DIGITAL TWINS

Nordic Land Mapping network ad hoc group

Report

Executive Summary

The Nordic Ad Hoc Group on Digital Twins was established at the Nordic Stora Chefsmöte in September 2023, with Finland serving as the chair. Representatives from all Nordic countries and Estonia participated. The group's primary objective was to explore the role of geospatial data and national mapping agencies (NMAs) in digital twin (DT) development across different data ecosystems. Additionally, it sought to assess the feasibility of a nationwide digital twin and to develop a common understanding of digital twins using geospatial data.

The group's work followed a structured approach, beginning with defining key questions, facilitating knowledge exchange, and conducting a questionnaire among participating countries to assess the state of digital twin initiatives. The questionnaire, open from June to August 2024, gathered insights from Denmark, Sweden, Finland, Iceland, and Estonia, revealing varying levels of digital twin maturity, thematic focuses, and technological implementations. Norway did not respond due to changes in group members.

Key findings from the questionnaire indicate that digital twin initiatives in the Nordic and Baltic regions are diverse, covering applications in urban planning, environment, traffic, weather forecasting, and infrastructure management. The integration of geospatial data is widely recognized as essential, though the understanding of real-time data and 3D modelling within digital twins varies. Some countries, such as Denmark and Estonia, have initiated nationwide digital twin strategies. In Sweden Lantmäteriet will primarily coordinate the provision of basic public geodata for various areas of use, including for different digital twins. In Finland the situation is quite the same as in Sweden. Iceland lacks a national digital twin but has foundational datasets that could support future developments.

To further benchmark best practices, the group engaged in discussions with Swisstopo (Switzerland), IGN (France), and the Singapore Land Authority, analyzing how these organizations' structure and implement their digital twin frameworks. These case studies highlighted key challenges such as interoperability, data integration, and governance. The benchmarking meetings underscored the need for standardized geospatial datasets and collaborative platforms to enable digital twin adoption.

This final report provides recommendations on how NMAs can support digital twin development. It suggests that NMAs should act as data coordinators, ensuring high-quality foundational geospatial datasets while fostering interoperability through standards such as OGC and ISO.

The study concludes that there is no common view on nationwide digital twins in the Nordic region. Some countries have initiated nationwide digital twin strategies, while others have not. But there is a growing interest, ongoing projects, and increasing investments in geospatial infrastructure indicate significant potential. Cross-border cooperation and EU-level support could for example help smaller countries, like Iceland, to integrate into larger digital twin ecosystems.

Moving forward, the group recommends continued knowledge exchange, follow the development of standardized digital twin frameworks, and further benchmarking with international initiatives.

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1. Background for the ad hoc group work

The ad hoc group "Digital Twin" was set up in the Nordic Stora Chefsmöte in September 2023. It was decided that Finland will act as a chair for this ad hoc group. There have been members from all the Nordic countries as well as from Estonia present in the ad hoc group.

In the concept note (Annex 1) the crucial questions to be solved in the ad hoc group were defined as:

- What is the role of geospatial data in the Digital Twin concept(s) within different data ecosystems?
- What is the role of NMAs in (a nationwide) Digital Twin concept(s)?

The scope of the ad hoc group was also to facilitate discussion and share knowledge between the participating NMA's. The ad hoc group should provide different views of the Digital Twin concept and the role of NMA's in that concept and give a platform to widen the (common) understanding on these issues.

The ad hoc group should also try to answer questions listed below:

- What kind of a Digital Twin (DT) concepts there are in the Nordic countries?
  - What is the role of geospatial in these DT concepts?
  - What is the role of NMA in these DT concepts?

- Develop a common preliminary definition of a DT, a DT using geodata and a Nationwide DT using geodata etc.
  - what new requirements (and data quality issues) there is/will be for geospatial data (to set up DT implementations)
  - how to get funding for DT implementations / to make DTs available for public.

- Is there a plan to establish a nationwide Digital Twin?
  - If so, what is the role of the NMA?
  - Is there a common understanding / policy backing these plans?

- How NMA's see their role and the most important tasks to facilitate the usage of (NMA's) geospatial data in DT concepts of different data ecosystems and/or the nationwide DT?

2. Workflow of the ad hoc group

The ad hoc group has had meetings only online. The first meeting was hold in January 16th 2024. In the first meetings in January and February the ad hoc group worked with the concept note which was then accepted in the Lilla Chefsmöte in March 2024. After the acceptance of the concept note and therefore also the acceptance of the goals for the ad hoc group, the work was steered to decide the next steps for the ad hoc group.

During springtime 2024 the ad hoc group decided which organizations to have benchmarking meetings with and who would arrange these meetings. The biggest work for the ad hoc group before summer was to set up a questionnaire together. This also involved some translation work in each NMA.

The questionnaire (Annex 2) was open approximately from mid-June to the end of August in each country. The ad hoc group went through the results (please see the section 3.2 in this document) in September.

In the early Autumn 2024 the ad hoc group set up three benchmarking meetings: Swisstopo, IGN France and the Singapore Land Authority (please see the section 3c in this document).

The temporary outcomes of the ad hoc group were presented in the Nordic management meeting in September 2024.

Later in the Autumn the ad hoc group started working with this final paper.

In winter 2025 the ad hoc group decided to book one more benchmark meeting.

The first draft of the outcomes was reported for The Nordic Director Generals (online) meeting in March 2025. The final report was approved by the ad hoc group 24.4.2025 and will be delivered for the Nordic Director Generals meeting (in September 2025).

3. Outcomes

In this section we will first go through country by country what is the situation concerning a “nationwide digital twin”- if there is a policy backing it or even an actual plan to accomplish a nationwide digital twin.

In the section 3.2 we will go through answers the ad hoc group received to a questionnaire that was made in each country during the work.

3.1. Status of a nationwide DT plan(s) in participating countries

3.1.1. Denmark

Denmark is currently working on a nationwide digital twin called *Denmark’s Digital Twin*. The Agency for Climate Data expects to launch a basic model (first version) in 2025, which will consist of buildings in LOD2, terrain in TIN and vegetation in the form of single standing trees. The plan is to further develop the DT for many different applications, including climate adaptation and flood warning.

Parallel to the work on the basic model, the agency is currently working on several development projects for Denmark's Digital Twin:

1. Forests: Adding more vegetation in form of forests. A pilot project was executed in 2024 for two test areas, where every tree in the forests were identified and assigned a species.
2. Hydro: Visualization of different hydrological data in the DT. Small tests were done in 2024 for sea level rise, but more tests will be done in 2025 for extreme rain events and flooding from rising groundwater levels.
3. Oblique images: Draping oblique images onto the buildings for a more realistic visualization. This will be done on-the-fly with the use of APIs. Great results were seen for this in 2024, and more tests will be done in 2025 before an integrated solution will be possible for the web client for Denmark's Digital Twin.

More development projects are in the pipeline for 2026 and beyond, but it will depend on the founding prospects.

The vision for Denmark's Digital Twin is that it should be a common public basic dataset that can be freely made available to everyone. This means that Denmark's Digital Twin can be used in many different contexts by municipalities, regions, government institutions and companies, and contribute to providing Denmark with the knowledge that is in demand.

Besides Denmark's Digital Twin, there is also a vision for the agency for *The Road's Digital Twin*. This project is in its very early beginnings. It will be able to handle real-time data of the roads, which will make both the use, maintenance and development of Denmark's roads more efficient.

3.1.2. Estonia

In Estonia, there are already two digital twins with national coverage – the Estonian Land Board DT and Ministry of Climate e-construction DT. The departments in charge of these two DTs have recently been merged into one organization from 2025. Therefore, plans for merging the two DTs are also underway, paving the way for a singular and more holistic national DT.

Furthermore, the primary data collection devices (cameras and lidar) have been renewed in 2024. This enables to increase data quality and experiment with new products (e.g. mesh) and processes, potentially reflected in the DT as well.

It is clear that a national DT cannot meet the needs of municipalities and other DT producers in need of very detailed local data. A national DT with such level of detail would be unnecessarily resource-exhaustive to create and maintain. However, NMCAs produce data with a national coverage that meets international standards for quality and interoperability. A national DT should therefore rather serve as a solid and trustworthy foundation to other more detailed DTs.

3.1.3. Finland

In Finland there is no state level policy about "a nationwide digital twin". There is no active project plan for a nationwide digital twin either. However, in 2022 a government report called "Digital Compass" was published. Purpose for this publication is to "*direct and manage the development of the digital transformation in Finland*". There were hopes and actions made to have the "Finnish digital twin" -concept as a part of the objectives in the paper but this did not happen. However, there are many principals in this document that are "backing" the development of a nationwide digital twin (such as data interoperability issues).

There is a plan to establish a digital twin of the transport network by the year 2030. There are several actors taking part in this framework, such as the Finnish Transport Infrastructure Agency and Fintraffic. Behind this development there is of course a need for advanced data governing but also a policy level decision made by the Ministry of Transport and Communications.

Other notable digital twin projects that are running in Finland concern the water ways (especially project Digital Waters) and forests. Bigger cities have their own digital twin projects running.

3.1.4. Iceland

Iceland currently does not have a nationwide Digital Twin. However, there are promising developments that may contribute to its foundation in the future. Several key datasets are being built up, such as a nationwide orthophoto database, a digital road network, and digital elevation models. These resources are fundamental for digital twin projects but are not yet fully integrated into a national initiative.

One major gap in the current digital infrastructure is the absence of a comprehensive national database with building footprints, and possibly, 3D building models. These elements are crucial for an advanced Digital Twin capable of simulating urban development, infrastructure resilience, and environmental planning.

Some national authorities have initiated steps relevant to digital twin development. Notably, agencies working with meteorological data or infrastructure management are engaging in digital transformation efforts that align with the principles of digital twins. However, these initiatives remain independent, without a unified national strategy to integrate them into a comprehensive Digital Twin framework.

The primary focus of digitalization efforts in the country is centered on enhancing state services for citizens with Digital Iceland. The emphasis is on enabling seamless digital interactions between the government and its people, particularly to ensure accessibility for those in remote areas.

The development of geographical simulation and Digital Twin technology is likely to be a later phase in Iceland's digitalization journey. Before such advancements can be realized, suitable policies and investments will need to be introduced to support this direction. The current approach follows a logical progression—strengthening fundamental digital infrastructure and services before moving towards more complex spatial and simulation-based digital twin systems.

3.1.5. Norway

The term “digital twin” is being widely used and misused in Norway (as for the rest of the World) for many types of digital representations of static real-world objects, either the data sets can be considered digital twins or not according to accepted definitions.

The Norwegian Ministry of Digitalization and Public Governance presented a national digitalization strategy for 2024-2030 in 2024, with an aim to make Norway the most digitized country in the World by 2030. Digital twins are not mentioned specifically in the strategy, but the importance that geospatial information and a spatial infrastructure will have for reaching the goal is clearly emphasized.

Besides, the strategy for the Norwegian Mapping Authority (NMA) for 2021-2025 points out three strategical goals, where the second is to develop the spatial infrastructure to become the society’s digital twin as the foundation for a sustainable society. All data that are managed by the NMA in collaboration with other public authorities is considered a part of the digital twin, although they are not the twin itself, only base data. This includes:

- The Cadaster (Matrikkelen) and accompanying infrastructure
- The nationwide and harmonized topographic data (from small scale to highly detailed data) and detailed elevation models covering land as well as sea
- The spatial infrastructure with contributions from more than 600 stakeholder organizations in Norge Digital
- The infrastructure for positioning, which is fundamental for combining data from different sources correctly

There are currently ongoing studies towards a strategy for 3D-representation of nationwide building data, which will play a crucial role in digital geospatial twins. Commercial actors and municipalities are already deriving and using detailed 3D-representations from building data and elevation models.

The national road database (NVDB) contains all roads (including forestry roads), restrictions and road equipment. NVDB is currently being further developed to become a digital twin of the road infrastructure, supported by BIM data from construction projects as well as sensors with real-time data.

Digital twins are also being referred to within the BIM domain, where large owners of road and rail infrastructure are investing time and finances in development and use of systems for planning, constructing and maintaining their assets. Geospatial information and location referencing play a vital role in these initiatives.

3.1.6. Sweden

There are expectations in Sweden that Lantmäteriet should be responsible for handling the coordination of a nationwide digital twin and there is no policy backing up these plans. It is also difficult to know what a national digital twin is as it has no accepted definition, nor are there many lasting implementations of networks of interconnected digital twins that could be considered a variant of such a definition. Therefore Lantmäteriet will not at present take on the task to be responsible for handling the coordination of a nationwide digital twin but will carefully follow the development of digital twins.

Lantmäteriet's role is primarily to coordinate the provision of basic public geodata for various areas of use, including for digital twins. This means that Lantmäteriet should manage and develop data provision within Lantmäteriet's area of responsibility, that is basic data such as image, laser, topography and property data. There could also be a need for a standardized national overview 2D and 3D map/model that can be used as background information in different applications. Lantmäteriet should also coordinate the data provision of other public actors' geodata. Today this is done for example via the National Geodata Platform and its framework. In the future this could be another type of data provision depending on how the technology develops, it could for example be federated solutions and linked data. Further, Lantmäteriet should, in cooperation with the Geodata Council, successively develop collection, storage and provision, from today's infrastructure to the information ecosystem of the future. That could for example include adaption of data models, storage, and provisioning to easily be used in various digital twins as well as by AI and other applications.

The main actors in Sweden who work with digital twins in different ways are:

- *the Geodata Council*, which developed the national geodata strategy and a Vision 2040 for the geodata area (https://www.lantmateriet.se/geodataradet).
- *the Digital Twin Cities Center* (DTCC) which is run by Chalmers University of Technology and has created a Digital Twin Platform and runs various research projects linked to digital twins (https://dtcc.chalmers.se/)
- *Research Institutes of Sweden* (RISE) an independent government research institute that runs some projects linked to digital twins (https://www.ri.se/sv/om-rise/rise-i-korthet)
- *Smart Built Environment* a strategic innovation program for the planning and building sector which, among other things, finances various projects on digital twins run by RISE and DTCC (https://www.smartbuilt.se/)

Lantmäteriet is closely following these actors and is also participating in projects that DTCC and RISE are responsible for.

3.2. Answers to the questionnaire

As one of the main tasks of the ad hoc group a questionnaire was made. The questionnaire was made together in English and then translated in each country before sending it out. The statistics and the results of the answers can be found in Annex 2.

Due to changes in the ad hoc group members from Norway, Norway did not respond to the questionnaire.

With the help of the questionnaire the ad hoc group wanted to get answers from each participating country to following questions:

- What kind of a DT concepts there are in the Nordic countries?
  - What is the role of geospatial in these DT concepts?
  - What is the role of NMA in these DT concepts?
  - How NMA's see their role and the most important tasks to facilitate the usage of (NMA's) geospatial data in DT concepts of different data ecosystems and/or the nationwide DT?

- Develop a common preliminary definition of a DT, a DT using geodata and a Nationwide DT using geodata etc.
  - what new requirements (and data quality issues) there is/will be for geospatial data (to set up DT implementations)
  - how to get funding for DT implementations / to make DTs available

3.2.1. Denmark

Denmark had previously held several workshops with stakeholders of Denmark's Digital Twin, and thus had already a large list of contacts to draw on. In total Denmark had 56 answers to the questionnaire, where most participants came from municipalities or private companies.

More than half of the respondents did not see that a digital twin has to include a spatial dimension, which may derive from the private companies, which work with all sorts of DTs, e.g. energy consumption, CO_2 capture plants, ventilation systems, etc..

In general, a lot of answers were dominated by these small-scale DTs, which has a geographical scope of down to one machine. But when asked about the use of geographical data, over half the answers said 3D buildings, Orthophoto and DEM are key data sets for a DT.

62% of the answers said they don't create or collect new geographical data, which is strong evidence that Denmark's open data program is widely used.

Most users want to follow the OGC standards, which is a great indicator that governmental standardizations are appreciated by the stakeholders.

The final question on thoughts of a nationwide DT, the answers were very clear pro! There were some few comments about concerns for "ruining the market" from private companies that offer similar solutions, but the 3 main feed backs were "Very useful", "Hugely valuable" and "Contribute positively".

3.2.2. Estonia

The survey was translated into Estonian and distributed among organisations that have created or been part of creating digital twins in Estonia. Potential respondents were scouted by Estonian Land Board (NMCA) using existing contacts and knowledge as well as web search and references from other respondents. In total, 6 responses were collected:

- 2 national scale (e-construction DT and maritime DT both by Ministry of Climate)
- 3 municipality scale (Tallinn DT, FinEst Smart Cities Tallinn Greentwin, Tartu University DT for self-driving vehicles)
- 1 micro scale (Hundipea DT)

As the producer of a national-scale digital twin, Estonian Land Board also filled in the survey. Thus, an analysis of responses from 7 organisations is presented in this summary. Responses were translated into English for the analysis.

Most digital twins (DT) are fairly new (start date between 2020-2024) and in ongoing development. Responses collected in this survey indicate that the state was the first to start experimenting with digital twins, as the two earliest DTs are those of the Estonian Land Board and the Ministry of Climate (e-construction DT).

Respondents struggled to define a digital twin. Responses to three yes/no questions reflect a general confusion or disagreement around the nature and conditions of DTs. Just over half of the respondents agree that a DT always has a spatial component and needs to include real time data, while nearly half of the respondents disagree or do not know. The question whether a 3D model is a digital twin seems to evoke least debate, with 5 respondents in agreement that it is not. It is possible that the difference between a 3D model and a DT is related to real time data, which was identified as a crucial DT component by 4 respondents. However, this was not explicitly described in comments.

Correspondingly, answers varied when respondents were asked to classify their project as a digital model, shadow or twin. Despite calling their projects digital twins, only three respondents chose this option when faced with alternatives. Digital model and shadow equally drew two responses. This further proves the confusion around terminology and the need to find a common definition for digital twin.

All surveyed DTs had a thematic scope. Most respondents marked more than one theme for their project. The most common option was built environment, selected by 5 respondents. Other common themes were forest, traffic and environment.

Data used in respondents' DTs mirrored the themes. Most common datasets were related to buildings and infrastructure as well as fundamental data such as orthophotos and lidar point clouds that give spatial context to any thematic analysis.

All respondents reported using existing spatial data for their DTs. The most popular data source is the national mapping agency, shortly followed by the building registry and municipalities. When asked about specific data format or quality requirements for their DTs, respondents are unable to define their needs in detail. Perhaps getting a more precise answer would require someone else from the team to respond or the question was too specific for this questionnaire. Nevertheless, one brings out constraints posed by their choice of software in terms of 3D model import and conversion formats, other claims that specific data formats are irrelevant and highlights the importance of chosen coordinate system instead.

Four respondents out of seven produce their own data for their DTs. These are mostly project-specific data such as plant inventories, traffic lights or maritime objects. Respondents are not keen to describe their efforts in making their DTs interoperable with other projects, platforms or datasets. The most popular choice of action is to use a widely used software/platform. Additionally, respondents indicate producing interoperable data and following common standards. Two respondents, however, claim that their DTs are not intended to be interoperable.

In some cases, DT is seen as a medium for precise analysis or simulations for a specific aspect, e.g. vegetation growth. „The project focuses on trees and grassy plants that are growing in the city, as they are different from those, growing in the countryside in terms of species, growth patterns and grooming." Responses suggested that while a DT may have a focus on one theme, digital twins are also seen as tools for integrating different themes and potentially solving complex problems. One respondent explains: "the direction is to further develop the twin as a spatial analysis and communication tool and to include climate issues relevant to construction."

Respondents were asked to comment what are their thoughts on having a national DT in Estonia. On the downside, one respondent questioned whether a national DT is a priority right now. Another raised concerns about the resources a national digital twin would require and stressed the need for a cost-benefit analysis. Still, most respondents agreed that the national digital twin is needed and useful. „The national digital twin definitely has a value, and different digital twins can build on top of each other. “One respondent even offered to contribute by devising data collection methods for the national DT.

3.2.3. Finland

In Finland there were 21 answers in total to the questionnaire. Most of the answers are from public organizations and from municipalities but also four companies shared their thought by answering the questionnaire.

More than half of the respondents see that a digital twin includes a spatial dimension. One third also sees that a digital twin also includes real time data. Only a few sees that a 3D model is a digital twin. The Finnish respondents described the goals and expected outcomes of their digital twin projects:

- Many projects focus on improving data management and utilizing real-time data.
- Projects often have long-term goals, such as managing transport networks, modeling forests and water bodies, and urban modeling.
- Some projects, like the UrbanAI project in the city of Riihimäki, utilize satellite data and real-time sensor data streams to optimize city management.

The ongoing digital twin projects in Finland focus on various themes. Such as the built environment, water, forests, traffic, environment, and archaeology. To sum up half of the projects deal with built-up environment and the other half mostly on rural data. The geographical scope of the projects ranges from regional to national and cross-border initiatives. One respondent also mentioned a global scope. Most of the projects are regional.

Many projects use existing geospatial data especially National Land Survey's topographic data, elevation models, LiDAR data, orthophotos, and 3D buildings. Some projects also collect new geospatial data for example more detailed Lidar data.

Various methods are used to achieve interoperability. Many projects utilize national or international standards (such as OGC). Some projects produce linked data or use widely known software and platforms.

The expected benefits of the ongoing digital twin projects are diverse. Mostly mentioned benefits were economic, social and environmental. Also, improvements in decision-making, technological advancements, and increased efficiency were often mentioned.

The respondents shared their thoughts on the concept of a national digital twin:

- The general perception is that a national digital twin would be beneficial but challenging to implement, requiring clear planning and resources.
- Some respondents are interested in supporting the development of a national digital twin.

3.2.4. Iceland

In Iceland, a total of 5 responses were gathered from various organizations in Iceland, including public authorities and private entities working on or considering digital twin projects.

The responses provide insight into the current landscape of digital twin initiatives in Iceland and the perspectives on key concepts, goals, and challenges.
The understanding of digital twins among the respondents varied:

- 60% believe a digital twin must have a spatial component, while 40% were unsure or disagreed.
- 40% agreed that a digital twin should include real-time data, though the majority did not see it as essential.
- Most respondents did not see a 3D model as a necessary component of a digital twin.

Several ongoing or planned digital twin projects were described. The goals of these projects generally include:

- Environmental monitoring and weather forecasting, such as the Destination Earth On-Demand Extremes Digital Twin project, which aims to produce high-resolution weather forecasts for areas experiencing extreme events.
- Urban planning and land use management to provide better insights for decision-making.
- Some organizations mentioned that their projects are still in the early planning stages or theoretical discussions.

The digital twin projects in Iceland cover a variety of themes, including:

- Environment (3 responses)
- Built environment, water, and forest (each with 2 responses)
- Traffic (1 response)

In terms of geographical scope, the projects are primarily focused on a national level (3 responses), with one project involving cross-border/international collaboration. One response indicated a broader or unspecified geographical focus.
Most projects utilize existing geospatial data, with frequent references to:

- Satellite data (3 responses)
- Road data, building data, and orthophotos (2 responses each)
- Governmental data, including datasets from Náttúrufræðistofnun and Þjóðskrá (3 responses)

Some respondents mentioned the use of OpenStreetMap and EU data, while others referred to specific needs like altitude data. One project collects new data, although it remains in a theoretical phase.

The technological sophistication of the digital twin projects in Iceland varies:

- Some projects are digital models with manual data flows, while others are digital twins with automatic data exchange between physical and digital objects.

When asked about interoperability:

- National and international standards like OGC were mentioned as a method to ensure compatibility between datasets and systems.
- Other methods include producing location-based information that is interoperable with other datasets and using widely known software platforms.

The expected benefits of digital twin projects are varied and cover a wide range of areas:

- Environmental benefits (mentioned by 4 respondents)
- Economic, societal, and efficiency improvements.
- Some projects aim to influence decision-making and policy development, with an emphasis on leveraging real-time data for improved accuracy in forecasts and management.

When asked about the idea of creating a nationwide digital twin in Iceland, the responses were mixed. While some respondents were optimistic about the potential benefits, others expressed concerns about the country's capacity to implement such a system effectively, citing the need for clear planning and sufficient resources.

3.2.5. Sweden

Sweden got nine responses on the questionnaire: three from academic organisations, one from a private company and five from municipalities.

In general, the academic organisations have many shorter projects, while the private company and the municipalities mainly work with ongoing development.

Examples of ongoing projects in Sweden are:

- Digital Twin Cities Centre – various projects for urban digital twins, mainly for simulations and visualizations, are being developed
- National Digital Twin Hub – development of a national hub for urban digital twins in Sweden
- Digital vision Kista – 3D model with sensor and IoT data for municipalities
- Virtual Gothenburg Lab – a testbed at the municipality
- 3CIM implementation and establishment – implementation and further development of 3D city models in accordance with information models from the 3CIM project. These can serve as the backbone for digital twins
- Data driven digital twin – a" product" from a private consultant
- Ongoing development at three municipalities, mainly to go from 2D GIS to digital twins

Summary of the answers regarding the role of geospatial in DT:

- 56% of the respondents thought that a digital twin always should have a spatial component.
- The most important thematic scope for all respondents were *built environment, environment, traffic* and *water*.
- The geographical scope for 50% of the respondents were city level, 25% regional and 25% cross border/international collaboration.
- *Digital terrain model, point cloud data* and *3D buildings* from municipalities were the most important datasets, but the same types of datasets from the National mapping agency (NMA) were also important together with *ortophotos, topographic data* and *traffic/road data* from municipalities.

There were a variety or thoughts about what role the NMA should have in digital twins and if Sweden should have a national digital twin:

- One respondent wondered why we do not have a national digital twin already,
- another thought it could serve as a platform for analyses and visualization of nationally comprehensive and connected data.
- Another one thought it depends on what is meant by digital twin.
- A national digital twin was also seen as a vision, and that there are lot of benefits just by getting the municipalities to start using data and technology in better way.
- One respondent did not think that a centralized nationwide DT is a good idea, and that it is better to have a distributed model where the responsibility for the different parts is clear

3.3. Lessons learned from the benchmarks

3.3.1. Swisstopo

Swisstopo, the Federal Office of Topography, is Switzerland's geoinformation center. They have been working with basic data in 3D for many years, where they themselves or their users make 2D- or 3D-products from this basic data in 3D.

Swisstopo measures objects how it looks in 3D, not to fit a 2D-map in a specific scale. This was a big culture change for the organization. They store their data in a database, the Topographic

Landscape Model. It contains simple geometries in 3D and has connections to other databases that includes attributes for different purposes.
Trees are collected, stored and provided as a 3D point for the treetop. If the user wants to make a 3D object, it can be created from the tree top and the ground height model (DTM). Buildings are collected, stored and provided as 3D roof surfaces and 2D bottom surfaces. If the user wants to make 3D objects, 3D walls can be created with the roof surfaces, bottom surface and ground elevation model (DTM). 2D-maps are another product that can be derived from the basic data.

The updating of the database is mainly done manually and in a number of sections per year. However, there are some hotspots where changes are detected more frequently and thus, updated in shorter intervals. On average it takes the cartographer one minute to update one building. Some automated/simplified workflows include:

- the use of predefined roof shapes/types
- groups of trees are automatically detected as forest
- updates to the basic data are automatically fed into other databases, e.g. cadaster.

To increases topicality and completeness in their data, Swisstopo uses a "feed-back loop" from users of 3D-data or the 2D-map, which is a type of crowdsourcing.

Swisstopo does not consider the data they collect to be a digital twin, nor do they see themselves as someone running a national digital twin. They see themselves as a data provider and can for example be a data provider for various thematic Digital Twins that are run by others.

Swisstopo also helps users on how to use the basic data in 3D to create their own applications, for example visualization for planning and building permits, noise pollution, and solar energy.

- Swisstopo has developed several use cases, they have used 3D data to understand dynamic natural phenomena. For example, by using the terrain model (DTM) and occurrences of landslides they can simulate dynamic changes in nature which in turn could help to predict potential landslides. suggestions:
    - Do not start your 3D development from scratch, start the development from what you have.
    - Point clouds are precise but stupid as they have no attributes or connections. So do not lose your semantic data. Build connections and networks with metadata.
    - Think ahead about the question of data spaces and data management.
    - Define your role. What services will you be providing? Where do you draw the line?

    - If you want to build a digital twin, start with a small one and in low-resolution.
    - Digital twins should not be a closed system, there are many different concepts.

3.3.2. Singapore Land Authority

Background
Singapore Land Authority is the national mapping agency and oversees national 3D mapping. Singapore, a small city-state between Malaysia and Indonesia, has only 12 SLA staff dedicated to mapping, supported by other agencies and third-party vendors. The separate Planning Authority oversees the master plan of Singapore, and Construction Agency issues building permits. SLA's work is organized into three pillars: Land and Properties, Geospatial, and Regulatory. The National Aerial 3D Mapping Program was launched in 2014, with subsequent captures in 2019 and 2024, forming the foundation of Singapore's digital twin combined with the Mobile mapping done in 2015, 2017 and now in tendering for the next version. This program leverages open standards for interoperability and sharing, aiming for high-resolution, consistent data accessible to various users.
Singapore in numbers:

- Territory: 735 sqm
- Highest point: 164m
- Buildings: 170 000
- Residential dwellings: 1,5 mln
- Land parcels: 146 000
- Trees 7mln

Mapping Techniques and Data Products
Data collection methods include fixed-wing airborne LiDAR, aerial imagery (nadir and oblique), and mobile mapping vehicles, capturing 3D environments for comprehensive data products like classified point clouds, DTM, DSM, orthophotos, and 3D building models. Mobile mapping (using cars) is updated periodically, aiding in high-detail situational data for various government needs, emergency operations and engineers.
Data products are structured to support urban planning, security, resilience, and sustainability applications, with additional tools for solar potential estimation, tree management, and asset mapping. Leveraging OGC CityGML for 3D geometry and with focus on additional semantics. Buildings are LOD2, facades are generated automatically from georeferenced oblique imagery.

Most of the data capture and modelling is outsourced.
- Use Cases and Applications

Government agencies use the digital twin for diverse tasks, including:
- National Safety and Security: Flood risk analysis, airport terrain mapping.
- Planning and Development: Shadow analysis for urban planning, road design.
- Sustainability: Carbon stock estimation, urban heat island mapping.
- Smart Navigation and Innovation: Supporting autonomous vehicles.
- Investigation: Scene reconstruction for road damage and encroachment detection.
- Digital Twin Motivation

Part of the digital government strategy. Cities of tomorrow are powered by DTs – safe, sustainable and smart. Singapore's digital twin is driven by three key goals: Safety (e.g., coastal protection, public safety), Sustainability (urban planning, green energy transition), and Smart Development (mobility, 5G deployment). The SLA's principles emphasize accuracy, consistency, and interoperability to enable seamless data use across agencies.

Going forward SLA will focus on collection the data. Agencies will do the modelling and then can share the results with them.

Development Framework
The digital twin is built on four pillars:
1. Capture**:** Coordinate systems, sensors, and mapping standards.
2. Model: Processing, data standards, and level of detail.
3. Manage: Data governance, database management, and update workflows.
4. Deliver: Product development, visualization, and geodata services.

Data Infrastructure
The digital twin comprises 14 Core Datasets (e.g., geodetic control, land use, 3D models) and 6 Add-on Datasets (e.g., 3D addresses, BIM). These datasets support comprehensive 3D modeling and analysis, offering a shared foundation for government and agency applications.

Core Datasets
Geodetic Control, Orthophoto, Waterbody, Administrative Boundaries, Land Cover/Use, Cadastre, 3D Building Models (LoD0, LoD1, LoD2), 3D Road, Vegetation/Tree cover, 3D Airspace, 3D

Geology, 3D Underground Asset, Point Cloud, 3D Reality Mesh.

Add-on Datasets
Imagery (Satellites, Oblique), Positioning Infrastructure, 3D Address/Unit, BIM, 3D Underground Asset, 3D Geology.

Leveraging AI
AI is applied in privacy masking, auto-labeling, and object detection (e.g., solar panels, fire hydrants). For instance, AI is used in solar panel mapping to estimate capacity and detect infrastructure changes. Challenges in AI include tree obstruction in imagery and the complexity of vectorizing urban data. Mostly focusing on road change detection development at the moment.

Challenges and Gaps
Key gaps include data integration, updating, real-time information, security, privacy, cost, and skills. Singapore's digital twin lacks a centralized update system, relying on third-party updates and other agencies. Future development aims to enhance interagency collaboration, real-time integration, and sensor data inclusion.
Funding – self-funded not centrally. We have some cost sharing schemes with other agencies.

Highlights
Summary: Mostly static DT at the moment. Other authorities use datasets to make their own DT. Hope for BIM.

Update Frequency: No centralized update structure; relies on agencies for interim updates, but no legal basis for it.

Digital Twin Definition: DT is not a single dataset – it is all about integration and scale. One building can also be a DT. Multiple digital twins for different agencies but core datasets are part of many of them.

Underground Mapping: Includes digital underground research using ground-penetrating radar. Trying to make standards that contractors need to comply to for data collection.

Public Engagement: Use by general public is low. Efforts include outreach via Minecraft, inspired by similar initiatives in Helsinki and the Netherlands. Difficulty in users knowing about the datasets and where they come from (to get funding).

SLA's digital twin supports national digitalization goals, enabling public and private sector applications through robust foundational datasets and continued development efforts.

3.3.3. IGN: Digital Twin of France and its territories

Definition
In the French digital twin concept, the "digital twin of a territory" is defined as "*a dynamic virtual replica of the region*". The dynamic virtual replica of the region contains:

- data (2D/3D, georeferenced, topographic, thematic, real-time...)
- visualization and/or interactions (data interaction services, handling, immersive navigation, XR..)
- simulations (modelling natural and social phenomena in response to identified use cases)

This dynamic virtual replica of the region including data, visualization and simulations is to answer complex, cross-thematic questions with the help of:

- Systemic analysis of scenarios to improve public policy management
- Scaling up, overcoming local geographical constraints, pooling resources

- Science and marketplace to facilitate access to knowledge and services

Context and vision
The ambition behind the Digital Twin of France and its territories is to "to build a common technical architecture, open to support the development of a new industry around digital twins of territories".

To achieve the goal the digital twin concept will promote:
- sharing initiatives to enable them to scale up, to exchange with each other (systemic vision)
- sharing knowledge bring about change in practice and tools
- sharing costs of research, development and deployment

There are 3 contexts mentioned (which will be taking part):
- steering public policies (search for optimization and compromise. The need for data, forecasting tools and mediation in the context of climate change)
- data & treatment capacities (in constant growth and progress. Mature information processing and visualization technologies (AI, deep-learning, XR, HPC, etc.))
- stakeholders (working and contributing to public policy and the green transition (public services, industry, start-ups, research, etc.))

On top of the ambitious goal and paths to achieve them there are also complimentary initiatives:
- national research program (a +4 years-research program); *Removing technological barriers by mobilizing a community of researchers. Running a science place.*
- common technical architecture (public/private stakeholders); *Developing an industry. Running a marketplace. Data and business applications.*
- use cases from the call for commons* (Public & private stakeholders); *Identify local initiatives / solutions. Identify needs. Prioritize DT use cases. Select areas for experimentation.*

*The call for commons was open for 5 months. The project received more than 160 answers. The idea was to collect needs and feedback about the Digital Twin of France and its territories. With the help of the call for commons the project also wanted to identify possible solution/service providers (that might use the digital twin in the future) and bring up an ecosystem that would make it possible to scale up the solutions provided/made possible in the DT.

The project
The core team that is running the project is IGN and Cerema and Inria (the two latter governmental research organizations). However, in the consortium there are approx. 15 organizations that include surveying organizations and companies. Other organizations close to the project are different local authorities and different stakeholders that are the probable use case organizations and startups.

The digital twin of a territory will be in close connection to the EDIC Local Digital Twins & CitiVERSE. The project has no funding yet, but IGN representatives were hoping to receive positive news from the governance regarding to the funding in the spring 2025.

Data and technological challenges
The "backbone" of the Digital Twin of France will be Lidar data. The campaign to collect tense Lidar data (10p/m2) from the whole country will end in 2025. In the French digital twin, there is also the idea to add other data sets (such as local city models) to the Digital Twin of France and its territories. Combining different data and different initiatives to the same platform obviously creates lots of challenges when it comes to the integration, interoperability and interconnection of digital twins. This in noted in the project and there will be research on "*how to propose and evaluate standard representation models and methods for datasets, their metadata and their interconnection links"*.
There are also questions regarding the 3D semantic reconstruction of digital twins. In the project they have found that the Digital Twin will "*require the development of new, more robust and flexible 3D modelling algorithms, capable of operating on a national scale with a polymorphic representation"*.

There are also still open issues also about the foundation, openness and use of the Digital Twin and also about the visualization and interaction with digital twins; how to "*find effective ways of understanding, analyzing and manipulating the data associated with territories?*"

3.3.4. Digital Twin Cookbook

Jack Metcalfe from University College London is doing research and his PhD about digital twins. Along the PhD Metcalfe is also writing a “Digital Twin cookbook” which is a project sponsored by the EuroSDR.

In Metcalfe’s research he has spotted some research gaps when it comes to understanding Digital Twins. In his research he is trying to “fill the gaps” such as:

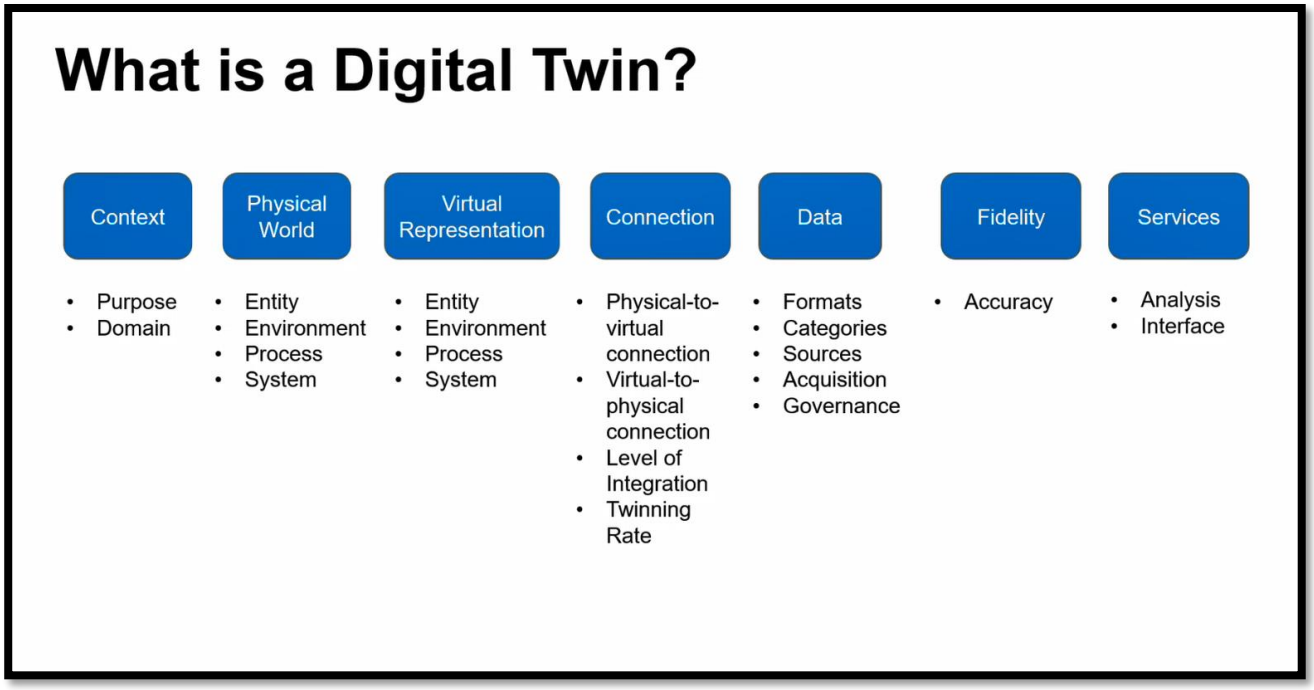
- The concept of DT
  - what are the geospatial characteristics of DTs?
- The value of DTs
  - what and how do NMA contributions affect the overall value of DTs?
- Connected DTs and National DTs
  - what is the role of NMA in connected and/or National DTs?
- The value of geospatial
  - how can the value of geospatial be expressed and/or quantified?

We can see that the questions and research gaps that Metcalfe is researching are quite the same as the crucial questions for the ad hoc group in the first place. Metcalfe also points that “there is currently a poor understanding of the role of NMAs in DTs”.

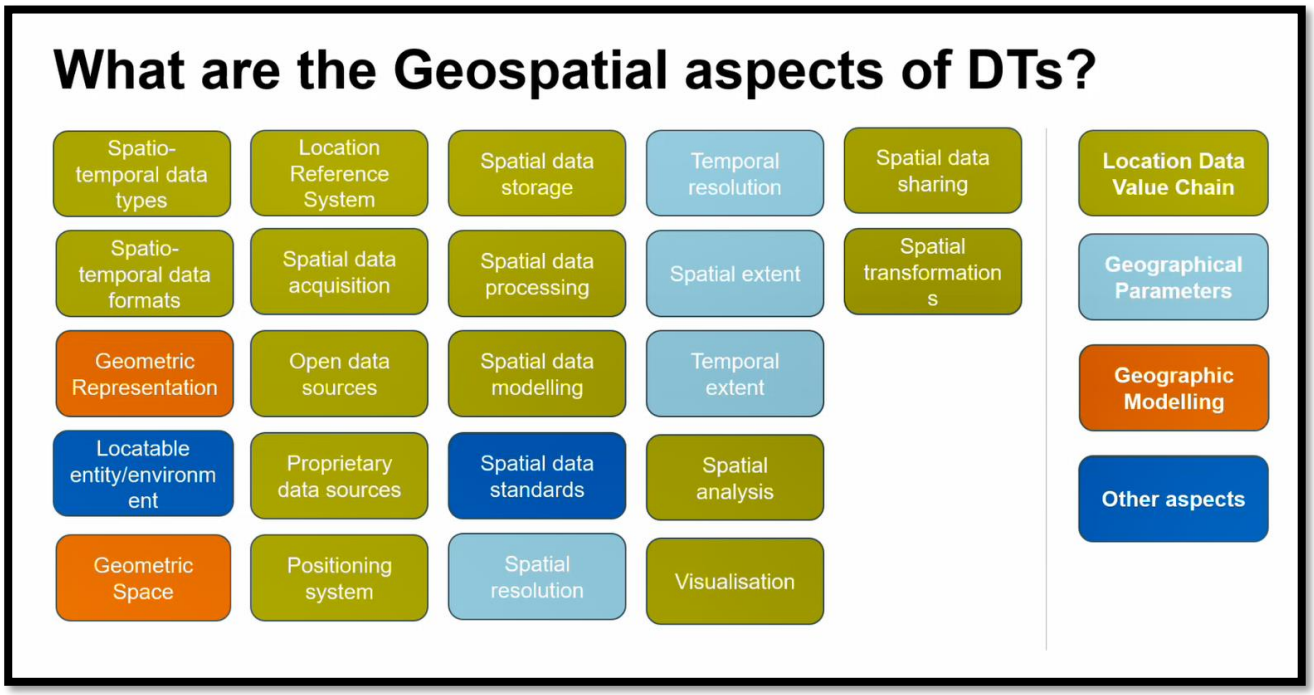
So far there is already an article published with title “Characterizing the role of Geospatial Science in Digital Twins” (International Journal of Geo-Information, 2024, Volume 13, Issue 9) that is trying to tackle questions about the DT concept and about the role of geospatial in DTs.

In his research Metcalfe is describing the building blocks of DT as shown in the picture 1. In picture 2 there are outcomes from a literature review made by Metcalfe (about already implemented DT initiatives and projects) and about the role of geospatial in them.

In addition to the PhD there will also be a Digital Twin Cookbook available in a few years’ time. The idea is to publish “a practical guide for NMAs to better understand how to engage with, and contribute to, DTs including tried and tested guidance and recommendations”. In the benchmark meeting it was agreed that it will be fruitful to follow the work and research made by Jack Metcalfe in the future for all the NMAs present in the ad hoc group. But also the work made by the ad hoc group will be useful for the Digital Twin cookbook project and for the PhD work as well.



Picture 1. Wat is a Digital Twin? Picture by Jack Metcalfe in his presentation for the ad hoc group 10.3.2025.



Picture 2. The role of geospatial in different DT implementations by Jack Metcalfe in his presentation for the ad hoc group 10.3.2025.

4. Discussion

During the work of the ad hoc group EuroSDR held a workshop “State-of-the-art 3D Mapping at national and regional mapping agencies” (22-23.1.2025). Many of the ad hoc group members also joined the workshop. The outcomes and “take aways” were discussed together in the ad hoc group meeting later on.

As one of the outcomes from the workshop it seems that digital twin is a hot topic all over Europe and also in EuroSDR. There is a wider need for future knowledge exchange on these issues as everyone has the same kind of a questions and challenges. Such as what are the most relevant use cases for 3D data and digital twins and what could or should be the role for NMAs in this development.

In the EuroSDR workshop most relevant questions (with no precise answers yet) were about topics such as:

- How to define a (nationwide) digital twin?
- An NMA data based digital twin should be an open platform to benefit the whole society (if NMA does not do that then there might be "closed" DTs for certain purposes like banking or insurance)
- Development of digital twins pushes NMAs out from the comfort zone (new topics, new things to learn) - new parties to join up with that might not have a geospatial background. All this is outside NMA's traditional domain.
- Base model - digital twin? How "deep should NMAs dive"? To develop analysis tools? Visualization tools? History-future data?
- What about a European level DT? Data spaces? Destination Earth/Global DT? Interoperability issues? Funding (EU-level - for example "rural digital twins").
- How to test new DT/data/solutions between different countries?

In the EuroSDR workshop there was lot of interest to our ad hoc groups work. We also learned in the workshop that there is a PhD coming with the title "Digital twin cookbook". The ad hoc booked a benchmark meeting with the PhD student and EuroSDR representatives involved in this work (please see previous section 3.3.4).

4.1. What is the role of geospatial data in the digital twin concept(s) within different data ecosystems?

4.1.1. Estonia

Respondents are divided on the question about spatial component, suggesting that perhaps it should not be a mandatory requirement when defining a DT. Nevertheless, spatial data has a role in digital twins. Similarly to 2D maps, DTs give users an understanding about the interconnections between places by allowing the analysis of several locations and datasets within one medium.

4.1.2. Finland

The role of spatial data in different digital twin concepts depends on the "origin" and also the scope of the digital twin. If the concept is very specific and/or covers only a small (geographical) area the role of spatial data seems to have less relevance (according to the answers to the questionnaire). However, "spatial" has a role in each of the digital twin concept - if the DT covers a large area or represents objects that might be situated for example nationwide (such as forests or rivers) the (nationwide) spatial data is crucial. In many of the DT concepts new spatial data will also be collected and/or generated.

4.1.3. Iceland

The spatial component is crucial to answer the question "where" in a digital twin, this seems to be clear also to all respondent of the survey. The 3D aspect of a digital twin seems a little less clear, maybe due to the fact that such geospatial datasets are still mostly missing in Iceland.

Interoperability has been mostly mentioned and is a crucial part of a digital twin and accessibility to it.

4.1.4. Sweden

The role of geodata is to directly or indirectly keep track of the positions of various features (for example object, process or system) on the globe.

4.2. What is the role of NMAs in (nationwide) digital twin concept(s)?

4.2.1. Iceland

The main role of NMA in digital twins should allow to answer the question where at a national scale, whenever a simulation is made with a digital twin or data is stored in the digital twin. A connection to a geographical location is the crucial role of NMA. Multiple organisations need to come together to build a digital twin, at least in Iceland, as it should be a shared digitalization effort, and the NMA might likely be the best authority to lead such endeavor or at least provide the crucial geolocation part of a DT. As of today, it is likely that Iceland, with its few inhabitants would prefer a Nordic or European Digital Twin attempt in order to share and dilute the digital burden of building such tool. It could come in form of a toolbox from EU, where simply data could be connected to, allowing then the processing and simulation units of a digital twin are developed internationally. Leaving to the country more the data formatting and connection part, while leaving the tool and simulation development to an international authority, for a more efficient cost relief for taxpayers.

4.2.2. Sweden

The definition of a digital twin using geodata does not differ from any other digital twins. Digital twins can use different types of data depending on their purpose.
A digital twin is a digital copy of an object, process or system in the physical world. The digital twin is driven by a purpose and creates added value. With the help of a digital twin, three questions can be answered:

- How is the physical twin doing today? (Analysis)
- What might the physical twin look like tomorrow? (Prediction)
- What did the physical twin look like yesterday? (History)

A nationwide digital twin can be described as a network of digital twins that is based on some form of common specification and are based on data from different areas within a country. Added value can be created when different actors within a country have access to a selection of each other's data. A nationwide digital twin may need a framework to ensure secure data sharing and efficiency, as well as a group that coordinates the participating actors.
An ecosystem of digital twins is similar to a nationwide digital, but it does not have to be nationwide or based on common specifications.

4.3. The different views of the role of the NMA’s regarding to the DT conceptualization (and of a nationwide DT)?

4.3.1. Estonia

The survey results confirm the importance of NMCAs as data providers for other DT developers. Of all the possible data sources, Estonian Land Board (NMCA) scored the highest among respondents. With their infrastructure, expertise and established processes for data collection and management NMCAs could be the frontrunners in the creation of DTs. In reality, they are often refrained to the

role of data providers. In 2025 Estonian Land Board underwent a major restructuring and became a part of the new Maru (Estonian Land and Spatial Development Board). The new organization aspires to be more than a data provider, rather a competence center for spatial data and planning. Thus, if a national DT were to be developed and managed, the role would naturally fall to the NMCA.

4.3.2. Finland

The role of the NMA data (spatial and positioning data) could and also should be to act as a "gloom" to ensure the interoperability between all the digital twins that are created (in Finland for example digital twin of forests and different digital twins of cities). The NMA's provide important spatial data for object or phenomenon specific DTs. NMA can also produce data that can ensure the continuity of data to make it possible to run analyses nationwide - for example by producing nationwide coverage of 3D buildings for areas where municipalities/cities do not produce their own DTs.

4.3.3. Sweden

Lantmäteriet is primarily a data provider. At present Lantmäteriet will not take on the task to be responsible for handling the coordination of a nationwide digital twin but will carefully follow the development of digital twins. Lantmäteriet's role should primarily be to coordinate the provision of basic public geodata for various areas of use, including for digital twins. This means that Lantmäteriet both should coordinate the data provision of other public actors' geodata and manage and develop data provision within Lantmäteriet's area of responsibility. Lantmäteriet will also successively develop collection, storage and provision to better suit the needs of the future.

There is no national digital twin in Sweden today. Everyone makes their own digital twins based on their needs. Lantmäteriet wants to be part of an ecosystem of national data provided by different authorities. Different digital twins with different purposes should then be able to use this data. There should be a federation that users must be part of in order to use the information, but no such federation exists today.

4.4. What next / next steps / suggestions for NMAs

4.4.1. Estonia

- Knowledge sharing needs to continue (e.g. trees)
- Trans-border projects could be interesting (testing the integration of neighboring countries' DTs)
- A common European DT? Look into ESA Destination Earth and integrations.

4.4.2. Finland

Finland also sees that it would be useful to continue knowledge change and look into possible co-operation possibilities for example to ensure cross border interoperability in the future.

4.4.3. Iceland

Next steps should be a common EU DT discussion, focus on dataset building and providing, share the knowledge and allow for trans border dataset harmonization.

4.4.4. Sweden

Sweden thinks that continuing with the knowledge sharing is a good idea. It is a bit too early to participate in trans-border projects before we know how the situation in our countries will evolve. But it could still be interesting to learn more about existing trans-border projects, for example by inviting them to give presentations.

5. Annexes

5.1. Annex 1. The concept note.

Concept Note – Digital Twins and Geospatial data in Ecosystems

The crucial questions:

- What is the role of geospatial data in the digital twin concept(s) within different data ecosystems?
- What is the role of NMAs in (nationwide) digital twin concept(s)?

Background

According to EuroSDR Workshop 2022 [1]: "The concept of a Digital Twin (DT) originates from industry and manufacturing. In the geospatial domain, the concept has been gaining significant momentum since it was introduced in 2012 Despite the frequent use of the term, there is no common definition in use and, consequently, the term is used in different ways: digital representation of the physical environment including its dynamic processes, as a digital replica of an asset in a BIM context, as a 3D city or landscape model, as a geospatial information infrastructure, etc."

In the EuroSDR WS 2022 it is also mentioned that: "Even though a single definition of a DT in the geospatial domain is lacking, there is consensus that it should be based on 3D city models, containing objects with geometric and semantic information; contain real-time sensor data; integrate a variety of analyses and simulations to be able to make the best design, planning and intervention decisions".

Today it is common to use DT for simple tasks, for example in municipalities for planning and visualization internally and for citizens. However, the DT concept has started gaining more interest also in such data ecosystems that are dealing with solutions outside urban areas (such as forestry).

The DT concept can have a significant role in solving and preparing to handle many complex problems and challenges our societies are facing. These are often referred as wicked problems – such as climate change and the loss of biodiversity. The DT concept can offer us a risk-free space where to test different kind of solutions before implementing them in the real world. Different 3D data sets (such as Lidar data) offer the possibility to simulate and analyze different phenomenon in a more realistic way than before. 3D data also gives the possibility to visualize different solutions and options to help us to choose the best solution and make the most effective and data driven decisions.

The DT concept is already widely used in many domains in the Nordic countries. In many of those DT plans or implementations, geospatial data provided by NMAs plays a significant role. DT's often uses geospatial and other data within a single data ecosystem. For example, a DT of fresh waters in Finland (https://www.freshwatercompetencecentre.com/digital-twin/). The DT concept therefore taggles with the same questions as before – such as what the role of geospatial data (and NMAs' geospatial data) in different data ecosystems is, and how to solve the data interoperability issues.

In some European countries there are also programs and plans to implement a nationwide digital twin to support multiple data ecosystems' use cases. These discussions are also present in the Nordic countries. What might still be unclear is what kind of a role NMA's can or should have when it comes to the rising amount of different DT concepts in each country, what is the role of the geospatial data provided by NMA's in these different DT's and what kind of plans are there in the Nordic/Baltic countries when it comes to the concept of a nationwide DT?

Scope of the ad hoc group

The scope of the ad hoc group is to facilitate discussion and share knowledge between the participating NMA's. The ad hoc group provides different views of the DT concept and the role of NMA's in that concept and gives a platform to widen the (common) understanding on these issues.

- What kind of a DT concepts there are in the Nordic countries?
    - What is the role of geospatial in these DT concepts?
    - What is the role of NMA in these DT concepts?

- Develop a common preliminary definition of a DT, a DT using geodata and a Nationwide DT using geodata etc.
    - what new requirements (and data quality issues) there is/will be for geospatial data (to set up DT implementations)
    - how to get funding for DT implementations / to make DTs available

- Is there a plan to establish a nationwide digital twin?
    - If so, what is the role of the NMA?
    - Is there a common understanding / policy backing these plans?

- How NMA's see their role and the most important tasks to facilitate the usage of (NMA's) geospatial data in DT concepts of different data ecosystems and/or the nationwide DT?

Time frame and roadmap

The ad hoc group will handle and define the scope of the group as well as the different tasks and expected outcomes in online meeting in January 2024 (16.1 and 30.1.2024).

The work will involve several meetings and inquiry work to be done in the participating counties between the meetings (such as gathering information on the different DT concepts in different countries etc.).
The ad hoc group will also have online meetings to benchmark other European countries NMA's and equivalent organisations that are already implementing nationwide DT programs (such as IGN France, The National Digital Twin Program (NDTP) UK [2], ...)

The final concept paper will be presented in the Lilla Chefsmöte March 2024.
The preliminary outcomes can be presented in the Stora Chefsmöte (autumn 2024).

The outcome (final paper) will for example consist of:

- the different DT concepts that have already been implemented in participating countries.
- a common preliminary definition of a DT, ecosystems of DT, a DT using geodata, a Nationwide DT etc.
- the different views of the role of the NMA's regarding to the DT conceptualization (and of a nationwide DT)
- benchmarks from other European countries
- discussion on the common issues and questions that need to be solved.

References:

[1]. https://www.eurosdr.net/workshops/digital-twins-nmcas
[2]. https://digitaltwinhub.co.uk/ndtp/

5.2. Annex 2. The results and statistics of the answers to the questionnaire.

5.2.1. Denmark

Digital Twin Development in Denmark

Results of the questionnaire answers

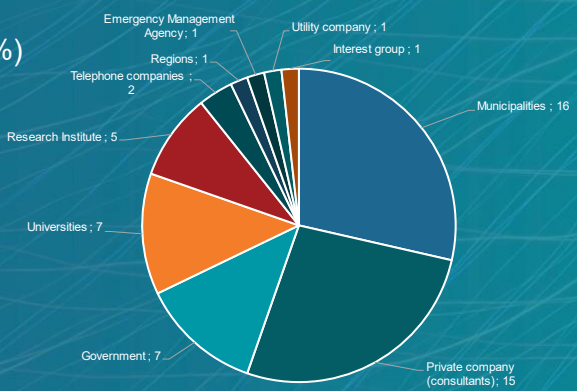
Agency for Climate Data

Participants

301 were invited to participate
137 started the questionnaire
79 answered that they work with digital twins (58%)
(mandatory to access the questionnaire)

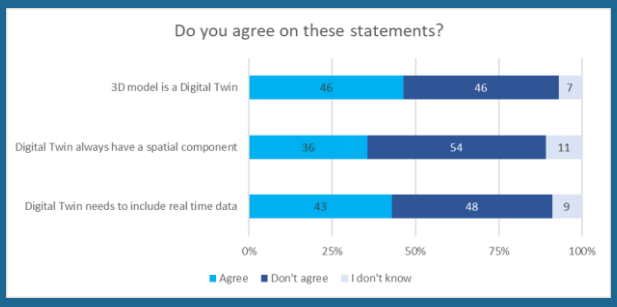
56 answered at least the first question

Of these 56 answers, there were participants from all sectors:



Agency for Climate Data

Question 1: Definition of Digital Twin

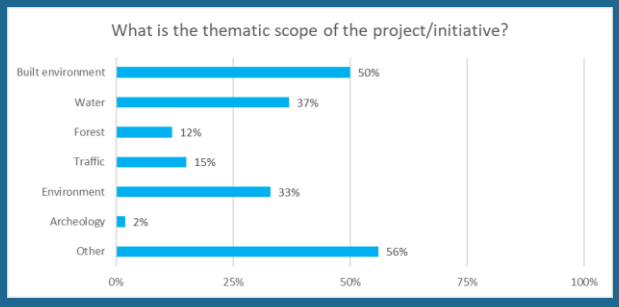


Question 2: A brief description of your Digital Twin project/initiative

Most frequent answers:

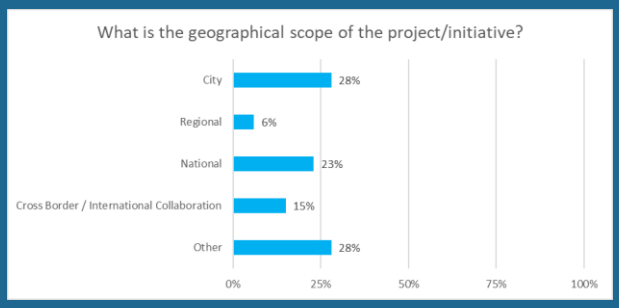
- The **city** (city planning, smart cities)
- The **landscape**, incl. tree model, renewable energy facilities (solar cells or wind turbines)
- **Ocean and atmosphere** (incl. weather forecast)
- **Logistics** (Ship navigation, traffic planning, road models)
- **Green transition** (energy consumption, surface water, CO_2 capture plant)
- Special **analyzes** (air pollution, antenna locations)
- **Simulations** (lighting installations, ventilation system, heating system, production system, food production)

Question 5: What is the thematic scope of the project/initiative?



Other:
Energy, weather, hydrology, production systems

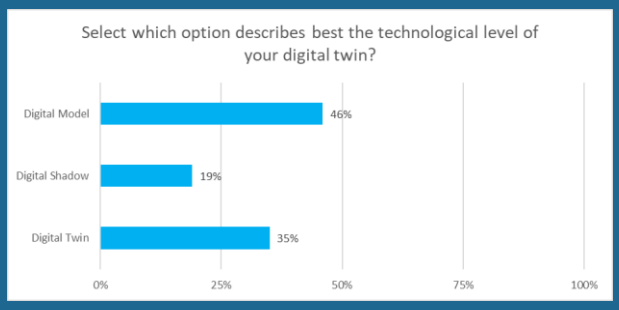
Question 6: What is the geographical scope of the project/initiative?



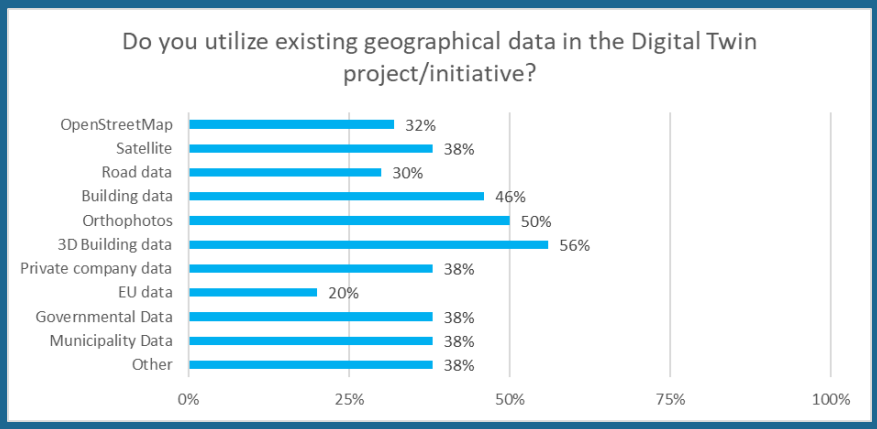
Other:
Municipality, borough, one building, one machine

Question 7: Select which option describes best the technological level of your digital twin?

	Data flow from physical object to digital object	Data flow from digital object to physical object
Digital Model	Manual	Manual
Digital Shadow	Automatic	Manual
Digital Twin	Automatic	Automatic



Question 8: Do you utilize existing geographical data in the Digital Twin project/initiative?

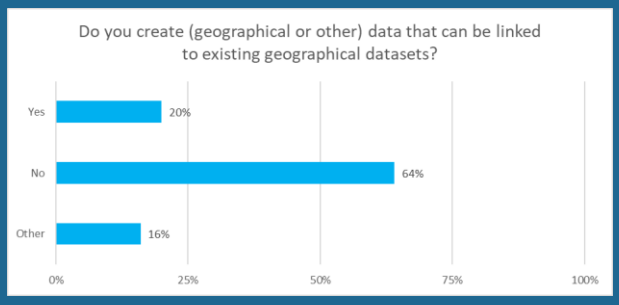


Question 9: Feel free to specify which geographical data used, this might help to improve the datasets or availability.

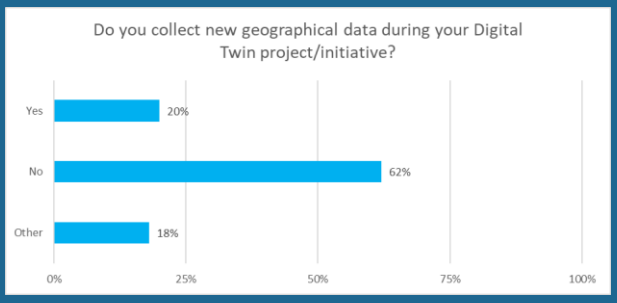
Most frequent answers:

- Digital elevation model
- Building footprints
- Orthophoto
- Addresses
- Other public registers/data (Building info, cadastres, trees)
- Sea data (sea level, water temperature, sediment particles, water depths, tides)
- Weather data
- Consumption data (water and heat consumption)

Question 12: Do you create (geographical or other) data that can be linked to existing geographical datasets?



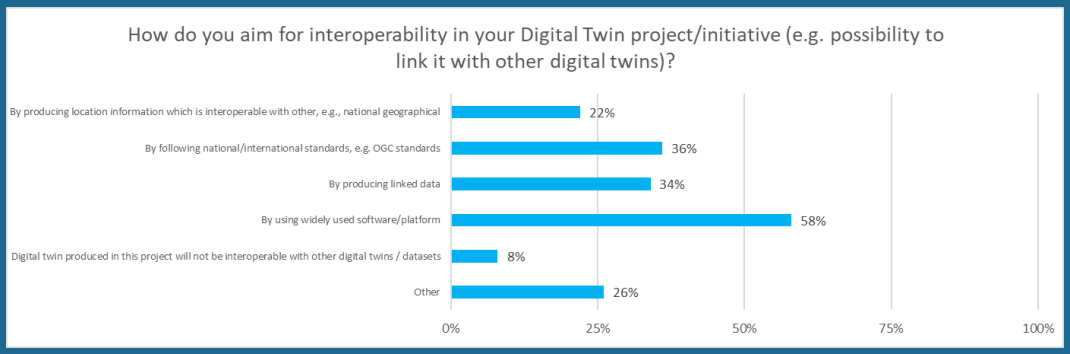
Question 13+14: Do you collect new geographical data during your Digital Twin project/initiative? If yes, what kind of data do you collect for your Digital Twin?



Most frequent answers:

- Drone surveying
- Real-time data (water level, mobility data)
- Enrichment (land use, degree of perviousness, surface material)
- Elevation model (terrain changes due to construction work, hydrological adaptations (tunnels, pipes))

Question 16: How do you aim for interoperability in your Digital Twin project/initiative (e.g. possibility to link it with other digital twins)?



Question 17: Please elaborate your answer about interoperability. E.g. which standards are followed? Which software is used?

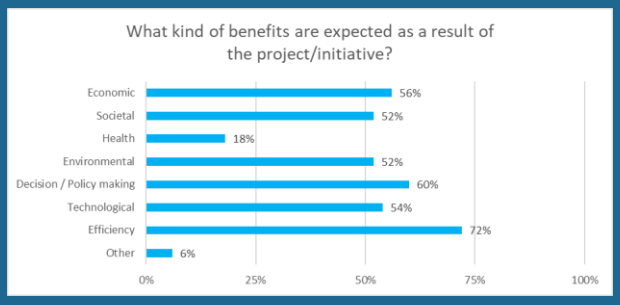
Most used standard:

- **OGC**
- .skp
- .dwg
- .shp
- The DestinE Data Lake
- WMO
- CityGML
- Rest API

Most used software:

- Web browser
- OpenCities Planner
- SketchUp
- QGIS
- Bentley products
- DHI
- Own software/code

Question 18+19: What kind of benefits are expected as a result of the project/initiative? Please, elaborate you answer about expected benefits:



Most frequent answers:

- Efficiency of workflows
- Better political decision -making processes
- Citizen involvement
- Increased security/warnings
- Environment/climate improvements
- Reduce energy/fuel consumption

Question 20: What are your thoughts on having a national (nation wide) Digital Twin in your own country?

5.2.2. Estonia

The survey was translated into Estonian and distributed among organisations that have created or been part of creating digital twins in Estonia. Potential respondents were scouted by Estonian Land Board using existing contacts and knowledge as well as web search and references from other respondents. In total, 6 responses were collected:

- 2 national scale (e-construction DT and maritime DT both by Ministry of Climate)
- 3 municipality scale (Tallinn DT, FinEst Smart Cities Tallinn Greentwin, Tartu University DT for self-driving vehicles)
- 1 micro scale (Hundipea DT)

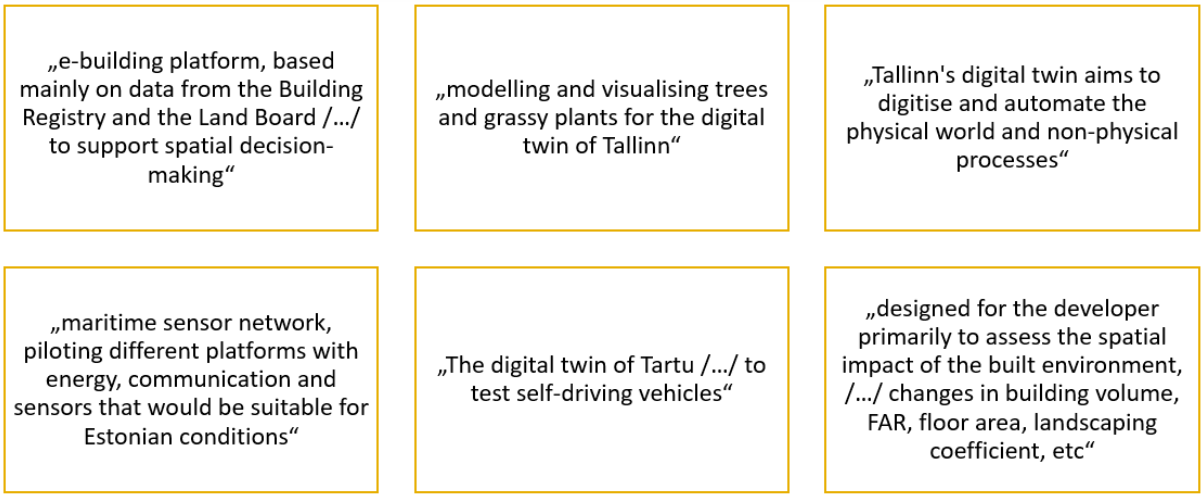
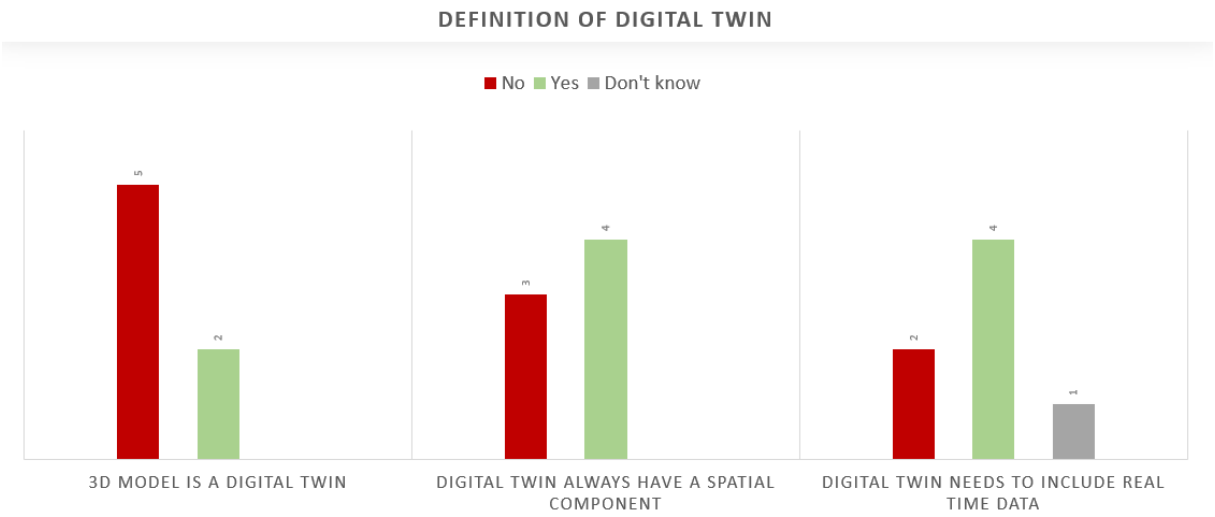


Figure 1 Brief descriptions of the respondents' DTs

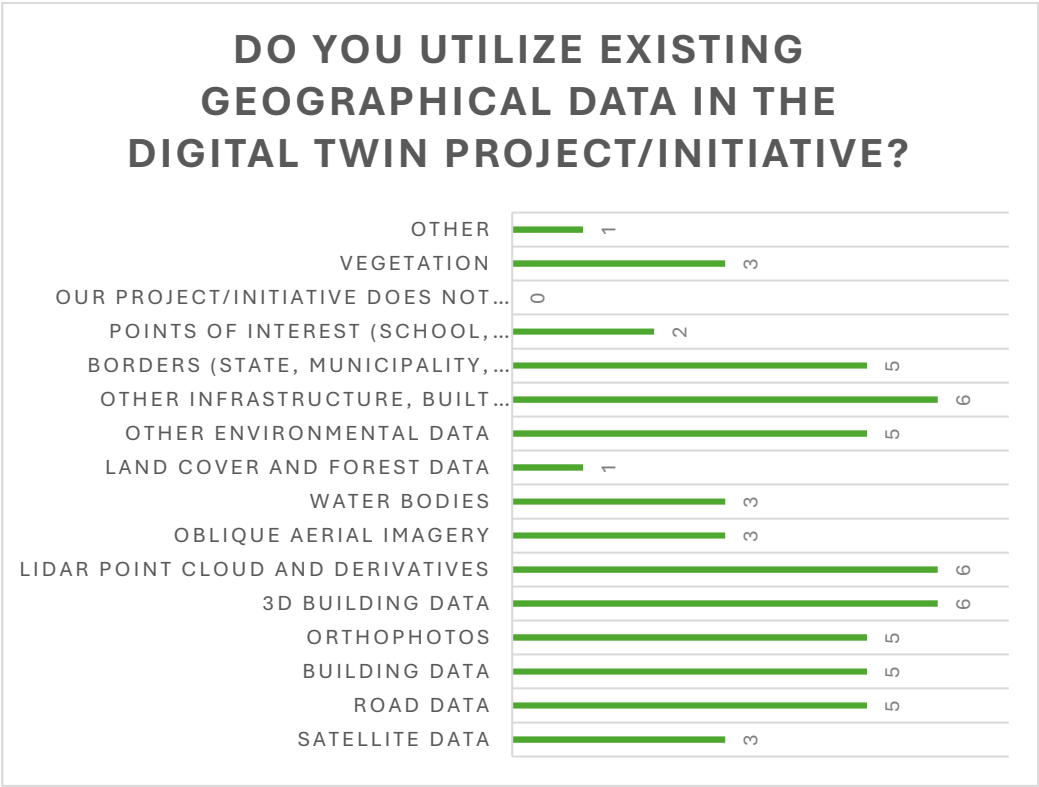
As the producer of a national-scale digital twin, Estonian Land Board also filled in the survey. Thus, an analysis of responses from 7 organisations is presented in this summary. Responses were translated into English for the analysis.
Most digital twins (DT) are fairly new (start date between 2020-2024) and in ongoing development. Responses collected in this survey indicate that the state was the first to start experimenting with digital twins, as the two earliest DTs are those of the Estonian Land Board and the Ministry of Climate (e-construction DT).

Respondents struggled to define a digital twin. Responses to three yes/no questions reflect a general confusion or disagreement around the nature and conditions of DTs. Just over half of the respondents agree that a DT always has a spatial component and needs to include real time data, while nearly half of the respondents disagree or do not know. The question whether a 3D model is a digital twin seems to evoke least debate, with 5 respondents in agreement that it is not. It is possible that the difference between a 3D model and a DT is related to real time data, which was identified as a crucial DT component by 4 respondents. However, this was not explicitly described in comments.

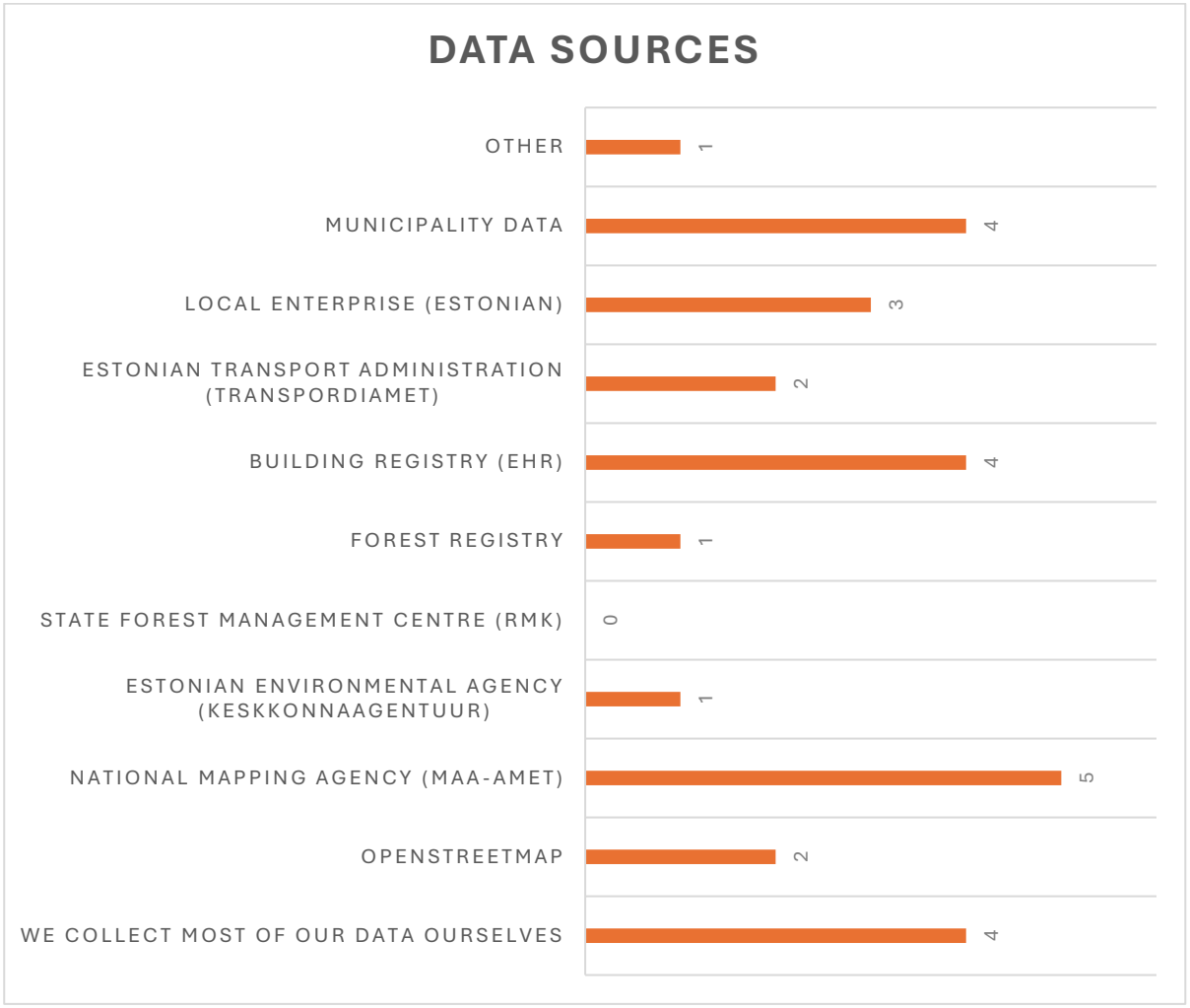


Correspondingly, answers varied when respondents were asked to classify their project as a digital model, shadow or twin. Despite calling their projects digital twins, only three respondents chose this option when faced with alternatives. Digital model and shadow equally drew two responses. This further proves the confusion around terminology and the need to find a common definition for digital twin.

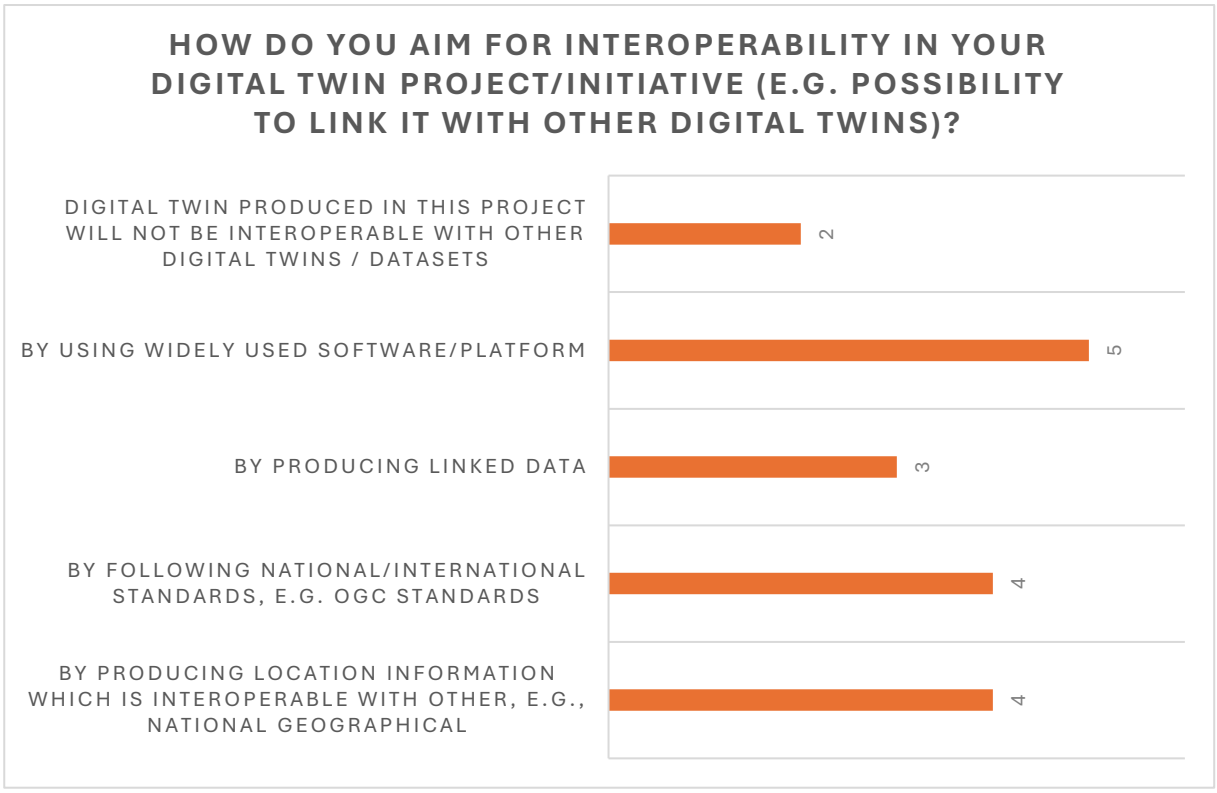
All surveyed DTs had a thematic scope. Most respondents marked more than one theme for their project. The most common option was built environment, selected by 5 respondents. Other common themes were forest, traffic and environment.
Data used in respondents' DTs mirrored the themes. Most common datasets were related to buildings and infrastructure as well as fundamental data such as orthophotos and lidar point clouds that give spatial context to any thematic analysis.



All respondents reported using existing spatial data for their DTs. The most popular data source is the national mapping agency (Estonian Land Board in the case of Estonia) shortly followed by the building registry and municipalities. When asked about specific data format or quality requirements for their DTs, respondents are unable to define their needs in detail. Perhaps getting a more precise answer would require someone else from the team to respond or the question was too specific for this questionnaire. Nevertheless, one brings out constraints posed by their choice of software in terms of 3D model import and conversion formats, other claims that specific data formats are irrelevant and highlights the importance of chosen coordinate system instead.



Four respondents out of seven produce their own data for their DTs. These are mostly project-specific data such as plant inventories, traffic lights or maritime objects. Respondents are not keen to describe their efforts in making their DSs interoperable with other projects, platforms or datasets. The most popular choice of action is to use a widely used software/platform. Additionally, respondents indicate producing interoperable data and following common standards. Two respondents, however, claim that their DTs are not intended to be interoperable.



In some cases, DT is seen as a medium for precise analysis or simulations for a specific aspect, e.g. vegetation growth. „The project focuses on trees and grassy plants that are growing in the city, as they are different from those, growing in the countryside in terms of species, growth patterns and grooming.“ Responses suggested that while a DT may have a focus on one theme, digital twins are also seen as tools for integrating different themes and potentially solving complex problems. One respondent explains: “the direction is to further develop the twin as a spatial analysis and communication tool and to include climate issues relevant to construction.”

Respondents were asked to comment what are their thoughts on having a national DT in Estonia. On the downside, one respondent questioned whether a national DT is a priority right now. Another raised concerns about the resources a national digital twin would require and stressed the need for a cost-benefit analysis. Still, most respondents agreed that the national digital twin is needed and useful. „The national digital twin definitely has a value, and different digital twins can build on top of each other. “One respondent even offered to contribute by devising data collection methods for the national DT.

Questions for the NMCA

- **What is the role of geospatial in these DT concepts?**

  Respondents are divided on the question about spatial component, suggesting that perhaps it should not be a mandatory requirement when defining a DT. Nevertheless, spatial data has a role in digital twins. Similarly to 2D maps, DTs give users an understanding about the interconnections between places by allowing the analysis of several locations and datasets within one medium.
- **What is the role of NMA in these DT concepts?**

  The survey results confirm the importance of NMCAs as data providers for other DT developers. Of all the possible data sources, Estonian Land Board (NMCA) scored the highest among respondents. With their infrastructure, expertise and established processes for data collection and management NMCAs could be the frontrunners in the creation of

DTs. In reality, they are often refrained to the role of data providers. In 2024-2025 Estonian Land Board is undergoing a major restructuring and will become a part of the new **Maru**. The new organization aspires to be more than a data provider, rather a competence center for spatial data and planning. Thus, if a national DT were to be developed and managed, the role would naturally fall to the NMCA.

- **Is there a plan to establish a nationwide digital twin? If so, what is the role of the NMA?**

  In Estonia, there are already two digital twins with national coverage – the Estonian Land Board DT and Ministry of Climate e-construction DT. The departments in charge of these two DTs will be merged into one organization from 2025. Therefore, plans for merging the two DTs are also underway, paving the way for a singular and more holistic national DT. Furthermore, the primary data collection devices (cameras and lidar) have been renewed in 2024. This enables to increase data quality and experiment with new products (e.g. mesh) and processes, potentially reflected in the DT as well.
  Iti s clear that a national DT cannot meet the needs of municipalities and other DT producers in need of very detailed local data. A national DT with such level of detail would be unnecessarily resource-exhaustive to create and maintain. However, NMCAs produce data with a national coverage that meets international standards for quality and interoperability. A national DT should therefore rather serve as a solid and trustworthy foundation to other more detailed DTs.

5.2.3. Finland

Questionnaire about Digital Twins in Finland

Number of answers = 21, an overall summary:

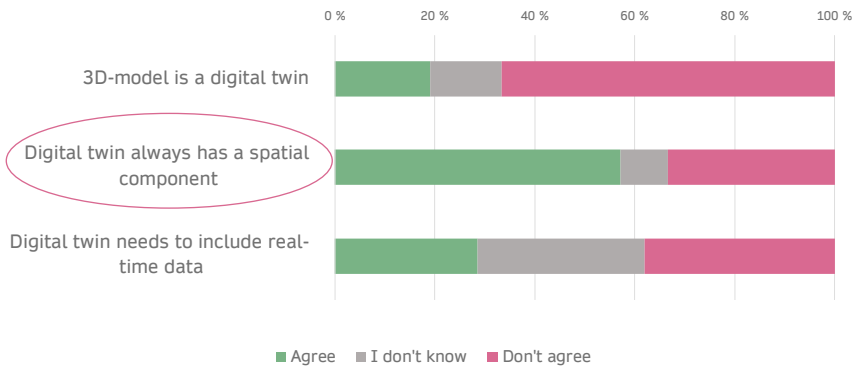
Based on the responses, creating a national **digital twin for Finland could provide significant benefits**, particularly in supporting decision-making, interoperability, and open data.

However, its implementation would **require careful planning**, realistic goals, clear use cases, national coordination, and consideration of costs and data security issues.

It is essential to start with a thorough **needs analysis and a pilot phase** to ensure that a national digital twin is relevant and provides real added value for all stakeholders.

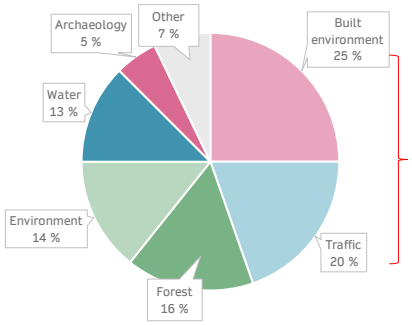
Digital Twin Definition

”What is your opinion about these statements?”



21 answers in total

Thematic Scope

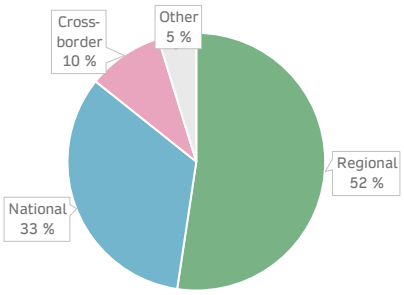


50/50 built infra/non-built areas

19 answers in total

Other:
- Land use plans
- Elevation
- Climate
- Biodiversity
- City ”bustle” analysis

Geographical Scope



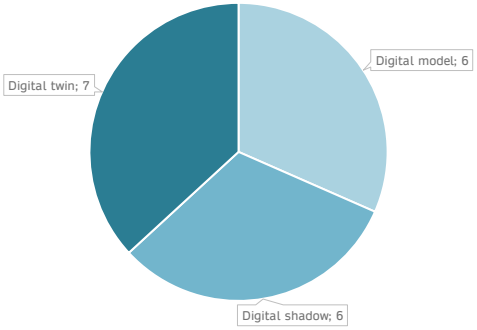
18 answers in total

Which option best describes the technological level of your Digital Twin project/initiative?

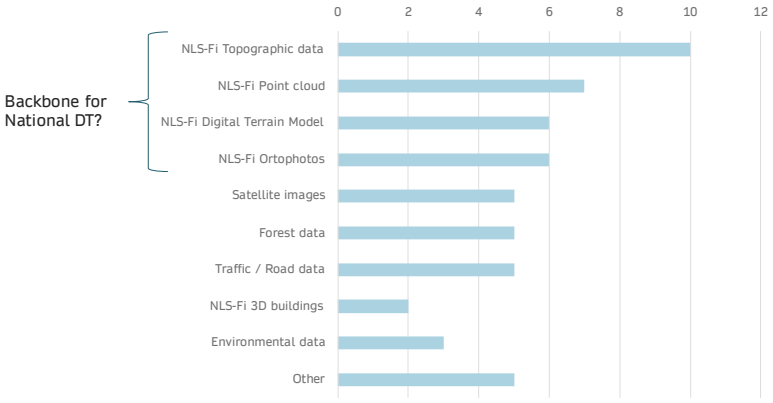
Table 1. Differences in data integration across Digital Model, Digital Shadow and Digital Twin (based on [2])

	Data flow from physical object to digital object	Data flow from digital object to physical object
Digital Model	Manual	Manual
Digital Shadow	Automatic	Manual
Digital Twin	Automatic	Automatic

Source:
https://www.sciencedirect.com/science/article/pii/S2212827119302525?via%3Dihub



Usage of existing data sources

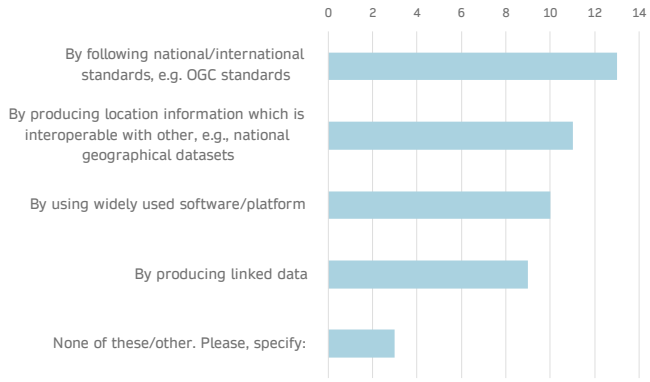


15 answers in total

Other:
- Drone data
- Sensor / measurement data
- Mobile data
- Registers
- More accurate GIS data (cities)
- Data produced by other governmental organisations

Reasons for NOT using existing data:
- Need for more accurate data especially in local level
- Spatial dimension is not relevant for certain projects

Interoperability



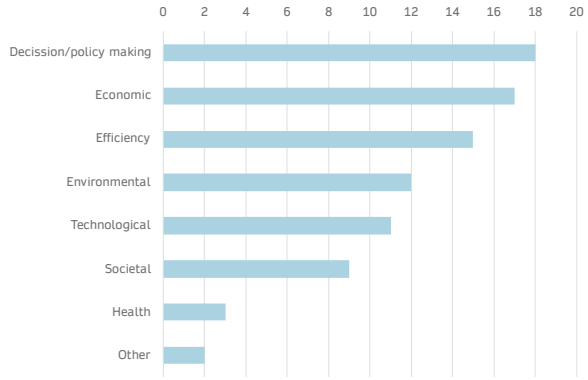
18 answers in total

Several standards mentioned in open responses

WMS, WFS, 3DTiles, I3S, GeoJSON, GeoTIFF, CityGML. CityJSON, LAS, LAZ, OBJ; DAE, glTF, FBX, OGC API Features, IFC 4.3, 3DCityDB

→ No common understanding what standards should be used when dealing with digital twins?

Expected benefits



18 answers in total

Some thoughts about expected benefits:

- More efficiency and economic benefits enabled by **data driven management, higher level of digitalization and automatized data flows**
- **Opennes and quality** of decission making
- **Visualization** possibilities
- Management and development of building/planning projects in order to achieve **better built up environment**
- Achieving **climate goals**
- Plans and decissions related to **forests,** even **possibilities to replace on-site visits** when planning the transportation of wood

Some opinions about National DT

1. **Challenges**
   - Concept is difficult and it is challenging to implement and keep up-to date with current resources and technologies. It would be wise to enhance digitalization and build technological base first in order to enable the DT development in future.
   - Local actors demand more accuracy than national DT could offer

2. **Possibilities**:
   - Useful concept that could save resources and enable more efficient usage of national and local data assets, e.g., when enabling the development of new services and products.
   - National DT would be a welcome addition to the digital twin of Earth

3. **Cooperation and interoperability**:
   - Digital twin cannot be built without collaboration
   - Commonly agreed standards and metadata needed for interoperability

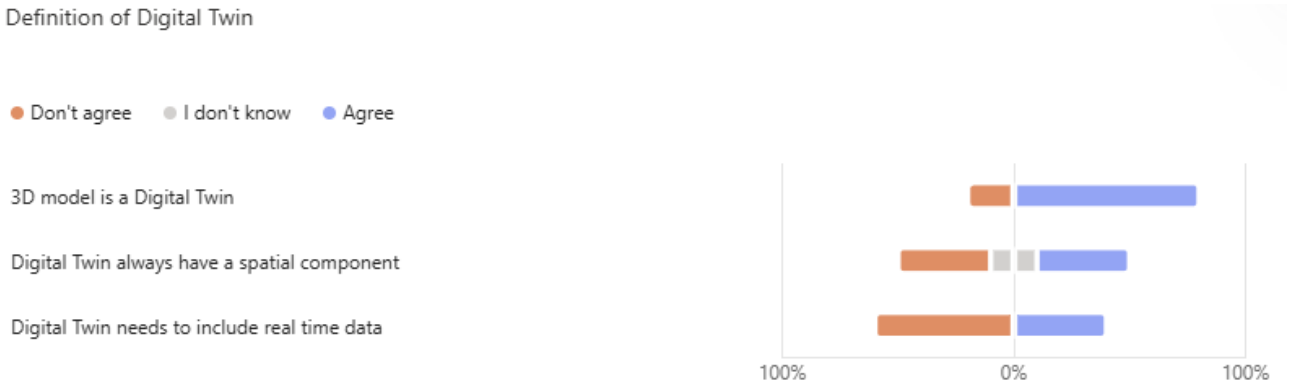
Conclusions

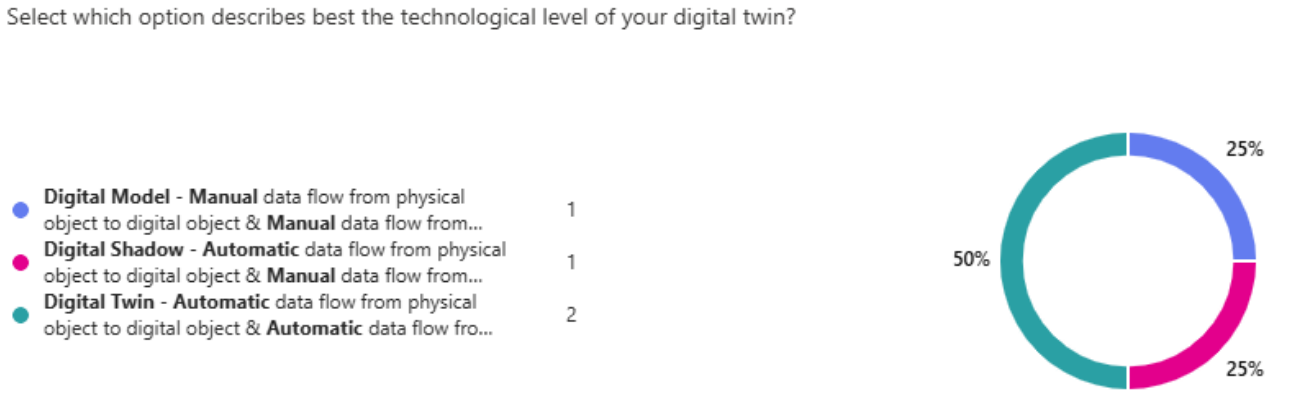
- Many open questions related to the fact that the concept is ”not specific” – difficult to estimate what would the benefits or use cases in practice.

- How to achieve interoperability? Could location data offer a framework for integration?
  - Point cloud data as a basis for digital model? → national digital twin?

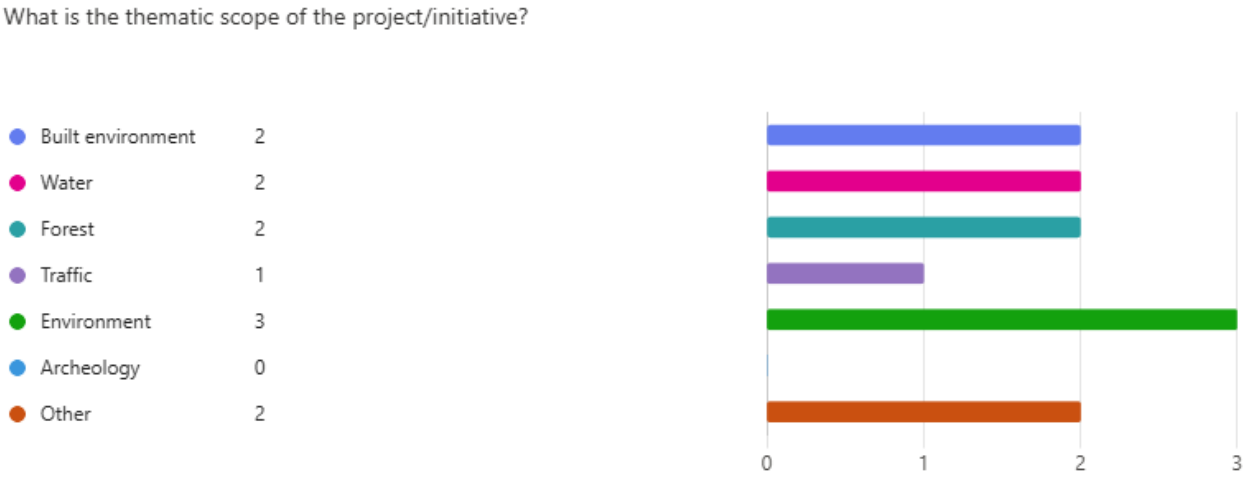
5.2.4. Iceland

Results from Questionnaire answers from a total of 5 participants ranging from public institutions to private companies:



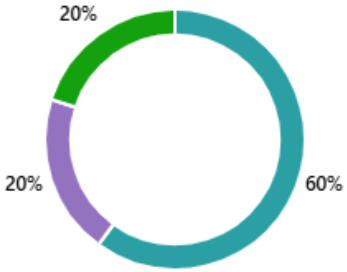


A brief description of the Digital Twin project/initiative – Projects range from environmental monitoring and weather forecasting to build environment applications and providing spatial visualizations of land areas.



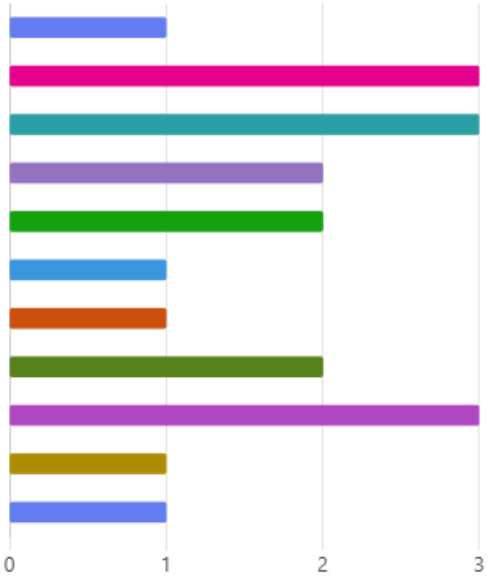
What is the geographical scope of the project/initiative?

City	0
Regional	0
National	3
Cross Border / International Collaboration	1
Other	1



Do you utilize existing geographical data in the Digital Twin project/initiative?

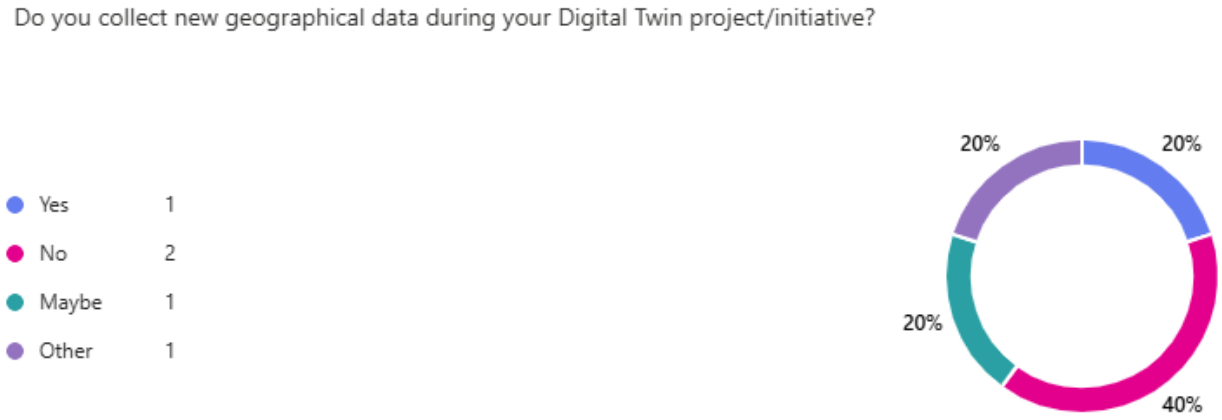
OpenStreetMap	1
Satellite	3
Road data	3
Building data	2
Orthophotos	2
3D Building data	1
Private company data	1
EU data	2
Governmental Data (Landmælingar, Þjóðskrá,...)	3
Municipality Data	1
Other	1



Geospatial data sources – Respondents referenced various datasets, including Copernicus, NOAA, IPCC, EU data, orthophotos, and numerical weather prediction models.

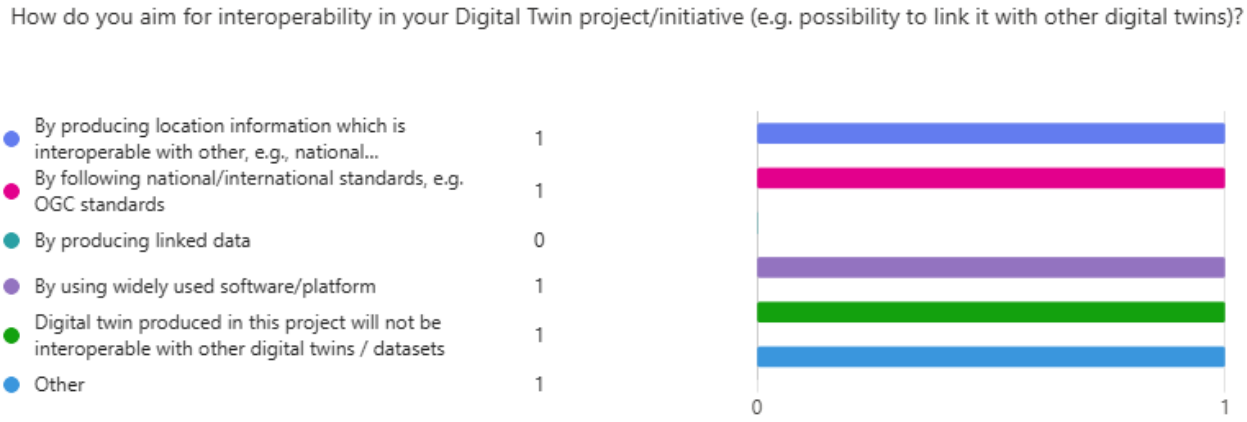
Do you create (geographical or other) data that can be linked to existing geographical datasets?

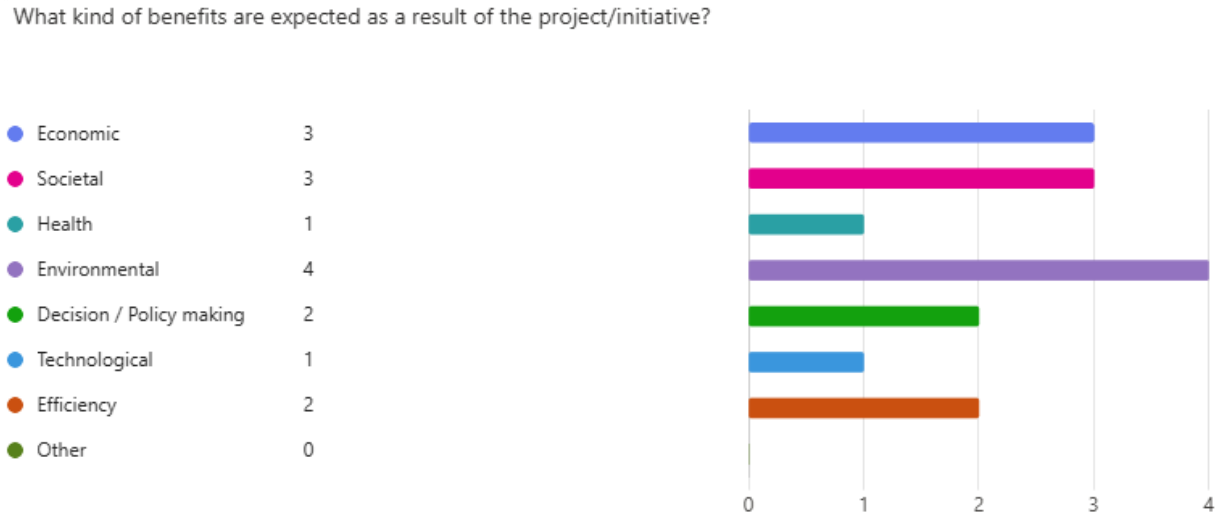
Yes	3
No	2
Maybe	0
Other	0



Type of new data collected – Some projects allow users to contribute data through different means, while others focus on collecting data from new road projects for integration into national GIS databases. However, for some initiatives, data collection remains at a theoretical stage.

Quality and format requirements – Various geospatial formats such as NetCDF, GRIB, and GeoTIFF were mentioned, with some projects relying on internally optimized data structures or prefer altitude data.





Expected benefits – Respondents highlighted environmental, economic, societal, and decision-making improvements, with some emphasizing the efficiency gains from better access to spatiotemporal data.

Thoughts on a national Digital Twin for Iceland – Mixed opinions emerged; some saw clear benefits, while others doubted Iceland's capacity to implement such a system, emphasizing the need for careful planning and global integration

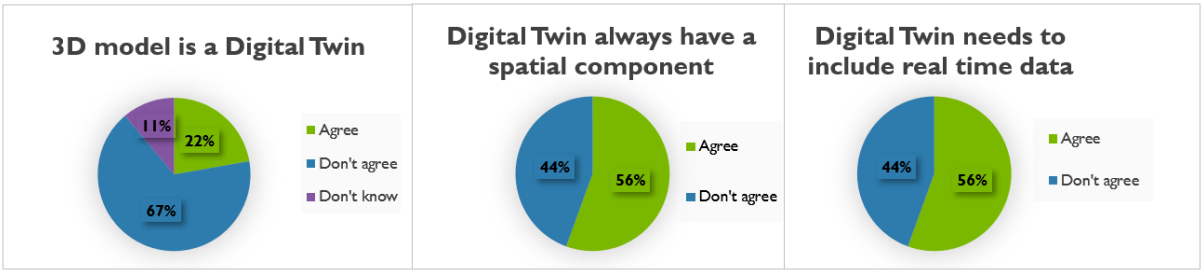
5.2.5. Sweden

Participants

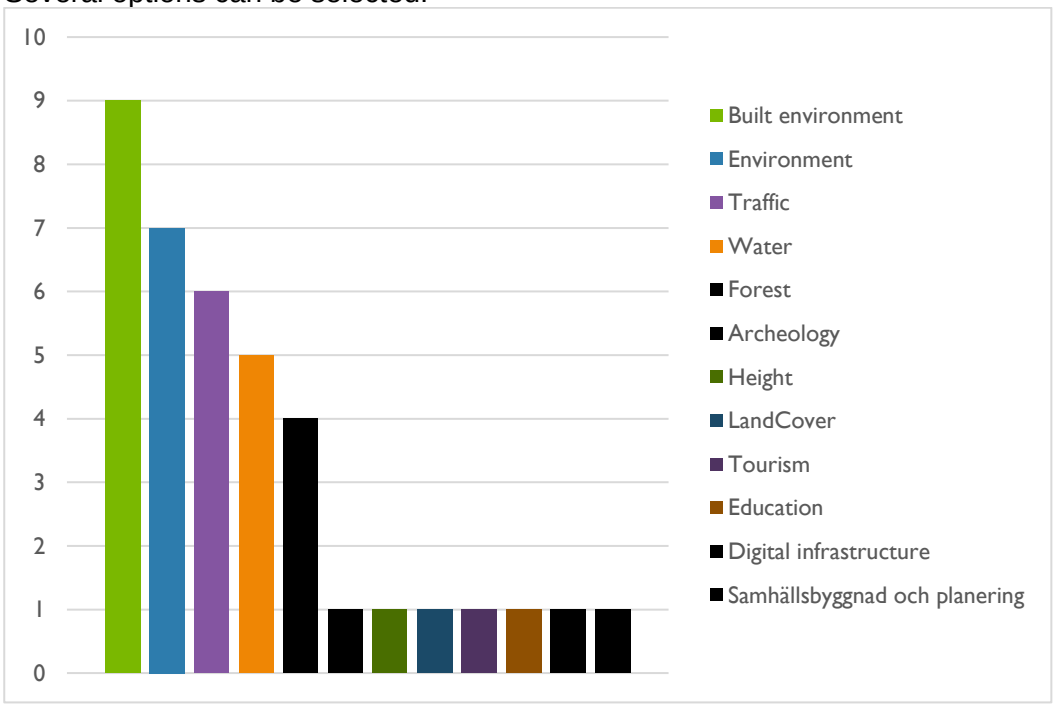
Sweden got nine responses on the questionnaire: three from academic organisations, one from a private company and five from municipalities.
In general, the academic organisations have many shorter projects, while the private company and the municipalities mainly work with ongoing development.
All participants responded to all questions.

Answers

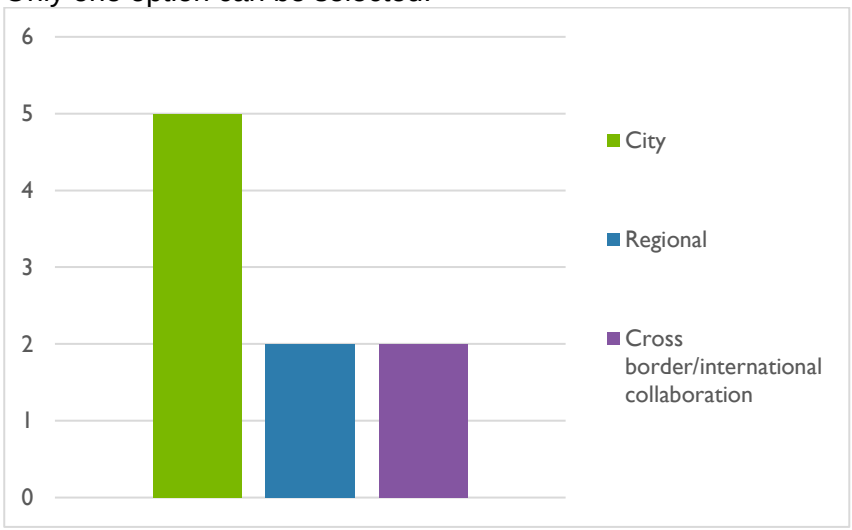
Definition of Digital Twin
Do you agree on these statements?



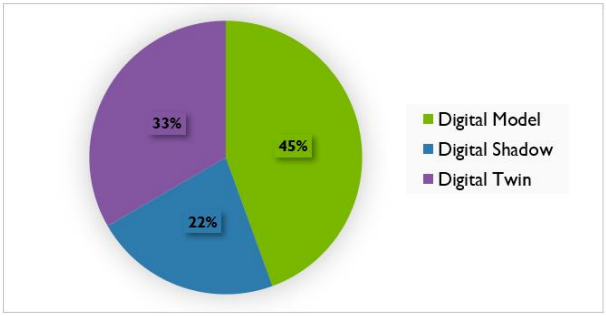
What is the thematic scope of the project/initiative?
Several options can be selected.



What is the geographical scope of the project/initiative?
Only one option can be selected.



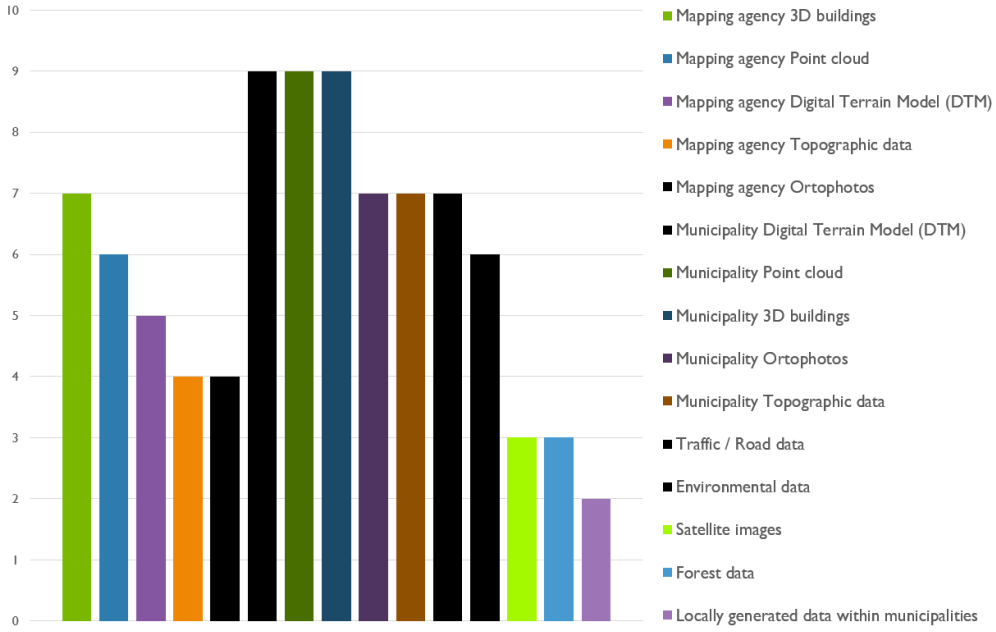
Select which option describes best the technological level of your digital twin



	Data flow from physical object to digital object	Data flow from digital object to physical object
Digital Model	Manual	Manual
Digital Shadow	Automatic	Manual
Digital Twin	Automatic	Automatic

Source: *Digital Twin in Services and Industrial Product Service Systems:: Review and Analysis*
https://www.sciencedirect.com/science/article/pii/S2212827119302525?via%3Dihub

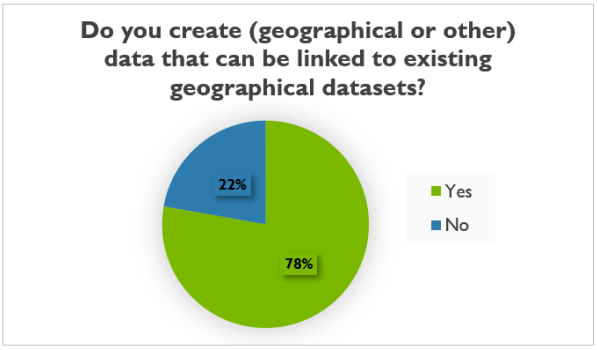
Usage of existing geographical data
Several options can be selected.

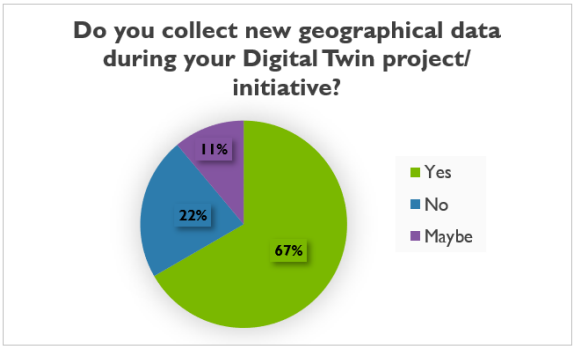


If you do not use existing geographical data, what are the main reasons, why?
Some comments from the respondents:

- Drones are something we want to use to texture the buildings and provide a better visual experience for citizens, but the Swedish Transport Agency does not issue permits so easily and the waiting time is far too long.
- The sad truth is that several times we have avoided integrating geodata from the national mapping and cadastral agency (NMCA) in our projects since the interfaces are so hopelessly old-school compared to other sources. The NMCA's REALLY have to start thinking more in terms of a Data Spaces provider, in line with the EU Data Strategy and the requirements of contemporary systems and platforms. The effect of not doing so is that Swedish actors integrate more and more with private and foreign (read Big Five) data providers, leading low resilience and unwanted leaking of sensitive data.

Creation of new data

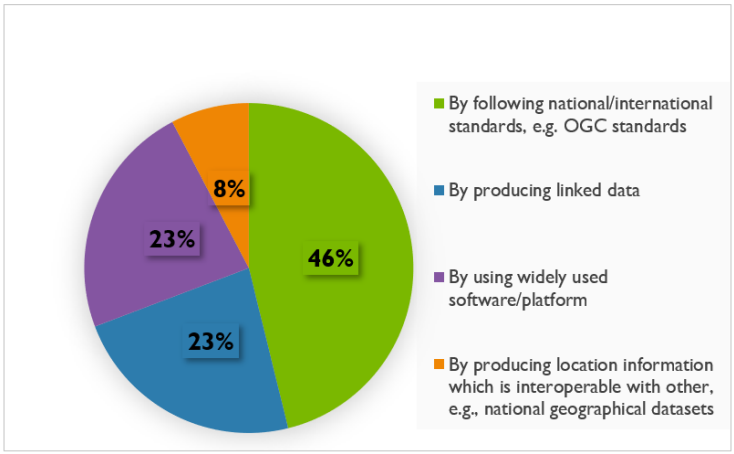




If new data was created or collected was dependent on what kind of data, you have and the purpose of your digital twin.
Some examples of data that the respondents had created or collected are:

- 3D models
- Surface material and facades from aerial and street view pictures
- Local drone and ground data
- Lidar data
- IoT sensor data
- Data about types of ground surfaces (e.g. areas with grass, concrete and sand)

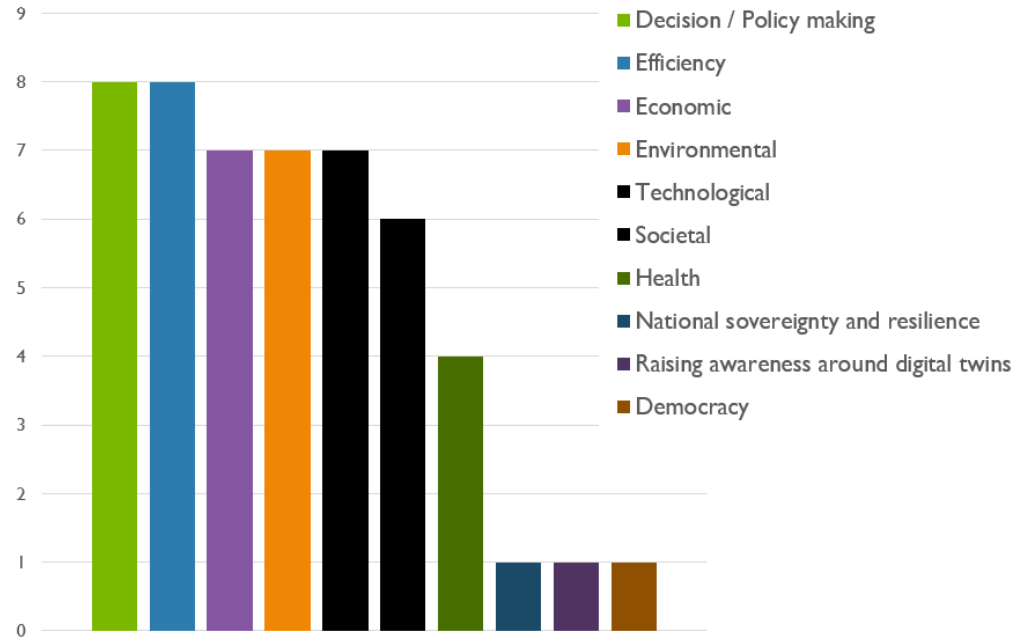
Interoperability and national digital twin cooperation
How do you aim for interoperability in your Digital Twin project/initiative (e.g. possibility to link it with other digital twins)?



Examples of standards used are CityGML, FME, PostGIS, 3DCityDB, CityEngine, Houdini, Unreal Engine and Cesium.

For knowledge graphs international (and if possible official) ontologies are used.
One respondent describes that low-level interoperability follows de facto standards and formats, and high-level interoperability maps to MIMS (Minimal Interoperability Mechanisms) and other frameworks.

What kind of benefits are expected as a result of the project/initiative?
Several options can be selected.



Some comments from the respondents:

- The twin will serve as a platform for developing applications for the whole city and its departments/administrations.
- Our projects mainly concern improvements to the built-up environments processes, often in a municipality context.
- The project focuses on understanding how digital twins can be used by a broad variety of users in Swedish municipalities. The focus lies on showing the possibilities and benefits of DT.

What are your thoughts on having a national (nationwide) Digital Twin in your own country?
Some comments from the respondents:

- Why do we not have one already? Unfortunately, you are 10 years behind where we as a nation should be considering our knowhow and capabilities.
- As a platform for analyses and visualization of nationally comprehensive and connected data. Environmental analysis, energy solutions/grids, transportation networks, logistics, circularity.
- That obviously depends on what is meant by digital twin. There are clusters of related digital twin initiatives, but they are very different. There is for example not always a 3D component or a 3D model involved. Within a city most of the actors struggle with interoperability questions (between their own DT-initiatives and others) so every initiative that helps solving this issue is greatly appreciated.

- Our work contributes to that vision, but there are lot of benefits just by getting the municipalities to start using data and technology in better way. It is important to think about the detail level and its purpose before going for a national twin.
- I do not think that a centralized nationwide DT is a good idea. It is better to have a distributed model where the responsibility for the different parts is clear. This requires that one organization has a coordination responsibility; this should be Lantmäteriet or another authority, it is not a task for a consulting company or for a university.