3D GIS-based visualisation tools for monitoring and planning

Blueprint for replication

Bodø, Norway

Contents

Digital twin

A digital city twin refers to a computer-generated virtual representation or digital counterpart of an actual city that employs cutting-edge information to create a dynamic and interactive simulation of the city's infrastructure, buildings, and services. A digital model of a city's assets, systems, and processes is utilized by city managers, planners, and stakeholders is used to examine data visually and analytically in order to make informed decisions regarding urban planning, development, and management.

The creation of a digital city twin involves the integration of diverse data sources, including but not limited to geographic information systems (GIS), sensors, traffic cameras, weather data, and social media feeds, into a unified platform. The platform employs advanced analytics and machine learning algorithms to analyse the data and construct a comprehensive model of the physical and social systems of the city.

The digital twin can provide real-time data regarding a city's traffic flow, energy consumption, air quality, and other parameters, allowing city administrators to monitor and optimize urban systems for efficiency and sustainability. It can also be used for urban planning and design, enabling stakeholders to simulate various scenarios and visualize the impact of urban development initiatives prior to their implementation.

The concept of digital city twins is acquiring popularity among city planners and technology companies, as it provides a potent tool for the creation of smart and sustainable cities. By providing a comprehensive view of a city's systems and processes, digital city twins can aid in optimizing resource use, carbon emissions, and enhancing the quality of life for citizens.

Sources:

- “Digital Twins for Smart Cities” by Carlo Ratti and Matthew Claudel, Scientific American, 2017.
- “Digital Twin Cities: What are they and how can they help us?” by Future Cities Catapult, 2021.
- “What is a Digital Twin City?” by IOTA Foundation, 2021.

Power BI

Microsoft's Power BI is a service for business analytics that enables users to integrate, analyse, and visualize data from multiple sources. It offers a variety of tools for transforming raw data into insightful observations, reports, and interactive dashboards.

Users can import data from diverse sources, including spreadsheets, databases, cloud services, and web APIs, using Power BI. Power Query, a data modelling tool that facilitates data cleansing, filtering, merging, and aggregation, can be used to transform the data once it has been imported.

Using Power BI's integrated visualization tools, such as charts, tables, maps, and gauges, users can then construct interactive visuals. These visuals can be combined and customized to generate informative and dynamic dashboards.

Power BI also offers a variety of collaboration and sharing features. Users can collaborate with team members by sharing dashboards and reports, as well as by developing content packs that can be distributed throughout the organization. Additionally, they can share dashboards and reports with external stakeholders via secure URLs or by embedding them on websites or SharePoint pages.

Power BI is a champion in the business intelligence and analytics platform market, according to a report by Gartner, with a strong emphasis on usability and an intuitive interface. It has been extensively adopted by organizations of all sizes and in all industries, including Fortune 500 firms, governments, and non-profit organizations.

Sources:

- Microsoft Power BI: https://Power BI.microsoft.com/en-us/what-is-power-bi/
- Gartner Magic Quadrant for Analytics and Business Intelligence Platforms, February 2021. Retrieved from: https://www.gartner.com/en/documents/3996944

Archicad

ARCHICAD is a building information modelling (BIM) software developed by the Hungarian software company GRAPHISOFT. It is a powerful tool for architects, engineers, and designers that enables them to create detailed 3D models of buildings and structures, as well as to manage the design, construction, and maintenance process.

ARCHICAD allows users to create a virtual building model in 3D, which can be viewed and edited from different angles and perspectives. The software offers a wide range of design tools, including parametric objects, building materials, and textures, as well as advanced modelling features such as morphs, shells, and beams.

One of the key features of ARCHICAD is its ability to generate detailed construction documentation directly from the 3D model. This includes plans, elevations, sections, and schedules, as well as detailed quantity and cost estimates. The software also supports collaborative work with other members of the design team, enabling multiple users to work on the same project simultaneously.

ARCHICAD has been widely adopted by architects and designers around the world and is recognized for its innovative features and ease of use. In a review by Capterra, ARCHICAD was rated 4.5 out of 5 stars, with users praising its powerful design tools and advanced BIM capabilities.

References:

- GRAPHISOFT ARCHICAD: https://www.graphisoft.com/archicad/
- ARCHICAD by Capterra: https://www.capterra.com/p/155338/ARCHICAD/
- "ARCHICAD 25: The Next Generation of BIM" by BIM+, 2021: https://www.bimplus.co.uk/news/archicad-25-next-generation-bim/

ArcGIS

ArcGIS is a geographic information system (GIS) software developed by Esri; a software company based in California. It is a powerful tool for managing and analysing spatial data, enabling users to create, edit, and analyse maps, as well as to share and publish them online.

ArcGIS provides a wide range of tools for working with geospatial data, including data management, visualization, and analysis. It supports a variety of data formats, including shapefiles, geodatabases, and web services, and allows users to combine data from multiple sources to create custom maps and spatial analyses.

One of the key features of ArcGIS is its ability to perform advanced spatial analyses, including spatial statistics, network analysis, and 3D modelling. The software also includes a range of mapping tools, including base maps, symbology, labelling, and annotation, that enable users to create professional-quality maps.

ArcGIS also includes a range of tools for collaboration and sharing, enabling users to share maps and data online through web applications, mobile apps, and social media. The software supports integration with other Esri products, as well as with third-party applications and systems.

ArcGIS is widely used by organizations and individuals around the world for a variety of purposes, including urban planning, natural resource management, environmental monitoring, and emergency response. According to Esri, ArcGIS is used by over one million organizations in more than 200 countries.

References:

- Esri ArcGIS: https://www.esri.com/en-us/arcgis/products/arcgis-online/overview
- "What is ArcGIS?" by GIS Geography, 2021: https://gisgeography.com/what-is-arcgis/
- "ArcGIS Desktop Review" by G2, 2021: https://www.g2.com/products/arcgis-desktop/reviews

Technical and physical requirements

In order to replicate Bodø's activities in Tool 11, it is not necessary to be in possession of the tools described above, however, it is necessary to use tools that can geographically place data. In extension of this, the replicator should be in possession of a software that can manage data, like Microsoft Excel.

Equipment

To run complex data analysis and processing tasks, it is often necessary to have a computer with sufficient processing power, memory, and storage capacity.

For instance, software applications like ArcGIS or Power BI can require a quite capable computer to handle large datasets and perform complex analyses. To run ArcGIS, Esri recommends a computer with a 64-bit operating system, a multi-core processor, at least 8 GB of RAM, and a dedicated graphics card for 3D modelling and visualization. Similarly, for running Power BI, Microsoft recommends a computer with at least an Intel Core i5 processor, 8 GB of RAM, and a dedicated graphics card for optimal performance.

Other software applications, such as ARCHICAD, may also require a capable computer for running advanced 3D modelling and visualization tasks. In general, the specific system requirements for a given software application will depend on the complexity of the analyses being performed and the size of the datasets being used.

The provider of the digital twin recommends a computer with at least an Intel Core i7 or equivalent processor, 16 GB of RAM, and a dedicated graphics card for optimal performance.

References:

- ArcGIS System Requirements: https://pro.arcgis.com/en/pro-app/get-started/arcgis-pro-system-requirements.htm
- Power BI System Requirements: https://docs.microsoft.com/en-us/power-bi/fundamentals/desktop-system-requirements

- ARCHICAD System Requirements: https://www.graphisoft.com/support/system_requirements/archicad-25/

Technical architecture digital twin

The architecture of the digital twin is represented in the illustrations under. In addition to the data sources presented in this model, other “ad hoc” data sources are used, like research data (e.g., CIRCULUS project), data from building consultants (BIM), sample data (NGI), architectural concept data (ref. architect competition).

In ArcGIS, Shapefiles (.shp) is generated and distributed to the digital twin. Shapefiles have been used to visualize noise zones from the demonstration project:

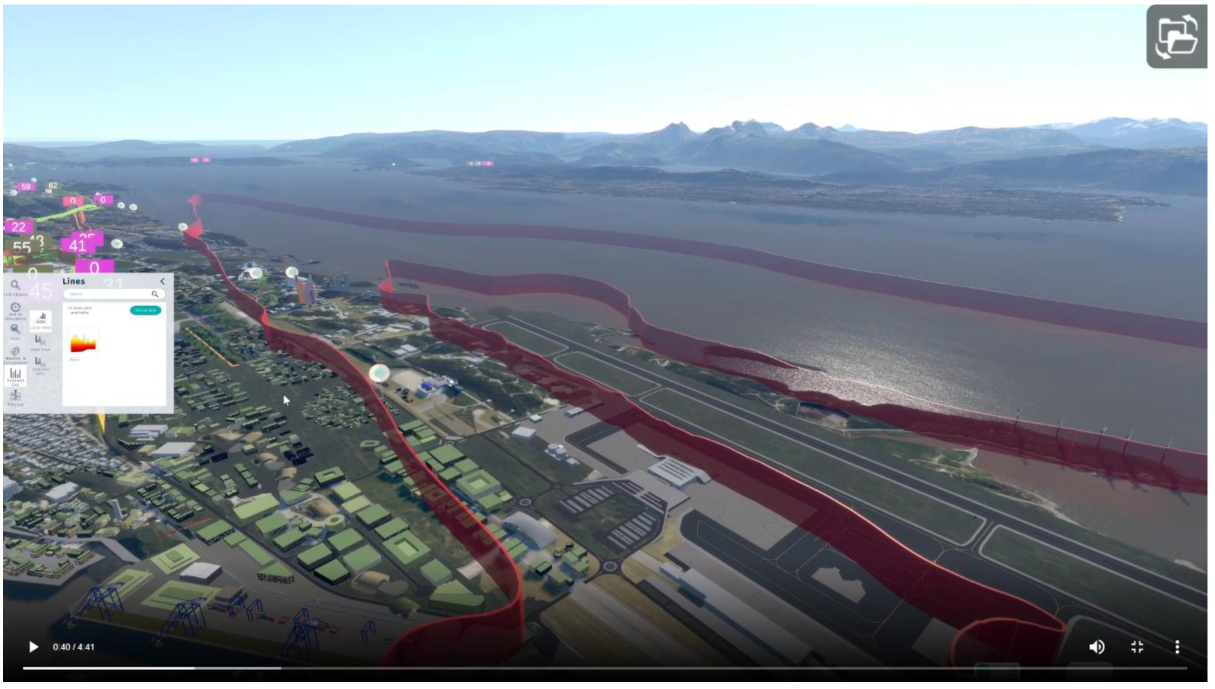


Illustration 1: Noise zones visualized over a 3D-model of the future airport.

Furthermore, shapefiles are used to create hypothetical roads from demonstration site and pilot sites to evaluate how they would affect existing infrastructure, traffic, emission, dust, and noise:

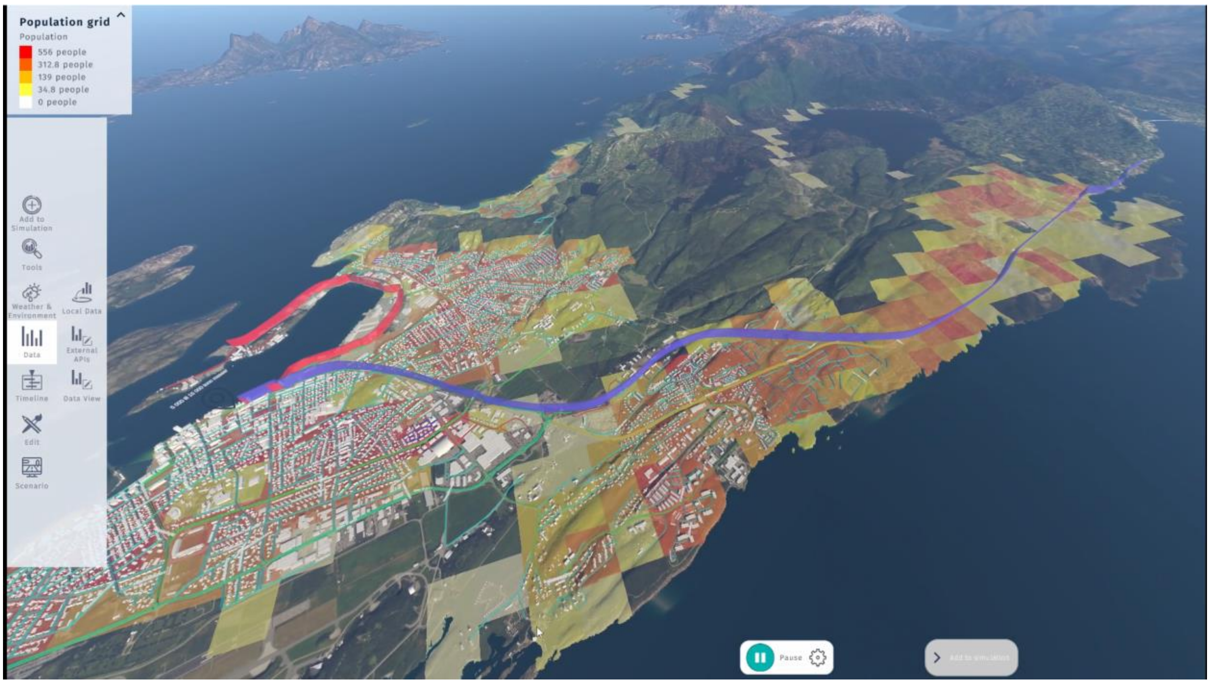


Illustration 2: Shapefiles that illustrates different mass transport alternatives from pilot site.

Architecture digital twin

The technical architecture of a digital city twin typically involves a variety of hardware and software components working together to collect and process data about the physical city and create a digital representation of it. In our specific case the architecture is illustrated in these models:

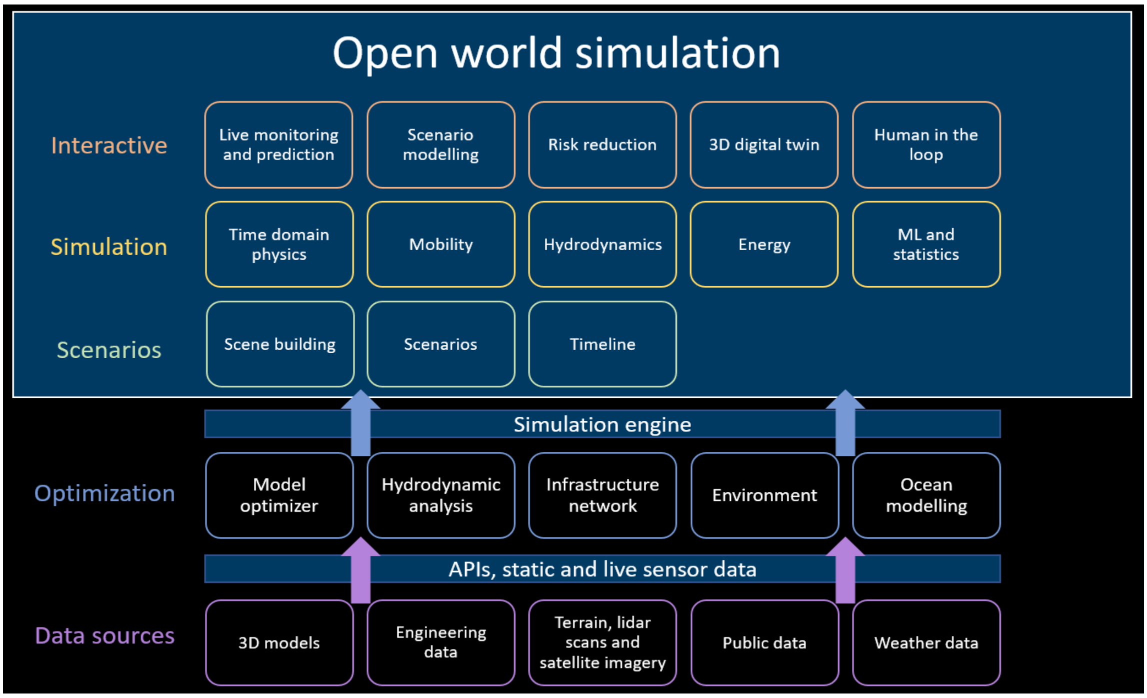


Illustration 3: General architecture

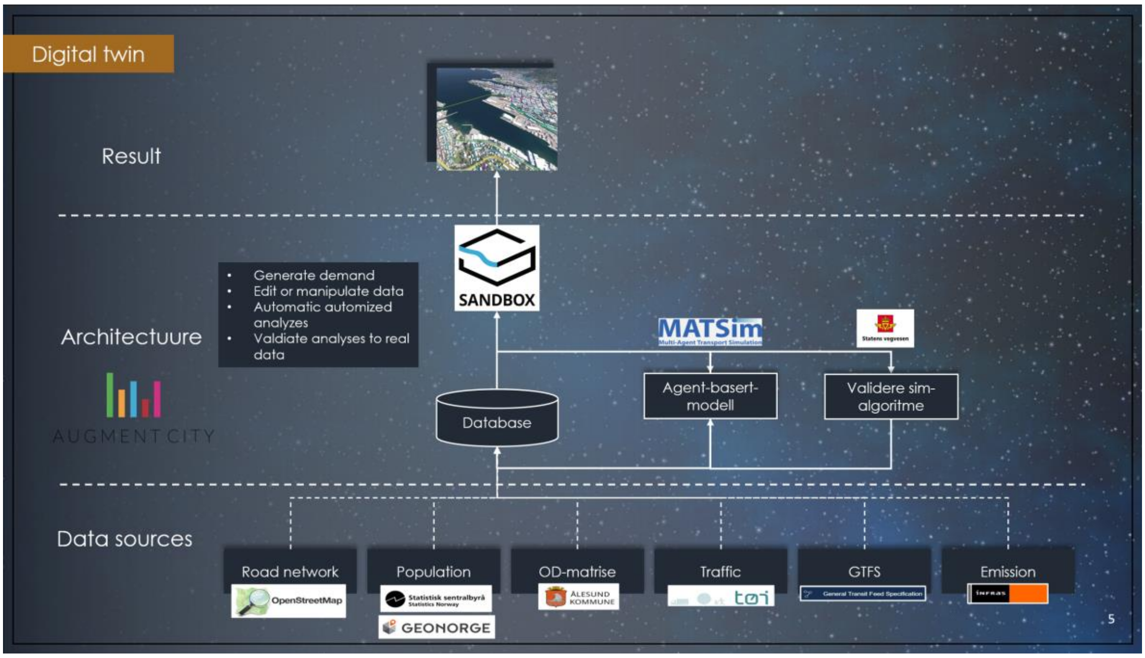


Illustration 4: Architecture digital twin

Procurement

Digital twin

Access to digital twin technology is not a procurement in the true sense of the term, as the access is through a research and development project with a software company that delivers 3D visualization solutions to offshore companies. Bodø participation in this RnD-project is to explore how such technology can be used for monitoring and planning for sustainable city planning. This is done in the CityLoops projects, and findings, lessons learned, usage potential are subject for replication.

Other softwares (ArcGIS, Archicad, Power BI)

The other software used together with the digital twin, are software that is previously used elsewhere in in the organisation. This means that the CityLoops project have not been procuring the software, but rather contributed with a small share of the license costs.

Usage

Data gathering

Data for visualization has been gathered from different sources, including these:

Mass quality data from demonstration site (Annex 1 Mass Quality.xls)

Instrument description: The observations of mass quality are mapped on a GIS-tool and the values are compared to a limit value (that classifies the soil's degree of pollution). When new observations are made, data will be plotted in the source document (Illustration 3), and the dashboard will automatically update. Visualisation of such data might be beneficial in terms of getting an overview of the soil in the relevant area. This will assist the dashboard user in city planning processes. In a CityLoops context, we use this dashboard to assist us in deciding which masses are ready for reuse, what needs to be cleaned, and what needs to be treated as polluted and/or dangerous soil – and its whereabouts.

- **Method**: Sampling from the whole demonstration area, including from masses underneath the surface. What masses consist of, it's degree of pollution and it's reuse potential is identified.
- **Collaborator(s)**: Norwegian Geotechnical Institute

- **Tools used for visualisation**: Power BI, Augment City Digital Twin
- **Usage**: Used for mass treatment planning. Analysis necessary to evaluate if masses should be sent to facility for cleaning or disposal. Heavily polluted and dangerous masses are identified, and this information is crucial for city planning purposes on demonstration area. A dashboard is created and can be used as a tool for decision makers on how masses should be treated, transported, and reused.
- **Example:**

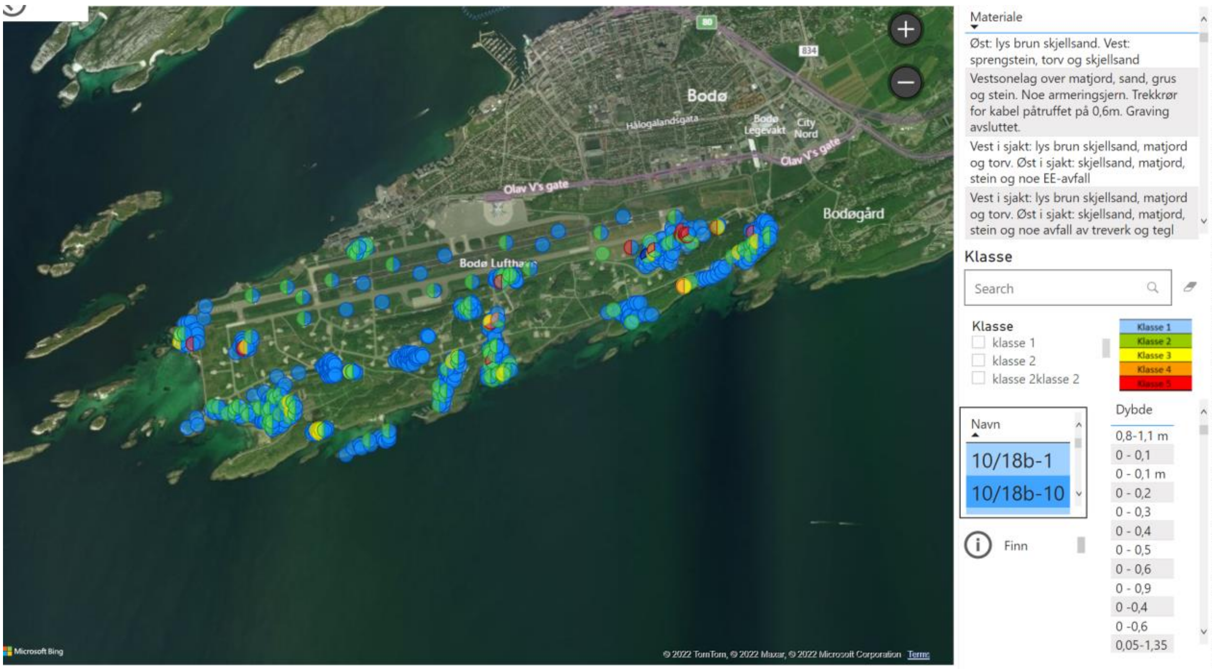


Illustration 5: Excerpt from Power BI Dashboard

Functions:

- Qualitative description of soil masses
- Classification of degree of pollution
- Depth information
- Link to detailed information about technical qualities

Replication potential: It is not necessary to be in possession of Power BI to use the dashboard. It can be presented by ex. an internet browser. To further develop it, or change its functionality, a free version of Power BI can be used. It is however recommended to use a paid version of Power BI. Many organisations have that in their

Office 365-license. Power BI typically relates to data formats that's available for most organisations (.xls, .csv, .txt, databases (like azure, sql, aws)). Basic data management skills are recommended.

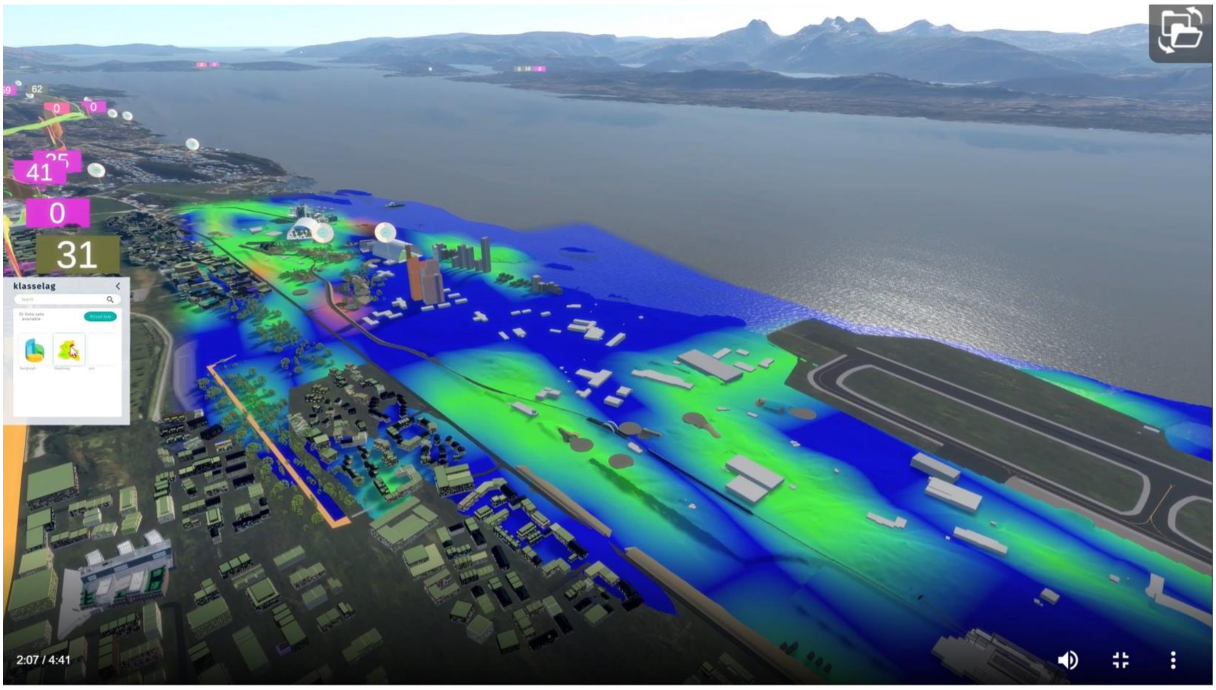


Illustration 6: Same data visualised in digital twin.

Technical guidelines

Material data from buildings on demonstration sites and pilot buildings

- **Method**: Scanning of building and their materials, assessment of quality, pollution, reusability. Testing of Tool 8) Databank and digital marketplace for recovered materials. Visualisation of data from "sister" project CIRCULUS.
- **Tool**s **used for visualisation**: Power BI, Augment City Digital Twin
- **Usage**: Used to get an overview of buildings that needs to be demolished, and buildings where that's not necessary, what materials they consist of, its quality, and reuse potential. Data gathered is presented in detail in the 3D visualisation tool. Presenting e.g., the amount of concrete on demonstration sites assists city planners in planning of reuse of the concrete.
- **Example**:

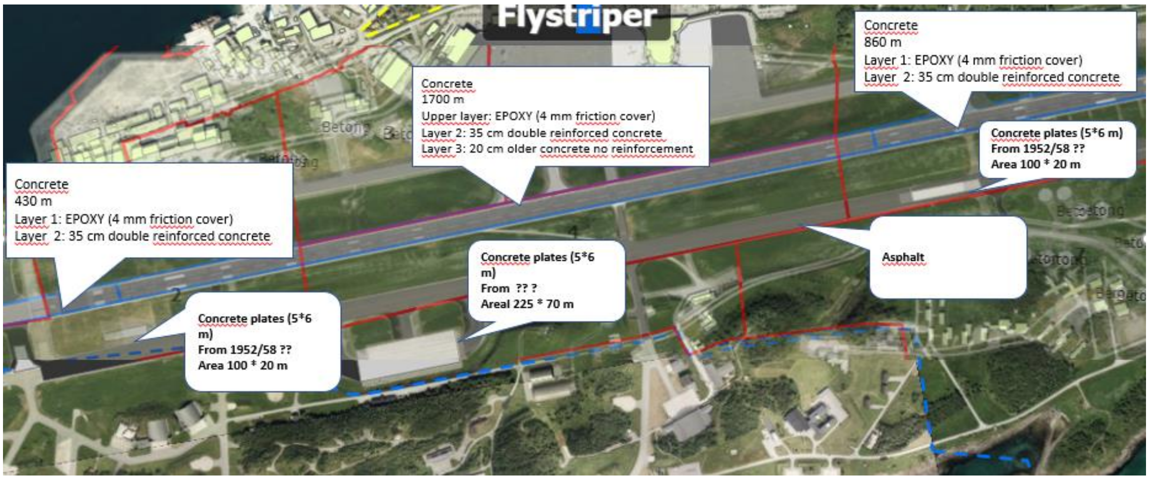


Illustration 7: Excerpt of data before visualization in digital twin

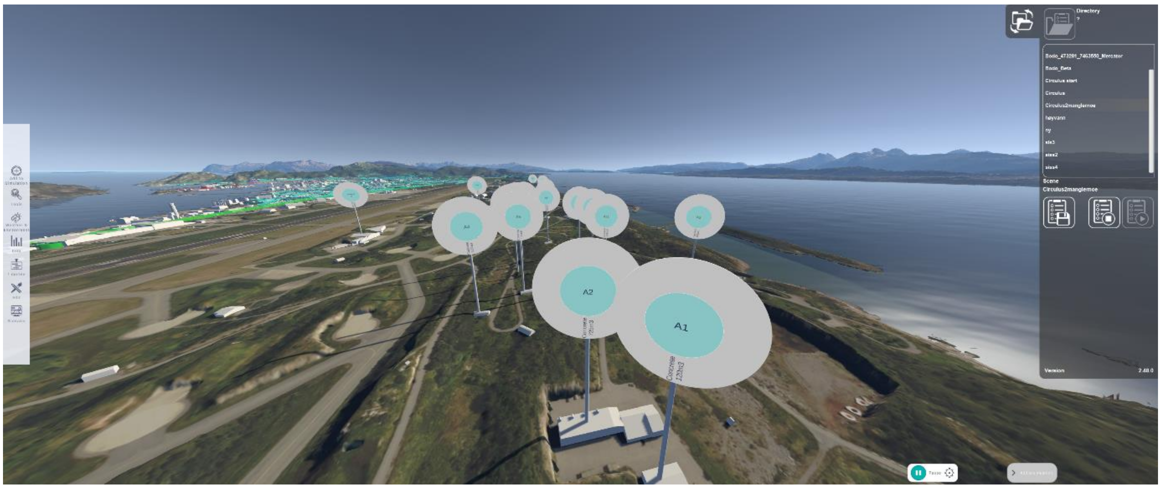


Illustration 8: Visualization in digital twin of volume(m3) of concrete that different buildings contain.

Illustration 9: visual representation of CO2 emissions from different scenarios on treatment of concrete on demonstration site.

Visualization of transport, infrastructure, and emission data

Method: Traffic data is gathered through an API-connection to the National Road Authority's traffic sensors. In that way, we get information about how much traffic load it is on the different streets in Bodø. This information is combined with *Tool 1) Life Cycle Assessment for demolition and renovated sites* to quantify the amount of emission on different sites in the city. This is visualized in the digital twin, and the height of the bars on the roads represents the amount of emission correlated with traffic on different times of the day.

Furthermore, hypothetical data about mass transport is populated in the digital twin. An estimation of the volume of masses from the demonstration project, and pilot project is done. This volume of masses needs to be transported to either waste management facilities or intermediate storage facility (ref business case). To evaluate which route for mass transport is best, visualisation of this data is done. This enables us to see how mass transport interferes with traffic, housing, infrastructure, tear on asphalt, and its emission (LCA-tool).

Tools used for visualization: Digital twin, LCA-tool.

Usage: Scenario-building for mass transport. Communication to decision makers – to influence where masses shall be transported, stored, and treated.

Example:

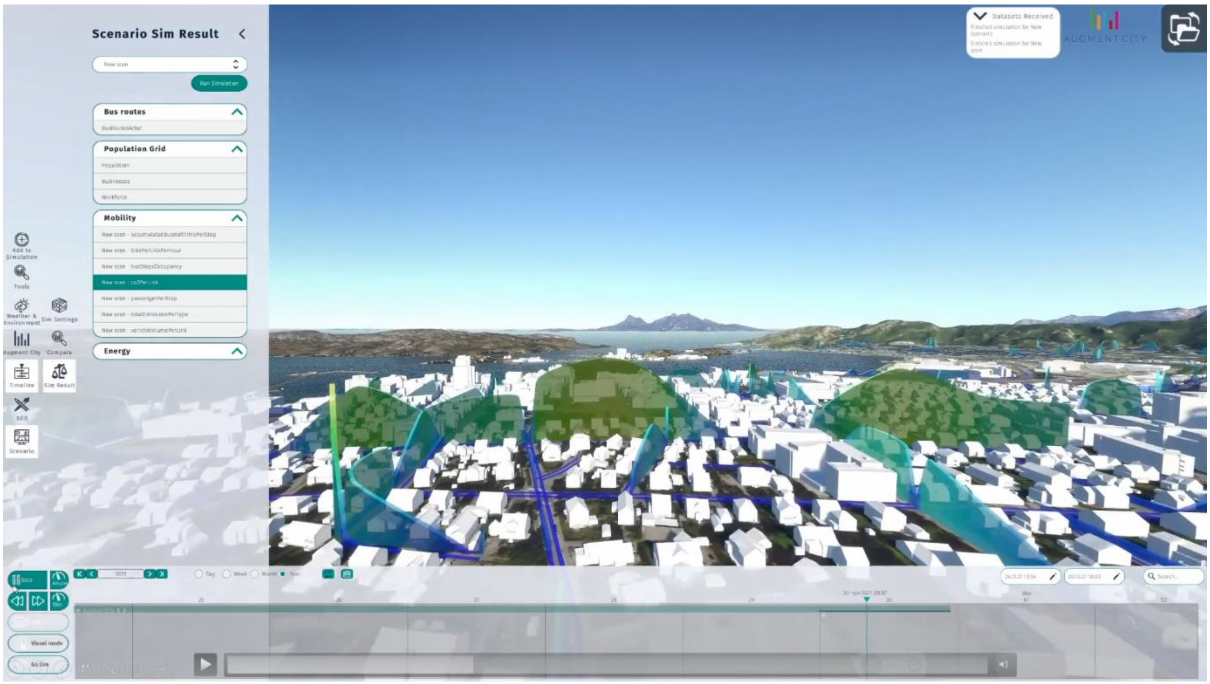


Illustration 9: Size of the bars represents co2-emission (correlated with traffic) on pilot project for demonstration project. LCA-tool used.

This helps us identify which routes are best for mass transport.

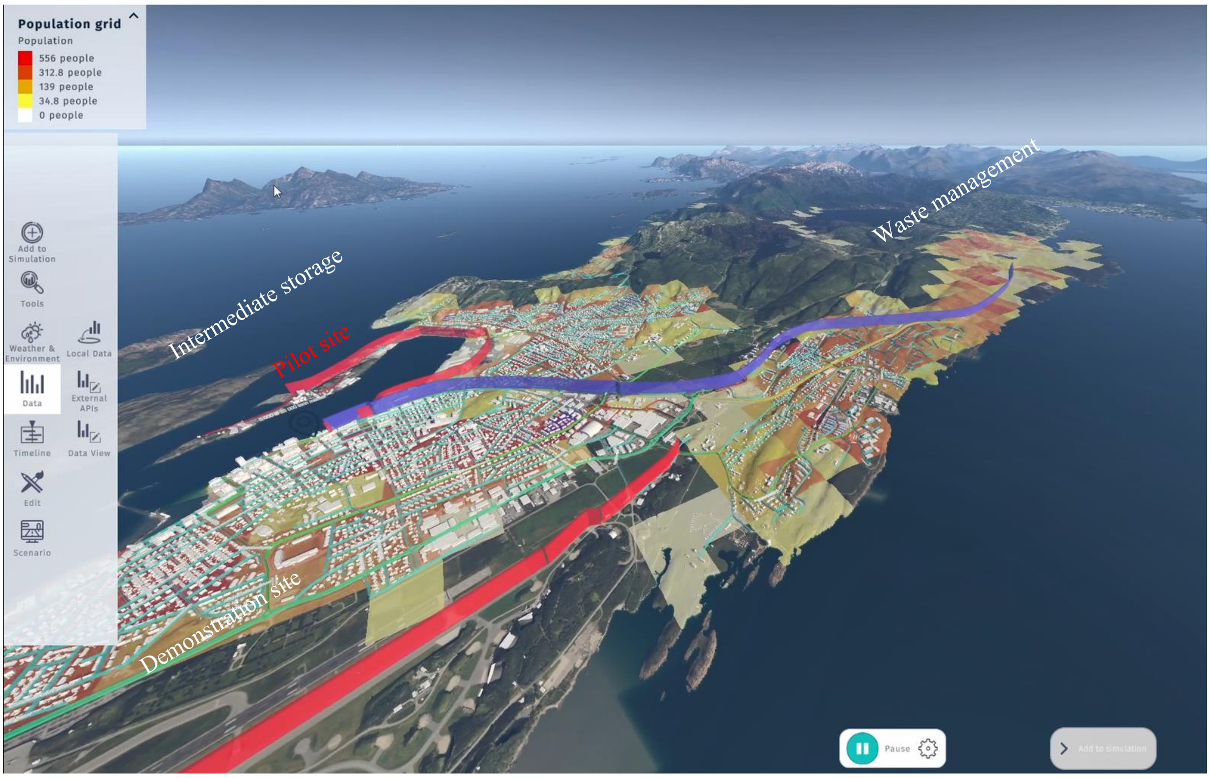


illustration 10: Mass transport routes. The colour on the heatmap represents the density of population on different areas.

Identification of loose sediments and potential sea level rise at demonstration site

Identification of loose sediments and potential sea level rise (based on statistics) is done on demonstration site.

Method: Sampling on demonstration site, statistics on how sea level rise will develop. These values are particularly interesting as the demonstration site is placed nearby sea.

Tools used for visualization: Digital twin.

Usage: Due to safety it is necessary to identify loose sediments as areas where this is identified might not be safe to be built on. Visualising areas with these observations help city planners and decision makers to plan where construction work can and cannot be done and might be guiding on how these masses can be treated. Potential sea level rise scenarios are also subject for visualisation, as it is necessary to plan long term in building the new part of the city and the new airport.

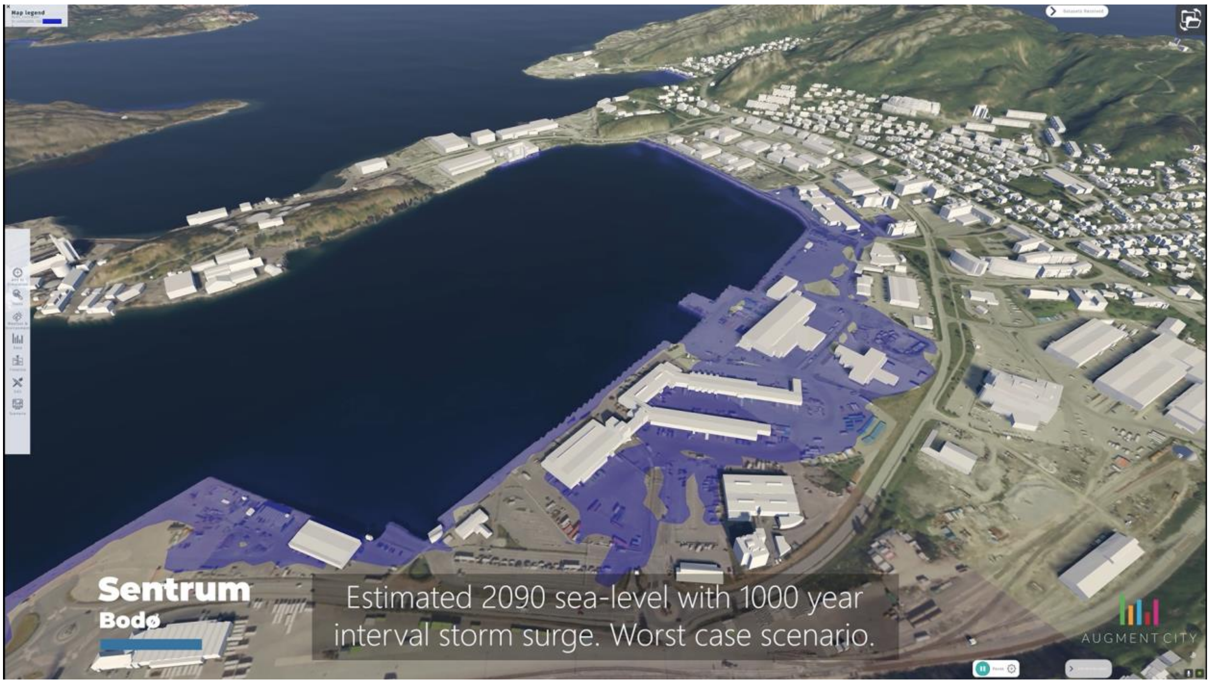


Illustration 11: Visualisation of sea level rise, estimate based on statistics.

Social values

In the demonstration project, triple bottom line is taken into consideration. The United Nations' triple bottom line refers to a framework for sustainable development that considers three dimensions: economic, social, and environmental.

In order to evaluate social values in the project, socio-demographic values have been gathered.

Method: Get public data from Statistics Norway. Data gathered is income, fortune, level of education, and age distribution. These values are divided in to 176 neighbourhoods in Bodø Municipality. The tool created in Bodø is inspired by the CityLoops tool 15) Wellbeing monitoring tool.

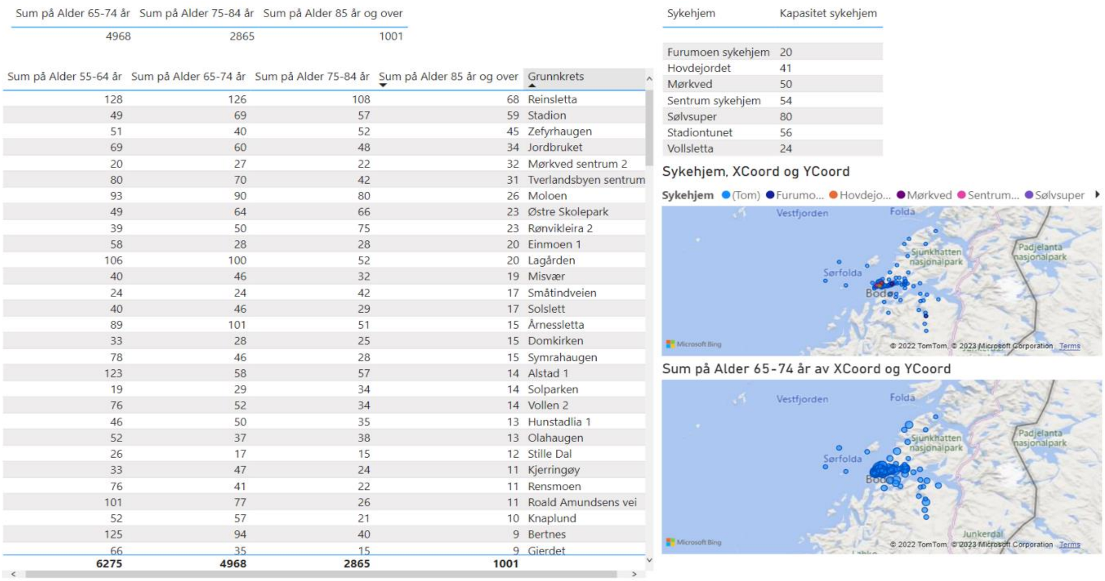
Furthermore, residential areas are mapped to evaluate how the inhabitants QoL in Bodø are affected by mass transportation on nearby roads. Factors related to heavy mass transport that might affect QoL is dust, noise, emission, safety, traffic.

Tools used for visualisation: Power BI, digital twin.

Usage: Tool is used to map sociodemographic values in the city. This information is then used to plan how the city can be developed in terms of e.g., nursing homes, kindergartens, facilities for refugees, youth facilities. Sociodemographic information gives insight about the city's status, but this can also be used to estimate future values. For example, if we know how many people from 64-85 that lives in the different neighbourhoods in the city, we can estimate how many people over 85 years old that lives in the city in 10-20 years. Supported by statistics on death rates, home service capacity, experience on how many over 85 that needs municipal support, we can use the data gathered to be proactive in city planning. Being in possession of social data, also enables us to identity correlations between increased practise of circular economy and decrease of emission. Having identified a need in the city, can help us decide which purpose a refurbished building from demonstration site can serve, and this can even be used as an argument for keeping buildings rather than demolishing them.

Examples:

In the illustration underneath is counted how many people from 65 to 84 year lives in Bodø in the city's 176 neighbourhoods. It is also counted how many over 85 that lives in the city. Findings: it will likely be more people over 85 years in Bodø in 10 – 20 years. This information might be used to plan how the buildings in demonstration site can be used to serve elderly inhabitants in Bodø.



Sum på Alder 65-74 år	Sum på Alder 75-84 år	Sum på Alder 85 år og over
4968	2865	1001

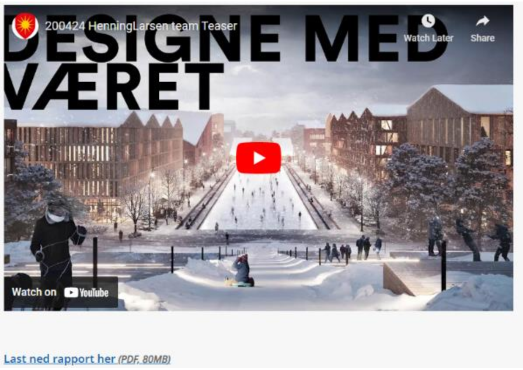
Sum på Alder 55-64 år	Sum på Alder 65-74 år	Sum på Alder 75-84 år	Sum på Alder 85 år og over	Grunnkrets
128	126	108	68	Reinsletta
49	69	57	59	Stadion
51	40	52	45	Zefyrhaugen
69	60	48	34	Jordbruket
20	27	22	32	Mørkved sentrum 2
80	70	42	31	Tverlandsbyen sentrum
93	90	80	26	Moloen
49	64	66	23	Østre Skolepark
39	50	75	23	Rønvikleira 2
58	28	28	20	Einmoen 1
106	100	52	20	Lagården
40	46	32	19	Misvær
24	24	42	17	Småtindveien
40	46	29	17	Solslett
89	101	51	15	Årnessletta
33	28	25	15	Domkirken
78	46	28	15	Symrahaugen
123	58	57	14	Alstad 1
19	29	34	14	Solparken
76	52	34	14	Vollen 2
46	50	35	13	Hunstadlia 1
52	37	38	13	Olahaugen
26	17	15	12	Stille Dal
33	47	24	11	Kjerringøy
76	41	22	11	Rensmoen
101	77	26	11	Roald Amundsens vei
52	57	21	10	Knaplund
125	94	40	9	Bertnes
66	35	15	9	Gierdet
6275	**4968**	**2865**	**1001**	

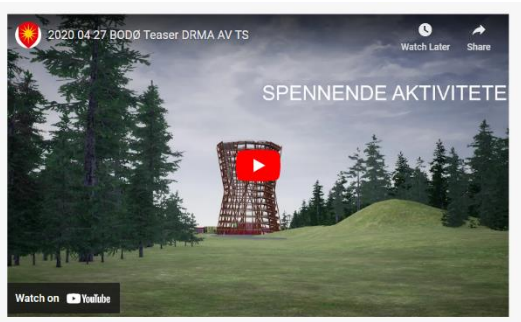
Sykehjem	Kapasitet sykehjem
Furumoen sykehjem	20
Hovdejordet	41
Mørkved	50
Sentrum sykehjem	54
Sølvsuper	80
Stadiontunet	56
Vollsletta	24

Illustration 12: Visual representation of how different neighbourhood's average income, net worth, level of education and age are placed in comparison to a city average.

Architect competition

A tender was created where architect and city planning companies were challenged to create concepts for the new airport, taking into account the municipality's environmental priorities. Three companies were chosen to work 3 months with their concepts.





The mission resulted in three concepts, including reports of 150-200 pages consisting of technical information and models on how the city would function.

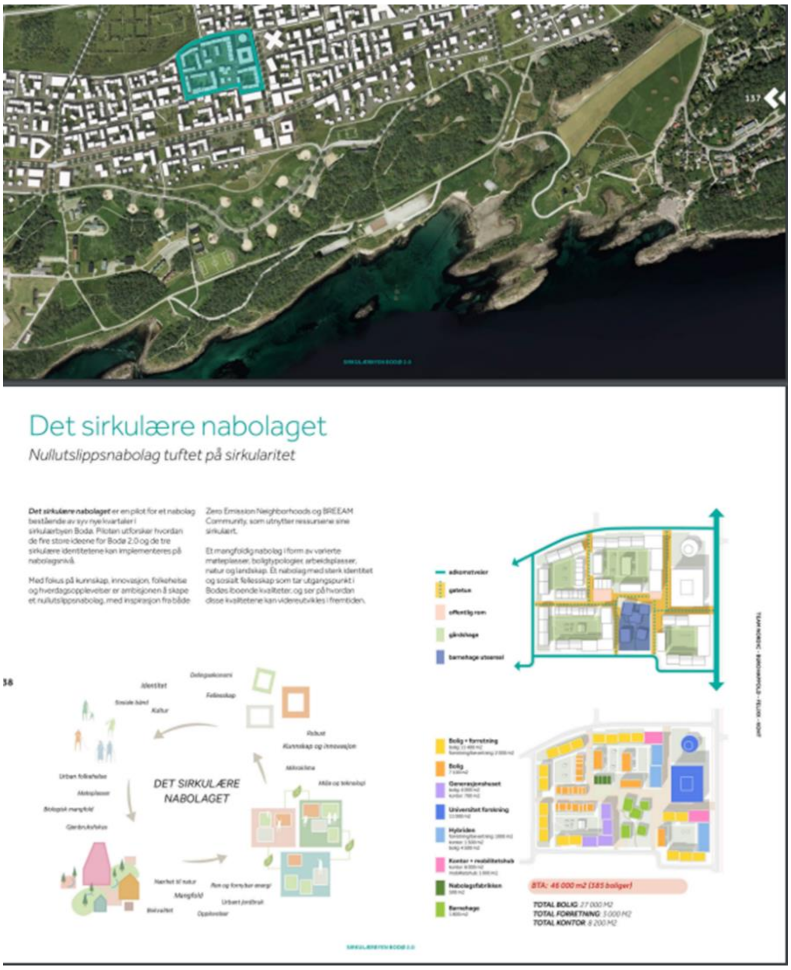


Illustration 13: The circular neighbourhood

One example is the company Nordic Architects provided a concept called Circular Bodø. This concept in modelled in the 3D Visualisation tool to evaluate its hypothetical effect on the city.

NY BY - NY FLYPLASS NY BYDEL BYUTVIKLING BODØ

Se bildene - her er det folket vil ha

3 / 7

Ny havn tilknyttet den nye flyplassen, og urbane, grønne forretningsbygg. Visualisering fra Bodø kommune.

Av Anders Bergundhaugen

Publisert: 07.06.21 13:13 Del

Artikkelen er over 1 år gammel

Vises fram i «Bodøs digitale tvilling".

Illustration 14: Visualisation of architect's made concept using digital twin, extract from local newspaper. Translation: Look at the pictures – this is what the people want. Source: local newspaper.

Shortcomings with digital twin

While the 3D Tool for monitoring and planning is working excellent for scenario building presenting complex data in an understandable way, to identify correlations between several factors and to communicate externally and internally, the system has some shortcomings in making data calculations. Therefore, systems like Power BI and ArcGIS are used in conjunction with the digital twin. This means that in some cases, data management has been done in this order: Data source – data management tool (Power BI) - Digital twin. It would strengthen the tool if the data management could be done directly in the digital twin – this would further enable the tool to be used in analytics tasks.

Visualization for communication purposes

One of the biggest strengths of using a digital twin is for communication purposes. The system can visualize complex data that typically are placed in excel or even PDF documents. By making this data easier to comprehend and accessible, decision makers and city planners will be able to make data-driven decisions with less time and mental strain. Efficient use of data visualization may help to support arguments for diverse purposes, rendering it very useful for communication.

Potential assessment of the terminal building

As we can see this tool can help us to evaluate different scenarios and current data, the terminal building project can be as well supported by the use of this tool to evaluate different structures that have reuse potential, design different scenarios and city plans for the new district, how to incorporate old structures into the new design and follow up of construction projects that provide the best solution for energy efficiency, reuse, repurpose and recycle materials where possible.

Different 3D visualizations that can as well showcase weather conditions are especially important for city planning as Bodø is located above the polar circle in the arctic region, and therefore highly impacted by weather changes or conditions.

Increasing competence and knowledge development

One of the barriers that can hinder organizations to embrace innovative solutions such as the use of a digital twin software are the dilemmas or incognita on how to use it.

Resources both economic aspects and capable human capital capable of using and manipulating the interface. Good project management and prioritization abilities are important aspects that should not be overseen. Therefore, here in the Bodø we:

- Engage participants in different activities to show that it is possible to have a better data visualization.
- Encourage colleagues and other stakeholders to reach us for support.
- Have used the digital twin in different projects or for decision making process.
- Have built scenarios that help others understand the potential of using such a tool.
- Have organized training for different employees, to assure that knowledge is shared and used in different departments.
- We are working to raise awareness among different employees and departments about this existent solution that we have at our disposal.

Conclusion

The digital twin of the city has proven to be a useful tool for urban planners, policymakers, and researchers alike. It allows them to gain a comprehensive understanding of the city's functioning, including its infrastructure, traffic patterns, and energy consumption, among others. This information can help identify areas of improvement, optimize resource utilization, and design interventions that lead to better outcomes for citizens. There is however still some potential for improvement in the digital twin's functionality, with the shortcomings on making data calculation in the program itself.

Overall, while the digital twin of the city has already proven to be a valuable tool, continued refinement and optimization can unlock even greater benefits for the urban environment and its inhabitants.

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and bio-waste, where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and bio-waste, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.