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Technologies for Smart Communities

Details of consultation activities and summary of components

This study has been prepared as part of the Local Digital Twins Toolbox project. The project is an initiative of the European Commission. Directorate-General for Communications Networks, Content and Technology of the European Union is responsible for contract management of the Local Digital Twins Toolbox project.

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Authors:	Giovanna Galasso; Carlo Montino; Danilo Bianchini; Eliana Gerardi; Massimo Pellegrino; Christian Pasquale Aprile; Carlotta Colagrosso; Elisabetta Trinca; Alessandro Gentile; Ingrid Croket; Philippe Michiels; Razgar Ebrahimy; Shahrzad M. Pour; Mohsen Banaei; Khurshed Ali; Taoufik Bakri; Nico Spijkers; Ivo Emanuilov; Katerina Yordanova; Tervel Bobev
Reviewers:	Hans Teuben; Eline Lincklaen Arriens

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List of acronyms

List of Abbreviations and Acronyms	
AI	Artificial Intelligence
AR	Augmented Reality
DEP	Digital Europe Programme
EU	European Union
IoT	Internet of Things
LDT	Local Digital Twin
MIMs	Minimal Interoperability Mechanisms
SB	Standardisation bodies
SMEs	Small and medium-sized enterprises
SCC(s)	Smart Cities and Communities
TP(s)	Technology providers
VR	Virtual Reality

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1 Introduction

The European Union's (EU) Digital Europe Programme, introduced in 2019, aims to strengthen critical digital capacities within the EU to accelerate the digital and green transition and enhance Europe's ability to deploy and scale Artificial Intelligence (AI)-powered digital technologies in key sectors such as energy, climate change, manufacturing, agriculture, and health. The programme acknowledges three groups of EU communities based on their digitalisation progress: those at an early stage, those preparing for digital infrastructure, and those with advanced strategies. Building on the experience of the latter, the European Commission aims to create a European Local Digital Twin (LDT) Toolbox to support cities and communities approaching the digital twin journey addressing several challenges, including lack of awareness and readiness, unbalanced development across communities, standardisation and interoperability, green transition, and the adoption of core EU values. The successful creation of such an LDTs Toolbox depends on the collaboration and involvement of various stakeholders. To this purpose, the European Commission launched the project "Procurement of the Technical Specifications for the Local Digital Twins (LDTs) Toolbox" to co-design the LDT Toolbox technical specifications for advancing the transformation of smart communities.

This document serves as the confidential version of the «Analysis of LDT requirements» report. It presents a detailed description of consultation activities carried out during the project and the key findings emerged.

1.1 Purpose of the report

To identify business, functional, technical, legal and security needs to inform the creation of the LDT Toolbox, a wide and open consultation was launched to capture stakeholders' perspectives on essential components and specific requirements for the future development of the Toolbox.

The purpose of this report is to analyse the findings of the consultation activities carried out between June 2023 and July 2023 and draw initial conclusions of the key building blocks needed to design an LDT. More specifically, the report presents:

- The methodology approach used for the consultation activities conducted, including the consultation strategy that was adopted to ensure a satisfactory and balanced contribution from key stakeholders (Chapter 2).
- An analysis of the consultation findings, detailed by business, functional and technical, legal and security aspects (Chapter 3).
- A summary of the key capabilities and building blocks that will inform the design of the future European Local Digital Twin Toolbox (Chapter 4).

The report is complemented by annexes providing more details on the activities underpinning the research.

1.2 Consultation objectives and scope

The stakeholder consultation had two main objectives. First, it aims to collect evidence that identifies stakeholders' needs when implementing one or more digital twin solutions and key challenges linked to it. Furthermore, results from the consultation will be used as a basis for the future design of the Toolbox, ensuring alignment between stakeholders needs. Consultation activities were set up to gather evidence from the following stakeholder categories:

- Smart Cities and Communities
- Technology Providers
- Standardisation Bodies and Fora
- Legal experts

2 Methodology

The consultation has been designed to comprehensively address different stakeholder groups through tailored tools, questionnaires, intersection study group, and a workshop. This section presents the consultation strategy and provides a detailed description of the consultation activities carried out and the data collection tools developed for these.

2.1 Consultation and dissemination strategy

The consultation strategy was developed to effectively gather insights from the highest number of stakeholders possible. The following table provides an overview on the consultation activities conducted, together with their objectives and the targeted stakeholders for each activity.

Table 1: Consultations objectives and targets

Consultation Activity	Consultation Objectives	Targeted Stakeholders
Interviews	• Collect evidence about stakeholder experience on LDT implementation and reach a detailed understanding of challenges, issues, needs; and • Identify the key requirements of the future European LDT Toolbox.	• Smart Cities and Communities • Technology provider • Standardisation bodies and Fora • Legal experts
Targeted Surveys	• Gather evidence and stakeholder views on functional, technical, legal and security aspects; and • Gather stakeholder views on the challenges experienced in the implementation of an LDT.	• Smart Cities and Communities • Technology provider • Standardisation bodies and fora
Intersection study group	• Identify best practices, lessons learned and pain points; and • Explore the purposes that an LTD Toolbox should serve.	• Smart Cities and Communities • Technology provider
Validation Workshop	• Present preliminary findings of the consultation activities; • Validate the business, functional & technical, legal & security aspects of the LDT Toolbox building blocks; and • Engage with stakeholders to co-create the LDT Toolbox.	• Smart Cities and Communities • Technology provider • Standardisation bodies and Fora • Legal experts

Given the tight schedule of the project, the consultation activities were carefully planned to ensure a meaningful data collection that will inform the analysis in a timely, robust, and consistent manner. To select and use the most valuable data collection tools, during the first two weeks of the project, the team dedicated a significant amount of internal and external consultation time to develop well-thought and informed questionnaires for surveys and interviews. Simultaneously, an intersection study group was delivered to engage with stakeholders, raise awareness on the project, receive initial feedback and improve the quality of the upcoming surveys. Once the first draft of the questionnaires was reviewed and approved, the project team launched the surveys and started to interview the key stakeholders. A final workshop was delivered to validate the information collected and analysed through the consultations. The figure below depicts the activities conducted during the timeframe of the consultation.

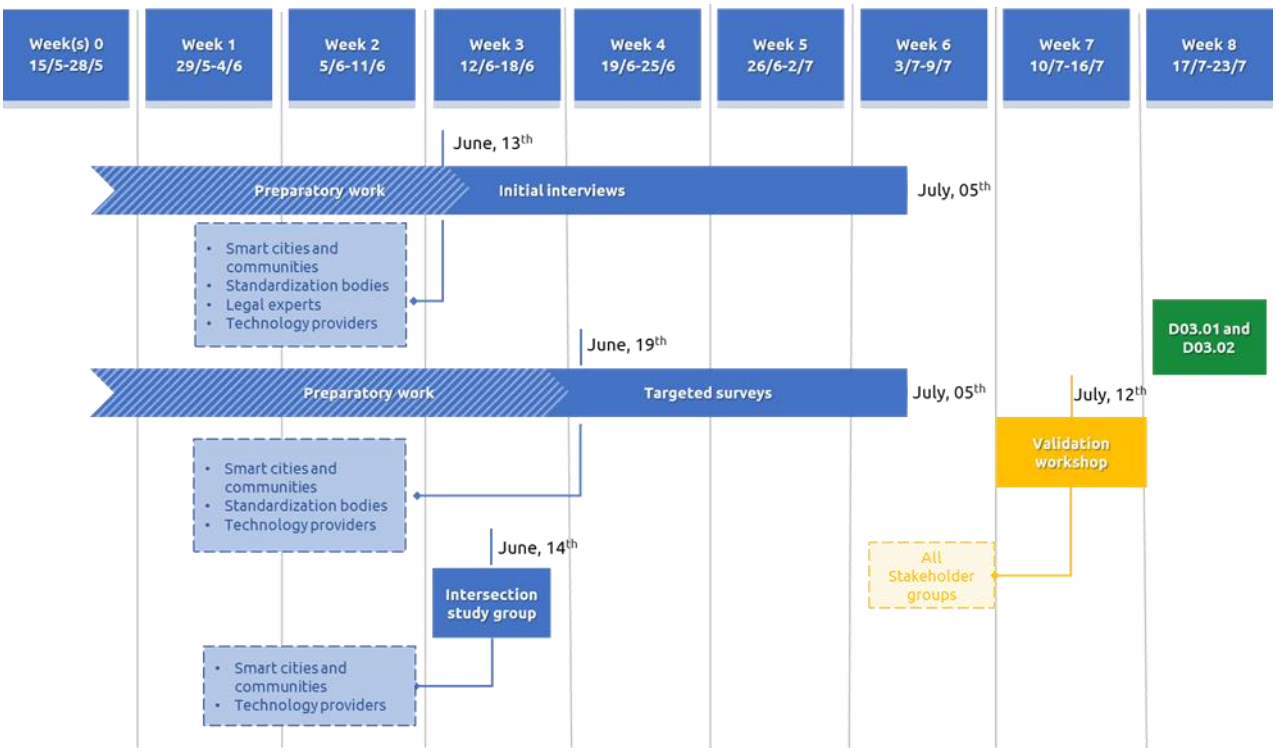

Figure 1: Consultation timeline and activities overview

To improve participation to the consultation activities, the project team developed a robust and flexible **dissemination strategy**, which was crucial to ensure contribution from all relevant stakeholders. The strategy was defined following the steps below:

1. **Stakeholder mapping and engagement**. An extensive stakeholder mapping exercise on the LDT community was conducted in the project. Here, all relevant stakeholders were mapped and grouped in different stakeholder categories. This mapping exercise was leveraged to disseminate the surveys and to invite interviewees for the consultation activities, and the initial list of stakeholders was further expanded by a snowball sampling that allowed the team to reach a congruous number of stakeholders working on or around LDTs. For optimal input, tailored stakeholder activities were conducted to ensure that the key stakeholders were involved in the consultation activities. In particular, starting from the team's involvement in other EU projects and initiatives focused on Smart Cities such as DUET, DIGISER, LEAD, the project team identified the key stakeholders whose inclusion is critical in the consultation process. All relevant stakeholders were mapped and were grouped in different stakeholder categories.
2. **Dissemination**. The consultation was widely disseminated using different channels:
    a. Emails were sent to invite stakeholders to partake in the survey, including regular reminders.
    b. To raise awareness on the ongoing consultation among relevant stakeholders, members of the project team participated in several European events (e.g., DT4Region – 21 June, Brussels; OASC General Assembly – 14 June, Brussels; CitiCom.AI – 27 June, Copenhagen). During these events, face-to-face interviews were conducted and QR Codes linked to the surveys were printed and distributed to invite stakeholders to share their experience.
    c. Messages to promote the consultation were published on social networks (e.g., LinkedIn) by all consortium members.
    d. News items were published on the Living-in.eu website and social media platforms.
    e. Leveraging on consortium network, invitation to surveys have been sent directly to so-called 'multiplier' organisations, including Eurocities, ERRIN, ENoLL, CEMR, ICLEI,

Digiser, DS4SSCC, CommuniCity. These organisations were invited to both take part to the surveys and to extend the invitation to their members.

The dissemination activities were regularly monitored, and the overall strategy was regularly updated to fill gaps emerging in terms of geographical coverage and representativeness of stakeholder groups.

2.2 Conducted consultation activities

To inform the functional and performance requirements for designing the LDT Toolbox, a mix of qualitative and quantitative data collection activities were conducted, including interviews, online surveys, intersection study group and a validation workshop. This section provides additional details of the different primary data collection activities implemented.

2.2.1 Interviews

During the interview period (13 June – 07 July), the **project team conducted 19 interviews** to delve deeply into participants' viewpoints, experiences, and knowledge on the business, functional and technical, legal and security aspects of LDT. In addition, **2 targeted interviews** were organised after the workshop (17 – 18 July) for data gap filling interviews with AI and complexity science experts. Overall, the project team conducted **21 interviews in total**. Interviews were carried out by videoconference, lasted between 60 to 90 minutes, and followed a semi-structured questionnaire, available in Annex A.

The interviews were distributed as follows: 9 Smart Cities, 4 Technology Providers, 2 Standardisation Bodies, 3 Legal Experts, 1 Project Representative, 1 AI expert and 1 Complexity Science expert. Through this consultation activity, the study team was able to retrieve information from 8 different European countries (Belgium, Bulgaria, Denmark, Finland, Germany, Italy, the Netherlands and Portugal).

An overview of the stakeholders interviewed is provided in the table below. The evidence collected during these interviews was compiled in an interview matrix and used to inform the analysis of key findings.

Table 2: Interviews participants

Country	Organisation	Date
Belgium	Digital Flanders	6/29/2023
	City of Bruges	6/16/2023
Finland	City of Vantaa	6/22/2023
	City of Espoo	6/21/2023
Italy	City of Milan	6/28/2023
	City of Parma	6/29/2023
	City of Bologna	7/05/2023
Denmark	Aarhus Municipality	7/05/2023
Netherlands	Municipality of Rotterdam	7/05/2023
Belgium[1]	Cegeka	6/15/2023
Bulgaria	Sofia University, GATE Institute	6/30/2023
Italy	Edison	6/30/2023
Portugal	NOVA IMS	6/22/2023
Germany[2]	ICLEI	6/26/2023
Netherlands	Geonovum	6/23/2023
Belgium	Digital Flanders	7/07/2023
Belgium	EDSON	6/28/2023
Bulgaria	Sofia University, GATE Institute	6/30/2023
Italy	CNR	6/13/2023
Luxembourg	LIST	7/17/2023
Switzerland	University of Lausanne	7/18/2023

2.2.2 Online surveys

The study team launched different online surveys based on respondent's role in connection with the LDT. All questionnaires included a mix of open-ended and close-ended questions. The surveys addressed three different categories of stakeholders: (i) Smart Cities and Communities, (ii) Technology Providers, (iii) Standardisation Bodies and Fora. The surveys were launched on 19 June 2023 and were officially closed on the 4 July 2023. The questionnaires developed for the surveys are available in Annex B.

The sample of the **Smart Cities and Communities group consisted of 39 respondents**, representing mostly smart cities and communities (69%), academia (15%) and European regions (8%). The remaining 8% of respondents belongs to other European projects currently ongoing in the field. Most respondents were based in the Netherlands (15%), Italy (15%), Spain (10%) and Portugal (10%). The map below shows that even though not all the EU countries were covered, all the European regions were represented in the survey.

[1] Cegeka is a European provider of IT solutions, services and consultancy with the headquarter in Belgium.
[2] ICLEI, located in Germany, is a global network of more than 2500 local and regional governments committed to sustainable urban development.

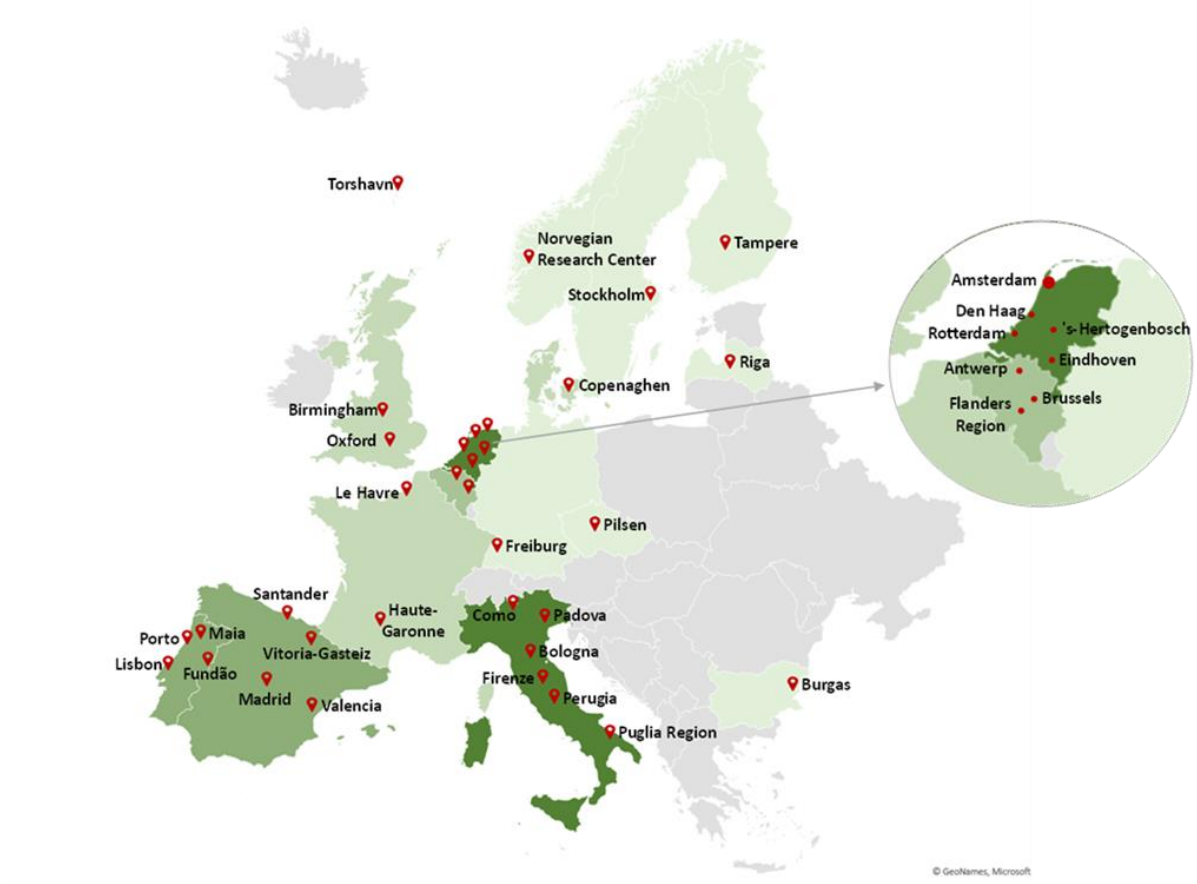

Figure 2: Map of respondents to the Smart Cities and Communities survey

The survey targeting **technology providers received 35 responses**, with most of the respondents representing European SMEs (49% of the total), followed by micro (23%), large (26%) and one independent company. The geographical distribution of the responses from technology providers is similar to that of the Smart Cities and Communities group seen above. In fact, most of the technology providers responding to the surveys are from Italy (23%), Germany (14%), Spain (14%).

Figure 3: Map of respondents to the Technology Provider survey

As shown in the map below, the survey targeting **standardisation bodies and fora** was the one receiving less responses. In fact, only **3 respondents** from this stakeholder group took the survey.

Figure 4: Map of respondents to the Standardisation body survey

2.2.3 Intersection study group

An intersection study group was organised during the OASC General Assembly, held in Brussels on 14 June 2023. During the event, the study team delivered a dedicated one-hour session entitled "*The DG Connect Local Digital Twin Toolbox*". The aim of the session was twofold. On one hand, given the audience of the event, it allowed the team to raise awareness of the project's goals and on the upcoming consultation, boosting the prospect of gathering insights into the world of LDT. On the other hand, it represented an opportunity to test some of the survey questions with the participants and to fine tune the questionnaires for the upcoming survey. In fact, during the event, participants to the intersection study group were asked to give their opinion and share their experiences and needs via a series of Slido polls. 22 stakeholders attended the event. A full list of the polls submitted during the session is available in Annex C, as well as the summary of key results.

2.2.4 Validation workshop

The evidence gathered during the previous consultation activities were presented and validated during the interim workshop entitled "*What should a local digital twin Toolbox look like?*". The workshop took place online on 12 July and was attended by 138 participants, distributed across sixteen European countries as shown in the map below. Please refer to D02.02 for more detailed information.

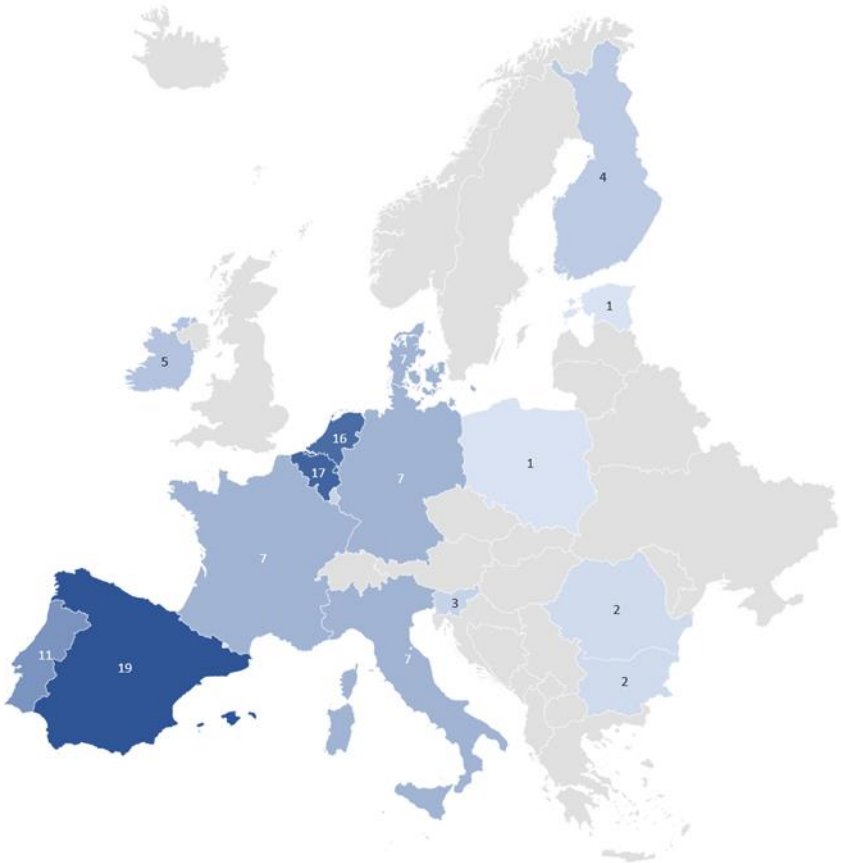

Figure 5: Map of workshop participants

The workshop was divided into three main sections, each tackling a specific task of the project. Namely, the validation of the LDT Toolbox components, the scenarios to deploy and maintain a sustainable Toolbox, and a roadmap for the Toolbox's deployment. The specific objectives of the validation section of the workshop, entitled "*What should be in a local digital twin Toolbox?*", were to present the findings of the consultation activities; validate business functional and technical, legal and security aspects of the LDT Toolbox building blocks; and engage with stakeholders to co-create the LDT Toolbox.

Of the total participants, 42 of them actively contributed to the validation of the building blocks which will guide the design of the Toolbox itself. In particular, participants were invited to validate the findings and select the most relevant building blocks that the future LDT Toolbox should include. Evidence was gathered using different tools, such as Slido. A summary of the strategy tools, technology building blocks, legal and policy guidelines presented during the workshop is available below.

Table 3: Summary of building blocks

Aspect	Building Block
Strategy tools	1. Reference architecture 2. Tool for ambition assessment and roadmap management 3. Tool for security and risk assessment 4. Certification Framework 5. Catalogue of tech solutions and use cases
Technology building blocks	6. Case & Scenario Manager 7. Integrated environment 8. Interaction Service 9. Message Broker 10. Model abstraction Service 11. Model Catalogue/Algorithm Register 12. Data Query Service 13. Asset Registry 14. Context Broker 15. Data Catalogue 16. IoT Agent 17. Simulation Service 18. Synthetic Data Generation Tools 19. Collaboration & community management system 20. Data Spaces Connector 21. Analytical Visualisation Components 22. Data Lake, data warehouse, data lakehouse 23. Geospatial Visualisation 24. Access Manager 25. Identity Manager 26. User Manager 27. Workflow Orchestrator
Legal and policy guidelines	28. Guidelines for data management 29. Guidelines for LDT procurement 30. Guidelines for generation of privacy-preserving synthetic data 31. Operational guidelines for stakeholder involvement in data protection impact assessments 32. Playbook for designing, implementing, and monitoring of transactions with private actor

Annex D provides a full description of the activities conducted during the workshop. The results from the activities are presented and analysed in section 4 of this document. The activities conducted during the workshop ensured a stronger stakeholder participation and, more importantly, allowed for their direct involvement in the definition of the LDT Toolbox building blocks.

3 Consultation findings

This chapter provides a detailed analysis of the evidence collected during the consultation activities. It considers different stakeholder's views based on their level of experience in the LDT field. The following sections examine their opinion regarding the composition of the future European LDT Toolbox under three main aspects, namely:

- Business features (Section 3). This section is further divided into sub-sections to analyse the definition and current state of LDT, identify benefits and key challenges for implementation, exploring governance and procurement options, as well as the key components that the future LDT Toolbox should include.
- Functional and technical features (Section 3.2). This section analyses the most relevant capabilities for cities to implement LDT and the requirement they impose to technology provider. In addition, capabilities most present in the LDT solutions deployed by technology providers are explored. Finally, existing EU guidelines and regulations on standards and technical requirements are analysed for each of the capabilities based on standardisation bodies views.
- Legal and policy features (Section 3.2.4) This section analyses the procurement and contracting, legal data provenance, data rights and licensing, open sources and open platforms, interoperability and regulatory sandboxes based on legal experts' contribution.

The analysis developed in sections 3.1 and 3.2 is further complemented by a selection of quotes from participants to the consultation and summarised in a box including the key takeaways.

3.1 Business features

3.1.1 Overview

The study of business features focused on exploring the current understanding and advancement of LDT solutions, identification of key drivers for LDT, its impacts and key challenges.

3.1.2 Analysis of results

The sections below provide a detailed presentation of consultation findings, analysed and summarised into a preliminary list of key building blocks that the future European LDT Toolbox should have from a business perspective.

3.1.2.1. Definition and current state of LDT

The starting point of both the surveys and the interviews was to deepen the knowledge on the definition of LDT. Consultation results suggest that there is a strong agreement on the definition of an LDT. In fact, the study team provided different types of definition to be able to enquire and assess all the aspects deemed most relevant for each stakeholder. Whilst some answers capture the generality of the LDT (*it is a virtual representation of the real world*), others are much more detailed (*LDTs must include predictive and simulation models that can be updated and modified as their physical equivalents change*).

Many respondents (63% of the total Smart Cities and Community group) agree that "*the purpose of local digital twins is to enhance evidence-based decision making*" and that an LDT "*combine several technologies (such as data analytics and AI) to process data and derive insights from it".* The diagram below shows a consensus on all the options provided and suggests how the definition of an LDT is homogenously distributed in the sample. These results imply that the questions developed for this consultation are likely to provide an accurate representation of the LDT nature and its core aspect.

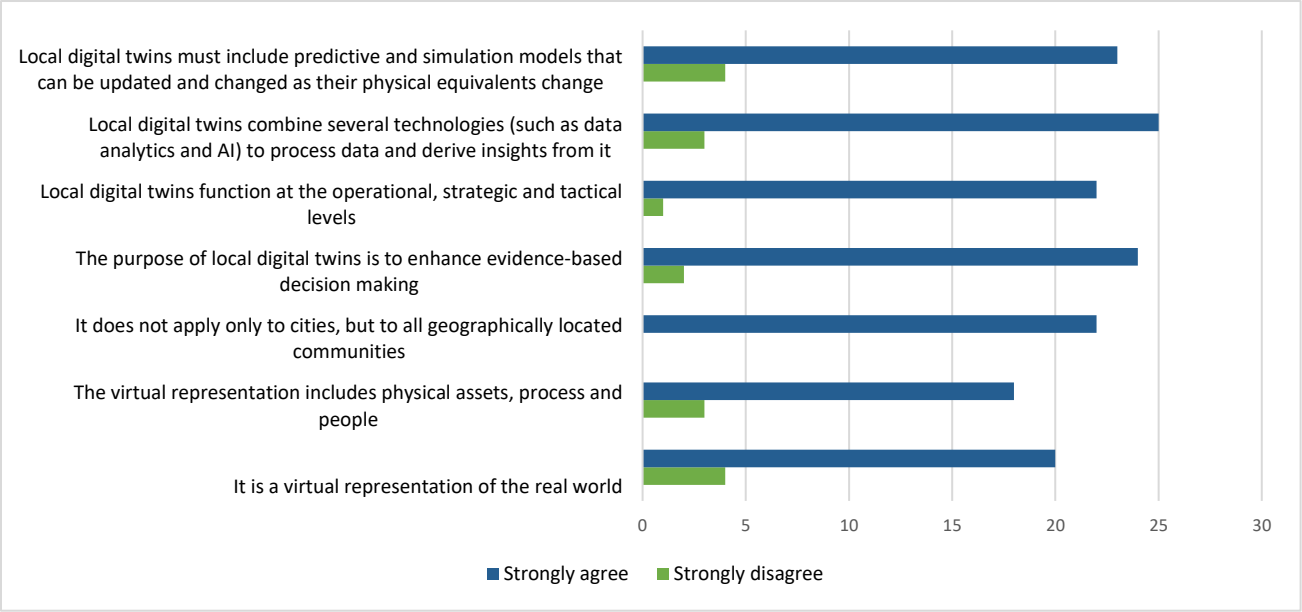

Figure 6: Definition of LDT

Although most of the respondents agreed with the options provided and listed in the diagram below, a definitive and unique definition of an LDT does not currently exist. In fact, evidence from the interviews and surveys highlights that the LDT and data platforms should be developed in parallel to provide new applications that support evidence-based decision making. In addition, some of the respondents to the interviews emphasised that a broader definition of LDT should consider both technical and cultural, as well as socio-political aspects to encompass a broader strategy that involves internal reorganisation of the administration, and implementation of comprehensive data ethics strategies. In general, the widespread underlying concept under the term LDT is the real-time virtual representation of physical assets or systems which must include predictive and simulation models that can be updated and modified as their physical equivalents change. Despite the heterogenous definition of LDT, some interviewees pointed out that, given the increasing momentum LDTs is gaining, a collective understanding is expected to emerge.

Another key objective of the consultation was to understand the progress of cities and communities that have already implemented or partially implemented one or more LDT solution. On the total number of respondents, half of the sample said they already had an LDT system and were also investing in it as a future programme (49%). This evidence shows that some cities are confident that a full implementation of one or more LDT solutions is possible. On the other hand, the remaining half of the respondents (43%) state that they do not own an LDT technology in their city yet but are planning future investments in it. This evidence indicates the need for some cities to be guided along this path of maturation, but it also represents a gap to be filled that does not allow a full implementation of a long-term strategy to create an LDT.

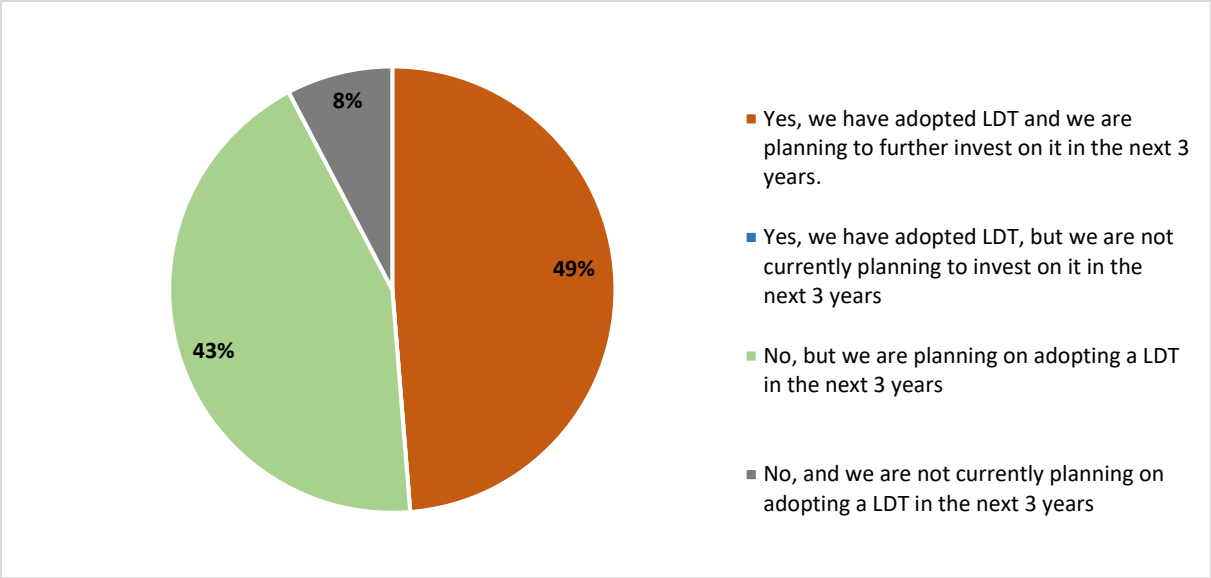

Figure 7: Adoption of LDT by SCCs

With regards to the perception of technology providers on LDT advancement, the figure below shows that most of them (73.5% of the total) interact with cities and local authorities which are planning to adopt an LDT in the next three years. This data suggests that while there is a clear tendency for local authorities to innovate, they tend to outsource services to third parties outside their organisation.

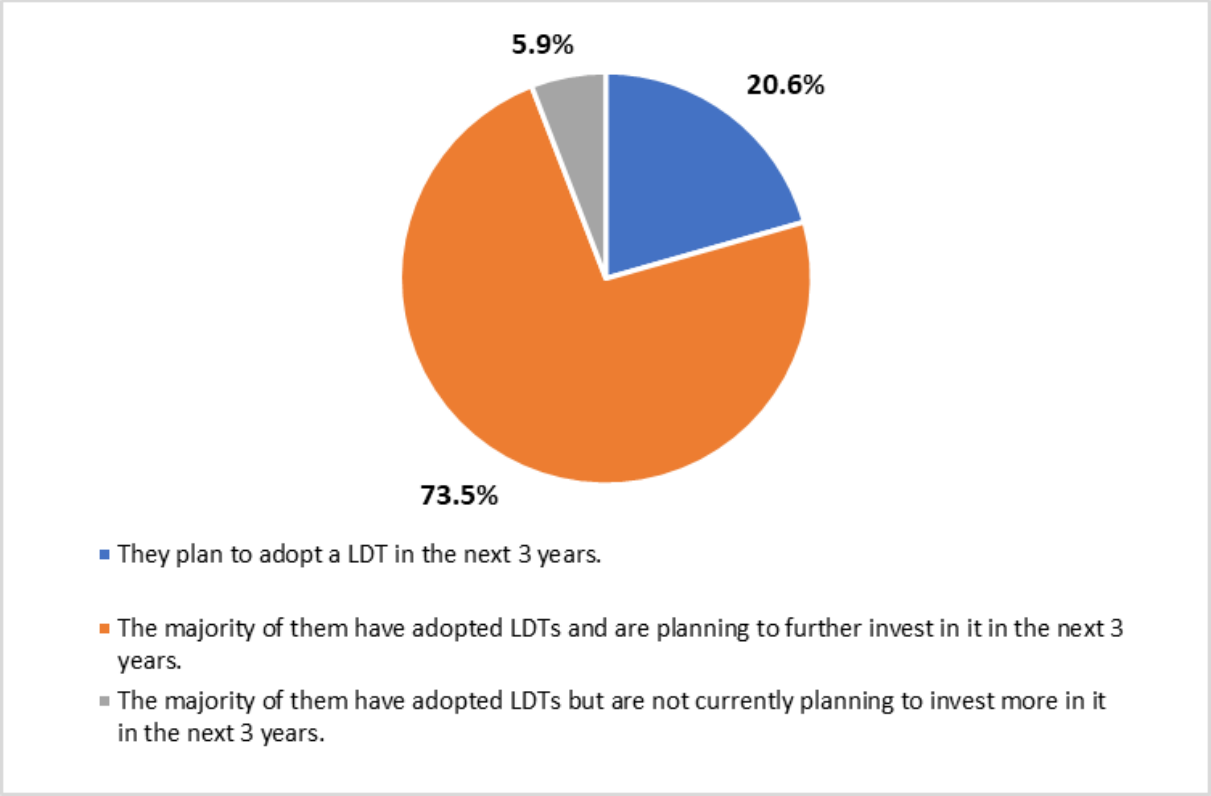

Figure 8: Adoption of LDT as answered by Technology providers

Cities surveyed report that while digital twins are widely used in some sectors of the economy (e.g., Industry 4.0), its application at urban and local level is still at its early stage. This is due to some key challenges that will be analysed below, but also to a lack of strategic vision, which has to do with the level of digital maturity of the cities.

Being a novel concept, it is difficult to elaborate a common well-defined strategy of implementation and strategic framework to be followed. However, the interest in pursuing an LDT grew while cities became aware of available funding opportunities and use case possibilities. The consultation assesses that the areas that have garnered the most interest by the cities include mobility, lighting, energy management, education, environment (air pollution, climate change), smart buildings, and healthcare.

In the context of the progress of cities and communities in the implementation of an LDT, the consultation activities further investigated the maturity level of digital twins. According to DUET project, maturity of digital twins can be classified in four ambition level, as following:

- **Awareness twin**: It is usually the start of the digital roadmap and concerns explorative visualisation with some layers, perhaps some sensors and sensor data. Limited data management capabilities are needed. It can be used for situational awareness in terms of traffic, logistics, environmental, demographic, health, etc.
- **Experimental twin**: It gives the possibility of running what-if simulations, requires more structured data and scenario management approach. Models are configured and deployed once with sufficient verification of the validity of their outcomes.
- **Predictive twin**: Predictive analysis allows for anticipating on events that happen, such as traffic congestion or flooding and study impact. This requires near-real-time data flows and vetted models, which may include AI, and unlocks the possibility for cases such as virtualising disaster exercises using replay of historic data. To achieve this, expertise such as domain experts and data engineers need to be available along with a mature data organisation.
- **Intelligent twin**: Autonomous operation of twins enables automating city infrastructure, for instance to anticipate critical events by guiding traffic, putting services on pre-alert, open/close levies, etc. This requires a high degree of maturity and an in-house team of technical, data and subject matter experts.

Regarding the different ambition level, evidence from the workshop shows **high maturity levels** across Europe. In fact, most of the respondents participating at the workshop are at an **experimental phase,** in which "what-if" scenarios become possible, followed by the **intelligent level**, which requires a high degree of maturity and an in-house team of technical, data, and subject matter experts. The figure below presents the different ambition levels of the 42 respondents to the poll.

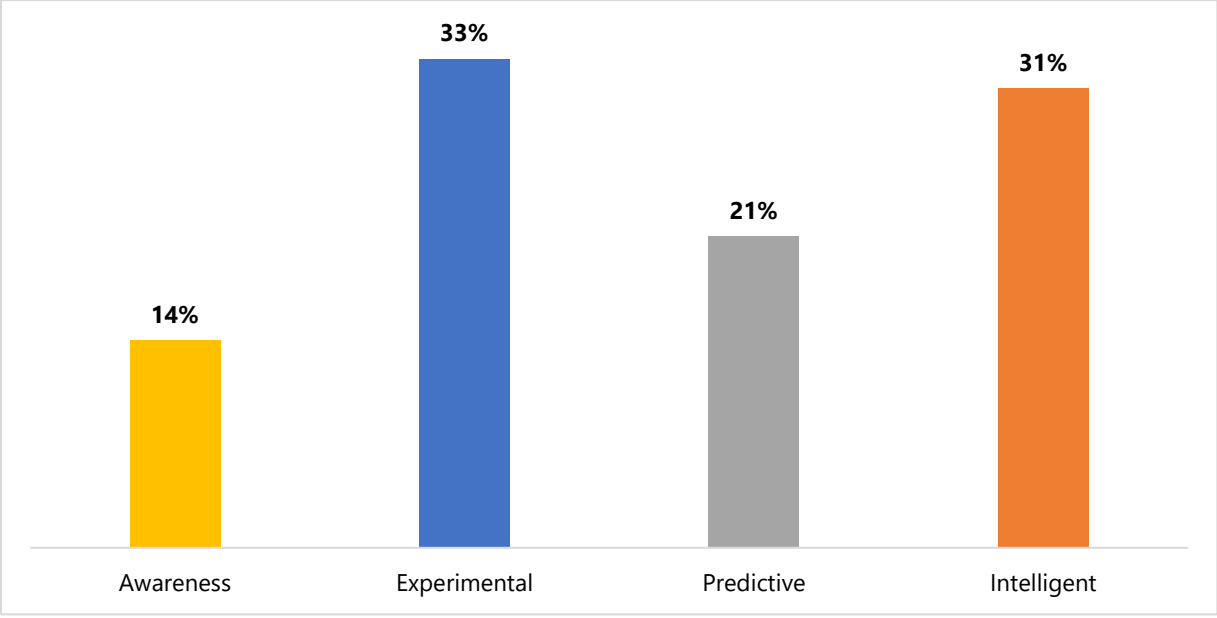

Figure 9: Most applicable ambition levels

Going further, the analysis on the characteristics that each ambition level should incorporate, most respondents of the workshop consider that ***data management & data governance*, including**

components like a data lake and asset registry, are the most crucial features for an awareness twin. *2D/3D visualisation* ranks second in importance, and *sensing and measuring components*, such as IoT devices, IoT agents, context brokers, and asset management tools, follows but at a relatively lower level of significance. These insights emphasise the significance of robust data management and governance capabilities in the context of an awareness twin, with visualisation and sensing/measuring tools playing supporting roles in the overall functionality of the digital twin. Moving onto the **experimental twin**, the **most important features identified are *case and scenario management* to facilitate a structured approach for conducting experiments**. Following closely behind are *data and model management*, including an asset registry, and *model discoverability*, which involves finding models in model marketplaces or data spaces. Many respondents identify ***near-real-time sensing and data streaming*** **as the key features for a predictive twin.** This is followed closely by *advanced analytical dashboarding with business intelligence (BI) capabilities* and *advanced data/model governance*. A significant number of participants view a ***real-time digital twin with live data streams*** **as the most crucial feature for an intelligent twin.** Following closely behind are *algorithm/model and data transparency* and *explainability in the twin's operations*. Explainability is very much relevant related to the introduction of AI models where the purpose is to explain the logic that is used in the automations and decision-making processes. Additionally, a *higher level of situational awareness, encompassing oversight and control*, is also regarded as an important aspect of an intelligent twin. These insights underscore the importance of real-time data, transparency, and situational awareness in achieving an effective and impactful intelligent twin implementation.

To summarise, cities surveyed have different starting points and necessities for their digitalisation journey. The results of the consultations suggest that in some cases there are those who already have a clear vision and awareness of what they are planning, particularly in terms of the capacity to attract funding and know how to use LDT in strategic planning decisions. In some other cases, cities are less advanced in their LDT process and require additional support. The type of support that the Toolbox can provide to cities is further analysed in the last section of this chapter.

Key takeaways

- The widespread underlying concept under the term "digital twin" is the real-time virtual representation of physical assets or systems which must include predictive and simulation models that can be updated and modified as their physical equivalents change. Despite the heterogenous definition of LDT, momentum is growing, and a collective understanding is expected to emerge.
- The consultation shows that most of the cities are confident that a full implementation of one or more LDT solutions is possible (49% of respondents to the surveys already have an LDT system and are planning to further invest in it). Similarly, most technology providers (73.5% of the total) interact with cities planning to adopt LDT in the next three years showing that LDT is gaining ground also in less advanced cities.
- Overall, maturity level tends to vary. Workshop participants confirmed that a third of them (33% of the total participants) are in an *experimental phase*, in which what-if simulations become possible. For a significant 31% of the sample, *intelligent level* - which requires a high degree of maturity and an in-house team of technical, data, and domain experts – is the best description of the context in which they operate.

3.1.2.2. Benefits and enablers

To better understand the added value generated by an LDT, the questionnaires focused on the identification of the main goals that a city aims to achieve through its implementation. Evidence gathered through the interviews with smart cities highlights that LDT should address tangible business cases that generate value for the cities and for it to be successful, it must align with the city's wider strategic vision.

Looking at the **main drivers that influence the application of the LDT**, smart cities and communities' respondents to the survey prioritise three points: (i) *improvements of the urban planning,* (ii) *improvements in decision-making processes, and* (iii) *more efficient operations and maintenance*. The figure below summarises the answers obtained.

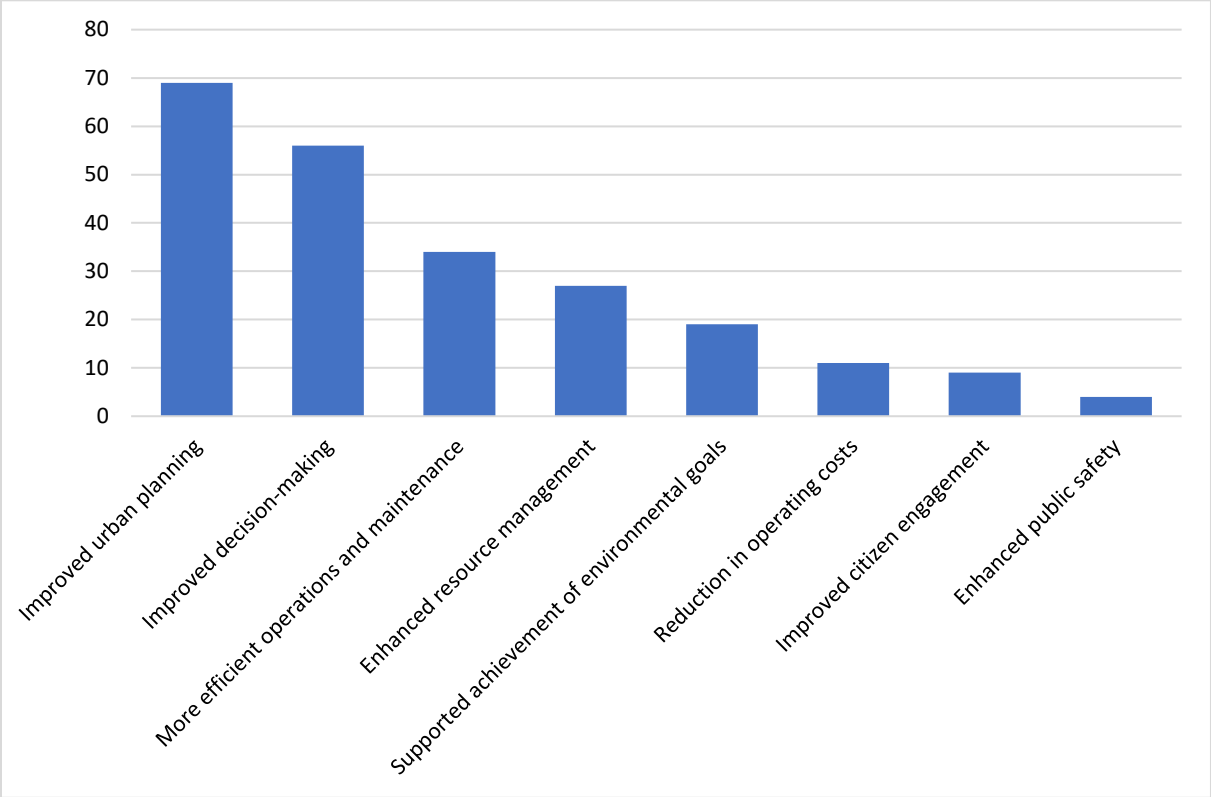

Figure 10: Drivers that influence the adoption of LDT in the Cities (for SCCs)

The evidence collected shows that the LDT should be considered as a tool by which cities manage and plan the interventions to be performed in the city to make it more efficient and functional for the citizens.

On this aspect investigated in the survey, the view of Smart Cities representatives was crucial to gather additional insights on the **impact that an LDT could have both on cities management and on citizens**. According to this category of stakeholders, LDT will enable the redefinition of internal processes, improvement of administrative practices, and professional development of employees. Indeed, most of the cities consulted agreed that data analytics tool, including LDT, significantly enhance workflow efficiency and decision-making processes.

Finally, consultation activities report that cross-departmental collaboration is crucial to identify the key use cases an LDT should address. Most of the cities interviewed, report that all the relevant departments within the city engaged or will engage in a collaborative way to jointly develop impactful LDT solutions. To this extent, **collaboration** is crucial to overcome siloed working and thinking and is identified as a key enabler for a successful LDT implementation.

When looking at the LDT design process**, collaboration with community stakeholders** is deemed significantly relevant, with more than half of the respondents (51%) considering participation in the **co-designing process** of the LDT **very important**, that is, decisive for the success of the process. The rest of the respondents are divided between fairly important (26%), important (10%) and slightly important (10%). None of the survey respondents felt that collaboration with stakeholders was not important.

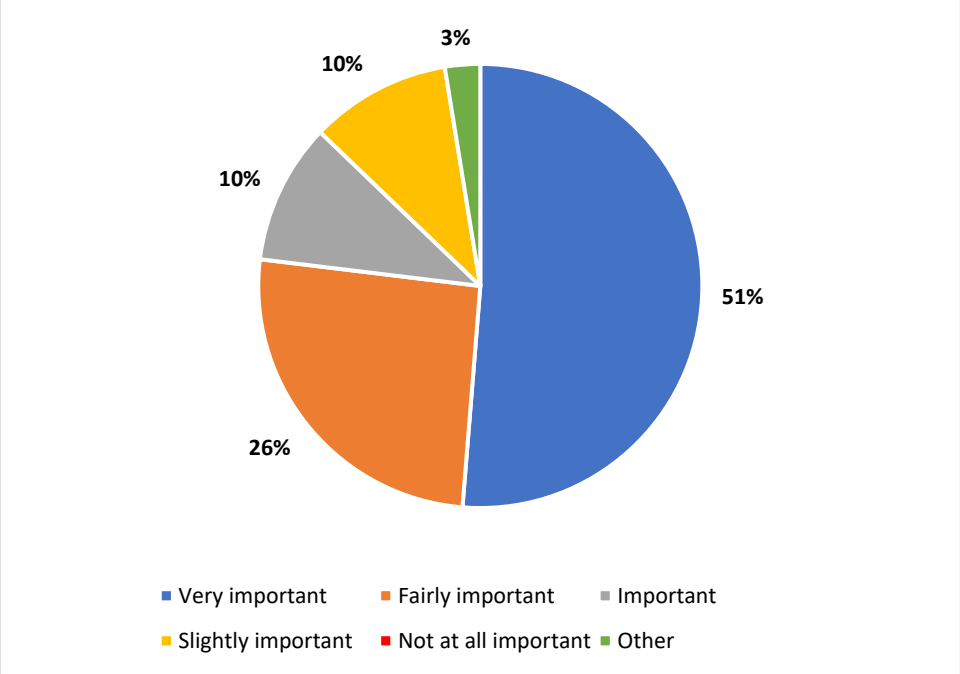

Figure 11: Importance of co-design process with your community stakeholders

Through the understanding of the main benefits and enablers that guide local authorities towards the implementation of LDT, the surveys explored the operations and processes that a local authority sees as most important for an LDT to support, the potential **uses cases,** i.e., all the needs that cities want to address through this LDT technology, are analysed through the lenses of both smart cities and technology providers. As shown in the figure below, among the different use cases, *traffic and transportation management, environmental monitoring and sustainability, smart city management and urban planning* are the most recurrent priorities for both SCCs and Tech providers. None of the respondents see *economic development and housing, administrative and public services* as one of their priorities.

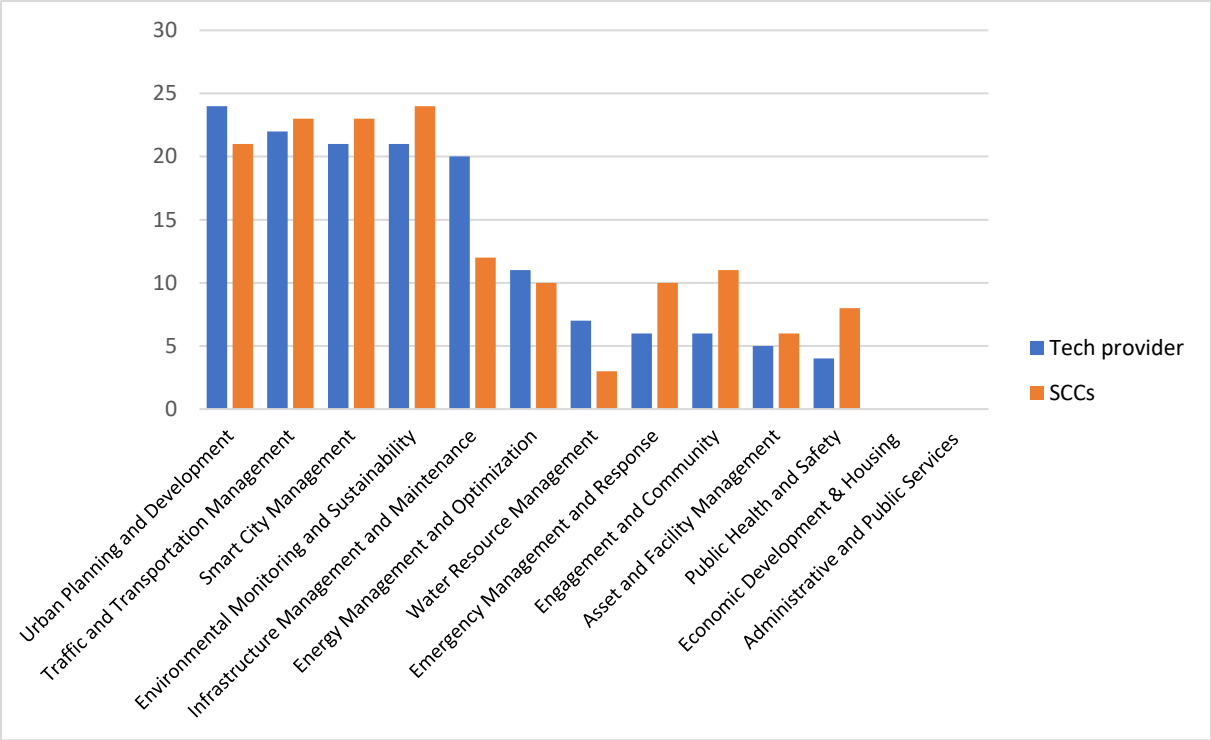

Figure 12: Use cases being prioritised by Local Authorities

The analysis of the interviews shows a convergence around some specific themes, which are in line with the use cases presented above. Urban planning, environmental issues, energy management, and traffic and transportation are the most frequently mentioned area. It is interesting to note that respondents have also highlighted other areas that are specifically citizen-oriented, such as reducing inequalities, housing policies, economic activities. Finally, other areas include service maintenance, data and legal support, control of tax payments, procurement decision. An overview of the key terms used by the different interviewees is presented in the figure below.

Figure 13: Most occurred use cases from the interviews

Key takeaways

- LDT's **purpose** is to support city planners and policymakers in making well-informed decisions regarding urban development, resource allocation, infrastructure planning, and policy formulation.
- The key **benefits** that LDT brings are identified by participant to the consultation as:
  - Improved urban planning,
  - Improved decision-making processes, and

    - More efficient operations and maintenance.

- Cross-departmental collaboration and engagement with the community stakeholders are key **enablers** for an impactful LDT implementation, and to overcome siloed working and thinking.
- SSCs and Tech providers report that the design of an LDT should necessarily start from the identification of **use cases**. In line with surveys results, the following use cases are deemed most relevant:
    - Traffic and transportation management,
    - Environmental monitoring and sustainability, and
    - Smart city management and urban planning

3.1.2.3. Key challenges

There are specific challenges that hinder the adoption of an LDT: *limitation on the collection and integration of data* is mentioned as the most important challenge, together with the *lack of technical resources and knowledge*. This is in line with what emerged on the possible impact of LDT on the city management: the desirable effect of the LDT on the cities is determined, in fact, by the quality of the data needed to lead it to its maximum operationalisation. Hence, it is mandatory for cities to enhance the deficient factors, together with *a more efficient bureaucratic procurement process and* compliance with *strict requirements* (Figure 14).

In this regard, both technology provider and smart cities agree on fact that digital maturity is required before implementing an LDT within cities, and that it starts with an improvement of data collection and analysis system. As stated by several stakeholders involved, the two main challenges are related to the absence of a proper databases, and, in general, to the sharing of data, specifically with time-related and granularity issues.

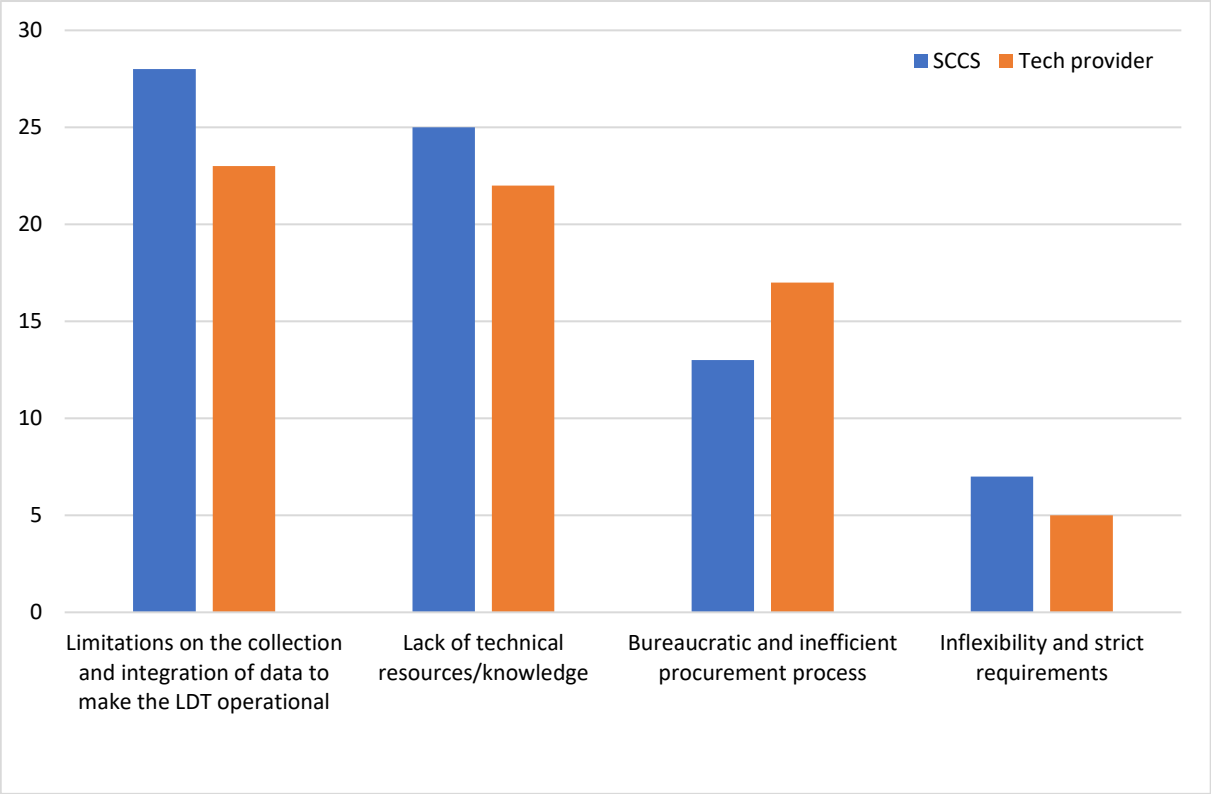

Figure 14: Key challenges of LDT implementation

Furthermore, evidence from the interviews underline that the **lack of sustainable funding mechanisms and sustainable economic business model** are some of the main obstacles to ensure an appropriate level of maturity and preparedness. From the interviews, it appears evident how the absence of **adequate fundings** is seen as a main obstacle for the development of an LDT solution, especially because LDT projects are city-related, hence of a public nature. Therefore, the main objective of a city, during the first year of development, is to define a sustainable economic business model.

According to some interviewees, another challenge that arises when promoting digital technology in communities is the **impact of legislation**. In fact, some interviews revealed that there is a strong emphasis on the significance of standardisation, prompting investigations into determining the appropriate data format for inclusion in a digital twin. Looking ahead, it becomes imperative to have public sector employees equipped with digital skills. This is particularly critical in the realm of LDT, where individuals with the ability to integrate diverse datasets in various formats are in high demand.

The data collected through the interviews lead to a first generalisation of the challenges the cities are facing. In addition to the lack of funding and resources, another major challenge is related to the availability of highly qualified employees both at operational and top level. Consequently, the lack of skilled employees lead to higher costs since cities are forced to outsource the service.

Key takeaways

- Limitation on the collection and integration of data, together with the lack of resources and knowledge are the key challenges for LDT implementation.
- The lack of fundings and resources, is another major challenge that influence a long-term vision. Sustainable economic business models are crucial for LDT development.
- From both SCC and tech provider perspective, digital maturity is required before implementing an LDT within cities.
- When promoting digital technology in communities, another challenge is the impact of legislation. There is a need to determine the appropriate data format for inclusion in a digital twin.

- There is the need to acquire appropriate skills and competencies by employees and managers working on the development of LDT.

3.1.2.3. Governance and procurement

Consulted local authorities prefer that the governance of the LDT remains of public responsibility, in the hands of public agencies and municipalities. On the other hand, many respondents point out that it is very difficult for a public entity to have all the necessary expertise to design and develop an LDT. For this reason, it is essential to collaborate with other stakeholders, including academics, researchers, business community.

From the responses received, no well-defined central roles or precise organisational chart within the cities clearly emerge and, in many cases, multiple departments work on the LDT. In fact, some of the interviewees highlight the need to have internal employees who can take care of all aspects pertaining to this function. Understanding the organisational culture, processes, structure, skills, and competencies becomes highly significant in the context of digital transformation. When making decisions based on data, there is a requirement for diverse skills and capabilities to analyse, visualise, and ensure data comprehension. Furthermore, it will be crucial to include public sector employees with digital skills in the future. Specifically, in the digital twin field, individuals with the ability to integrate diverse datasets in various formats are essential. The lack of public and internal competencies in municipalities thus opens the door to outsourced procurement, and this denotes a hybrid nature of the divisions that make up the LDT development team in the city.

Although results vary across the different stakeholders, several capabilities are purchased by local authorities from third parties. Please refer to section 3.2 of this report for a detailed presentation of capabilities. An approximation of data collected during the consultation suggest that cities are most likely to outsource the following capabilities:

- *Communications, Network and Transport capabilities*: Capabilities that enable the interaction and exchange of data between devices and field equipment between themselves and with applications residing on some “back-end systems” often referred to as “management systems”.
- *Device Asset Management and Operational Services capabilities*: Capabilities that enable the delivery and assurance of the assets supporting the device communications and integration including positioning capabilities.
- *Integration, Choreography and Orchestration capabilities*: Capabilities to manage, choreograph and orchestrate processes and services in support of system integration and human computer interaction.
- *Generic City and Community capabilities*: Capabilities that enable the deployment of generic (non-city or community specific) capabilities with respect to the roles and duties within any given urban environment.
- *Stakeholder Engagement and Collaboration capabilities:* Capabilities that enable cities and communities to engage and collaborate with a large variety of stakeholders and to manage the strategic goals agenda and roadmap. Here, within the context of the EIP SCC, the EU climate goals reflect the needs of such capabilities around energy efficiency, GHG reduction, and wider use of renewable energy.
- *Privacy and Security capabilities*: Capabilities regarding integral Privacy and Security apply across physical sites and assets, devices, networks, data, application, and people. Compared to physical security, cyber security is aimed at protecting confidentiality, availability, and integrity in the digital context, by applying a myriad of tools and measures, including identity

management, authentication and (both functional and data oriented) authorisation, intruder detection and auditing.

Conversely, the capabilities that to remain in-house are:

- *Field Equipment/Device capabilities*: Capabilities that enable the external environment (field equipment, devices, IoT) to be sensed, measured, and controlled.
- *Data Management and Analytics capabilities*: Capabilities that enable the use of urban (field) data by applications. It includes core data management and life cycle (e.g., ingest, assure) related capabilities, as well as capabilities to analyse, share and publish (open) data.
- *Specific City and Community capabilities*: Capabilities that enable the deployment of specific city/community capabilities. Here within the EIP SCC, with three main streams: Sustainable Urban Mobility, Sustainable District and Built Environment, and Integrated Infrastructure and Processes.
- *Common Services capabilities*: Capabilities that support other Capabilities regardless of the layer in which the Capability is found; these are more generic technical capabilities, not city-related programme or goal specific.

Key takeaways

- A precise governance model dealing with LDT has not yet emerged. In fact, each city involves different stakeholders to implement different capabilities needed.
- Cities opt for procurement to third-party services to make up for the absence of specific skills and capabilities.

3.1.2.4. Future EU LDT Toolbox components

Generally, several cities and municipalities across Europe appear to be dealing with the same issues. Most of the interviewees shared that it would be good to have a set place where all business, functional, technical and legal requirements are stored. The consultation provided an initial idea of the components that the LDT Toolbox should contain. According to the interviews, the Toolbox should contain a sort of handbook for recognising the transformative impact on decision-making, analysis, and collaboration. Figure 15 presents the most common elements that cities and communities identified as essential for the development of the future Toolbox. Although these covered mainly the business aspects, some functional, technical and legal needs emerged from the interviews.

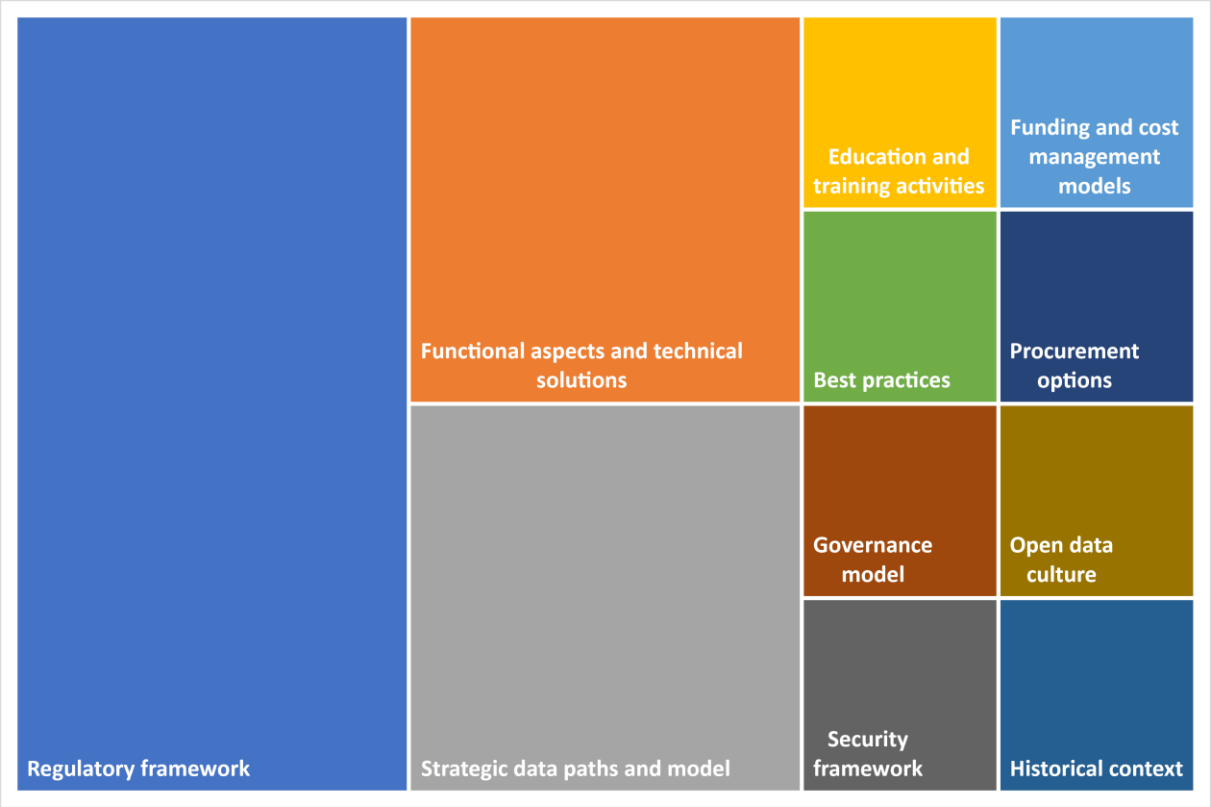

Figure 15: Key components of LDT Toolbox

From a **business perspective**, the Toolbox should provide guidelines and options with respect to different aspects, such as **procurement options, governance model and funding and cost management models**. Indeed, potential solutions for financing, together with best practices and example the implementation of an LDT solution would be valuable. For example, the Toolbox may include realistic examples of timelines to help with planning and scheduling, various budget estimation approaches, highlighting the resources required from cities. Recommendations regarding data **strategic paths,** based on observations of how other cities are implementing digital twins, should also be considered in the creation of an LDT Toolbox. As highlighted by some interviews, it is important for the Toolbox to provide **education and training support** to facilitate LDT adoption for those cities that do not have high levels of technological maturity. The Europe Union can provide valuable support in terms of education to raise awareness about the advantages associated with digital twins and enhance skills and competencies through training initiatives. Establishing standards and benchmarking practices is also crucial, considering the diverse applications of digital twins across various European regions and the different ways they have been utilised in various countries. Interviewees also suggested that the Toolbox should have an informative aim, providing an historical context of the LDT, outlining the evolution of its concept, and raising awareness on the open data culture.

Furthermore, the interviewees suggested that the Toolbox should also focus on processes and describe what options are available in terms of development, infrastructure, data collection and architecture. To achieve this, comprehensive support is needed for the architectural and functional aspects of LDT projects. Moreover, a panorama of the features an LDT should contain, the options it can generate, and concrete technical solutions that can also help those starting from scratch would be beneficial. The **technical and functional aspects** that should be included in the Toolbox are further analysed in Section 3.2 of this report.

Lastly, most of the interviewees identified reference to **regulatory framework** as an essential element that the Toolbox should include. To a less extent, **security framework** is also deemed an important

component of the Toolbox. According to the interviewees, the Toolbox should provide clear guidance with recommendations and general guidelines on aspects such as standardisation. Please refer to Section 3.3 of this report for an in-depth analysis of these aspects.

The project team analysed all the insights and feedbacks gathered during the interviews to compile all the desired components into a list of building blocks which should inform the design of the future LDT Toolbox. The resulting strategic components the Toolbox should include are listed below and further analysed in section 4 of this report:

1. Reference architecture
2. Tool for ambition assessment and roadmap management
3. Tool for security and risk assessment
4. Certification framework
5. Catalogue of tech solutions and use cases

To understand the most relevant tools, respondents to the workshop polls prioritised the presence of a reference architecture tool. The figure below shows that on a scale from 1 to 5, the importance of reference architecture tools is very high (average 4.22), compared to other tools, such as certification frameworks which ranked the lowest.

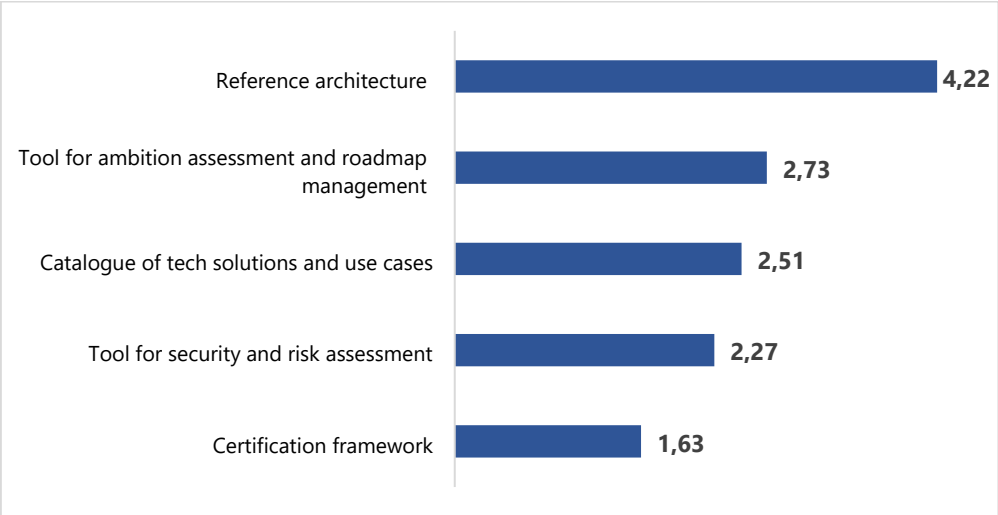

Figure 16: Most important strategic tools for an LDT

Key takeaways

- According to interviewees, from a business perspective the essential elements and features to be included in the Toolbox are:
  - guidelines and roadmaps for implementation,
  - procurement options, governance model, funding, and cost management models.,
  - recommendations regarding data strategic paths to consider, based on observations of how other cities are implementing digital twins,
  - historical context, thus outlining the evolution of the LDT concept during the years.
- Insights from the workshop highlight that, reference architecture should also be included in the Toolbox as part of the strategy tools.
- All the tools mentioned above should help speeding up adoption and usage of LDTs for the benefits they bring and support cities developing the right skills, competencies, and capabilities to implement LDTs in all relevant domains.

3.1.3 Business key takeaways

The key insights collected through consultation activities are summarised in the paragraphs below.

The most common LDT definition involves real-time virtual representations of physical assets or systems with predictive and simulation models that can be updated as their physical counterpart's change. Momentum is growing, with many cities and technology providers showing confidence in implementing LDT solutions. Similarly, maturity is increasing across and ambition level ranges from experimental to an intelligent level.

LDT's purpose is to support city planners and policymakers in making informed decisions for urban development, resource allocation, infrastructure planning, and policy formulation. Improved urban planning, decision-making processes, and more efficient operations and maintenance are the key benefits linked to LDT implementation, while cross-departmental collaboration and community engagement are crucial for its success.

With regards to the most relevant domains an LDT should address, the following use cases have been identified through the consultation: traffic and transportation management, environmental monitoring, and smart city management.

The key challenges for LDT implementation include limitations in data collection and integration, lack of technical resources and knowledge, as well as funding and resource constraints. Digital maturity is considered a prerequisite from both SCC and tech provider perspectives. In addition, the impact of legislation and determining the appropriate data format for inclusion in a digital twin are other two important challenges. To address these challenges effectively, it is crucial for employees and managers involved in LDT development to acquire the necessary skills and competencies.

A standardised governance model for LDT is not currently available and is challenging to establish, due to the involvement of diverse stakeholders with varying capabilities. Consequently, many cities choose to address this issue by procuring third-party services to compensate for the lack of specific skills and expertise internally.

From a strategic point of view, the Toolbox should comprise essential elements such as guidelines and roadmaps for implementation, realistic timelines for planning and budgeting, different budget estimation approaches, data strategic path recommendations based on other cities' experiences, and a historical context outlining the evolution of the LDT concept over the years.

Based on the evidence collected, the key strategic tools of the Toolbox are listed below:

1. Reference architecture
2. Tool for ambition assessment and roadmap management
3. Tool for security and risk assessment
4. Certification framework
5. Catalogue of tech solutions and use cases.

For a description of the five strategic tools lists, please refer to Section 4 of this report.

3.2 Functional and technical features

Before analysing the results of the functional and technical features of LDT from different stakeholders' perspectives, it is important to highlight that the categorisation in this part has been conducted separately for survey responses and interview findings, but also organised by specific groups of interviewees. This differs from the conceptual categorisation presented in sections 3 (business features) and 3.2.4 (legal and security features).

The reasons for categorisation per interviewees' group is because types of technical or functional questions asked by Smart City and Communities, Technical Providers, and Standardisation Bodies are significantly different from each other. This distinction is logical since each group plays a different role: one group uses technologies as users, while the other group provides them.

Moreover, as mentioned the results of findings have been put separated by the type of activities i.e., survey and interviews. Given the most extensive aspect of technical and functional questions among others (business and legal) in both surveys and interviews, it has elevated to the comprehensive quantitative assessment of the survey's result to generate the structured results per stakeholder group. Meanwhile, qualitative assessment of open-ended questions revealed various technical aspects, that were not captured in the surveys. Accordingly, the results of analysis have been discussed separately in following charts. Although, the subsequent analysis, focusing on the recognition of LDT building blocks, helped consolidate all the opinions into a cohesive outcome.

3.2.1 Capabilities overview

This section presents the results and functional analysis of the questionnaire on the LDTs' capabilities. The capability category descriptions as defined by [DIN SPEC 91357] were used in the interviews and surveys to gather feedback on expectations for requirements of the LDT Toolbox from different stakeholders. These results are presented in section 4.2.2. Based upon the feedback from the participants and the consortium members, the Capabilities overview for the LDT Toolbox was established, including functional (data, integration, analytics, IoT, visualisation, security), strategy and legal capabilities as presented in Figure 17 which are described in Annex E.

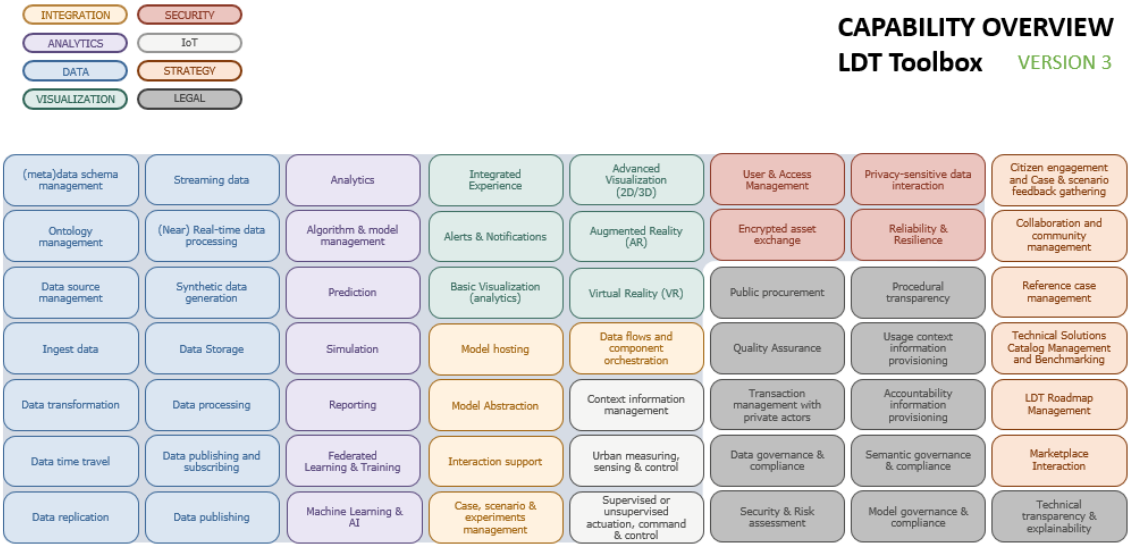

Figure 17: Overview of capabilities of LDT Toolbox

The main defined capabilities for LDT Toolbox are listed below, grouped by the capability categories as defined by [DIN SPEC 91357][3]. Please refer to Chapter 4 of this document for a more detailed analysis of the capabilities.

Field Equipment/Device capabilities

Capability category description	Capabilities
Capabilities that enable the external environment (field equipment, devices, IoT) to be sensed, measured, and controlled.	• Supervised or unsupervised actuation, command & control (functional) • Urban measuring, sensing & control (functional)

[3] Reference Architecture Model Open Urban Platform (OUP); Available at https://www.beuth.de/en/technical-rule/din-spec-91357/281077528

Communications, Network and Transport capabilities

Capability category description	Capabilities
Capabilities that enable the interaction and thus the exchange of data between devices and field equipment between themselves and with applications residing on some "backend systems" often referred to as "management systems".	• Ingest data (functional) • Streaming data (functional) • Replicate, process & store data (functional)

Device Asset Management and Operational Services capabilities

Capability category description	Capabilities
Capabilities that enable the delivery and assurance of the assets supporting the device communications and integration including positioning capabilities.	• Context Information Management (functional) • Alerts and notification (functional) • Urban measuring, sensor & control tooling (strategic)

Data Management and Analytics capabilities

Capability category description	Capabilities
Capabilities that enable the use of urban (field) data by applications. It will include core data management and life cycle (e.g., ingest, assure) related capabilities, as well as capabilities to analyse, share and publish (open) data.	• Meta)data schema management (functional) • Ontology management (functional) • Data transformation (functional) • Prediction (functional) • Simulation (functional) • Analytics (functional) • Data source management (functional) • Algorithm & model management • Semantic governance & compliance (e.g., metadata framework) (strategic)

Integration, Choreography and Orchestration capabilities

Capability category description	Capabilities
Capabilities to manage, choreograph and orchestrate processes and services in support of system integration and human computer interaction.	• Model abstraction • Data flows and component orchestration • Interaction support • Case, scenario & experiments management

Generic City and Community capabilities

Capability category description	Capabilities
Capabilities that enable the deployment of generic (non-city or community specific) capabilities with respect to the roles and duties within any given urban environment.	• Public procurement (legal) • Technical Solutions Catalogue Management and Benchmarking (strategic) • LDT Roadmap Management (strategic)

Specific City and Community capabilities

Capability category description	Capabilities
Capabilities that enable the deployment of specific city/community capabilities. Here within the EIP SCC, with three main streams: Sustainable Urban Mobility, Sustainable District and Built Environment, and Integrated Infrastructure and Processes.	• Integrated Experience (functional) • Basic Visualisation (functional) • Advanced Visualisation, Virtual Reality (VR), Augmented Reality (AR) (functional)

Stakeholder Engagement and Collaboration capabilities

Capability category description	Capabilities
Capabilities that enable cities and communities to engage and collaborate with a large variety of stakeholders and to manage the strategic goals agenda and roadmap. Here, within the context of the EIP SCC, the EU climate goals reflect the needs of such capabilities around energy efficiency, GHG reduction, and wider use of renewable energy.	• Basic Visualisation (functional) • Advanced Visualisation, Virtual Reality (VR), Augmented Reality (AR) (functional) • (Case) reporting (functional) • Citizen engagement and Case & scenario feedback gathering (strategic) • Collaboration and community management (strategic) • Reference case management (strategic)

Privacy and Security capabilities

Capability category description	Capabilities
Capabilities regarding integral Privacy and Security apply across physical sites and assets, devices, networks, data, application, and people. Compared to physical security, cyber security is aimed at protecting confidentiality, availability, and integrity in the digital context, by applying a myriad of tools and measures, including identity management, authentication and (both functional and data oriented) authorisation, intruder detection and auditing.	• Privacy-sensitive data interaction (security) • Procedural transparency (legal) • Technical transparency & explainability (legal) • Model governance & compliance (e.g., Fairness parameter information) (legal) • Usage context information (legal) • Accountability information (legal) • Synthetic data generation (functional, legal) • User & Access Management (security) • Security & Risk assessment (legal)

Common Services capabilities

Capability category description	Capabilities
Capabilities that support other Capabilities regardless of the layer in which the Capability is found; these are more generic technical capabilities, not city-related programme or goal specific.	• Marketplace interaction (strategy) • Quality Assurance (e.g., Certification framework) (legal) • Transaction management with private actors (legal) • Data governance & compliance (e.g., data protection assessment) (legal)

3.2.2 Analysis of results

The results are analysed by data collection tools (i.e., surveys and interviews) and detailed by stakeholder groups. During the consultation, Smart Cities and Communities (SCCs) were asked about

the most relevant capabilities to implement an LDT, the most important functional aspects of LDTs, and the requirements they impose on potential LDT technology providers. Technical Providers (TPs) were asked about the capabilities they can offer and the capabilities most present in the LDT solutions they deploy. SBs were asked about their level of agreement with the need to strengthen existing EU guidelines and regulations on standards and technical requirements for each one of the abovementioned capabilities. In the next subsections, the answers to these questionnaires are summarised, visualised, and evaluated.

3.2.2.1 Analysis of survey's result

In the next three sections, we will elaborate on the significant aspects of surveys conducted by three groups: Smart City and Communities, Technology Providers, and Standardisation Bodies.

3.2.2.1.1. Smart Cities and Communities

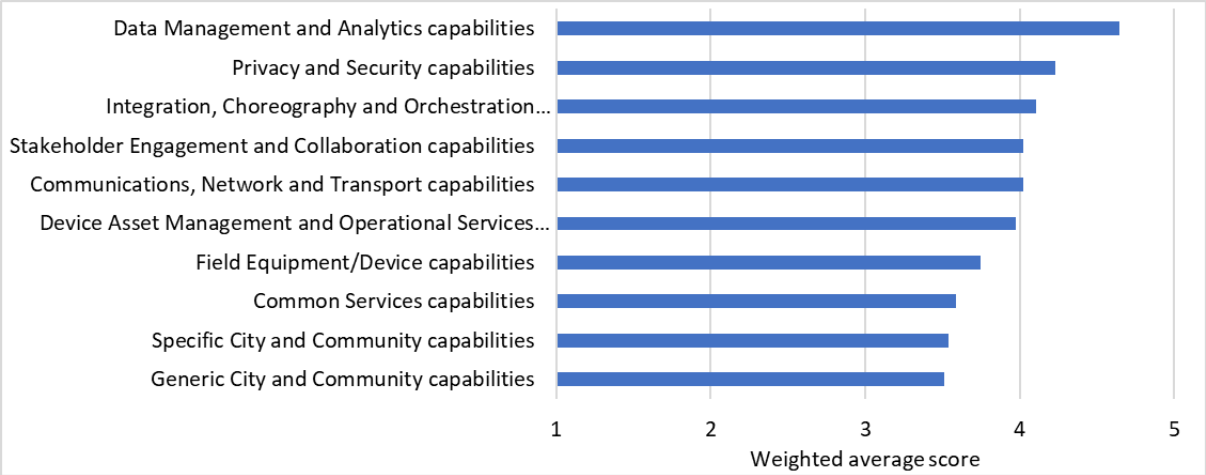

Figure 18: Average Weighted Score of relevant capabilities to implement LDTs for SCCs in the survey

Figure 18 represents the most relevant capabilities to implement an LDT from the perspective of smart cities and communities. The y-axis represents the capabilities, and each capability's ranking value (averaged based on number of respondents ranking score from 1 to 5) is depicted by the horizontal bar. The bars display the rankings of the capabilities, indicating their relative importance in implementing an LDT.

From observations, *Data Management and Analytics capabilities* (Rank 1) and *Privacy and Security capabilities* (Rank 2) have the first and second ranks among others, highlighting their significant importance for the implementation of an LDT. This indicates that SCCs considers the data management and analytics together with privacy measures the most significant capabilities that the LDTs solution should implement. On contrast, it seems the generic, specific, or even common capabilities have the lowest ranking value from the SCC's perspective with ranks of 10, 9, and 8 respectively. This highlights low focusing on generalisation, commonality or tailor-making capabilities which does not have higher priority from the SSC's perspective to implement the LDT but focusing mainly on the actual capabilities of an LDT.

SCCs share almost similar weighted scale values for the remaining capabilities: *Integration, Choreography, and Analytics Capabilities* (Rank 3), *Communications, Network and Transport capabilities* (Rank 4), *Stakeholder Engagement and Collaboration capabilities* (Rank 4), *Device Asset Management and Operational Services capabilities* (Rank 5), and *Field Equipment/Device capabilities* (Rank 6). This indicates the comparable levels of significance within the SCCs focusing on hardware infrastructures as physical counterpart of LDT, inclusion of domain expert, and end-users, and highlighting the importance of understanding that efficient and reliable data via communication

aspect, when it comes to development of an LDT. In other terms, this highlights the holistic approach taken within SCCs when developing the LDT.

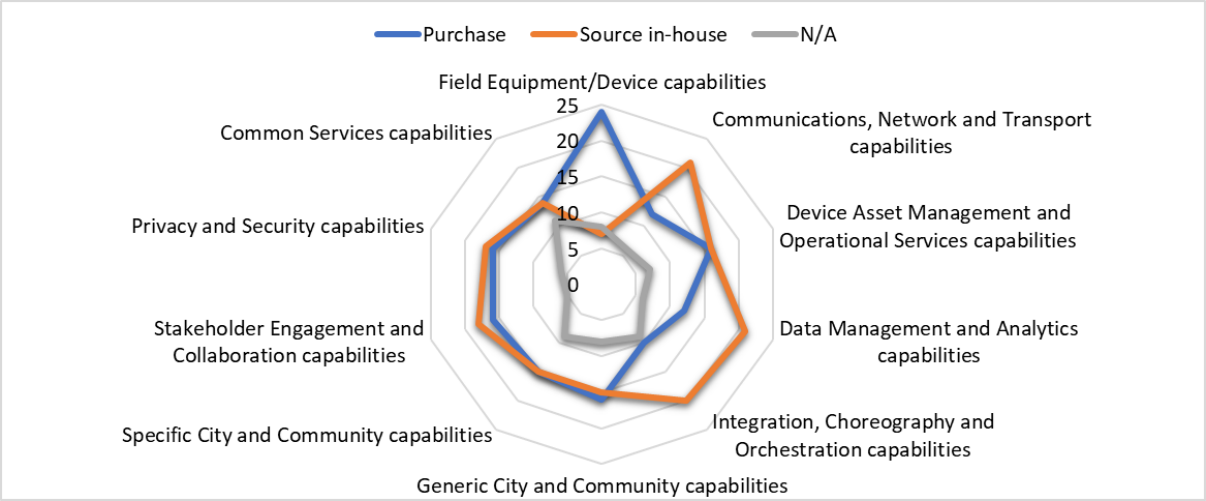

Figure 19: Preference of SCCs in the survey to purchase the capabilities or source them in-house

Figure 19 represents the distribution of SCCs preferences on the willingness to implement LDT per capability category by purchasing from third parties, sourcing in-house, or considering no preference/opinion as not applicable. The blue line shows the number of respondents in favour of purchasing from third parties, red line indicates in-house development preferences, and grey shows the not known or no knowledge.

Regarding purchase from third parties versus in-house sourcing based on the analysis in figure 19, the number of SSCs preferring to purchase from third-party vendors is more for Field Equipment/Device capability than those choosing for in-house sourcing. On a higher level, half of the capabilities such as Common-Service, Privacy and Security, Stakeholder's engagement and collaboration, Specific City and Community, and Device Asset management capabilities, received mixed response whether to be purchased from third parties or built in-house. While few capabilities got higher importance to be implemented in-house than purchase from third party.

The Communications, Network and Transport capabilities, Data Management and Analytics capabilities, and integration, choreography and orchestration capabilities, the number of decision-makers favouring in-house sourcing is higher, indicating a desire for more control and customisation in these areas.

The N/A category represents the number of SSCs opinion on capabilities which are not relevant or necessary for their specific requirements or that they are already adequately addressed through other means. Notably, the Common Services capabilities category has the highest number of SCCs marking it as not applicable, suggesting that these services may not be considered essential or relevant in the implementation of LDT.

Generally, we can see a mixed responses for 6 (out of 10) capabilities in-house development or purchasing from third parties, except in certain areas where in-house development (3 out of 10) or purchasing (1 out of 10) is preferred by SSCs.

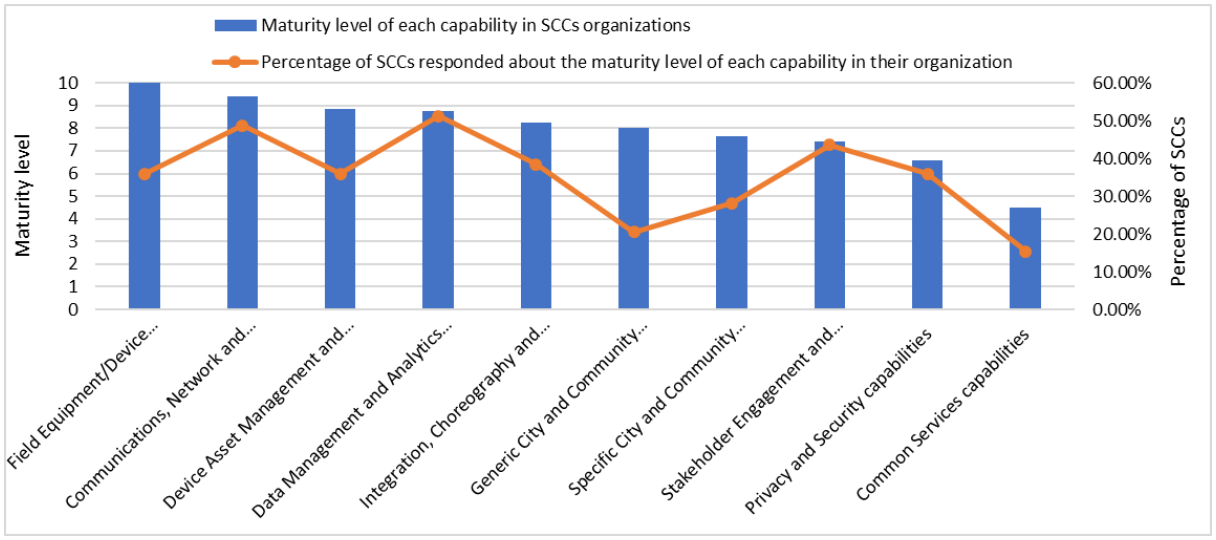

Figure 20: Level of maturity of each capability available in solution at participant SCCs organisation

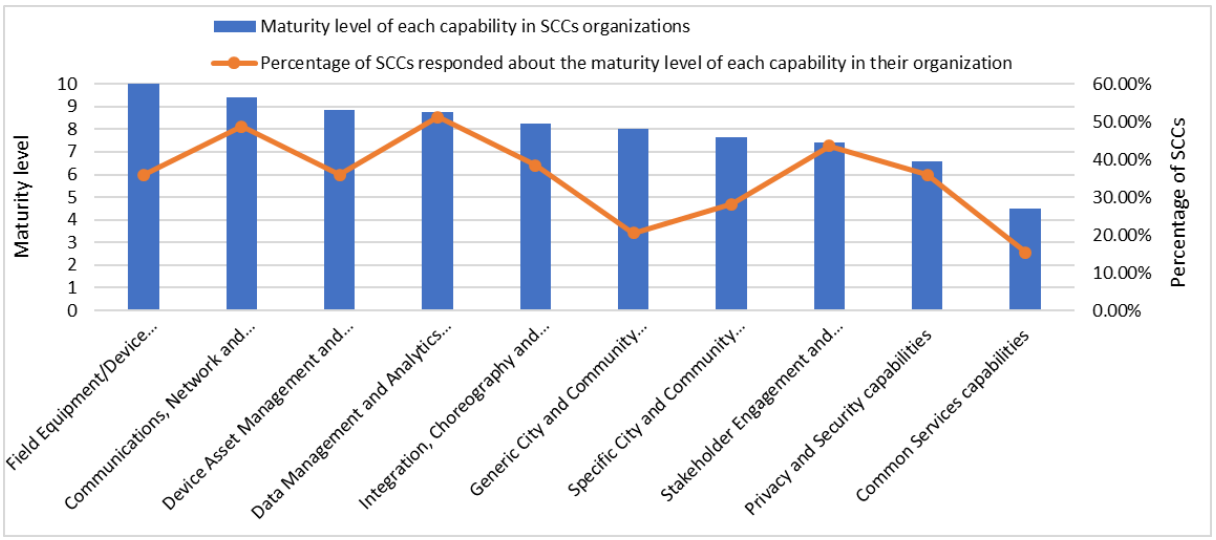

Figure 20 represents the maturity levels of different capabilities in the SCCs organisation, with a maturity level from 10 (highest maturity) to 1 (lowest maturity) by SCCs.

Around 30% of the respondents ranked Field Equipment/Device capability as most mature capability available in the SCC organisation. The common service capability is considered less mature by around 12% of the respondents. Communications, Networks, and Transport Capabilities and Data Management capabilities received second most maturity level (8-9) in the SCCs organisations from nearly half of the SCC respondents (50%). This shows that SCCs consider these capabilities to be the most mature and developed capabilities considering highest number of respondents with assessing these capabilities as nearly most mature.

Common service capability is considered least mature (maturity level 4) with least number of SCC respondents (around 15% of respondents).

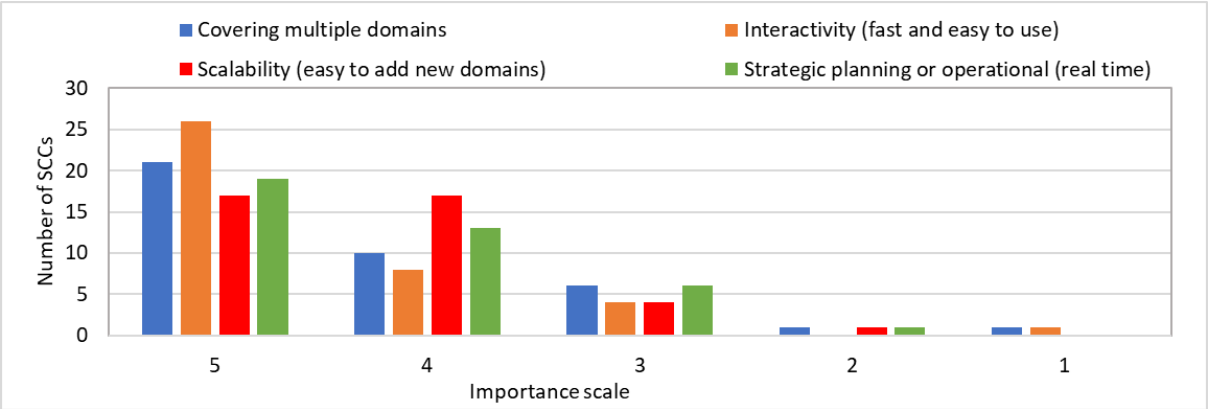

Figure 21: Importance of functional aspects of an LDT

To evaluate the importance of different functional aspects of an LDT, the respondents of SCCs were asked about the four main following aspects of an LDT:

- Covering multiple domains
- Interactivity (fast and easy to use)
- Scalability (easy to add new domains)
- Strategic planning or operational (real time)

The results of the questionnaire are presented in Figure (21). It can be seen that at least 31 out of 39 SCCs give the importance levels of four and five to all the above-mentioned functional aspects and importance levels one and two are chosen by at most one of the SCCs. This highlights the high importance of all proposed functional aspects for SCCs. Among all aspects, the interactivity aspect (fast and easy to use) receives the highest importance value. This shows that it is important for stakeholders that the LDTs be easy to work with and fast in response. LDTs covering multiple domains achieved the second highest importance from respondents. This means that the stakeholders are interested more in an LDTs that can be used for different purposes and consider the mutual impacts of different sectors and domains.

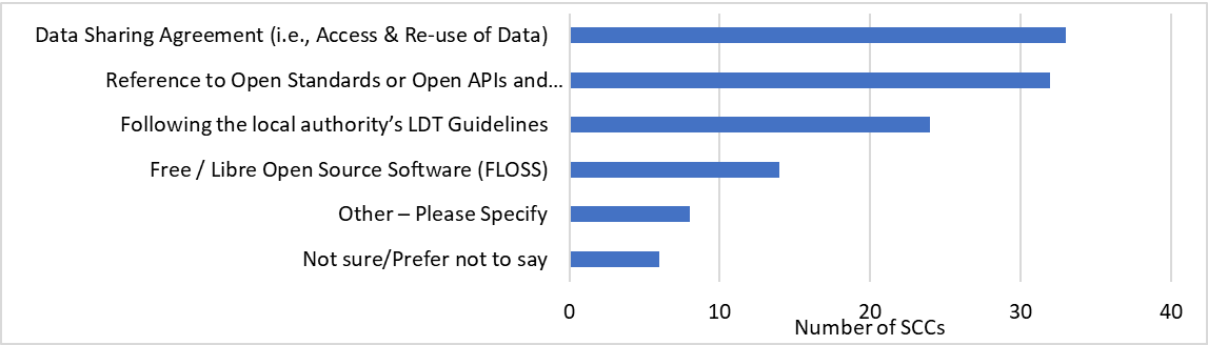

Figure 22: Requirements to impose on LDT technical providers

In the next step, the SCCs were asked to choose all the requirements that they would like to get implemented by the potential LDT technology providers from the below list:

- Data Sharing Agreement (i.e., Access & Reuse of Data)
- Reference to Open Standards or Open APIs and Technical Specifications
- Free/Libre Open-Source Software (FLOSS)
- Following the local authority's LDT Guidelines
- Not sure/Prefer not to say.

The respondents are also allowed to propose other requirements. The questionnaire results are presented in

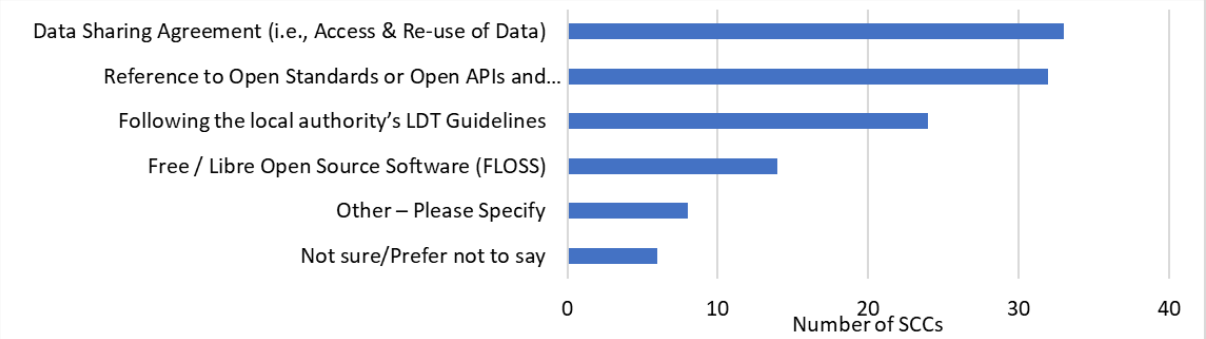

Figure 22. As shown, 33 out of 39 respondents indicated that having a **data sharing agreement** is important for the digital twin. The requirements related to open standards and open APIs are in second place. Open standards and APIs promote interoperability, allowing different systems to communicate and share data effectively which seems to have a significant importance for SCCs as indicated in their data sharing aspect. More than half of the respondents (24) also emphasised the importance of following the guidelines provided by the local authority's LDT. This means that they value alignment with the local regulatory framework. From the analysis, 35% of the respondents expressed their interest in using free and open-source software in the development and implementation of the digital twin. This feature has the lowest importance for SCCs among the closed-form requirements defined above for imposing on technology providers.

Respondents also listed some "other'' requirements that were not listed above as follows:

- To voluntarily subject themselves to the authority of the governance board interoperability at all levels, 100% open source and not partial as usual, GDPR compliance, and AI ethics. No vendor lock-in preferred; no provision of a whole technology or stand-alone solution but tools or Toolboxes (such as standardised analysis).
- Respecting the rules and regulations related to the Security of Information Systems at the national level.
- LDT will also have a strong need for monitoring, auditing, public scrutiny, and efficient means of recourse for citizens, in case local communities are affected in negative ways.
- Data provided from an API should be in the Smarty Data Model format.
- Open GIS API.
- MIMs and MIMs compliance.

Key insights from Survey's result from Smart City and Communities

- Data Management and Analytics capabilities and Privacy and Security capabilities are the foremost capabilities required for the implementation an LDT.
- Capabilities desired for in-house implementation: The Communications, Network and Transport capabilities, Data Management and Analytics, integration, choreography and orchestration capabilities are the capabilities, which SCCs prefer to develop them by themselves.
- Covering multiple domains and Interactivity (fast and easy to use) are top two most favourable functional aspects demanded from LDT Toolbox. Data Sharing Agreement (i.e., Access & Reuse of Data) and Reference to Open Standards or Open APIs and Technical Specifications are the most key requirements to implement the LDT imposed to technology providers

3.2.2.1.2. Technology Providers

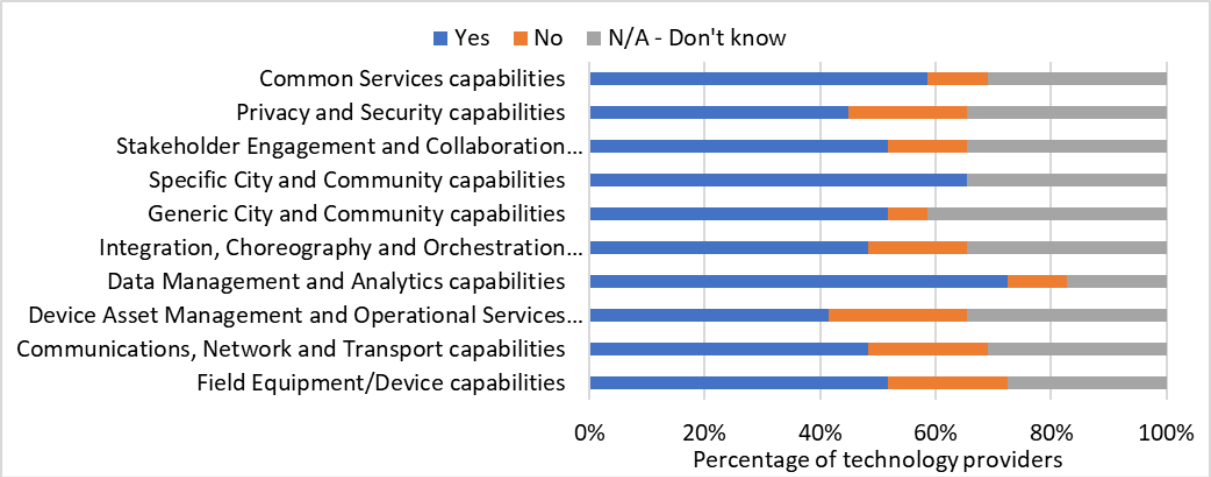

Figure 23: Capabilities and features offered in LDT solutions of tech providers

The *Figure 23* represents the responses to whether certain capabilities are present in the LDT solutions deployed by a technology provider. The responses are categorised as "Yes," "No," and "N/A - Don't know." This information can be valuable for understanding the current state of the capability deployment. It also highlights the uncertainty or lack of knowledge among some respondents, indicating potential areas for clarification or further investigation. This information can be useful for evaluating the comprehensiveness and alignment of the LDT solutions with the users of LDT.

Technology providers responded with a majority "Yes" (21), and “19” when asked if their LDT solution offers Data Management and Analytics capabilities, and Specific City and Community capabilities, ranked as first and second, respectively. The former capability plays a crucial role in data pipelining as automate data collection, process, and analyse the data generated within smart city environments. In fact, this capability is the gateway to initiate implementing an LDT solution, and the high number of respondents acknowledging the presence of Data Management and Analytics capabilities in their solution is a positive indication. The latter refers to confirmation of presence of tailored-made and specific capabilities in the technology providers solution. By offering tailored features and functionalities, the LDT solutions can better align with the specific context and requirements of different SSC LDT implementations. Moreover, this confirms the level of awareness of technology providers with the varying requirements from one SCC to other.

For other remaining capability categories, such as Field Equipment/Device capabilities, Communications, Network and Transport capabilities, Device Asset Management and Operational Services capabilities, Integration, Choreography and Orchestration capabilities, Generic City and Community capabilities, Stakeholder Engagement and Collaboration capabilities, Privacy and Security capabilities, Technology providers responded with a majority "Yes", or "No," indicating a mixed level of offering mentioned capabilities in their LDT solution.

Technology providers selected similar numbers of "N/A - Don't know" for different capability categories, indicating that they are unsure or lack knowledge about those specific capabilities. This indicates that most of the TPs require additional information or guidance to enhance their knowledge on various capabilities to add in their LDT implementation to their solution.

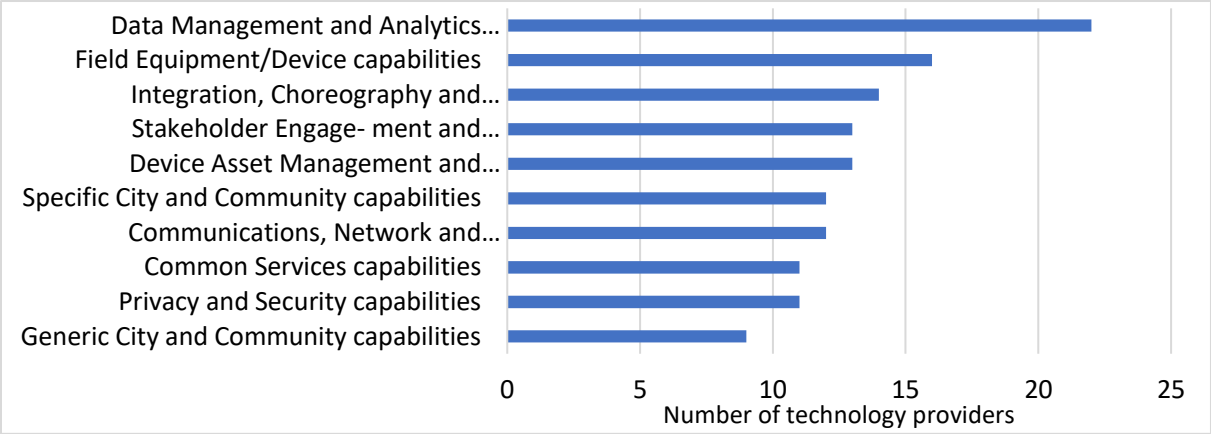

Figure 24: The most recent capabilities deployed by tech providers in the survey

The**Error! Reference source not found.** *Figure 24* provides insights into the existence of different c apabilities within the LDT solution of TPs, highlighting their varying levels of presence. It indicates the emphasis placed on capabilities of Data Management and Analytics capabilities, Field Equipment/Device capabilities, Integration, Choreography and Orchestration capabilities, and Stakeholder Engagement and Collaboration capabilities. These three categories simply emphasis on importance of collecting big data both historical but also the real-time data from devices (such as sensor data) and integrating them properly for LDT operations and decision making. This emphasis is not surprising, considering the need for seamless coordination and engagement in any digital twin applications including LDT.
Generic City and Community capabilities, Common Services capabilities, and Privacy and Security capabilities are the least provided capabilities by TPs. The generic and common capabilities may be less prevalent because of lack of enough number of SSCs as customers of LDT solution, resulting in lack of knowledge by TPs to include such services as part of their provided capabilities in their solution. However, the lower occurrence of common capabilities might imply that specific functionalities or domain-specific capabilities might have received more focus in the LDT solution by TPs.

Regarding Privacy and security capabilities, as this is a vital capability, it may be considered essential but are often incorporated elements across multiple capabilities rather than being standalone features. Their importance may be recognised and embedded throughout the LDT solution, making explicit mentions of these capabilities by TPs less frequent.

Regarding the rest of the capabilities, there is a moderate level of offering by technology providers i.e., Stakeholder Engagement and Collaboration capabilities, Device Asset Management and Operational Services capabilities, Communication, Network and Transport capabilities, and Specific city and Community capabilities. Such moderate level may suggest that TPs are still developing and refining their capabilities in this area. They may be incorporating features and tools to facilitate stakeholder engagement and collaboration, but further enhancements and customisation may be required to meet the diverse needs and expectations of different LDT's end users.

Key insights from Survey's result from Technology Providers

- Data Management and Analytics, and Specific City and Community capabilities are the most existing capabilities in LDT solution by TPs.
- The most recent deployed capabilities by TPs are Data Management and Analytics capabilities and Field Equipment/Device capabilities.

3.2.2.1.3. Standardisations Bodies

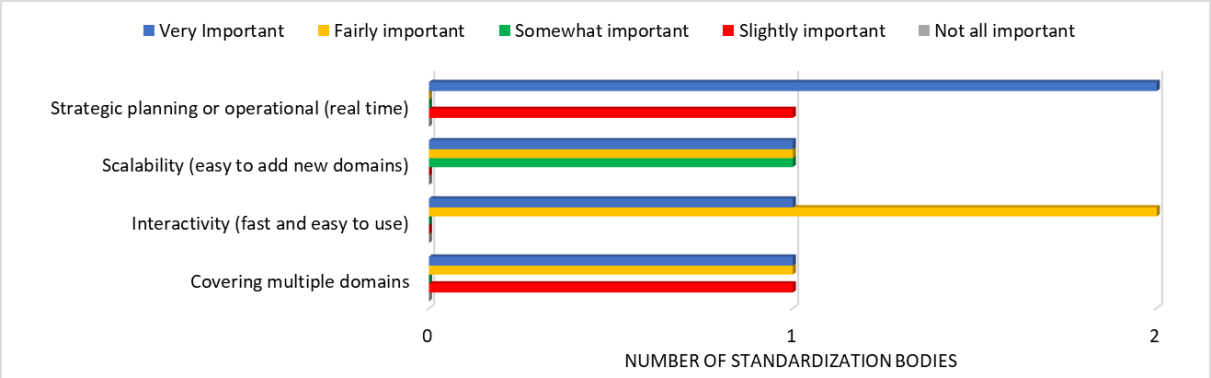

Figure 25: Importance of different functional aspects for standardisation bodies

In the figure above, the SBs were asked about the importance of different functional aspects defined in SCCs survey. The strategic planning and operational (real time) aspect receives the highest vote (2 out of 3) as the very important aspect. Aggregating the result of fairly and very important aspects shows that the interactivity (fast and easy to use) aspect receives the full score (3 out of 3) which shows that all SBs consider this aspect as an important aspect. This result is similar to the SCCs responses about the functional aspects in earlier SCCs feedback evaluation. So, it can be observed that both SCCs and SBs believe that being fast and easy to use is very important feature for functionality of an LDT. Other aspects receive 2 out of 3 score as fairly or very important aspects which is also significant and shows the necessity of taking all these aspects in designing the LDTs' functionalities.

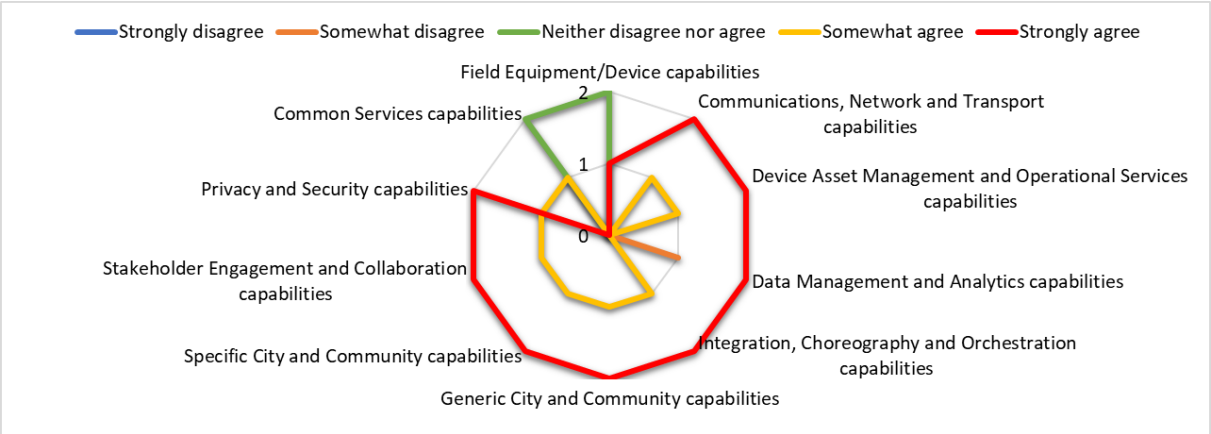

Figure 26: Need to strengthen existing EU guidelines on capabilities

Figure 26 presents the survey results from SBs regarding the need to strengthen existing EU guidelines on the defined capabilities. The respondents can choose among strongly disagree, somewhat disagree, neither disagree not agree, somewhat agree, and strongly agree options. As shown in *Figure 26*, none of the SBs strongly disagrees with strengthening the guidelines and only one of the SBs somewhat disagrees with strengthening the data management and analysis capabilities guidelines. Except for common services capabilities and field equipment/device capabilities, most respondents agree (somewhat agree and strongly agree) that the existing EU guidelines on Stakeholder Engagement and Collaboration capabilities should be strengthened for LDT implementation.

It appears that most of the respondents (except for Field Equipment/Device capabilities and Common Services capabilities) somewhat agree with the need to strengthen existing EU guidelines on various capabilities of LDT solution. Particularly, the data indicates a general agreement among the respondents that existing EU guidelines on capabilities in various areas such as communications, data management, integration, stakeholder engagement, and privacy/security should be strengthened.

These findings highlight the importance of enhancing and updating guidelines to ensure the effective implementation and operation of required LDT technologies and services, fostering sustainable and inclusive smart city development.

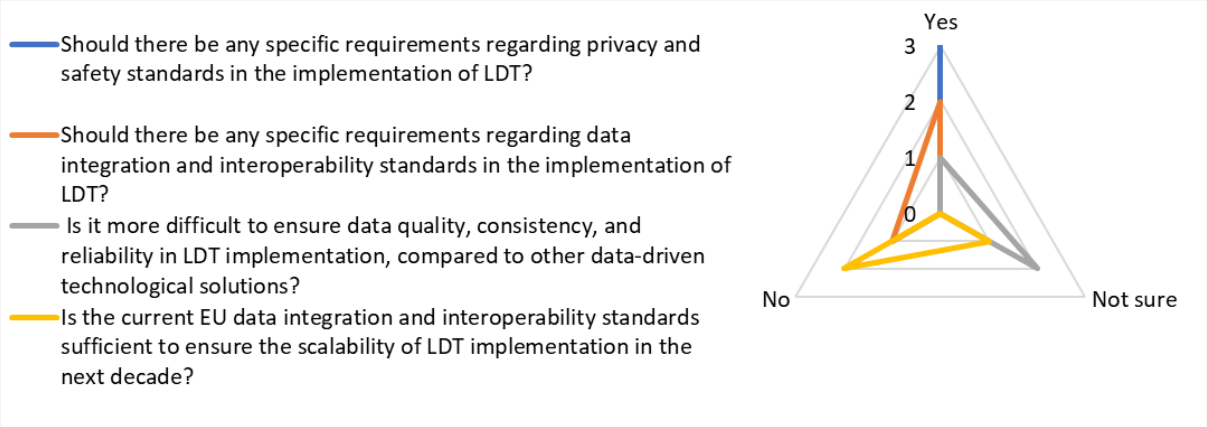

Figure *27: Other standardisation requirements*

Figure 27 represents the results regarding specific requirements for privacy and safety standards, data integration and interoperability standards, the difficulty of ensuring data quality in LDT implementation, and the sufficiency of current EU data standards for the scalability of LDT implementation.

As seen, 100% of respondents answered "Yes," indicating agreement on the need for specific privacy and safety standards requirements. 66.7% of respondents answered "Yes," indicating the majority's agreement on the need for specific requirements for data integration and interoperability standards. 33.3% of respondents answered "No" suggesting a minority opinion against specific requirements i.e., 0% of respondents selected "Not sure".

33.3% of respondents answered "Yes," indicating a minority opinion that ensuring data quality, consistency, and reliability is more difficult in LDT implementation. 66.7% of respondents selected "Not sure," suggesting a lack of consensus or uncertainty on the difficulty i.e., 0% of respondents answered "No".

The data suggests that there is a significant level of scepticism on the sufficiency of current EU data integration and interoperability standards to ensure the scalability of LDT implementation in the next decade. None of the respondents answered "Yes," indicating that there is no consensus on the effectiveness of these standards. Approximately one-third (33.3%) of the respondents selected "Not sure," reflecting uncertainty or a lack of confidence in the current standards. However, the majority opinion (66.7%) among the respondents is that the current EU data standards are insufficient for future scalability. This indicates a prevailing belief that further improvements or advancements are necessary to address the evolving technical needs and complexities of LDT implementation in the coming years.

Key insights from Survey's result from Standaridsation Bodies

- Strategic Planning and Operational (real time) are the most key functional aspect from SBs perspective.
- All SBs agree that existing standardisation on most of the capabilities should be revised to strengthen existing EU guidelines.
- Specific requirements for privacy and safety standards, data integration and interoperability standards are the main requirement to be implemented in the LDT Toolbox.

3.2.2.2 Analysis of interview results

In the next three sections, we will elaborate on the significant aspects of interviews conducted by three groups: Smart City and Communities, Technology Providers, and Standardisation Bodies.

3.2.2.2.1 Smart Cities and Communities

The status of LDTs in interviewed SCCs

The status of LDTs implementations among the interviewed SCCs is widely different. Most SCCs are in initial stages of analysing the need for LDT. Some other SCCs have already started some simulations. One of the SCCs has successfully developed a PoC, and certain components of its project has progressed or are currently transitioning to the production stage. Some interviewees are not cities but has been actively collaborating with various cities and communities on projects related to digital twins.

The most relevant functional capabilities for implementing LDTs for interviewed SCCs

The interview results are summarised in *Figure 28*. The weighted average score of all defined capabilities is greater than 3 (out of 5). This means that the interviewees believe that all the defined capabilities are necessary for having a successful implementation of LDTs. Among all relevant capabilities, "specific city and community capability'' receives the highest attention. In fact, it is important for interviewees that the capabilities of the LDT Toolbox are aligned with the specific outlook, plan and objectives they have already defined for their SCCs. "Data management and analytics'' and "privacy and security'' capabilities are two other capabilities that achieve high scores. These two capabilities provide the foundation for effective analytics and decision-making and enable organisations to unlock the full potential of their data for LDT.

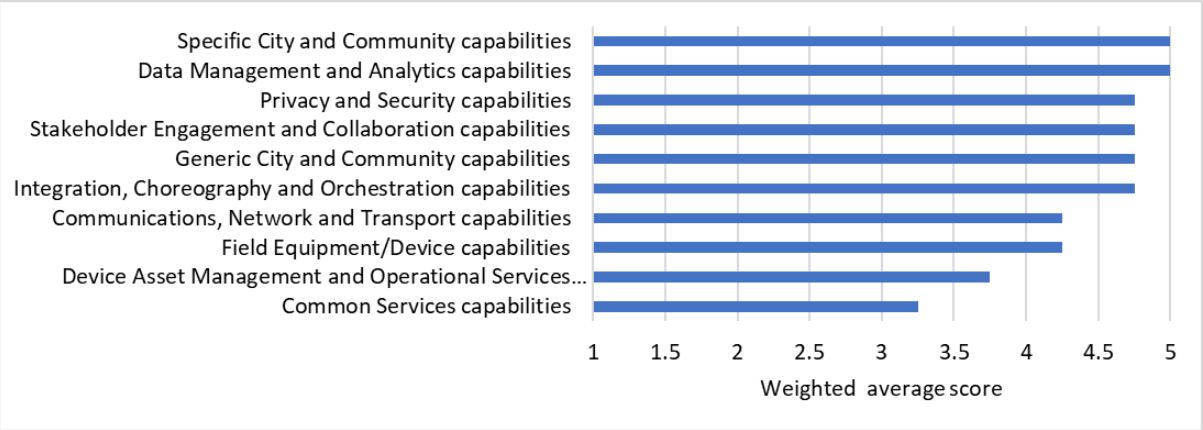

Figure 28: Weighted average score of relevant capabilities for interviewed SCCs

Technical supports required by interviewed SCCs

Interviewees were asked whether they can source the relevant capabilities internally or are willing to purchase related technologies. The results are presented in

Figure 29. According to Figure 29, the interviewees are more interested to purchase the following capabilities:

- *Data management and analytics* capabilities.
- *Stakeholder engagement and collaboration* capabilities.
- *Specific and generic city and community* capabilities.

Capabilities which received mix response, i.e., by both purchasing from third parties or sourcing in-house are:

- *Privacy and security* capabilities.
- *Common services* capabilities.

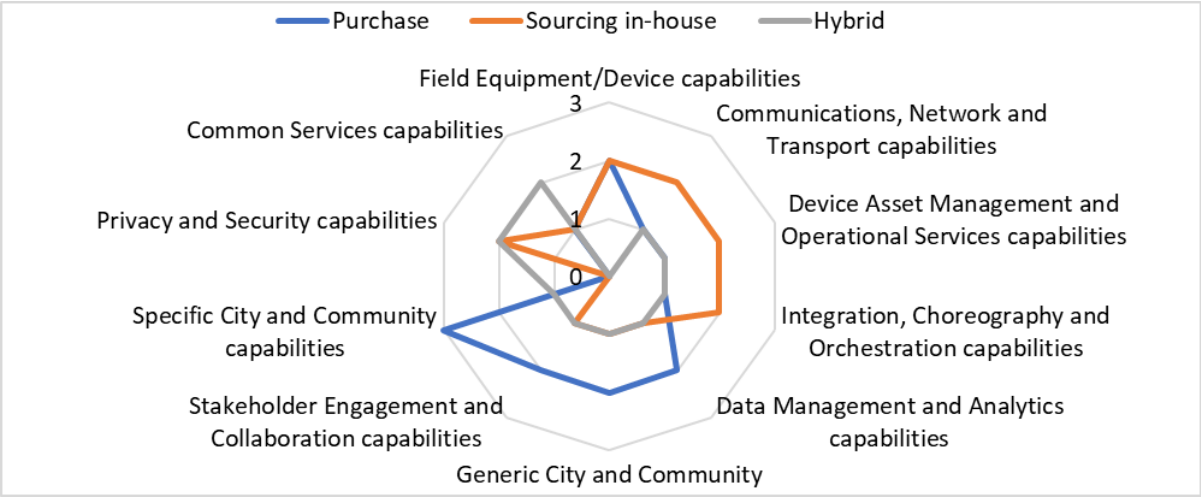

Figure 29: Preferences of interviewed SCCs in purchasing or sourcing the capabilities

Highlighted use cases by SCCs

- LDT for air quality in relation to mobility within cities.
- LDTs for building, environment, and city planning and design by providing 3D city models.
- LDT for energy conservation in buildings, optimising space utilisation, and enhancing security and surveillance.
- LDT for smart mobility.
- LDT for smart cities, and lighting.

Concerns/Issues

- An LDT needs to be updated and modified. It is important to define who is responsible for this task.
- The existing components lack interoperability, preventing seamless integration and collaboration.
- The acquired data should be in a suitable format.

Key Insights of Interview's from Smart Cities and Communities (SCC)

- The most prominent functional aspects of the LDT Toolbox that the most SCCs would like to have the integration of specific city and communication capabilities, data management and analytics capabilities, and the privacy and security capabilities.
- SCC believe that the existing infrastructure should be upgraded to cater the needs for the implementation of the LDT Toolbox.
- Most highlighted use cases for the LDT Toolbox from the SCC perspective are for the smart cities, mobility, and building and energy conservation.

3.2.2.2.2 Technology Providers

Type of support provided by TPs interviewees to cities and communities in relation to LDTs

The technology providers offer a range of support to cities and communities. Based on the analysis, one group of providers offers a cloud platform that provides data visualisation, statistical analysis, and simulation capabilities, helping cities to visualise data, derive insights, and simulate future scenarios. Another group of providers is currently not directly involved in LDTs but anticipates their future adoption for various activities involving simulations or predictive models. Additionally, one provider collaborates on "Parametrical Urban Planning," conducting analyses to enhance urban design. Lastly, some providers utilise LDTs for building management and foresee their broader adoption in the future.

Highlighted Use cases by TPs

- LDT for mobility, sustainability on air quality, water quality, and climate change

- LDT for Data-Driven Decision Making in various local authorities
- LDT in Urban Planning and Real Estate, transportation optimisation
- LDT for District Planning and Construction
- LDT for building, mobility and lighting
- LDT in Bike Sharing System to predict the hourly origin–destination demand in the Lisbon BSS network
- LDT for data sources integration

Opportunities

- The key positive impacts of using LDTs for cities is combining all information across policy domains and simulating future scenarios
- Accelerating the information awareness in a small- to medium-sized city
- A tool to support cities' strategic decisions
- Cities can be more liveable as LDT can be a guide in the decision-making process

Threats

- Gap between what is the available technology and where the local authorities are from technological perspective, thus it is important to help local authorities to understand the added value and the positive effects that digital twin could have in politics decision
- The financial liability of local government
- Lack of awareness of added values of LDT for small cities and rural areas
- Lack of awareness on impact of data quality in LDT by governments
- Unwillingness to share the data in an open ecosystem
- Digital maturity level of the local authority
- Acquiring a deep knowledge of the subject i.e., digital maturity
- Lack of data since only large amount of data is functional to build information models
- Municipalities' verticality, which cannot occur and needs to be smoothen because digital twins by nature foresees a holistic approach
- Lack of Skills in the organisations
- Creation of a knowledge base of the physical characteristic of the territory
- Lack of people capabilities to make questions in widget analytical dashboards for strategic and operational purposes
- No demand from public administration for LDTs but they do it out of entrepreneurship
- Unavailability of funds
- Issue of legislation which needs to push the digitalisation
- Challenge of data collection and integration limitations

Procurement

- Develop a digital twin framework, inspired by FIWARE and OASC, with the aim of encouraging regional and national authorities to adopt a standardised framework can be highly beneficial.

Architectural principles

- MIMs, SaaS (three layered visualisation, analytics, and simulation)
- ISO, but there is need for interoperability standards

Recognised the data source types

- IoT data from sensors, open data, official statistics data, data generated by citizens and users
- Data from operational systems of local authorities, data from Public Administration internal databases, data generated by citizens and users (e.g., from social)

Recognised steps of Data pipeline for an LDT by TPs

- The data flow includes quality checks (data cleaning, data processing), building APIs, standardise data and then visualise data in digital twin
- Data sources, data normalisation, service exposure, UX

Interoperability Perspectives

- Integration with many standards as possible
- Open APIs
- Close working with market players
- Willingness to engage all the authorities to define interoperability rules
- Need for interoperability specification in the public tenders
- Use of Smart Data Models provided by FIWARE Foundation

AI Simulator, AI Integration and aspect

- Simulation and Integration for Traffic
- Simulation with Python or Stata

GIS Visualisation

- Only for mapping

IoT protocols

- Use of IoT provider protocols
- Protocols for Open data

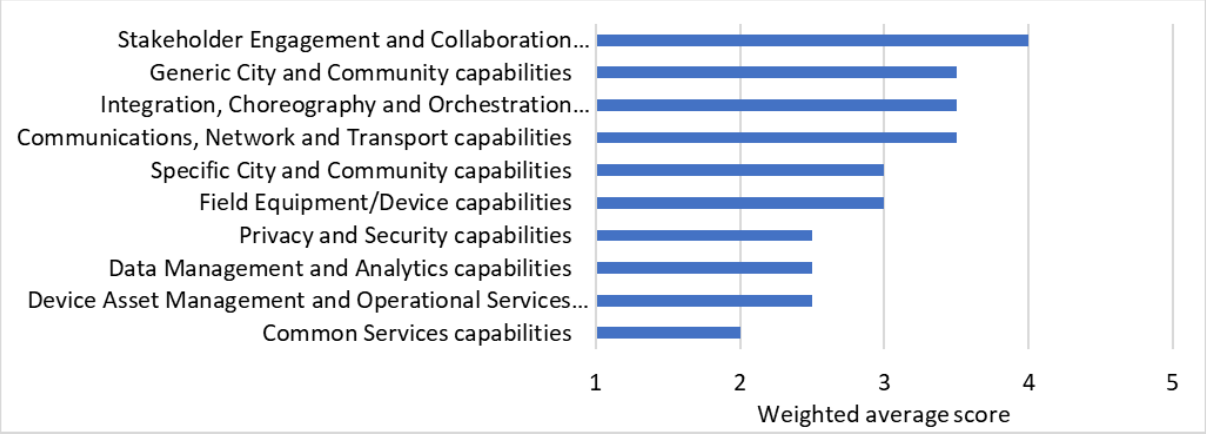

Figure 30: Most challenging capabilities for TPs to implement LDT

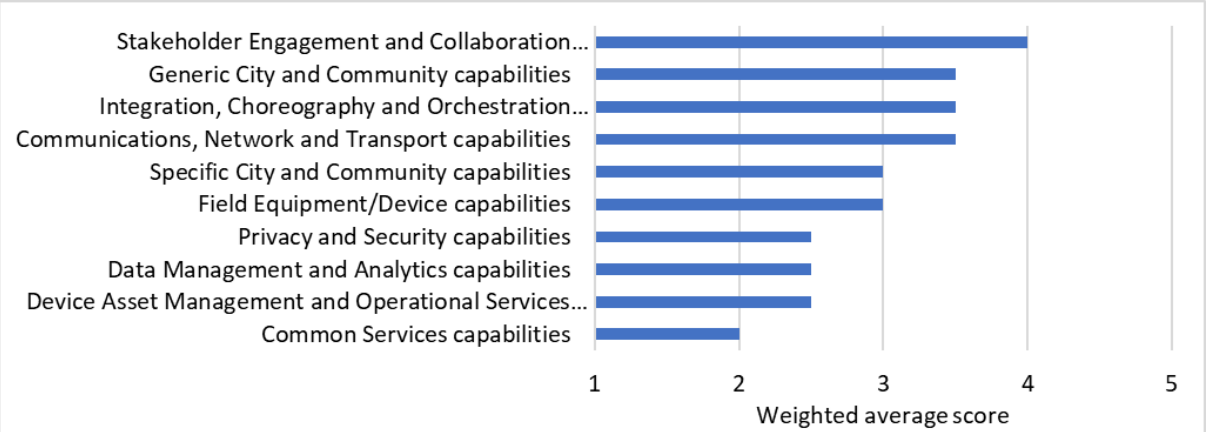

Figure 30 represents the most challenging capabilities to deliver when implementing an LDT, as indicated by the weighted average scores. According to the results, TPs (presumably referring to technology professionals or experts) identify Stakeholder Engagement and Collaboration capabilities as the most difficult capability in LDT implementation. Successful collaboration in this area may need effective communication, negotiation, and consensus-building skills.

The TPs also recognise three other capabilities, namely Generic City and Community, Integration, Choreography and Orchestration, and Communications, Network and Transport, as the second most challenging when implementing an LDT. The difficulty of the first capability may arise from the need for close collaboration with stakeholders, which TPs find challenging in terms of initiating engagement with them.

The second capability's difficulty can be attributed to understanding the workflow of activities in data pipelines and subsequently organising and orchestrating these activities within the LDT framework. The communication aspect of this capability can be challenging due to technical complexities and the requirement for coordination among various stakeholders.

Common Services capabilities are typically perceived as relatively easier to deliver by TPs when implementing LDT. These capabilities often involve foundational services that are widely needed across different areas, making them more familiar and accessible for implementation.

In the moderate capabilities category (Average Ranks of 2.5-3), crucial aspects of LDT implementation are highlighted. These include managing and optimising device assets and operational services, handling and analysing data, ensuring privacy and security, integrating field equipment, and addressing the specific needs of a city or community. While these capabilities may present moderate challenges, they are essential for effective asset management, data utilisation, security, equipment integration, and customisation to meet the unique requirements of the LDT.

Key insights of interviews from Technology providers (TPs)

- TPs feel the need of more stakeholder engagement and communication to understand the key challenges of cities requirements and policy guidelines for the LDT implementation.
- Lack of funds: TPs are concerned about funds and need financial support to design and build LDT Toolbox.
- Lack of skills and awareness: TPs highlighted the lack of required technical skills and human resources to set-up the LDT Toolbox.
- Lack of data: TPs are concerned about the unavailability of quality data, resources for data collection and integration.
- Lack of awareness: TPs feel there is a lack of awareness at local authority's level regarding standards and guidelines for LDT Toolbox design and added value that LDT Toolbox would bring to cities and communities.

3.2.2.2.3 Standardisation Bodies

Type of support provided by SBs interviewees to cities and communities in relation to LDTs

Digital twins are used in multiple projects such as district heating, networks and mobility, and the development of multiple data sources as highlighted in Matrix project.

Notable Use Cases by local authorities for implementation of LDTs mentioned by SBs

- LDTs for circular economy initiative
- LDTs focusing on mobility purposes
- LDTs considering well-being of citizens and their engagement

Opportunities

- Formation of task groups for data interoperability and integration standards across the domains for LDTs implementation
- Identification of overlapping issues within standards and formulate quality standards
- Formulation of data production standards

Concerns/Issues

- Lack of interest and engagement from stakeholders across the EU (not within national level) for formalisation of standards
- Deficiency of quality standards across the domains due to inconsistencies and overlapping issues
- Firms tighter control on data sharing, visualisation and operational of the data (analytics and decision-making) within the organisation than sharing with other domains/firms

Key insights of interviews from Standardisation Bodies (SBs)

- SBs would like to identify the existing overlapping issues within standards and revise the standards for better data interoperability and integration
- Like TP's concern, SBs are concerned about the lack of stakeholder's engagement across the EU for standards formulation and guidelines to implement an LDT Toolbox

3.2.3 Functional and technical key takeaways

The overall key insights from surveys and interviews from each stakeholders' perspective regarding functional capabilities are given as follows:

- Most SCCs considers that LDTs solution should be easy to use, provide data management and analytical capabilities, and ensure proper integration of security and privacy measures. Besides, SCCs gives much or equal importance to avail third parties' or build in-house capabilities to implement an LDT solution except for data management and operational capabilities which carries higher value to be implemented in-house. Additionally, SCCs prioritise an LDT solution should be fast easy to use across multiple domains and flexible to add new domains in it. Most SCCs want an LDT solution that integrates data-sharing agreements and data interoperability, follow the local authorities' guidelines, and leverage open standard APIs on EU level. SCCs are welcoming to utilise an LDT solution for multiple purposes and sectors, such as LDT solution for mobility, optimal buildings and urban planning, security and surveillance monitoring, and smart city.
- The LDT solutions deployed (are available) by TPs include multiple features. The data management and analytical capabilities and field equipment capabilities features are the topmost available features integrated with the LDT solution. However, privacy and security capabilities features are in directly integrated with the LDT solution. TPs lack of knowledge should be addressed and provided enough resources to extend their technical and required knowledge for the implementation of an LDT solution covering generic and specific city requirements with the integration of local authorities' guidelines, utilising open-source data sharing mechanism for data interoperability and integration and integrating privacy and security standards.
- The SBs also highlight the importance of an easy-to-use LDT solution scalable to across multiple domains. Besides, SBs consider strengthening the guidelines and standards for various capabilities that the LDT solution should have. Particularly, LDT solutions should integrate privacy and security requirements standards and follow the data management and analytics capabilities.

Next three points highlights the most common and differences from stakeholders' perspectives:

- Since data is the key element in LDT, there is a special attention on Data Management and Analytics capability for all SCCs, TPs, and SBs. SCCs identify data management as the most relevant capabilities to implement the LDT. On the other hand, data management technologies are the most common technology that TPs can provide. Also, as mentioned by SCCs in the survey they are willing to source the Data Management and Analytics capability in house. So, there won't be a big issue regarding the required technologies to implement data management and analytics capability.
- Privacy and Security capability is the second most relevant capability for SCCs and around 50% of SCCs in the survey and interview are willing to purchase it from third parties. However, these technologies are among the least frequent technologies that the TPs can offer or deploy. So, there might be a need for more attention to these technologies.
- In short, an LDT solution should be interactive (fast and easy to use), scalable to extend across domains, follow the privacy and security requirements, and provide data management and analytics capabilities. The LDT solution should be interoperable, fast and secure, provide open data sharing mechanism across multiple domains with the incorporation of most advanced standards and guidelines. Existing guidelines and standards need to be strengthened in view of EU level than local and national considerations. This gives a road map towards the open source LDT solution which provides secure interoperability across multiple domains and open data-sharing mechanism.

3.2.4 Building Blocks out of Surveys and Interviews

Here we use the same terminology for the relevant building blocks according to section, but out of opinions of stakeholders.

Building Blocks out of Surveys and Interviews

1. Mapping and visualisations are highlighted (highlighted for mapping in the interviews).
   - Relevant building block**: Geospatial Visualisation**

2. Having a master data plan has been mentioned by TPs to set the ground for a digital twin.
   - Relevant building block**: Data Lake, data warehouse, data lakehouse.** However, the feasibility of a master data plan being in an unstructured or semi-structured format in data lakes or in a structured format in data warehouses can be open to discussion and consideration.

3. Data Spaces framework has been mentioned in the interviewed by TPs.
   - Relevant building block: **Data Spaces Connector**

4. AWS, cloud based (SAAS/PAAS), and Edge Computing in vertical cases
   - Relevant building block: **Data Spaces Connector**

5. TPs mention about the data flow includes quality checks (data cleaning, data processing), building APIs, standardise data and then visualise data in digital twin.
   - Relevant building block: **Workflow Orchestrator**

6. TPs highlighted the key positive impacts of using LDTs for cities in combining all information across policy domains and simulating future scenarios.
   - Relevant building block: **Case & Scenario Manager**

7. Use of Open APIs and communication with external systems have been mentioned by TPs.
   - Relevant building block: **Context Broker**

8. The acquired data should be in a suitable format.

- Relevant building block: As part of the workflow modules which needs to be orchestrated via **Workflow Orchestrator**

3.3 Legal and security features

3.3.1 Overview

The study of legal and security features focused on the questions of procurement, contracting, legal data provenance, data rights and licencing, open source and open platforms, and interoperability and regulatory sandboxes. The main takeaway from the analysis of evidence shows that public organisations, such as local governments, should strengthen their capacity in terms of procurement and contracting. To this end, one of the main suggestions is to develop guidelines for data management and procurements. These should facilitate the designing, implementing, and monitoring of transactions with private actors. These guidelines should equip decision-makers with a framework for reasoning about procurement and data management in transactional terms and should contribute to building technical expertise that is essential in negotiations with private organisations.

3.3.2 Analysis of results

The sections below provide a detailed presentation of consultation findings, analysed and summarised into a preliminary list of key building blocks that the future European LDT Toolbox should have from a legal and security perspective.

3.3.2.1 Procurement and contracting

The use of **standard contractual terms** is widespread in the procurement of ICT solutions, including AI solutions for digital twins. Currently, the procurement of AI solutions for digital twins does not seem to be a major issue for public bodies, and AI is largely perceived as a tool used to automate or optimise certain processes.

One of the main challenges faced by public bodies is the **lack of technical expertise and capacity** to negotiate favourable terms that balance the commercial interests of companies with the public interest. For local municipalities, for example, understanding the content of the technical specifications can be a challenge. This could lead, for example, to public bodies procuring digital twin solutions without properly understanding the specifications so that there's only one company that can respond to a public tender.

Public governments could also make **decisions based on historical precedents**. For example, if they already use a particular type of data or a group of standards, even if they are proprietary, they would not typically question it. In many cases, they would readily put in the specifications for their next public tender a requirement that the system must be able to work with that kind of data or comply with a particular standard. Effectively, in doing so, they could inadvertently, without acting in bad faith, give preference to one vendor.

Getting the details of the procurement contract right from the outset is critical because it is not common that a company or a public organisation, certainly not a public government, would continuously check and monitor the performance of their contractual counterpart's obligations, inspecting if they are doing what they are supposed to be doing.

In summary, there is a need for **education and awareness campaigns among public governments** about the technical and contractual pitfalls in the public procurement of ICT solutions. This should include **operational guidance** in the form of a **framework for reasoning in transactional terms** but also general awareness of ongoing standardisation efforts and their impact on avoiding (or reinforcing) vendor lock-ins.

3.3.2.2 Legal data provenance

Data provenance, in legal terms at least, does not seem to be an issue in cases where the public bodies have 'purchased' the data and have had them transferred. Most digital twin solutions are built on top of existing data infrastructures. Legal provenance, understood as tracing and tracking the rights that may subsist in different data, datasets, or databases, is **built in by design in the metadata** of the data sets that are procured or received.

The situation could be slightly different where access to data is provided on a **solution as a service** basis. In this case, the service provider would usually update the data continuously, so there may be a need to **contractually specify service level agreement targets** in terms of availability, integrity and accuracy, especially for data in security-sensitive industries.

The practice in the case of non-conformity seems to be that of **collecting evidence** to support a claim of non-compliance. These issues are usually resolved as **part of the typical contract management lifecycle** (e.g., escalation of issue to a supervisory team) and rarely require the intervention of a legal advisor.

Overall, the issue of legal provenance of data is typically **resolved on a technical level** by specifying a service level of how recent, how accurate, how precise the data must be. Even if the issue is not resolved on technical level; however, issues are usually dealt with as part of the typical contract management procedures.

3.3.2.3 Data rights and licensing

The pragmatic view seems to be that the **licensing of data rights is managed contractually** by most organisations, usually under the heading of 'intellectual property'. The question of whether intellectual property rights subsist in the data is not a matter that is raised in practice.

It is not uncommon to see private organisations building, for example, a digital twin of a city and then providing it to the city at a considerably discounted price. The ***quid pro quo*** in these types of transactions is the **non-exclusivity** that private contractors impose in such transactions so that they can **further monetise** the collected data towards third-party organisations. Furthermore, in some cases private organisations have solid reasons for exclusivity, e.g., in industries where collecting the data could be prohibitively expensive, such as satellite imagery.

Public bodies in these cases are not necessarily unaware of the conditions or unwilling to accept them. To the contrary, many seem to be **satisfied with having a non-exclusive licence** to use the digital twin because they **do not have a clear strategy of what they would do with exclusivity**, and they get a good deal.

In summary, while exclusivity seems to be a concern for private organisations, it is not seen as critical by public bodies, such as local governments.

3.3.2.4 Open source and open platforms

Some respondents highlighted that **giving precedence to open source**, not only in terms of software but also other assets, could be seen as **distorting the level playing field** because it imposes a specific licencing model or even a specific business model. Effectively, this leads to favouring one approach over another which could have an **impact on the open and fair competition**.

Furthermore, the reality is that the **data acquired by governments is usually proprietary**, e.g., satellite imagery data. This data typically comes with commercially justified restrictive conditions on further disclosure, including release under open licences. What is released to the public usually is the aggregated outcome, i.e., the outcome of the data analytics applied to the raw data. However, the raw data is almost never released publicly, and its processing is often subject to strict terms and conditions.

On the other hand, there are also companies that are **unsure of how to monetise data in a legally compliant way** (e.g., telecom data). Similarly, when other organisations ask for access to this data, these requests are usually denied because of uncertainty around the legal status of these data.

Furthermore, when asked for data, those willing to cooperate usually only provide unstructured data in PDFs and not data sets ready for analytics. Some respondents shared that it is **hard to convince the stakeholders to share their data** either because of fears of non-compliance with data protection law, or because of proprietary rights. Some of the participants saw synthetic data to improve the organisations' overall compliance with data protection law but only subject to further investigation of the effect they have on data and algorithmic accuracy.

Yet, as most public projects rely on public money, there is a clear trend towards following the principles of open science and open data in implementing data platforms. Respondents believe that these **platforms should be built** in such a way that they can **easily be integrated with proprietary** platforms and other tools and platforms.

To sum up, the *status quo* implies the need for further awareness raising and capacity building around data governance and compliance and, more generally, improving the data culture of stakeholders.

3.3.2.5 Interoperability and regulatory sandboxes

Sandboxes are typically seen as working solutions because they allow an organisation to test a particular setup before deploying it in a real-world environment. But how this will work for different digital twins, different countries, different cities, where there's somehow different regulations, some local policies, is not clear, and organisations and governments should think of **how to integrate local policies, local rules, and regulations** with you once and to make a tool that will work for all.

Data silos and the **lack of data interoperability** is seen as a major issue by some of the respondents. Both data silos and the use of different formats and databases prevent effective sharing and use of data between departments in the same organisation and across organisations.

Some of the respondents, however, were critical to the potential of regulatory sandboxes. In their view, already today, local governments and partners engage in “pilot projects”, “proofs of concept”, and “prototyping” types of exercises. Very often this is done in good faith (e.g., to foster innovation) but in practice it often boils down to state-sponsored R&D. Or even if the market participant does not get money, they use their presence in the **“pilot project” as a competitive advantage** over other companies that are less good at making contacts with governments or simply came later in the market. This implies that while a regulatory sandbox may be set up in good faith, it will not lead to a level playing field.

The “happy few” that will be involved in the sandbox will either have the resources to afford to do it for free, or they will be small and receive funding from the government. In both instances, those left out will be at a competitive disadvantage.

Sandboxing may also lead to **individual companies influencing (at least subliminally) regulators** around certain policy choices. When a regulator wants to introduce a more burdensome regulation, a company in the sandbox could try to influence this decision under the pretext of their close relationship with the regulator and their understanding of the regulated activity. There is a risk that sandboxing may prove to be an incentive to find loopholes in regulation and design ways *around* it rather than respecting it.

3.3.3 Legal key takeaways

Based on the evidence collected and analysed, the following tools should be included in the Toolbox in terms of legal and security features:

- **Guidelines for data management**, which should facilitate breaking the data silos and improving the data culture of administrations. These should be combined with training and awareness raising on how to break the silos between data stored by different administrations, in different formats and different databases, with a view to improving the data culture of organisations (e.g., to provide structured data).

- **Guidelines for LDT procurement**, which should provide steering on how to implement standardised fair, reasonable and non-discriminatory terms of reference and conditions for local administrations that procure private ICT solutions for use in projects involving LDT.
- **Guidelines for generation of privacy-preserving synthetic data**, comprising standardised procedures and guidance on how to create pipelines for generation of synthetic data which preserve the privacy of original personal data or other data which may be subject to third-party rights.
- **Operational guidelines for stakeholder involvement in data protection impact assessments**, which should provide practical guidance on how to involve meaningfully the general public in data protection impact assessments.
- **Playbook for designing, implementing, and monitoring of transactions with private actor**, which should equip decision-makers with a framework on how to reason and negotiate transactional terms in public procurement in a way that promotes open and fair competition while ensuring the best protection of the public interest.

4 LDT Toolbox design

This chapter makes an additional step and links the evidence collected during the consultation activities with the technical building blocks, strategy, and legal tools relevant for the development of the future European LDT Toolbox. However, on request of the Commission, it is decided that the elaboration of the Toolbox requirements in task 5 will focus on technical building blocks only, as strategy tools will be addressed in Lot 2 "Scale the deployment of an enabling digital infrastructure" project and most of the legal tools to support governance & compliance capabilities are already analysed as part of DS4SSCC.

4.1 Capabilities mapping

To guide the future design of the LDT Toolbox it is crucial to understand what are the key components that should be included. To this end, the capabilities illustrated in section 3.2.1 and presented in Annex are mapped against the ambition level presented in section 0. This mapping exercise will facilitate the selection of capabilities and hence building blocks that should be included in the Toolbox. Depending on the needs of the city, capabilities are initialised to support a certain functionality or need, and new capabilities can be added when the ambition level changes. The tables below present capabilities by the four identified ambition levels.

1. **Awareness Twins**

For the creation of the awareness ambition level, the basic data capabilities need to be in place to ensure that data traceability and interoperability is guaranteed throughout the development of the LDT. To provide the data-driven insights to the user, a basic visualisation and reporting is part of the LDT setup and user and access management for the LDTs needs to be in place. On the strategic side, the LDT roadmap capability is put in place to define, manage, and operate the digital twin and on the governance and compliance level, the public procurement activities are initiated, and security & risk assessment should be initiated.

Table 4: Awareness Twins capabilities

Domain	Capability Category	Name
Functional	Data	(meta)data schema management
Functional	Data	Ontology management
Functional	Data	Data source management
Functional	Analytics	Reporting (general)
Functional	Visualisation	Basic Visualisation
Functional	Security	User & Access Management
Strategy	Strategy	LDT Roadmap Management
Legal	Governance & Compliance	Security & Risk assessment
Legal	Governance & Compliance	Public procurement

2. **Experimental Twins**

The experimental twin gives the opportunity to run 'what-if' simulations and needs integration and analytics capabilities that ensure that data and models are working together to create scenarios and run simulations. Context information provided by IoT devices can be considered as a data capability but requires specific approach to handle the IoT sources. The experimental twin deals with substantial volumes of data that need to be processed and the results of the simulations are stored in the LDT data storage. From a user perspective, more advanced visualisations and dashboarding is needed that is part of the integrated environment that connects data, models, simulations for a user. Marketplaces come into the picture where models can be hosted and interaction with the users is captured for citizen engagement and collaboration and community management. On the strategy and governance level,

the associated guidelines and best practices are installed to guide cities in the development of the experimental twin.

Table 5: Experimental Twins capabilities

Domain	Capability Category	Name
Functional	Data	Data replication
Functional	Data	Data publishing
Functional	Data	Data time travel
Functional	Data	Data processing
Functional	Data	Data Storage
Functional	Analytics	Simulation
Functional	Analytics	Algorithms & Models
Functional	Analytics	Algorithm & model management
Functional	Visualisation	Advanced Visualisation & Geo dashboarding
Functional	Visualisation	Integrated user experience
Functional	Integration	Model abstraction
Functional	Integration	Model hosting
Functional	Integration	Data flows and component orchestration
Functional	Integration	Interaction support
Functional	Integration	Case, scenario & experiments management
Functional	IoT	Context information management
Functional	Security	Encrypted asset exchange
Strategy	Strategy	Marketplace interaction
Strategy	Strategy	Citizen engagement and Case & scenario feedback gathering
Strategy	Strategy	Collaboration and community management
Strategy	Strategy	Reference case management
Strategy	Strategy	Technical Solutions Catalogue Management and Benchmarking
Legal	Governance & Compliance	Quality Assurance
Legal	Governance & Compliance	Data management & compliance
Legal	Governance & Compliance	Model governance & compliance
Legal	Governance & Compliance	Semantic governance & compliance

3. Predictive Twins

The predictive twin allows to anticipate on events to happen and requires near-real-time data flows and may include models based upon Artificial Intelligence. The data capabilities and IoT capabilities are highly developed and can be even extended by synthetic data generation and federated learning and training capabilities. At this point, also associated governance and security capabilities are to be put in place.

Table 6: Predictive Twins capabilities

Domain	Capability Category	Name
Functional	Data	Ingest data
Functional	Data	Streaming data
Functional	Data	Data transformation
Functional	Data	(Near) Real-time data processing
Functional	Data	Data, publishing and subscribing
Functional	Data	Synthetic data generation
Functional	Analytics	Prediction
Functional	Analytics	Federated Learning & Training
Functional	Analytics	Machine Learning & AI
Functional	Visualisation	Alerts and Notification

Functional	IoT	Urban measuring, sensing & control
Functional	Security	Privacy-sensitive data interaction
Legal	Governance & Compliance	Transaction management with private actors

4. Intelligent Twins

The intelligent digital twin makes full usage of advanced visualisation services such as virtual reality and augmented reality and can create an Extended Reality environment for a user. In addition, the supervised or unsupervised actuation or commands capabilities can be used where the intelligent twin performs operations (semi-) automatically. In this respect, the necessary capabilities ensuring transparency, explainability and accountability are required that complement with the security capability to deliver reliability and resilience.

Table 7: Intelligent Twins capabilities

Domain	Capability Category	Name
Functional	Visualisation	Virtual Reality (VR)
Functional	Visualisation	Augmented Reality (AR)
Functional	IoT	Supervised or unsupervised actuation, command & control
Functional	Security	Reliability & resilience
Legal	Governance & Compliance	Procedural transparency
Legal	Governance & Compliance	Technical transparency & explainability
Legal	Governance & Compliance	Usage context information provisioning
Legal	Governance & Compliance	Accountability information provisioning

4.2 Building blocks overview

Building blocks are the foundational components used to develop an LDT. According to the consultation results and based on the LDT Toolbox capabilities presented above, the project team identified a number of technical and non-technical building blocks which are presented below.

The following building blocks have been identified to match the functional capabilities listed above and have been listed in descending order of relevance. The technical building blocks will be further analysed in D05.02.

- **Case & Scenario Manager.** Scenario manager enables structuring and managing the different types of experiments that are done with digital twins. As such they fulfil a practical role, but they also have a technical part to play. The contain all the data models and controls that the Interaction Service uses to persist and bundle data manipulations and they aggregate and structure all the information that the Simulation Service needs to properly run simulations of scenarios. They are an essential part of the abstraction that allow different models from developers and data sources from data providers to be used in combination.
- **Integrated environment.** A shell that offers access to all the independent services that the LDT is comprised of with one login/session.
- **Interaction Service.** A building block that provides the tools to manage and persist user induced changes to data sets available to the LDT and aggregate them into scenarios.
- **Message Broker.** Provides the tools and operations to permit seamless communication between the different LDT Technical Building Blocks.
- **Model abstraction SDK/Service.** An abstraction layer on top of models to facilitate transferability and interoperability. which can be for instance translated into a software development kit (SDK) to facilitate the integration and seamless connection of models within the digital twin environment. This facilitates connection to input and output data channels as well as interoperability with other models and the interactive digital twin virtual environment.

- **Model Catalogue/Algorithm Register.** An Algorithm Register that serves as a comprehensive repository that presents a Catalogue of accessible algorithms or models. Its fundamental characteristics encompass functionalities like searchability, metadata browsing, provision of license information, and an emphasis on transparency to enable the interpretability of algorithmic outputs. The register also highlights aspects such as the algorithm's applicability, limitations, and other pertinent details.
- **Data Query Service.** Technical components that make LDT data available to the outside world and that provide a homogenous set of capabilities to query, manage, and modify data. This tool allows a horizontal collaboration between communities and vertical collaboration between communities, their citizens, and other parties.
- **Asset Registry.** Rephrase more briefly: A digital twin needs to be efficient and trustworthy at the same time (GEMINI principles), in a context where it uses a lot of external assets such as data, simulation models, and AI algorithms. An asset registry allows to keep track of all these assets including key metadata to facilitate trustworthy and transparent application of the digital twin data and algorithms. The asset registry encompasses some of the other building blocks: data Catalogue, Model Catalogue/Algorithm register, Ontology manager, transformation manager, and Schema manager.
- **Context Broker.** A Context Broker is an API that can integrate data from multiple systems, creating a holistic view of information by describing different types of data and providing an interface to view and interpret said data. It is also a gateway for performing actuations.
- **Data Catalogue.** A Data Catalogue is a list of available datasets. Essential features of a data Catalogue include searching, browsing metadata, license information and access details to the datasets themselves. The data Catalogue can also manage the training data sets.
- **IoT Agent.** Component responsible for receiving all messages from IoT devices and sensors and distributing the across subscribed consumers. Can include IoT device management features as well.
- **Simulation Service.** A component that provides the tools/controls to orchestrate the execution of models in the context of LDT scenarios and report on their status and results.
- **Synthetic Data Generation Tools.** Synthetic data generation tools are software tools or frameworks designed to create artificial or simulated data that closely resemble real-world data. These tools use algorithms and statistical models to generate data with similar statistical properties, distributions, and relationships as the original data. Synthetic data generation tools are useful for various purposes, such as data augmentation, privacy protection, and testing machine learning algorithms and models.
- **Collaboration & community management system.** Digital space to connect cities and communities (e.g., forum) and facilitate exchange of best practices, transfer of knowledge, etc. This may include an AI chatbot that allows users to ask questions about LDT tools, building blocks, guidelines, and deployment.
- **Data Spaces Connector.** Data spaces facilitate the interoperability discoverability and exchange of data in the context of agreed upon policies. A data space connector can be useful for exchanging assets across LDTs as well as a gateway to remote datasets and (simulation) services.
- **Analytical Visualisation Components.** Components that provide analytical visualisations of the data available in the LDT to the stakeholders of the system. These can be dedicated platforms such as well-known BI-tools and dashboards as well as plug-in components for an integrated environment.
- **Data storage: Data Lake, data warehouse, data lakehouse.** Data lakes and data warehouses are key infrastructure for data analysis. They can be combined into a data lakehouse where on top of the data lake, structured data and indexes (data warehouse) are kept with a reference to the raw base data underneath (data lake data). This in fact allows to create a uniform access layer on top of heterogeneous data.

- **Geospatial Visualisation Components.** Components that provide the tools to create geospatial visualisations which focus on the relationship between data and its physical location. Both 2D and 3D visualisations are possible.
- **Access Manager.** A part that provides the tools to dynamically restrict access to different functionalities, inputs, and outputs of the LDT. This includes, but is not limited to, API's, UI's, data sets, and configurations. This can consist of "simple" access management methods such as Role Based Access Managements or more advanced methods such as Policy Based Access Management which is common in Data Spaces.
- **Identity Manager.** A component that provides the tools to uniquely identify and authenticate stakeholders in the LDT ecosystem.
- **User Manager.** A component that provides tools for user management, such as the management of accounts linked to specific identities and access policies.
- **Data workflow and component orchestration.** A BB that provides Data Flow Orchestration (the ability to execute multiple separate steps in a data flow in the right order which is needed to support data pipeline and is thus relevant for all types of DTs, from the first level) and Control Flow Orchestration (the ability to execute multiple separate steps in a workflow in the right order to support model interactions which is needed for intelligent DTs or predictive Twins).
- **Community management tools.** Tools & practices for building up a community and communicating with it. This includes blog posts, social media posts, chat groups, content sharing, etc.
- **Data replication client.** Allows to replicate a data source in proximity to the consumer (a model or a Visualisation client) to ensure responsive system behaviour. This also ensure experiments can be created and that real-time data streams can be replayed for the sake of simulation experiments.
- **Event based data publishing service.** A service that allows to publish data sources as a series of update events or version objects to enable full data time travel capabilities.
- **Encryption tools.** Encryption tools allow for the secure exchange of digital assets and safeguarding the integrity of both data and other assets. Aside from that, encryption tools can be used in the context of privacy preservation, using it to conceal identity-sensitive fields in the data for instance.
- **Extended Reality (AR/VR Services).** In the context of an urban digital twin, Virtual Reality (VR) and Augmented Reality (AR) services are used to visualise, interact with, and understand the digital replica of a city. These services transform complex urban data into immersive, three-dimensional, and real-time digital experiences.
- **Failover.** Failover infrastructure plays a critical role in digital twins when used in an operational context where high availability is required. Especially when LDT technology is used to control real-world assets, special care needs to be taken towards ensuring high availability and operational continuity.
- **Federate learning service.** A service that orchestrates this process of distributed, privacy-preserving machine learning. This might include managing the overall process, ensuring models are sent to and updated at each node, and aggregating the updates into a global model.
- **IoT and Edge.** IoT and edge infrastructure required for sensing, monitoring, and controlling the urban environment. This should discuss some patterns and concerns regarding the deployment and dependencies of these components.
- **Model usage guidelines.** A framework that allows to determine appropriate modelling techniques with the problem that needs to be solved. This includes guidelines on how to implement models as well considering aspects on the algorithms/techniques to use, appropriate space/time resolutions for processing data, streaming requirements, data quality considerations and so on.

- **Model & Algorithms.** In the context of urban digital twins, models are used to understand, analyse, and predict the city's behaviour and its various subsystems under different conditions. Different types of models exist, for instance Dynamic systems models, Simulation and analysis models, Predictive models, AI & ML models.

As already discussed, results from the consultations suggest the Toolbox should include a mix of technical and non-technical building blocks. However, some of the strategy tools identified will be analysed in the upcoming Lot 2 "Scale the deployment of an enabling digital infrastructure" project and most of the legal tools are already part of the DS4SSCC project. For this reason, the following tools, although relevant for stakeholders, are discarded and technical specifications will only be developed for the technical building blocks.

Table 8: Discarded strategy and legal tools

Category	Tools
Strategy tools	• **Reference architecture.** Blueprint for the LDT solution expressed in terms of the technical building blocks in relation with the ambition levels. • **Tool for ambition assessment and roadmap management.** Tool for assessing current maturity versus the ambition and a roadmap from the gap analysis. • **Catalogue of tech solutions and use cases**. Possibility to select geography penetration, use cases reference, technology stack, range of costs, certifications and having the list of solutions/providers serving the specific criteria. Comparison tool configured for instance as a Web Portal with the possibility to select geography, use cases, and compare solution already implemented in term of performance with defined KPI or the quality of deliverable (e.g., using SonarQube report as input uploaded by the tech provider). • **Tool for security and risk assessment**. Security assessment tooling as a web-based questionnaire that can lead to a risk score. • **Certification Framework**. List of certifications, gap evaluation, step suggestions, document checklist, competence assessments, and organisational assessment. • **Ambition assessment tool & roadmap management.** Tool for assessing current maturity versus the ambition and a roadmap from the gap analysis. • **Case study publishing & reporting tools.** A template for publishing case reports in a consistent structure and layout. • **LDT use case portfolio.** A Catalogue of digital twin use cases including case reports, assets used, and a discussion of technical and non-technical challenges for the realisation.
Legal tools to support Governance & compliance	• **Guidelines for data management**. Guidelines on breaking the data silos and improving the data culture of administration. • **Guidelines for generation of privacy-preserving synthetic data**. Guidelines for privacy-preserving generation and use of synthetic data. • **Guidelines for LDT procurement**. Guidance on how to implement standardised fair, reasonable and non-discriminatory terms of reference and conditions for local administrations that procure private ICT solutions for use in projects involving LDT. • **Operational guidelines for stakeholder involvement in data protection impact assessments**. Operational guidelines on how to involve meaningfully the public in data protection impact assessments. • **LDT deployment coordination mechanism**. A tool for exchanging information on specific local regulatory conditions which may require different modes of deployment or more/less stringent compliance with certain rules. • **Playbook for designing, implementing and monitoring of transactions with private actors.** Playbook with suggestions on how to reason and negotiate transactional terms in public procurement in a way that promotes open and fair competition while ensuring the best protection of the public interest.

	• **Guidelines for using Privacy sensitive data.** Guidelines on breaking the data silos and improving the data culture of administration. • **Guidelines on data and algorithm ethics.** Guidelines and best practices around the use of models and their potential impact on people and society. It addresses things like selection, confirmation and other kinds of bias, untransparent and inexplicable outcomes, concept drift, surveillance, accountability and accessibility. • **LDT Quality assurance Toolbox.** The quality assurance (QA) Toolbox contains processes, methodologies, and standards used to ensure the accuracy, reliability, and validity of the simulation models and their outcomes. Quality assurance in this context could cover several aspects, including data quality, model quality, convergence, concept drift, and the quality of the simulation outcomes.

4.3 Building blocks mapping

Lastly, the selected building blocks are mapped against the ambition levels to understand what are the key components that should be included and to guide the future design of the LDT Toolbox. Although non-technical building blocks will not be addressed as part of this project, the tables below include an analysis of both technical and non-technical building blocks. Technical building blocks will be further developed in D05.

1. Awareness twins

The table below presents the identified capabilities and the associated building blocks for **awareness twins**.

Table 9: Awareness Twins building blocks

Capability Category	Capability	Building Block
Analytics	Reporting (general)	Case study publishing & reporting tools
Data	(meta)data schema management	Asset Registry
Data	Ontology management	Asset Registry
Data	Data source management	Asset Registry
		Data Catalogue
Visualisation	Basic Visualisation	Geospatial Visualisation
Security	User & Access Management	Access Manager
		Identity Manager
		User Manager
Strategy	LDT Roadmap Management	Ambition assessment tool & roadmap management
		Guidelines for LDT procurement
		Reference Architecture
		Tech solutions catalogue & benchmark tool
Governance & Compliance	Public procurement	Guidelines for LDT procurement
		Reference Architecture
Governance & Compliance	Security & Risk assessment	Access Manager
		Security & Risk Assessment Tool

2. Experimental twins

The table below presents the identified capabilities and the associated building blocks for **experimental twins**.

Table 10: Experimental Twins building blocks

Capability Category	Capability	Building Block
Analytics	Algorithms & Models	Analytical Visualisation Components
Analytics	Algorithms & Models management	Model Catalogue
Analytics	Simulation	Models & Algorithms
Data	Data replication	Data replication client
		Data storage: Data Lake, data warehouse, data lakehouse
		Event Based Data Publishing Service
Data	Data publishing	Data Query Service
Data	Data processing	Data storage: Data Lake, data warehouse, data lakehouse
		Data workflow and component orchestration
		Event Based Data Publishing Service
Data	Data Storage	Data storage: Data Lake, data warehouse, data lakehouse
Data	Data time travel	Event Based Data Publishing Service
		Data storage: Data Lake, data warehouse, data lakehouse
Integration	Case, scenario & experiments management	Case & Scenario Manager
Integration	Data flows and component orchestration	Data workflow and component orchestration
		Message Broker
Integration	Interaction support	Interaction Service
		Message Broker
Integration	Model abstraction	Model abstraction SDK/service
Integration	Model hosting	Model abstraction SDK/service
IoT	Context information management	Synthetic Data Generation Tools
		Context Broker
Security	Encrypted asset exchange	Encryption tools
Visualisation	Advanced Visualisation & Geo dashboarding	Analytical Visualisation Components
Visualisation	Integrated user experience	Integrated environment
Strategy	Citizen engagement and Case & scenario feedback gathering	Collaboration & community management system
		Stakeholder involvement guidelines/Toolbox
Strategy	Marketplace interaction	Data space Connector
Strategy	Reference case management	LDT Use case portfolio
Strategy	Technical Solutions Catalogue Management and Benchmarking	LDT deployment coordination mechanism
		Tech solutions catalogue & benchmark tool
Strategy	Collaboration and community management	Playbook for designing, implementing and monitoring of transactions with private actors
		Collaboration & community management system
		Community management tools
Governance & Compliance	Data management & compliance	Stakeholder involvement guidelines/Toolbox
		Guidelines for Data management & conformance Toolbox
		Guidelines for Data management & conformance Toolbox

		Data Catalogue
Governance & Compliance	Quality Assurance	LDT Quality Assurance Toolbox
		Certification Framework
Governance & Compliance	Model governance & compliance	Guidelines on data and algorithm ethics
		Model usage guidelines
Governance & Compliance	Semantic governance & compliance	Asset Registry

3. Predictive twins

The table below presents the identified capabilities and the associated building blocks for **experimental twins**.

Table 11: Predictive Twins building blocks

Capability Category	Capability	Building Block
Analytics	Machine Learning & AI	Access Manager
Analytics	Federated Learning & Training	Federated Learning Service
Analytics	Prediction	Models & Algorithms
Data	(Near) Real-time data processing	Event Based Data Publishing Service
		Message Broker
Data	Data transformation	Data storage: Data Lake, data warehouse, data lakehouse
		Data workflow and component orchestration
Data	Data, publishing and subscribing	Event Based Data Publishing Service
		Message Broker
Data	Ingest data	Message Broker
Data	Streaming data	Message Broker
Data	Synthetic data generation	Guidelines for generation of privacy-preserving synthetic data
		Synthetic Data Generation Tools
IoT	Urban measuring, sensing & control	IoT Agent
		Message Broker
		Tech solutions catalogue & benchmark tool
		IoT and Edge
Security	Privacy-sensitive data interaction	Guidelines for using Privacy sensitive data
Visualisation	Alerts and Notification	Message Broker
Governance & Compliance	Transaction management with private actors	Data space Connector

4. Intelligent twins

The table below presents the identified capabilities and the associated building blocks for **intelligent twins**.

Table 12: Intelligent Twins building blocks

Capability Category	Capability	Building Block
IoT	Supervised or unsupervised actuation, command & control	Message Broker
Security	Reliability & resilience	Access Manager
		Failover
Visualisation	Augmented Reality (AR)	Extended Reality (AR/VR Services)
Visualisation	Virtual Reality (VR)	Extended Reality (AR/VR Services)
Governance & Compliance	Accountability information provisioning	Model Catalogue

Governance & Compliance	Procedural transparency	Asset Registry
Governance & Compliance	Usage context information provisioning	Case & Scenario Manager
Governance & Compliance	Technical transparency & explainability	Asset Registry
		Asset Registry
		Data storage: Data Lake, data warehouse, data lakehouse
		Data workflow and component orchestration
		Data workflow and component orchestration

5 Conclusion and recommendations

The consultation activities were carried out from the 13 June to the 12 July, with the aim of collecting evidence on the stakeholders' needs when implementing one or more digital twin solutions and key challenges linked to it. The consultation has been designed to comprehensively address different stakeholder groups through tailored tools, questionnaires, intersection study group, and a workshop. The stakeholders involved were smart cities and communities, technology providers, standardisation bodies and fora, legal experts.

To delve deeply into participants' viewpoints, experiences, and knowledge on the business, functional and technical, legal and security aspects of LDT, the project team conducted a total of 21 interviews and obtained 77 answers to the surveys. Prior to the launching of the survey, an intersection study group was conducted to engage with stakeholders in a collaborative way and fine tune the questionnaires for data collection. The evidence gathered during the previous consultation activities were presented and validated during the interim workshop.

In summary, consultation findings highlight the growing interest in LDTs, their potential benefits, challenges, and the need for comprehensive strategic tools and guidelines to support their successful implementation. The key insights collected through consultation activities are summarised below:

Business features. Consultation findings highlight the growing interest in LDTs, their potential benefits, challenges, and the need for comprehensive strategic tools and guidelines to support their successful implementation.

Functional and technical features. Stakeholders emphasise the importance of LDT solutions being easy to use, having data management and analytical capabilities, integrating privacy and security measures, and being interoperable and flexible. Guidelines and standards should be strengthened at the EU level.

Legal and security features. The analysis of evidence shows that public organisations, such as local governments, should strengthen their capacity in terms of procurement and contracting.

The consultation activities allow to gather a list of requirements on the technical, strategic, legal and security components relevant for the development of the future European LDT Toolbox. By aggregating and consolidating those requirements, the project team identified several capabilities and developed a catalogue of building blocks which have been mapped against the four ambition levels of digital twins, namely awareness, experimental, predictive and intelligent.

The building blocks, presented below, are the outcomes of the consultation results and of the analysis of them. These building blocks will be further developed in Task 5 of the project, which includes the technical specifications to design the LDT Toolbox.

Technical and Functional Building Blocks
1. Case & Scenario Manager
2. Integrated environment
3. Interaction Service
4. Message Broker
5. Model abstraction SDK/Service
6. Model Catalogue/Algorithm Register
7. Data Query Service
8. Asset Registry
9. Context Broker
10. Data Catalogue
11. IoT Agent
12. Simulation Service
13. Synthetic Data Generation Tools
14. Collaboration & community management system

15. Data Spaces Connector
16. Analytical Visualisation Components
17. Data storage: Data Lake, data warehouse, data lakehouse
18. Geospatial Visualisation Components
19. Access Manager
20. Identity Manager
21. User Manager
22. Data workflow and component orchestration
23. Community management tools
24. Data replication client
25. Event based data publishing service
26. Encryption tools
27. Extended Reality (AR/VR Services)
28. Failover
29. Federate learning service
30. IoT and Edge
31. Model usage guidelines
32. Model & Algorithms

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