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Application of Digitalization in The development of a port master plan project in Southern Vietnam

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Abstract: Port master plan is a comprehensive document that defines vision, goals, and strategies for the development and management of ports. This paper describes the field survey processes, as well as hydrodynamic studies conducted to evaluate the pre-feasibility study of the area, in order to deliver advanced finishing products on a cloud-based management platform. The described workflow can be termed as 'Survey/Scan to BIM-GIS-Digital Twin', which is converting survey or scan data into BIM or GIS ensures an accurate and efficient representation of existing conditions, reducing field survey costs, and create a comprehensive digital twin for better management and operation. In a complex site with distinct areas, various survey methods are employed to the specific characteristics of each zone. This entails the utilization of diverse techniques, including Unmanned Aerial Vehicles (UAVs), Terrestrial Laser Scanning (TLS), and Unmanned Surface Vehicles (USVs), and Mobile Mapping System (MMS) mounted on vehicles.

All these technologies are used to fuel the data, in the form of point cloud and mesh characterized by their high precision or in-depth analysis information, for the BIM-GIS-Digital Twin system. This dynamic tool synchronized across various cloud-connect platforms for data management, extraction, simulation, and monitoring of both temporal and spatial alterations. This transformation enables the port master plan to be stored, accessed, and analyzed electronically, providing a comprehensive view of the port's infrastructure, assets, and related information. This integration aids in better decision-making, efficient management, and future development of the port area.

Keywords: Port master plan, BIM, GIS, digital twin, transformation

Introduction

Vietnam's rapid integration into the global community requires effective implementation of international commitments, particularly in infrastructure development. While the economy faces challenges like unsustainability and rapid urbanization, the national sector plans for 2021-2030, with a vision for 2050, aim to address these issues. These plans prioritize synchronized infrastructure investment for socio-economic development, national defence, and environmental protection. Notably, the Fourth Industrial Revolution and its influence on transportation necessitate strategic development of port infrastructure.

Ports have formed a crucial part of human civilization since ancient times, and the commerce that goes through them serves as a catalyst for economic growth and development. Nowadays, they are becoming one of the key elements of the globalized world economy, allowing developing countries such as Vietnam to export the products of its rapidly expanding economy. Due to the specific geographical characteristics of Vietnam, its seaport system plays an important role in the process of social development and economic growth [1].

Traditional port development planning involves General Planning for the entire seaport system and Detailed Planning for port groups. However, Detailed Planning often falls short due to its broad scope, limited budget, and short timeframe, resulting in insufficient data for comprehensive assessment [2].

In recent years, the Southern Focal Economic Area (SFEA) including Ba Ria – Vung Tau Province and Ho Chi Minh City is expanding its port system to keep pace with the development of the region (Figure 1). Decision No. 1579/QD-TTg of the Prime Minister on approving the General Planning for the development of Vietnam's seaport system for the period 2021 - 2030, with a vision to 2050, designed Ba Ria - Vung Tau seaport system as one of the two special seaport system in the country, functioning as a key international gateway and transhipment port, capable of accommodating large container ships and various cargo vessels [3].

To attract investment and expedite planning, parallel planning of land and water areas for Ba Ria - Vung Tau seaport alongside Detailed Planning for other south-eastern seaport groups is crucial.

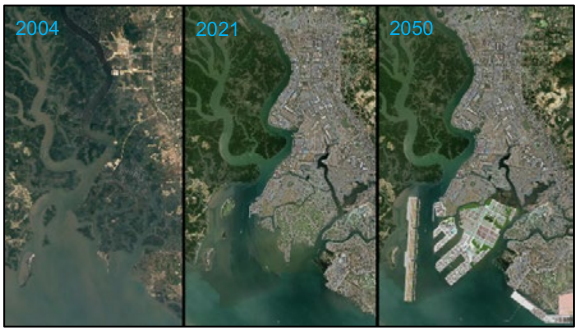

Figure 1 The seaport system in Ba Ria – Vung Tau Province and Ho Chi Minh City for the period 2004 - 2021, with a vision to 2050

In the realm of traditional port master plan development, critical phases such as site survey, data collection, and conceptual planning are central, encompassing a multitude of essential steps and methodologies. These phases collectively gather vital information that lays the foundation for a comprehensive and functional port design, forming the core of the entire planning process. During the conceptual planning phase, this data is utilized to sketch out preliminary designs and layout options for the port, heavily relying on seasoned expert knowledge and experience. Typically, these plans are materialized through conventional drafting and mapping techniques.

Traditional bathymetric surveys, relying on echo sounders and sonar systems mounted on boats, are invaluable for port development. However, their limitations become apparent in complex underwater environments, leading to inaccurate depth measurements, and potentially missed hazards. Additionally, the time-consuming nature of these surveys can cause delays and budget overruns, impacting project feasibility.

Advanced technologies are revolutionizing port master planning by offering faster, more cost-effective, and accurate data collection. LiDAR (Light Detection and Ranging) technology, for example, provides high-resolution 3D maps of the seabed and surrounding terrain, while Unmanned Surface Vehicles (USVs) equipped with multibeam sonar systems can efficiently survey large areas with detailed bathymetric data [4] (Figure 2). Advanced Geographic Information Systems (GIS) then integrate this data with other crucial information, allowing for comprehensive analysis and visualization of potential port layouts. Building Information Modelling (BIM) software further enhances the planning process by creating dynamic 3D models of the port infrastructure, enabling simulation of traffic patterns, environmental impacts, and financial viability. This data-driven approach allows for optimized designs and informed decision-making, ultimately leading to the development of more sustainable, resilient, and future-proof port infrastructures [5].

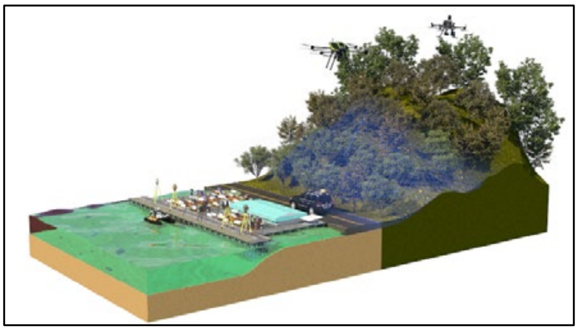

Figure 2 Advanced survey technology for port site; Revolution in the field of surveying and data collection

This paper is to examine the transformative potential of advanced technologies in Vietnam's port master plan development, aligning with the country's 2021-2030 sectoral plans and 2050 vision. By incorporating Building Information Modelling (BIM), Geographic Information System (GIS) technology, and the concept of digital twins, the paper demonstrates how these technologies can fundamentally enhance the efficiency, accuracy, and comprehensiveness of port master plan development. Then the transformative potential of these technologies is showcased in revolutionizing port master planning, leading to more informed decision-making and efficient management, thereby paving the way for the sustainable and strategic development of port infrastructures.

Methodology

Application of advanced Terrestrial Laser Scanning (TLS) technology for digitalization of construction and infrastructure

The adoption of Terrestrial Laser Scanning (TLS) technology in surveying practices offers significant practical implications for enhancing productivity and accuracy in survey results. This technology enables a substantial increase in survey volume and point density, far exceeding what is achievable with traditional survey methods. Additionally, the digital data acquired through TLS forms a foundational basis for developing Building Information Modelling (BIM) systems. This integration not only streamlines data collection but also facilitates more precise and detailed modelling, crucial for efficient construction management and planning. By leveraging TLS technology, surveyors and project managers can achieve a higher degree of detail and accuracy in their models, thereby enhancing the overall quality and effectiveness of construction projects.

Figure 3 Terrestrial Laser Scanning

To ensure the meticulous accuracy required in surveying, 3D laser scanning devices employ diverse positioning methods, each carefully calibrated to the specific equipment in use (Figure 3). For ground-based scanning, Leica Scanstation P50 is positioned at pre-determined locations with known coordinates and elevations, which are established using the Leica TS60 electronic total station. Similarly, when utilizing the Leica RTC360 and Faro Focus S350A devices, targets with pre-defined coordinates and elevations are employed to assign and calibrate the devices' positional data accurately. In the case of UAV-based surveying, specifically with the Stormbee S20, a base station is set up at a location with known coordinates and elevation to ensure accurate and reliable data capture (Figure 4). Each of these methods is tailored to the requirements and capabilities of the surveying equipment, ensuring the collection of precise and reliable data for various surveying and mapping needs as illustrated in Figure 5.

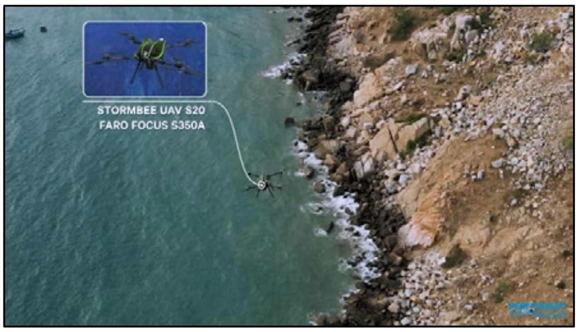

Figure 4 Stormbee UAV S20 & FARO Focus S350A

The data collected using 3D laser scanning devices are processed using specialized software such as Leica Cyclone, FARO® SCENE, and BEEFLEX. Throughout the data collection process, these softwares allow for the direct input of coordinate systems, ensuring that the resulting point cloud data are accurate in both coordinates and elevation. This capability significantly streamlines the process of data processing and analysis, making it more efficient and convenient for subsequent tasks.

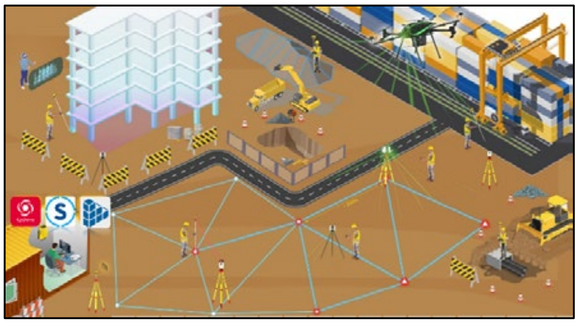

Figure 5 The survey process with Terrestrial Laser Scanning technology

Once processed, the data is converted into a point cloud format, typically in *.e57, *.las, or *.lgs files. This data is then directly imported into software such as Cyclone 3DR, Autodesk Civil 3D, or ArcGIS Pro to create a triangulated mesh surface, contour lines, and develop topographic maps from the point cloud data in a 3D environment. Further processing includes interpolating areas with ground objects or noise to ensure the accuracy of the topographic maps.

Mobile Mapping technology for revolutionizing terrain surveying

Traditional surveying methods for construction and infrastructure are being steadily overtaken by cutting-edge mobile mapping technology. Mounted on vehicles or unmanned aerial vehicles (UAVs), these systems equipped with LiDAR, laser scanners, and photogrammetry sensors are transforming the landscape of terrain surveying (Figure 6).

Figure 6 Mobile mapping systems mounted on vehicles and unmanned aerial vehicles technology combined with sensors like LiDAR, Laser Scan and Unmanned Surface Vehicles combined with Multibeam echo sounding or LiDAR

In this research, the Trimble MX50 utilizes LIDAR technology and is equipped with two 3D laser scanners capable of scanning up to 80 m based on the GNSS/IMU positioning system. Besides significantly saving survey time and easily accessing complex terrains, mobile mapping mounted on vehicles and UAV technology can also provide a large and uniform density of collected data. This assists in delivering intuitive, seamless, and varied products such as 3D point clouds, 3D meshes, Digital Elevation Models (DEMs), 360-degree panoramic images, and quick retrieval of cross-sections. The application of LiDAR and Laser Scanning on drones has made terrain data collection much easier and improved the accuracy of the data. This technological evolution has greatly enhanced the efficiency and accessibility of topographic surveying and 3D mapping (Figure 7).

Besides, the integration of multiple advanced tools like Unmanned Surface Vehicles (USVs), Multibeam echo sounding, and LiDAR in a single, compact unit unlocks even more possibilities, highly mobile unit for application in shallow water areas and other terrains inaccessible to traditional survey vessels represents a novel approach. By enhancing mobility and accessibility, this innovative amalgamation of technologies opens new possibilities for conducting surveys in previously challenging environments, streamlining the process while ensuring detailed and accurate data collection.

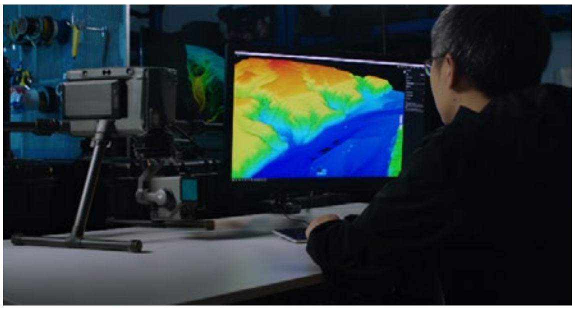

Figure 7 LiDAR and Laser Scanning technology on Unmanned Aerial Vehicles

The process of applying Unmanned Aerial Vehicles (UAVs) integrated with LiDAR, Laser, Photogrammetry technologies

DJI Pilot 2, Flight Hub 2, and DJI Terra facilitate the automation of flight paths and real-time detailed information collection, assisting pilots in planning, visualizing, processing, and analyzing data for unmanned aerial mapping either directly on-site or in the office before fieldwork commences. Depending on the type of object that needs to be digitized, such as survey topography, architectural structures, current status of constructions, or roads, appropriate flight modes and parameters (speed, altitude, overlap ratio, Ground Sampling Distance) are selected (Figure 8).

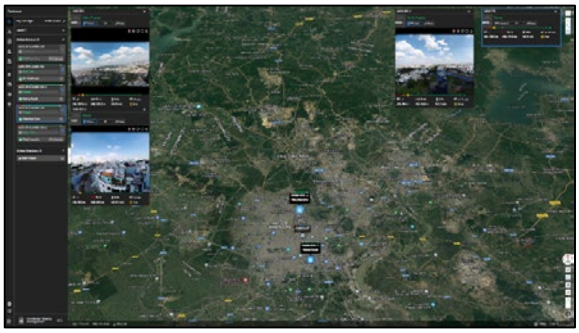

Figure 8 DJI Pilot 2, Flight Hub 2, and DJI Terra facilitate the automation of flight paths and real-time detailed information collection

Some primary methods before commencing a flight to collect data for mapping are Ground Control Points (GCPs), Real-Time Kinematic (RTK) positioning. The Ground Control Points method involves placing markers on the ground which are then used to reference and correct the aerial data (Figure 9). The RTK method provides real-time corrections to the drone's location, significantly enhancing positional accuracy as data is collected.

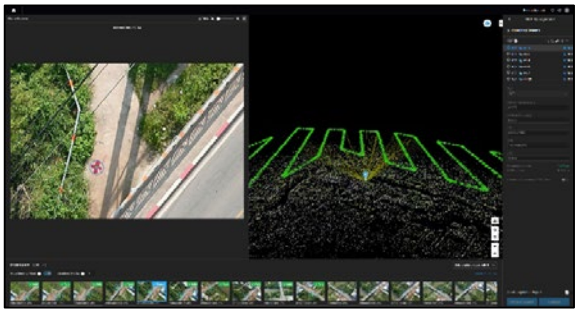

Figure 9 DJI Terra utilise Ground Control Point markers to reference and correct aerial data

The LiDAR device - Zenmuse L1 - integrated on the Matrice 350 RTK is capable of penetrating vegetation cover to collect ground data. The L1 can perform triple-return scans, significantly improving results in vegetated areas. It has the ability to achieve 240,000 points per second, which increases to 480,000 points per second during triple-return scanning. The oblique camera system - SHARE 203S Pro, equipped with five lenses totalling a 225 MP image sensor - integrated on the Matrice 350 RTK, provides high-quality imagery from five different angles.

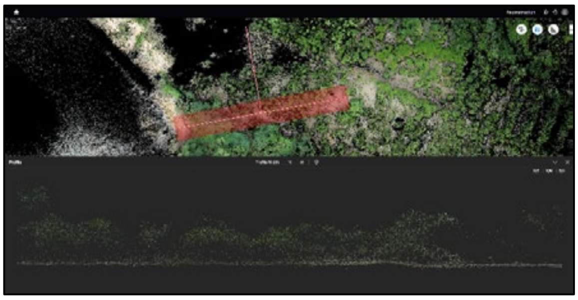

Figure 10 DJI Terra processing LiDAR data

The L1 data is processed in DJI Terra into a point cloud model, typically *.las files (Figue 10). This data is then directly imported into software such as Cyclone 3DR, Autodesk Civil 3D, and ArcGIS Pro to create a triangulated mesh surface, contour lines, and develop topographic maps from the point cloud data in a 3D environment. Whilst, The SHARE 203S Pro data is processed in DJI Terra into texture mesh, typically in *.B3DM, *.OBJ, *.I3S formats. Both data from the L1 and SHARE 203S Pro are calibrated using Ground Control Points (GCPs) to enhance accuracy and are further verified with check points (CPs).

The data were processed using Real-Time Kinematic (RTK) positioning and Post-Processed Kinematic (PPK) methods. The initial stage of processing data from 3D mobile mapping involves using POSPac MMS software, followed by further processing in Trimble Business Centre (TBC) software. The main tasks include processing the trajectory of the route, creating a Point Cloud model, verifying the point cloud accuracy along the established path, and exporting 3D point cloud models with x, y, z coordinates and colour parameters that intricately simulate the details of the terrain and features. These models are exported in desired formats to serve various purposes, such as constructing foundational 3D infrastructure models, establishing survey topography, creating as-built drawings, and analyzing discrepancies between the designed model and the current conditions.

For the project, a control network of elevation and coordinates is established, typically based on the coordinate and elevation benchmark system set up for the entire project. Additionally, an automatic water level monitoring station and a base station (for the Real-Time Kinematic (RTK) measurement method) are established onshore.

The USV device (with Two GNSS receivers with functions for collecting coordinates, elevation, and orientation) is deployed into the water and a control station is established onshore for remote operation. The survey path is designed and checked for any obstructions in the area before launching. Once launched, the Norbit-iWBMS Multibeam echo sounding device, mounted on the USV, is activated. The USV then automatically navigates along the pre-designed route according to appropriate operational modes. Concurrently, an integrated Norbit-iLiDAR system scans the above-water portion of the existing structures along the shoreline.

Survey data from Norbit-iWBMS and Norbit-iLiDAR devices will be processed using Hypack software, creating a raw point cloud model for underwater terrain and riverbanks, which are assigned coordinates and elevations according to the national elevation system, followed by exporting the Point Cloud data files in formats (*.E57, *Las...). The point cloud data from both onshore and underwater will then be integrated using software such as Cyclone 3DR, Autodesk Civil 3D, or ArcGIS Pro for noise reduction, data merging, error checking, and exporting the final data result as a combined point cloud dataset.

Integrating scan & survey data into BIM-GIS cloud-based platform

All survey and scan data to be combined onto a BIM-GIS cloud-based platform represents a significant advancement in digital infrastructure and environmental management. This approach involves harmonizing detailed land surface data, subsurface layers, and underwater topography into a cohesive model within a BIM framework, enhanced further by reality capture technologies such as LiDAR or photogrammetry [6].

The processed point cloud data is imported into building information modelling (BIM) applications such as Autodesk Revit and Leica Cyclone 3DR. This dual approach capitalizes on the inherent precision of the point cloud data, converting it into a detailed and comprehensive BIM representation [7].

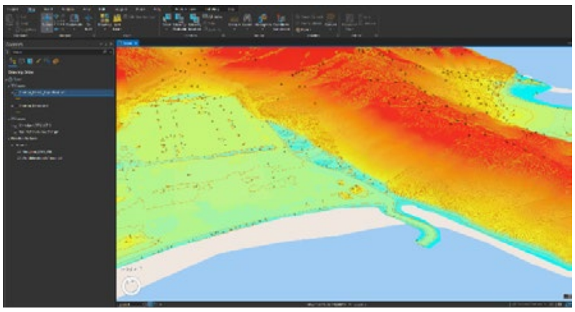

Figure 11 ArcGIS Pro processing LiDAR data

For effective integration into a GeoBIM environment, a BIM model must first be georeferenced within a GIS platform like ArcGIS Pro (Figure 11). Georeferencing involves aligning the BIM model to a specific coordinate system used in GIS to ensure that the model accurately represents its real-world geographical location. This integration facilitates improved planning, design, construction, and management of buildings and infrastructure by allowing users to visualize, analyze, and simulate real-world contexts alongside detailed building or infrastructure models [8].

The use of Unreal Engine as a platform for digital twins, integrated with Extended Reality (XR) technologies, further amplifies its potential, offering immersive and interactive experiences. As these technologies progress, they promise to revolutionize spatial analysis, visualization, and design, opening up new possibilities for innovation across various fields.

By integrating XR with the powerful visualization capabilities of Unreal Engine, bolstered by Autodesk's design tools and Esri's geospatial data, developers and professionals can create more engaging, informative, and interactive 3D applications.

Results and discussion

Revolution in the field of surveying and data collection

Point cloud data applied to projects have been collected using 3D laser scanning devices at ground stations, combined with data acquired from 3D laser scanning equipment integrated on Unmanned Aerial Vehicles (UAVs) comprehensively and fully represent the area of interest, adding substantial value to surveying efforts. The use of 3D laser scanning technology significantly shortens the surveying timeframe on-site, enhancing efficiency. The application of 3D laser scanning in surveying, design, structural inspection, and its use in building BIM models for construction management represents a viable direction and offers numerous future benefits. This technology not only improves the accuracy and detail of surveys and designs but also contributes to more efficient and informed construction and asset management practices.

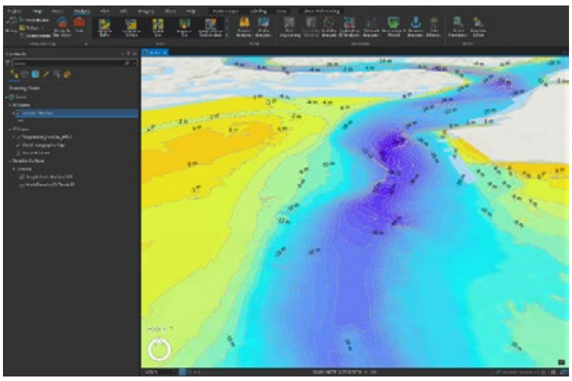

Figure 12 Point cloud data of underwater and shoreline

The utilization of UAVs along with car-mounted Mobile Mapping Systems (MMS) leverages the speed and efficiency of surveying, enabling extensive coverage over wide areas, including regions with complex terrains. Survey data (Point cloud and Mesh) collected using a combination of UAVs and MMS mounted on vehicles allows for high-precision data collection, meeting the diverse requirements for terrain surveying necessary in construction and land administration with conventional and customized map scales, as well as for integration into BIM and BIM-GIS models. This robust approach significantly reduces survey time compared to traditional measurement methods while ensuring a comprehensive, detailed, and accurate collection of spatial data crucial for advanced modelling and analysis in various projects.

Point cloud data of underwater and shoreline collected using Multibeam echo sounding devices combined with integrated LiDAR on Unmanned Surface Vehicles (USVs) are highly accurate (Figure 12). This data comprehensively covers the entire surveyed area, especially the areas in front of docks and along shorelines, where traditional surveying methods previously struggled to reach. The speed of data collection with these technologies significantly reduces survey time and the need for survey personnel, streamlining the entire process. By capturing detailed and accurate representations of underwater and shoreline environments, these advanced surveying methods provide a substantial improvement over traditional techniques, offering a more efficient and detailed understanding of these critical areas.

Comprehensive visualization cloud-based platform enables centralized data management and access

Building Information Modelling (BIM) is increasingly becoming the norm in Architecture, Engineering, and Construction (AEC) projects, with architects and engineers frequently utilizing Geographic Information System (GIS) data to enhance their project designs with geospatial context. The integration of BIM and GIS into a unified cloud-based common data environment represents a significant advancement for enhancing collaboration and communication among project stakeholders across various disciplines.

GIS enhances BIM by supplying essential real-world context about the existing environment of an asset, offering a spatial framework within which designers and engineers can assess and refine their designs and construction plans. Conversely, BIM enriches GIS with detailed, information-rich models of assets that bolster the operation and maintenance phases, contributing valuable specifics about the physical and functional characteristics of infrastructure. The amalgamation of BIM and GIS results in a dynamic context model that merges geographic information with project design data, fostering a comprehensive understanding of how assets function and interact with their surrounding environment, be it built structures or natural landscapes. This synergistic relationship not only deepens the insights into asset management but also enhances the planning, implementation, and sustainability of infrastructure projects, leading to more informed, efficient, and effective outcomes. Planners can analyze and visualize the interactions between the port and its surroundings, assess the impacts of potential changes, and make more informed decisions (Figure 13).

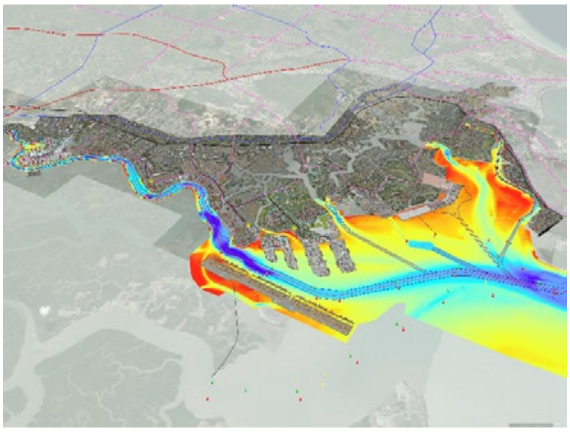

Figure 13 Digital Twin platform for Vietnam's Southern seaport master plan system on BIM-GIS platform

Immersive game engine platforms with XR technologies for digital twins

The application of BIM-GIS and game engine platforms, enhanced by XR technologies, is setting new standards for Digital Twins. Companies like Esri, Autodesk, and Unreal Engine are providing the necessary tools and platforms to create these detailed, interactive, and dynamic models.

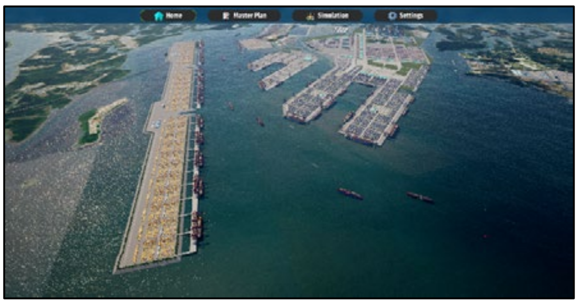

Figure 14 Digital Twin platform for Vietnam's Southern seaport master plan system

Game engines allow for dynamic simulations within the Digital Twin, including lighting, physics, and environmental changes, providing valuable insights into how the asset will perform under various conditions (Figure 14). Game engines' capabilities extend beyond visualization and interactivity; it can also connect to various Internet of Things (IoT) devices and APIs, including CCTV cameras, sensors, and other data sources. This allows the Digital Twin to reflect current conditions accurately. Users can interact with the Digital Twin and see how changes affect the system in real-time, thanks to the data fed from IoT devices.

Lastly, Artificial Intelligence (AI) is being increasingly employed in the processes of data analysis, noise reduction, object classification, 3D modelling, and optimization of workflows, with rapid, exponential advancements enhancing the speed and efficiency of these tasks. This application of AI significantly accelerates and refines various processes, allowing for quicker and more effective completion of tasks.

Conclusions

As Vietnam is in the midst of accelerating its digital transformation, the adoption of the Building Information Modelling (BIM) framework within the construction industry is becoming increasingly essential. In parallel, the application of processes and technologies such as Scan To BIM-GIS to serve the BIM-GIS model will further refine and enhance the effectiveness of these models. The ongoing research and application of software for Scan to BIM-GIS technology will progressively advance the field of surveying to a new level of proficiency and innovation. The utilization of Unmanned Aerial Vehicles (UAVs), Terrestrial Laser Scanning (TLS), Unmanned Surface Vehicles (USVs), and Mobile Mapping Systems (MMS) mounted on vehicles following established operational procedures yields high work efficiency.

Integrating BIM-GIS with game engine platforms and Extended Reality (XR) technologies for Digital Twins significantly enhances the port master planning process. This multidimensional approach brings a new level of precision, interactivity, and insight to the development and management of port infrastructure, offering even more sophisticated tools for simulation, analysis, and stakeholder engagement.

Acknowledgement

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