APPLICATION OF DIGITAL TWIN TECHNOLOGY IN POST-WAR CITY RECONSTRUCTION: NEW HORIZONS FOR RECOVERY

Mnatsakanian Mariia
Mariupol State University, Arnhem Municipality
ORCID ID: 0000-0002-1829-2334,

Abstract:

Digital Twins represent an innovative technology that is increasingly being adopted in urban planning, management, and infrastructure recovery. This article discusses the development of a digital twin for Mariupol (Ukraine), a city severely affected by military actions and currently under occupation. The digital twin will be developed based on data collected before the occupation, with the goal of facilitating the efficient reconstruction of the city after its liberation. The primary objective of implementing digital twin is to create tools for the rapid restoration of the city and provide convenient simulation of urban planning scenarios. The article also discusses the development algorithms and mathematical models that can be used to build and manage such systems.

Introduction:

Mariupol, a key city in southeastern Ukraine, has suffered significant damage due to military actions and occupation. Its reconstruction after liberation will be one of the most critical tasks for the Ukrainian government, international organizations, and local authorities. To effectively and quickly restore the city's infrastructure, innovative approaches are required, one of which is the use of Digital Twin technology (fig.1).

A city's digital twin is a virtual model that integrates data about urban infrastructure, buildings, transportation, and other city components in real-time[1]. Through the use of digital twin, it is possible to analyze and simulate various reconstruction scenarios, significantly accelerating the planning and decision-making processes.

The main goal of creating a digital twin for Mariupol is to enable the rapid restoration of urban infrastructure after liberation (fig.2). An important feature of digital twin is its ability to simulate various development and urban planning scenarios and provide analytical data for selecting the best solutions in each case [2].

Fig. 1. *Interactive map of the destruction city Mariupol [2]*

The digital twin of Mariupol will allow:

1. Rapid restoration of critical infrastructure, such as roads, bridges, and utility networks.
2. Simulation of different urban development scenarios for optimal land use and resource allocation.
3. Optimization of transport flows and urban transport systems.
4. Development of energy efficiency plans and sustainable urban development.
5. Provision of data for rapid responses to emergencies, such as natural disasters.

Fig. 2. *Opportunities for creating a digital twin with subsequent scenario simulation for the Mariupol railway station area*

The creation of a digital twin for a large, war-affected city like Mariupol requires a comprehensive development algorithm that includes several key stages (fig.3).

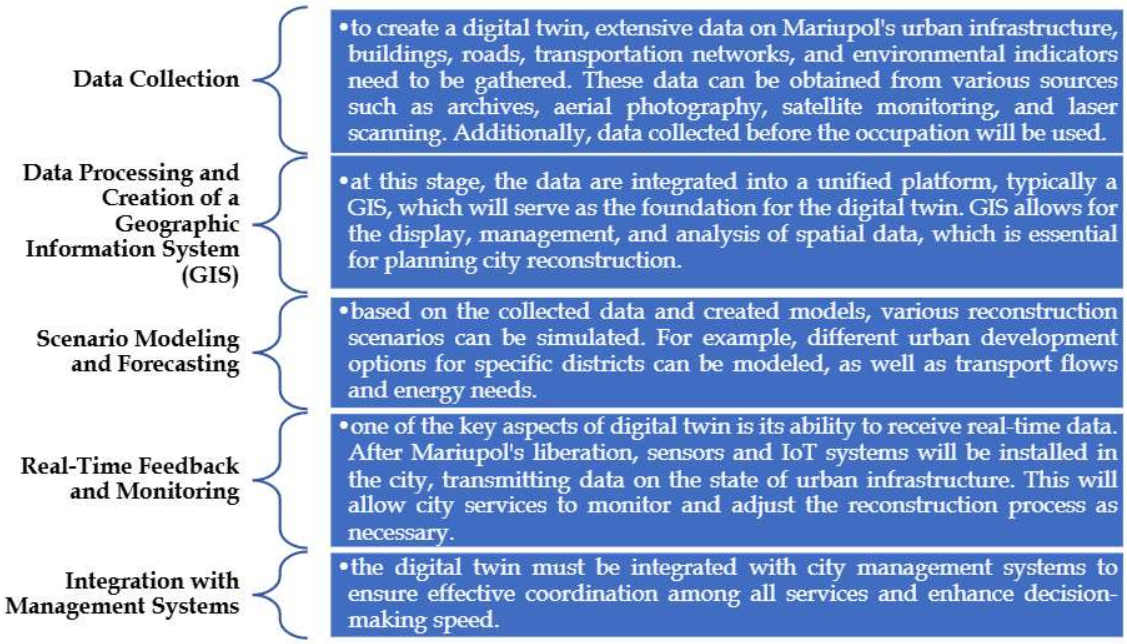

Fig. 3. *Development algorithm a digital twin for Mariupol*

Several types of mathematical models are used to build a city's digital twin, each serving a specific function within the digital twin system. Here are the main models that can be applied to the reconstruction of Mariupol:

a) Geometric Models: these models form the basis of any digital twin and represent the buildings and infrastructure. They are created using data from laser scanning, aerial photography, and satellite images. For Mariupol, these models will be essential for restoring accurate city planning blueprints;

b) Physical Models: physical models account for factors such as building loads, weather conditions, and other environmental impacts on infrastructure. These models are crucial to ensuring the resilience of structures in Mariupol during reconstruction;

c) Scenario Models: scenario models allow the simulation of various reconstruction and development scenarios. These models will be used to analyse multiple urban development options and select the best outcome based on criteria such as energy efficiency, accessibility, and traffic flows;

d) Transport Models: transport models forecast vehicle movements, pedestrian flows, and road load. In Mariupol, these models will help optimize transport flows and minimize congestion;

e) Economic Models: a vital component of the digital twin is economic modelling, which assesses the cost-efficiency of reconstruction efforts. These models are used to forecast recovery costs, evaluate project profitability, and plan resource allocation.

Advantages of using Digital Twins in reconstruction: using a digital twin for the reconstruction of Mariupol will offer numerous advantages. First, it enables the simulation of various urban development scenarios without real-life experimentation,

saving time and resources. Second, it will optimize planning and construction processes, ensuring the city's sustainable development. Additionally, Digital Twins will help minimize risks and simplify urban environment management.

Conclusions:

The creation of a digital twin for Mariupol after its liberation will be a key step in its reconstruction process. Digital Twins technology offers unique opportunities for modelling and optimizing urban processes, which is particularly important in the context of rapid recovery following military actions. The use of digital twins will not only speed up the city's restoration but will also make Mariupol an example of a sustainable and modern city ready to face future challenges.

REFERENCES

1. Batty, M. (2018). Digital twins. Environment and Planning B: Urban Analytics and City Science, 45(5), 817-820. https://doi.org/10.1177/2399808318796416
2. Treffers, F & RO3KVIT team (2023). Vision for Mariupol - the easternmost gateway of Europe. Dom publishers, 90.
3. Grieves, M. (2014). Digital Twin: Manufacturing excellence through virtual factory replication. White Paper, 1-7. https://doi.org/10.4271/2015-01-0247
4. Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W. (2018). Digital Twin in manufacturing: A categorical literature review and classification. IFAC-PapersOnLine, 51(11), 1016-1022. https://doi.org/10.1016/j.ifacol.2018.08.474
5. Tao, F., & Zhang, M. (2017). Digital Twin shop-floor: A new shop-floor paradigm towards smart manufacturing. IEEE Access, 5, 20418-20427. https://doi.org/10.1109/ACCESS.2017.2756069