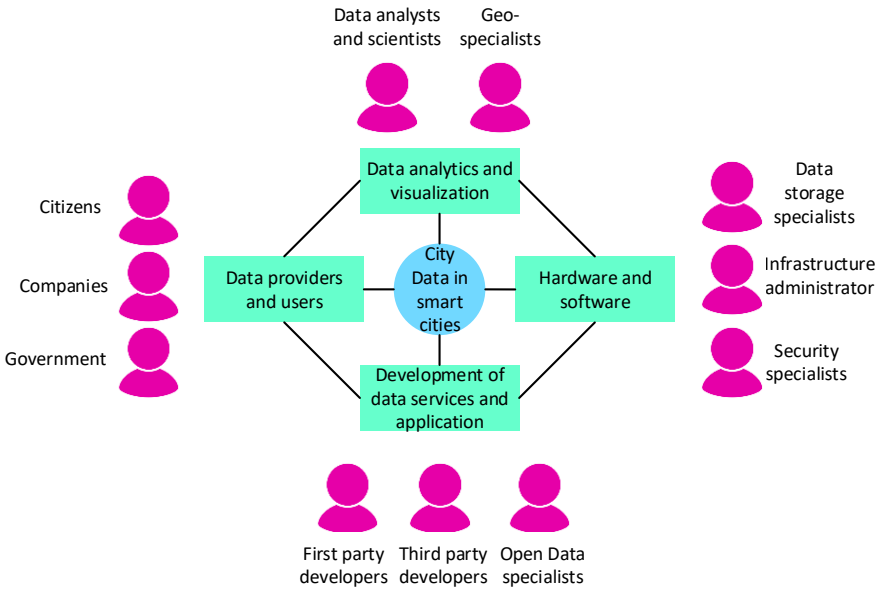


Figure 15: The roles of stakeholders to involve, adapted from (Costa & Santos, 2016)

On its turn, these requirements are required for the proceeding phase where the UDP will be put out to tender, developed, built, tested and implemented.

What can be learned from Umea?

UDP Visual functionality definition: as mentioned in table 4, one of the main challenges is to collect enough data on the platform, to convince stakeholders of the value of publishing and sharing data as open data. A lesson learned is that this works better with a portal which has a visually attractive user interface. Contributors can see the data, and understand that the combination of different data sets could yield novel and relevant knowledge. In addition, citizens viewing the data on the UDP can realize themselves how they could contribute with missing data.

A procurement lesson: requirements considered as self-evident e.g. an open data platform should not require registration in order to view the data, might not be that evident for the vendors. Clearer requirements would have saved time spent on explaining to vendors for whom it was unclear on which grounds their offer got rejected.

What can be learned from Glasgow?

Disclose Use Cases early in the development process to ensure that they are captured by the UDP scope. Understand the data environment within the organisation to ensure the solution developed will work well within the existing IT environment and be supported into the future by the in-house IT team (essential so the platform has life beyond the RUGGEDISED project). To this end, Glasgow opted to develop the DBDP in-house to align with corporate IT systems. Furthermore, access to sensitive datasets meant that putting the DBDP on an externally hosted cloud solution was not an option, therefore an internal Azure instance was used instead. Glasgow already had an open data platform that gathers data from a range of sources, all of which are presented to the public via data.glasgow.gov.uk. Therefore the DBDP did not need to emulate this functionality, rather it simply consumes data from this and other internal and external data sources.

4.3.3. Data Management

Data quality and integrity

Can users trust insights derived from UDPs? This question is, among others, related to the challenges regarding the data quality and integrity. In line with the common saying in data analysis of “Garbage in, garbage out”, the quality of insights derived directly from a UDP, or via data provided through a UDP, is difficult to validate if the data is of insufficient quality. The quality of the data can be impacted by the technology used and the human involvement in the generation of the data, but also in the cleaning and processing of data and the choices made for data generalization, calibration, formatting etc.

These challenges should be minimized by implementing robustly designed and tested processes and procedures for data generation and handling (in those cases that the data comes from city operated sources), and thorough screening processes (in those cases data is derived from external sources). These processes should be well documented and included in the metadata, besides metadata on source and timeline alone.

What can be learned from Rotterdam?

Different parties or departments within the municipality, are not used to think and work outside the borders of their own silo. A novel way of willingness is needed to get these parties involved. Several reasons can be mentioned for this hesitation in the willingness to cooperate, namely: lack of capacity and specific skills, fear of the unknown, and the fact that some people do not understand the necessity or added value of it, etc.

Working together on the basis of mutual responsibility requires a new way of working together from the partners involved, which requires patience and a long term vision. The existing silos can also be used to slowly grow together in a certain direction. The existing activities and procedures within such silo are needed to gather a particular dataset in the first place. But make sure that the data can also be used outside the silo by making arrangements about ownership, standards and so on.

Data interoperability and integration

How to publish, link and analyse data from heterogeneous sources? In the mission of UDPs to act as a platform which connects the various data sources in the city, it is a recurring challenge to deal with the data coming from heterogenous sources. The heterogenous sources can be established and operated by organizations using alternative data and metadata standards and formats. This results in interoperability issues. In line with the different typologies of UDPs, i.e. market places, repositories, showcases and city scores, data integration is an aspect which can be designed based on the envisioned city data and UDP strategy. Badidi and Maheswaran (2018) propose three types of data integration methods which can cope with the data interoperability issues:

1) *Data consolidation* pertains to the collection of data from various sources and its integration into a unified datastore. This technique enables to cope with data duplication and reduces the costs of multiple databases. A downside of this technique is that there is a delay between the generation or update of data and the publication on the central datastore, because the data is coming from multiple sources. The extent of this delay depends on the communication infrastructure behind the UDP.
2) *Data federation* refers to software technology allowing a single and logical view of the data from the federated databases. When an enquiry comes for a certain data view, the data federation engine derives the data from the relevant federated sources, adapts it to the appropriate format for the viewer, and visualises it for the relevant user in e.g. City Scores or Data Showcases.

What can be learned from Umea?

When government data bases become more intertwined with public open data bases, security issues do come up. The internal IT Department particularly expressed their concerns on this issue, for instance when API's are opened to get IoT real-time data on the platform. In the Umea case this is data from sensors to measure sea water temperature. This data is not recognized and held back by the government firewalls. A solution is to externally batch the data and push it to the UDP.

3) *Data propagation* refers to the event-driven transfer or push of data from one or multiple sources towards target locations according to specific propagation rules. For instance, the move of large volumes of data, from a datastore or data repository towards other systems. Data propagation entails a data delivery guarantee, regardless of the synchronization applied, and this is one of its key distinguishing factors. The data transfer is executed in batches to minimize the impact on the performance of the datastores or repositories.

Ownership

What can be learned from Rotterdam?

The municipality has to take a role in arranging agreements on how the data is exchanged to the municipality, i.e. the format of the data and the requirements on the meta-data.

Not all open data standards are easy to use. The municipality has to test what works best in the given situation, or use the experiences of other municipalities.

Although the use of open data standards is preferred, it is more complicated then it seems. This regarding how to cope with the many definitions of open standards, the subsequent ambiguity and large amount of standards, and the dilemma between open data and privacy. However, for the long run and purposes such as accessibility to all, it is worthwhile to invest in it.

What can be learned from Rotterdam?
Ownership in the ecosystem takes many forms. There is ownership of data, ownership of (the rules of) the platform and ownership of developped services and applications.

Regarding the ownership and governance model of the (operational) UDP, Rotterdam is researching the different options, working towards a broader discussion on the topic.Regarding the ownership of developed services and applications this will belong to the developer.

Regarding 'ownership' of data the answer for us is rather complex. A large variety of data (combined, reformed, newly generated, meta-level and log data) are extracted from heterogeneous sources. Afterwards it is unclear to whom the data belong, and who has the control over it. The basic principal is that the data source is owning the data. But after reuse by others via the platform the whole pallet becomes much more complicated. For now, it is important to recognize the aspect of creating (log)data by the platform. It is mostly this data in which the large platform companies are interested. The collection and use of this data are possible, and can be part of a business model, but the municipality also wants to have (some) control over how it is used and for which purposes (remind the Facebook/Cambridge Analytica incident). Rotterdam also looks to explore the idea of self-sovereign identity and the principals around the data vault. We believe in the democratizing aspect of it, and it will also help in the

Ethics and privacy

Is the UDP ethical? How about privacy? Regarding ethics, the following questions can be asked: How can it be guaranteed that UDPs are used ethically? And how can it be ensured that the UDP handles city data ethically? Regarding the first question, UDPs can be used to establish location profiles and histories by linking and visualising data related to a certain area. These insights can be utilized by commercial parties to segment their marketing strategies per region, and by governments to carry out area specific policies. Area specific policies include, for instance, subsidies specific to the population characteristics of a certain neighbourhood to stimulate the social cohesion in that neighbourhood. Or they may include 'readiness to shift to renewable energy'. The UDP can thus be used to differentiate between areas and treat them differently, which may impact the quality of life. For policy making not to discriminate based on these insights, it is important to assess what these risks may be and put in critical checks in the utilization of the UDP for local policy making (Kitchin & McArdle, 2017).

Ethics in UDPs is inevitably related to privacy. Although UDPs publish and analyse city data, rather than personal data, privacy still is a re-occurring challenge in UDPs. City data pertains aggregated data on a certain system: for instance data on the electricity grid on the level of the postal code. UDPs may include methods to anonymize data in order to be published over the UDP, while complying with privacy regulation. Hence, it is important to continuously assess whether utilized anonymization methods guarantee the privacy of citizens.

What can be learned from Rotterdam?

There is a certain tension between the essential goal of a UDP (sharing and (re)use of data) and the GDPR. Also, there can be a certain tension between ethical use of data and the GDPR. This leads to the need to think about how ethical frameworks can help us to come to better judgements on the use of data, while complying with the GDPR. How can we use these frameworks to assess a case the moment it surfaces? Instead, what is now being asked is to assess all possible uses of a particular dataset upfront (which would also make data reuse much more difficult).

Moreover, privacy is mainly experienced as a social issue, rather than a technical issue. A general lesson learned in the context of the UDP and the Digital City is that the current model for safeguarding privacy is untenable in the long term. The GDPR is an important legal framework in this regard, but there is still no case law. On the one hand, the AVG is still flexible, for example when it comes to the possibilities for scientific research. As a result, knowledge institutions play an important role in the design and implementation of a UDP. On the other hand, the AVG requires that before the data is collected and shared, it must be known who the end users will and how they will use the date. This is not always possible with a UDP that develops organiscally over time. The principles underlying the AVG challenge those underlying a UDP and a Digital City.

4.4 Phase 4: Building the UDP

The business case together with the UDP's technical and functional definitions contribute to extuallly build the UDP. Mainly, there are three scenarios:
a) a journey of in-house design and building,
b) a journey of heading to the market with a tendering process, or
c) a combination of in-house development and activities left over to the market.

In figure 16, scenarios A and B are visualized, with scenario C being in-between these two extremes. During the pahse of building the UDP an agile approach is taken to continuously iterate in small cycles. The aim is to learn from experiments and proof of concepts, and to gradually improve the UDP. Processes are established to guarantee the functionality and utilization of the UDP, and its gradual evolvement. During this phase citizen and stakeholder engagement will boost the match between the UDP design and the demand for data and applications.

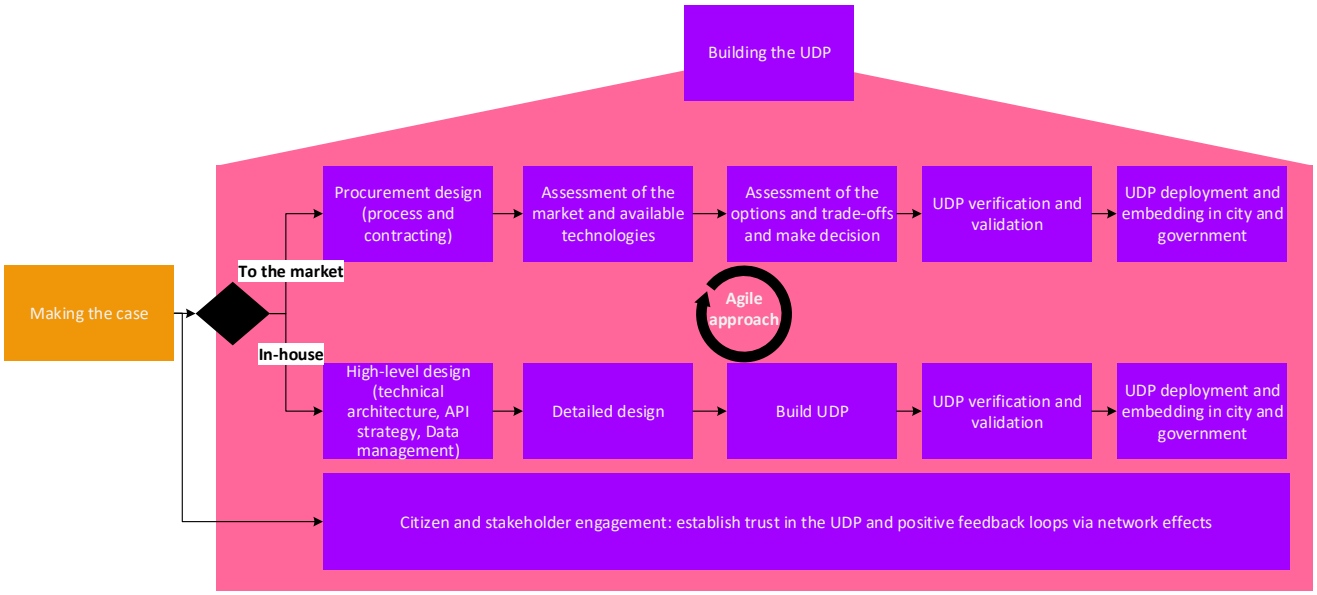


Figure 16: Phase 4 - "Building the case", either through in-house development or procurement

This phase results in:

- A procurement procedure (for scenario A) or a design and build process (for scenario B), which allows for innovation and prevents vendor lock-ins.
- Governance agreements on:
  - the role of government in UDP and data ownership,
  - data access and sharing conditions,
  - control mechanisms for data management, entailing data quality, interoperability and integrity.
- A working UDP implementation in the city.
- Guides on:
  - UDP Operation and Maintenance
  - UDP Use
  - UDP Evolvement
  - KPI's for UDP performance assessment

Models for innovative public procurement

The public procurement of UDPs, in terms of hardware, software and services (or combinations), requires procurement approaches that take into account:
1) the innovative nature of UDPs. Off-the-shelf solutions are not yet available. Solutions need to be flexible to adapt to future innovations.
2) the complexity of the interactions to be captured in the UDP.
3) the challenges related to city data on i.e. data quality, integrity and interoperability, privacy and security, and the visualization and analytic support towards users, and
4) vendor lock-in. The situation that the public authority, as product owner, is tied to a single vendor beyond the duration of the initial procurement contract, should be avoided.

ESPRESSO, a project on the standardization of smart cities, proposes 4 innovative public procurement models that can also be suitable for UDPs. These models allow for an improved scope of interaction and dialogue with the market. The 4 innovative public procurement models, elaborated in table 5, are 1) Competitive dialogue, 2) Competitive procedure with negotiation, 3) Pre-commercial procurement, and 4) Innovative partnership. In figure 17 these 4 models are displayed in a flowchart with the steps to determine the appropriate procurement model for the specific case. This choice depends on: 1) the knowledge of the market and the technologies, 2) the need for research and development, 3) the need to acquire products/services on a commercial scale and 4) the options to develop a concept of the service or product to be procured.

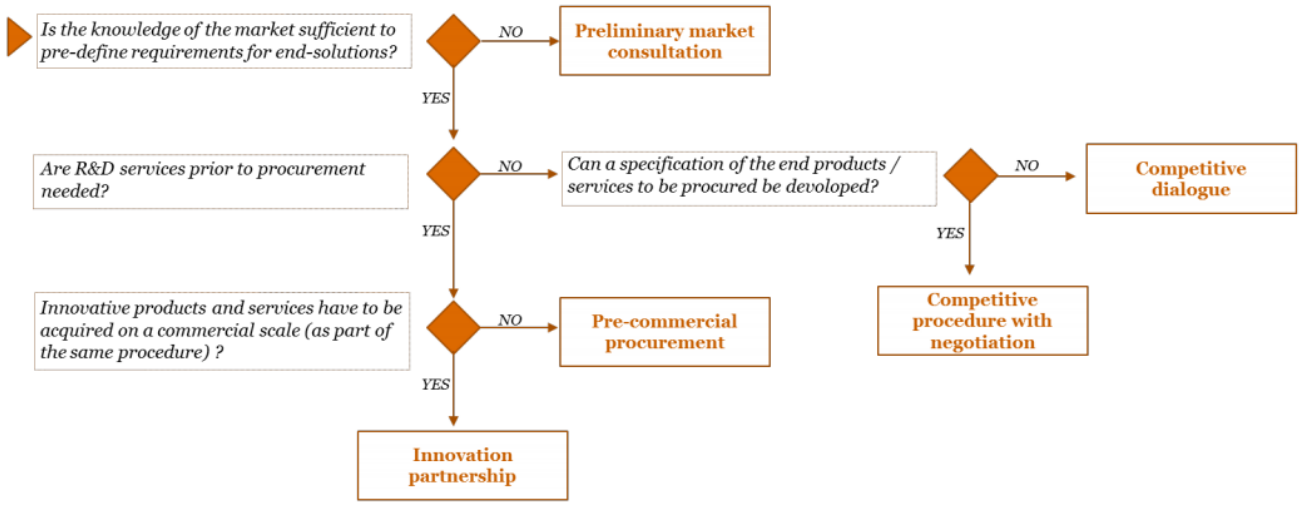


Figure 17: Flowchart for innovative public procurement, derived from (Senatore et al., 2016)

Table 5: Elaboration on the four models for innovative public procurement, adapted from (Senatore et al., 2016)

Pre-commercial procurement	
What?	Procurement of R&D of solutions not yet available on the market, from prototype to first test. For the resulting product or service to be acquired, a new procurement is needed.
When?	Can be deployed when the market needs motivation to develop new solutions. It is suitable when market consultation results in a lack of effective solutions.
How?	1) Prepare PCP and call for tender 2) Explore the solutions 3) Develop assessment process, including test and validation, standardization etc. 4) Prototyping
Innovation partnership (IP)	
What?	Research, development and procurement of new products and services on a commercial scale. It allows for the award of a phased contract covering all stages, from R&D to the acquisition on the commercial scale of the end products/services.
When?	When the innovative needs cannot be met by products or services already on the market, and innovative products and services need to be acquired on a commercial scale.
How?	1) Prepare IP, release call and selection a. Publication of call for competition with requirements b. Selection of operators for negotiation 2) Negotiation a. Rounds of written submissions b. Negotiation, possible with vendors/developers filtering through the rounds 3) Award: Notification of negotiation result 4) Development: Product / service development 5) Commercial acquisition
Competitive Dialogue (CD)	
What?	Awarding a contract to vendors, for services or products after a dialogue with selected participants who have submitted an offer according to the needs outlined in the tender.
When?	Can be used for large complex projects, where it is difficult to precisely define the specifications in advance. Moreover, the needs cannot be met by adapting existing solutions.
How?	1) Prepare CD and call for vendors/developers a. Publication of contract notice b. Selection of vendors/developers for dialogue 2) Dialogue with vendors/developers a. Issue of descriptive document b. Rounds of dialogue, possible with vendors/developers filtering through the rounds

	3) Award a. Closure of dialogue b. Invitation of final tenders c. Fine-tuning of offers d. Selection of bidder and confirmation of terms
Competitive procedure with negotiation (CPN)	
What?	Procuring services or products, including elements of adaptation, design or innovation, which require negotiation. Compared to CD, the required requirements need to be specified prior to the tender.
When?	Can be used for large complex projects, where it is difficult to precisely define the specifications in advance.
How?	1) Prepare CPN, release call and selection a. Publication of call for competition with requirements b. Selection of vendors/developers for negotiation 2) Negotiation a. Rounds of written submissions b. Negotiation, possible with vendors/developers filtering through the rounds 3) Award: Notification of negotiation result 4) Development a. Product / service development b. Commercial acquisition

Box2. A hybrid model in Rotterdam

In Rotterdam the 3D Urban Platform is developed over three Proof of Concepts (PoC), starting in 2017, with go/no go moments after each PoC and a general Go/No Go in 2019. The first PoC was conducted in 2017 with the goal to prove the technical feasibility of the municipal vision on the meaning and form of the platform. To this end, the first PoC successfully published real time parking lot utilization data in the 3D city model.

The second PoC in 2018 addressed the information need. After proofing the technical feasibility of the platform, the aim was to establish the desired flexibility and functionality of the platform to provide the support in answering real life questions. Therefore, in the second PoC, real-time data regarding traffic, public transport and bridges were disclosed. In addition, PoC 2 tested the usefulness of several open data standards for all data needed (from source to the data platform and to the 3D city viewer). In this PoC significant lessons were learned about disclosing real time data from (private) data sources, but owned by the municipality, and the use of open data standards. In the meantime, different scientific studies led to improved understanding of the necessary platform functionality.

The third PoC targets the communication, the two-way street of information flow. PoC 3 entails experiments to determine what is needed on the platform to enable this communication, taking into account the lessons learned from the previous two PoC's. PoC 3 is the last phase of development and will be proceeded by the operational phase. The third PoC and the operational phase will both be part of a new procurement that the municipality is preparing.

Once operational, the process will be continued by a development in three directions: 1) scope (increase the time and geographic scale), 2) functionality and interactions, and 3) Themes and subject included in the UDP.

Innovation Partnership in Rotterdam

The city of Rotterdam engaged on a journey of the Digital city of which the UDP is an integral part. There is a long-term vision and a determined development process. Those can be characterized by short development cycles where the main goal is to end each development cycle with a PoC to demonstrate the value of the platform. This is a journey where the UDP and the 3D model of the city will gradually evolve over time. It shows the necessary characteristics to be executed with an Innovative Partnership with vendors whom can join the journey and develop together. In 2020 the city will start with the market consultation to gain an understanding of what the market can offer in terms of ready-made products or services. What does still need to be developed in order to match the needs of the Rotterdam UDP? This phase will be followed by the next step in procurement where a partner for the innovative partnership will be selected. The development phase will be kicked-off in 2021 for the operational platform to go live in 2022.

Box3. **In-house UDP development in Glasgow**

Some products or tools were found to have the functionality close to that required by the DBDP, but none were able to be deployed easily within the GCC corporate IT environment. Furthermore, to ensure the solution developed has a legacy within the council, the tool had to align with the existing GIS product suite and data environment. Many of the tools identified – some of which were open-source – would potentially have to be maintained in-house after the RUGGEDISED project finishes. For these reasons Glasgow opted for the in-house development of the DBDP, such that the expertise and commitment to the platforms can be developed and maintained internally. The platform was built on existing Glasgow City Council infrastructure (open data platform) on the Microsoft azure platform, meaning that the system is bespoke and unique to Glasgow. This was conducted in cooperation with the City Data Team of the council. Because the platform has been developed in house, there is a willingness to share this with other cities across the RUGGEDISED consortium and Europe. The platform also has the capability to pull data from the European Commission and other partner cities, allowing Smart Solutions to be compared.

This development process followed an agile philosophy consisting of short development cycles. The development of UDPs is relatively new for the majority of cities. In software engineering, and in general the digital domain, an agile approach of short development cycles with working prototypes is commonly the standard. For UDPs, this is also recommended, due the novelty and pace of innovation. By working with concrete prototypes, stakeholders and potential users can be demonstrated of the added value.

From a technological perspective, the DBDP was designed to utilise existing toolsets as much as possible for, with the following two benefits:

1) Familiarity to users already used to the ESRI suite of products within GCC and
2) Utilisation of a ESRI Software Development Kit to ensure compatibility with existing ESRI flows and to reduce support required. The latter point reduces the resource required to support the tool in the future and is the most important from a business model perspective.

4.5 Phase 5: Operating the UDP

Once in the operational phase, the desired performance of the UDP is ensured through frequent monitoring. The development of the UDP gradually continues, based on e.g. innovation and the changes in the needs and data supply in the city.

The products of this phase are:

- Monitoring reports on the UDP utilization and performance, based on the KPI's
- UDP iterations as a result of continuous improvement of the UDP. Continuous improvement can be related to performance improvement, new functionalities, new data compatibility, changes in architecture or changes in communication and security protocols.

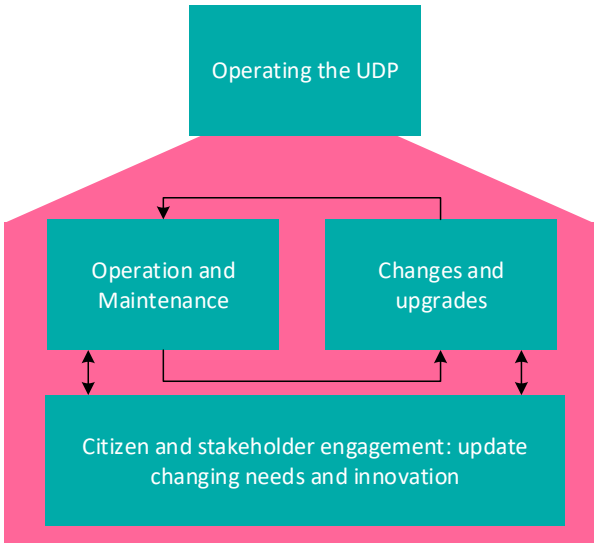


Figure 18: Phase 5 – UDP operational phase

Box4. UDP operating costs in Glasgow

Once in operation, Glasgow reports on the following costs to keep the DBDP up and running:

Maintenance & Support costs
Costs made to fix bugs and maintain the DBDP. The cost of the resource to provide this support is anticipated to be around €18,000 annually, equivalent to around 30 days of a suitably qualified software developer. Beyond bug-fixing, there are no plans to provide support to users, other than through help pages. However, this will be reviewed on an ongoing basis.

Hosting costs
The DBDP will have to be hosted in order to be available to users via the web interface. The cost associated with this, as well as the cost of the URL, is anticipated to be circa €4,400 annually. The breakdown of these costs is as follows (subject to change, depending on functionality that may be changed or added and extra capacity to deal with an increased number of users):

Staging environment = 23%
Live environment = 44%
Shared database = 29%
Miscellaneous= 3%

What can be learned from Rotterdam?

- The Rotterdam 3D Urban Platform enabled the city to gain experience on the basic functionalities for an UDP, e.g. storage, conversion, geo-functionality, context management, security and privacy, market place, 3D digital twin and an open API-strategy. Furhtermore, you need a framework on ownership an governance of the platform, the data and the services/applications.

- The development of the UDP was executed according to an innovative and iterative process. This process allowed the team to gain novel knowledge and a whole new way of working. To really understand what is needed to have a functional UDP with high-quality and relevant data available to all, it is essential to follow such an agile process. For this, we created a 'community of knowledge' in which together with several knowledge institutes we researched all kinds of relevant topics. Moreover, we created a 'community of practice' in which we built, together with others, on the open urban platform.
- With the current state of the platform, three follow-up steps have been defined for the 3D digital twin:
    - Graphical quality of the street level
    - Streaming data of the 3D model
    - Making a distinction between buildings as a whole and individual living units.

4.6 Relevant guides and material

To support the guidance on the development of UDPs as proposed in the previous section, city leaders and staff involved in the UDP can derive additional support from:

- EIP-SCC Urban Platform Management Framework: Enabling cities to maximize value from city data (EIP-SCC, 2016)
- Rethinking the city: using the power of data to address urban challenges and societal change - A guide for city leaders (EIP-SCC, 2017)
- Requirements Specification For Urban Platforms (EIP-SCC, 2016)
- Future trends in economic, financing and procurement models (Senatore, Galasso, Brunelleschi, & Ghellere, 2016)
- 2019 state of the art Urban Data Platforms in Europe – management summary (van Oosterhout et al, 2020), available via EIP-SCC website

5. Recommendations for UDP deployment and utilization

A solid strategy on city data and a sound development of a UDP, bring you a long way. However, the real success and impact of a UDP lies in the implementation and the extent to which the UDP is utilized.

Think in value creation

Many governments nowadays have some form of open data portal that allows them to share public data with citizens and organisations. Between these platforms the use rate and successes are vastly varying. It is of the utmost importance for a UDP to align with the current and future needs of all relevant stakeholders in the urban innovation ecosystem. **Identify the public service/policy priorities across the city to steer a UDP strategy.** By targeting the appropriate priorities, the UDP can derive more political, cross-silo, support. In figure 19, a framework is presented, as proposed in the Management Guide for Urban Platforms by EIP-SCC (2016). This framework can be used to characterize the city data and political priority in order to decide on a city data strategy.

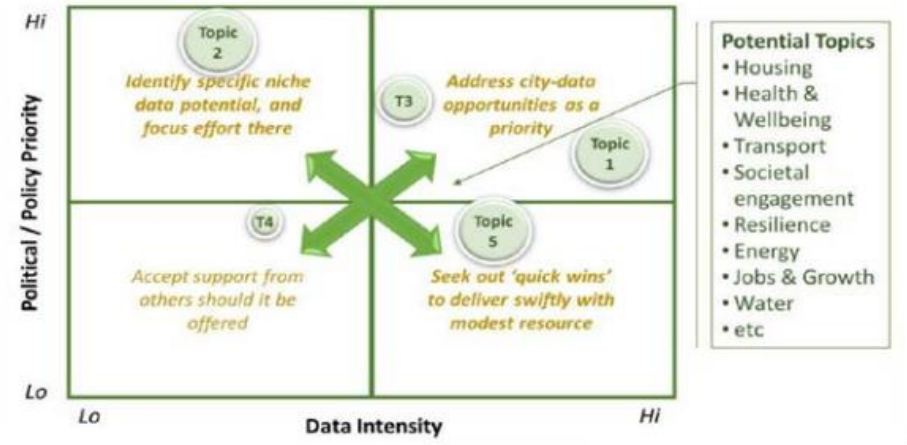


Figure 19: A framework to shape the city data strategy, adapted from (EIP-SCC, 2016)

In addition to the political priorities, a widely supported and used UDP entails that citizens and private parties also gain value from the UDP. These users should be inspired with possible use-cases and their contribution to the improvement of life, business, policies etc.

With the demand side addressed, the stakeholders on the supply side of city data will equally need to be sustainably kept on-board by providing them with value for their data. Potential data providers will only consider making their data available when it is clear to them what the needs are and what they can get in return, i.e. monetization or valuation of data. UDP operators should take active initiative to gather and present the questions for data from the potential UDP users and developers to the potential data providers.

The potential data providers also include citizens. By creating awareness on the value of data, the willingness to share data is stimulated, e.g. by crowdsourcing and sensing. Citizen awareness is also essential with regards to how to use UDP facilities smart and safe, e.g. practice of good safety, security and privacy practices. It potentially reduces citizens' fear to share data on the UDP.

To intensively link the demand and supply side, the UDP manager should **create and maintain a healthy ecosystem.** This entails the creation of synergies and minimize conflicts between data-related stakeholders.

In general, it should be ensured that **the value is evidenced from UDPs**. Already in the development phase, evidenced value via agile prototypes can contribute to keep the potential users and suppliers on-board. Work with proof of values on top of proof of concepts.

Embrace innovation and change

Technology in the field of data and its use is rapidly changing, it is essential to acknowledge and embrace this in the design, procurement and operation of a UDP. Flexibility to adopt these technologies in the future are key for a future-proof UDP.

Aim for scale on the long run and cooperate with other cities

To build and operate a UDP in a city, it requires significant resources. The opportunities for a UDP and effective use are significant. However, the up-front costs can be a challenge. While the operational costs are moderate (Glasgow indicate about €22,000 annually for hosting and maintenance with in-house expertise) the up-front investment are significantly higher. In the Management Framework for Urban Platforms by EIP-SCC (2016), investment indications are provided ranging from Euro 100,000,- to Euro 5 million.

Due to the significant costs, in particular for smaller cities, e.g. cities without in-house data scientist or geo-data staff, it is recommended to pool UDP resources with neighbouring cities. This can be done in the form of joint procurement, e.g. to establish a stronger position towards the market, and to benefit from scale, for instance by acquiring larger server capacity to share. Moreover, sharing resources can reduce the costs of investment and operation. Data scientists and other staff can be shared among cities to increase their efficiency and cross-border cooperation. It is also possible to share licences which can be costly, or cooperate in promotion campaigns to create UDP awareness, while sharing resources.

Finally, it is worth mentioning that many lessons can be learned from the UDPs already established in the bigger European cities. By taking these lessons into account, other cities can prevent costly mistakes.

Government, take your role, and embrace organizational change

An impactful UDP is not only about the technology and data on it. The extent to which a UDP is embraced within the municipality is essential. To external users, it is confusing if isolated UDPs per department are developed. A dispersed field of UDPs within a city will reduce the opportunities to link data for rich insights, because the data is dispersed over various platforms. Moreover, it will cause inconvenience for users required to visit different platforms for the data. Internally, this division will lead to little commitment to share data and resources internally and jointly promote a UDP strategy. Having said this, organizational change, e.g. cross-silo cooperation, is essential.

Keep close monitoring on data challenges

A flashy UDP with the best user interface and state-of-the-art in-cloud storage and communication architecture realises very little of its potential impact if the data on the UDP is of bad quality. Ensure the mechanisms and necessary capability development, i.e. data scientists, to ensure that data challenges - availability, quality, ownership/governance, privacy, valuation and monetization - are dealt with effectively.

Think beyond sharing data

We have arrived in the ear of data analytics.This entails that facilitating the data landscape in a city does not only entail the sharing of data. It is about data analytics and questions as to how to derive knowledge from the data which can be of added value for life, business and governance in our smart cities. For a city data strategy and UDP to be future-proof, the inclusion of data analytics and means to communicate the derived knowledge are essential.

6. Conclusions

City data has immense potential to improve the quality of life, business and governance in smart cities. Urban Data Platforms (UDPs) are addressed in this guide as the bridging infrastructure between the city data that can be of public or private nature. The lighthouse cities in the RUGGEDISED project, the cities of Glasgow, Umea and Rotterdam, are all engaged in the development of UDPs. UDPs differ in shape and process, but have the same goal: to process and use data for a resilient city that can cope with grand challenges such as climate change and rapid urbanization. This guide provides guidance for developing a city data strategy and an UDP for cities.

From realising UDPs in the RUGGEDISED lighthouses, the following can be concluded:

- UDPs are an essential means in the journey towards smart cities. Due to their novelty it is common that UDP projects start off as an innovation project. However, for support of the UDP and the desired impact in the smart city, thorough embeddedness of the UDP over the entire local government and alignment with the needs and resources of the stakeholders in the ecosystem is essential. This entails that organizational change could be required, and that a government wide strategy on city data (availability, processing, and use) should be developed.
- Stakeholders should have sufficient trust in the UDP for sharing data and using the UDP to create new use cases. Creating an environment in which involved stakholders have trust in each other and in the UDP software, hardware and governance, is therefore of utmost importance. Thorough stakeholder engagement strategies, as well as a charter that sets the governance rules of collaboration in the ecosystem of the UDP aid this trust.
- Data management challenges, e.g. availability, quality, interoperability, ownership/governance, privacy, valuation and monetization are essential elements of a city data strategy and influence the design of the UDP. This should be acknowledged by new UDP projects for the design and governance of the UDP and the city data.
- UDPs should be developed in a demand-driven manner, as value creation in a user-centric business-model is essential. However, it is recommended to incorporate sufficient room in the platform design to cater in the unkown or future demands as demands could change and are currently not fully articulated. In addition to economic aspects, the business model should also account for the environmental and social aspects. In order to have a city wide impact, the UDP should address needs of the politicians, planners, businesses and citizens. Already in the development process, clear value cases should be defined together with the potential users. The added value of the UDP should be evidenced by means of functional prototypes to convince the potential users and data providers of its added value, also known as the “show, don’t tell” strategy
- In line with a demand-driven strategy, the UDP should be visually appealing and convenient to use by the target groups. This entails convenient APIs, user friendly interface, open source development, cost efficient, and innovative visualization (3D, VR/AR).
- The UDPs in the three lighthouses go beyond data sharing and create opportunities for decision-making support for first of all the government, and to a varying extent, for citizens and businesses in the city. Moreover, the UDPs enable the co-creation of digital products and services by the various stakeholders.
- Depending on resources and expertise available, the municipality needs to make an important decision whether or not to develop, host and maintain the UDP in-house, or partly or completely outsource the development, hosting or maintenance of the UDP. This process is critical for the success of the UDP and needs to be done at all times with an agile and user-centric philosophy with room for innovation (due to the rapidly evolving technological change in this field), while preventing vendor lock-ins.

These conclusions are captured in an UDP development process consisting of 5 main phases. This process is summarized in Figure 1 and combines state-of-the-art knowledge about developing UDPs, for instance coming from the European Innovation Partnership for Smart Cities & Communities, with the lessons learned from the UDPs in the RUGGEDISED lighthouse cities. The depicted development process provides guidance for cities that want to start with development of a UDP, leads them through the different phases, and provides an overview of the aspects to take into account in each phase.

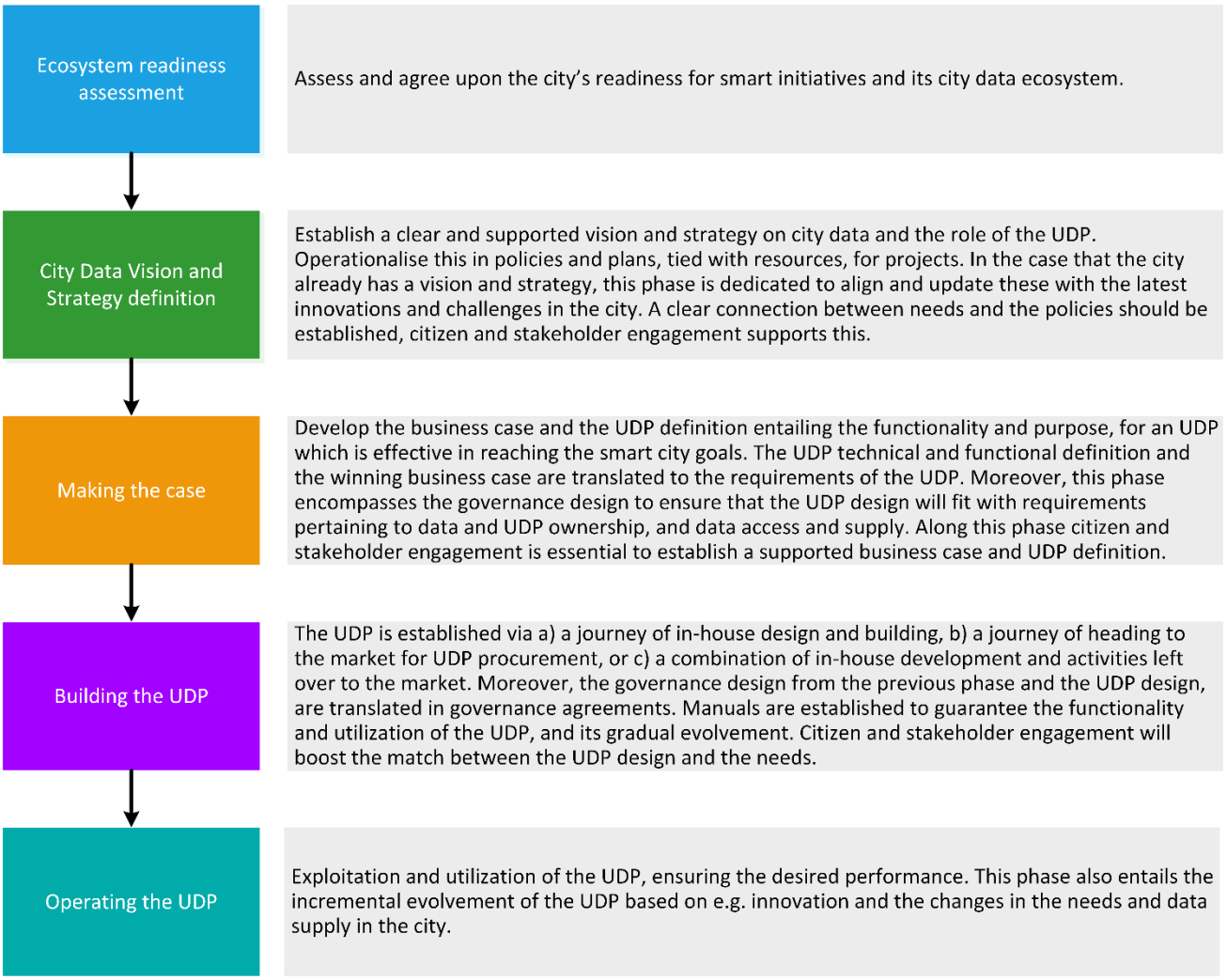


Figure 20: A proposed process for UDP development in your city.

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