5th PIANC World Congress, 29 April – 23 May 2024, Cape Town, South Africa
Paper Title: Digitalization of the port infrastructure: Case study of Baria Serece Port in Vietnam
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Digitalization of the port infrastructure:

Case study of Baria Serece Port in Vietnam

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Abstract: Although BIM and GIS are distinct technologies, they can be used together to improve the planning, design, and operation of buildings and infrastructure. The integration of BIM-GIS on the cloud-based platform enables stakeholders to access building and geospatial data, observe their visualization in 3D, and analyse them for management and operation from anywhere, at any time. This paper will describe the process of integrating BIM data into web GIS to create the comprehensive virtual 3D model for port infrastructure project in Vietnam.

Keywords: Digitalization, multi-sensor, BIM-GIS integration, port infrastructure

Introduction

The transformation towards digitalizing port infrastructures heralds' significant advantages. It fosters heightened operational efficiency, improved resource utilization, and streamlined decision-making processes. This transition represents a paradigm shift in modernizing port facilities, ensuring enhanced competitiveness and sustainability within the maritime domain [1].

Globally, the shift toward digitizing maritime infrastructure has been gaining momentum. Developed countries have spearheaded these initiatives, utilizing advanced technologies such as IoT, AI, and cloud computing [2]. However, within Vietnam, while strides have been made, the pace of digitalization in port facilities remains a work in progress [3].

Several challenges obstruct this digital transition [4]. These include but are not limited to the complexity of integrating diverse data sources, ensuring data accuracy and consistency, and bridging technological gaps within existing infrastructure. Moreover, regulatory frameworks and data security concerns pose additional hurdles to seamless digitization efforts in Vietnamese port facilities [5].

In response to these challenges, the proposed technical solution, which is applying for digitalization of infrastructure for Baria Serece port in Vietnam, lies in the amalgamation of multiple data streams on a web GIS platform. This integrated approach not only addresses data compatibility issues but also facilitates comprehensive spatial analysis, enabling informed decision-making. The utilization of web GIS platforms offers a scalable, accessible, and collaborative environment for handling diverse data sets and fostering efficient management of port infrastructure.

Area descriptions

Baria Serece is one of the first deep-sea ports in Vietnam, located in Phu My Town. The port has a very convenient location, just 17 nautical miles from the mouth of the sea, 70 kilometers from Ho Chi Minh City, and 40 kilometers from Vung Tau City (Figure 1). The port was established in 1993 and has since grown to become a major gateway for international trade in Vietnam. Baria Serece is strategically located on the Thi Vai River basin and distributed over a large area 20ha of land and water surface, giving it access to both domestic and international markets. The port has experienced a notable increase in annual cargo volume in recent years, reaching approximately 6.5 million tons. The port infrastructure consists of two piers with a total length of 555.38 meters. Bridge section A (upstream) has a length of 300.74 meters and can accommodate vessels with a deadweight tonnage (DWT) of up to 80,000. Bridge section B (downstream) has a length of 254.64 meters and can accommodate vessels with a reduced load capacity of up to 87,000 DWT. Baria Serece Port plays a vital role in the Vietnamese economy, creating thousands of jobs and generating billions of dollars in revenue. The port is also a driving force for the development of Ba Ria-Vung Tau province.

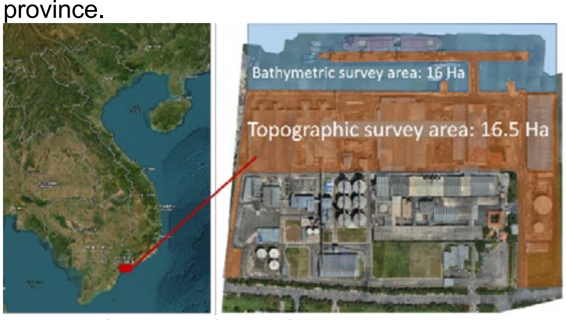

Figure 1: Overview of Baria Serece Port

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Methods and Techniques

In today's infrastructure development, digitalization merging with port projects is a crucial frontier, promising enhanced efficiency and management. This shift unfolds in three stages: starting with a thorough GIS-based survey mapping the port's landscape. Next, Scan to BIM revolutionizes blueprinting, creating detailed three-dimensional digital models. Finally, the fusion of BIM and GIS harmonizes spatial and structural data, improving operations and decision-making. This three-step strategy marks a new era in port development, reshaping efficiency in the maritime domain with integrated digital tools.

- Survey to GIS

The convergence of Survey to GIS within the context of port project digitalization represents a fundamental cornerstone, establishing an intricate web of spatial intelligence that underpins subsequent developmental phases. At the forefront of this endeavor stands ArcGIS Online, a dynamic platform that serves as the bedrock for amalgamating diverse data streams into a coherent, accessible interface. This integration unfolds through a multifaceted approach, employing cutting-edge methodologies to acquire and synthesize crucial spatial data.

The utilization of terrestrial laser scanning constitutes a foundational component, facilitating high-resolution point cloud acquisition of the port's terrestrial topography. This method enables the creation of detailed, three-dimensional representations, capturing the nuanced features and contours of the port infrastructure with unparalleled accuracy.

A variety of scanning equipment was used in the Baria Serece project, including multi-stations and dedicated scanners. The Leica RTC360 (Figure 2, bottom) is a long-range specialized scanner with a range of up to 130m and a speed of 2 million points per second. A total of 940 scanning stations were used to cover the entire port. The number of stations for each area is tabulated in Table 1. The coordinates of the scanning stations were determined using traditional positioning techniques such as GNSS and Total station. The multi-station SX12 (Figure 2, top) is a total station itself, so in addition to scanning, it also has the ability to measure and determine the coordinates of the scanning station, making it a suitable choice for developing additional measuring stations for obscured areas.

Figure 2. Multi-station SX12 on the wharf (top) and Leica RTC360 under the pier (bottom) for laser scanning

Table 1: Number of scanning stations for each area

Area	Number of scanning stations
Wharf	156
Pier	10
Warehouse and internal roads	668
Office building	35
Pier underneath	71

The integration of Unmanned Aerial Vehicles (UAVs) equipped with cameras and LiDAR technology introduces a dynamic aerial dimension to the survey. This aerial reconnaissance captures panoramic views and generates high-resolution aerial imagery, while LiDAR scanning enhances this perspective by providing detailed elevation data. The synergy between these methods delivers a bird's-eye view of the port, enabling a comprehensive understanding of the spatial layout and topographical variations.

The UAV Matrice 300 RTK equipped with the Zenmuse P1 camera and Zenmuse L1 LiDAR system provided a comprehensive aerial view of the port area. Flight paths with 70% overlap coverage captured 25,250 images, covering 16.5 hectares. These images, processed with 20 ground control points, generated orthoimages and a 3D mesh model on a web-based GIS. The UAV and flight paths applied in Baria Serece are illustrated in Figure 3.

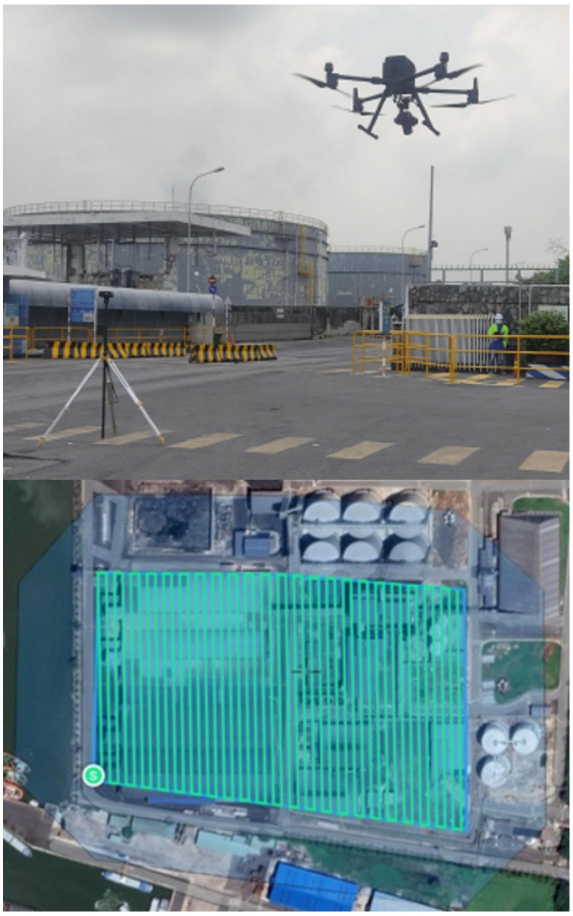

Figure 3. UAV Matrice 300 RTK (top) and the flight paths (bottom) covering the port area

Expanding beyond traditional terrestrial and aerial methods, the incorporation of Unmanned Surface Vehicles (USVs) equipped with multibeam echo sounders and LiDAR systems adds an aquatic dimension to data acquisition. These autonomous vessels navigate the port's waters, employing multibeam echo sounders to chart underwater terrain while LiDAR scans the port's perimeters from a waterborne vantage point. This dual functionality captures both submerged topography and shoreline details, enriching the GIS with comprehensive data for holistic port management and development.

In Baria Serece, the USV Otter, equipped with the Norbit multibeam echo sounder and iLiDAR system, surveyed the riverbed before the dock and scanned waterfront structures (Figure 4, top). Survey lines (Figure 4, bottom) with a 20% overlap covered the area, including confined shallow water sections.

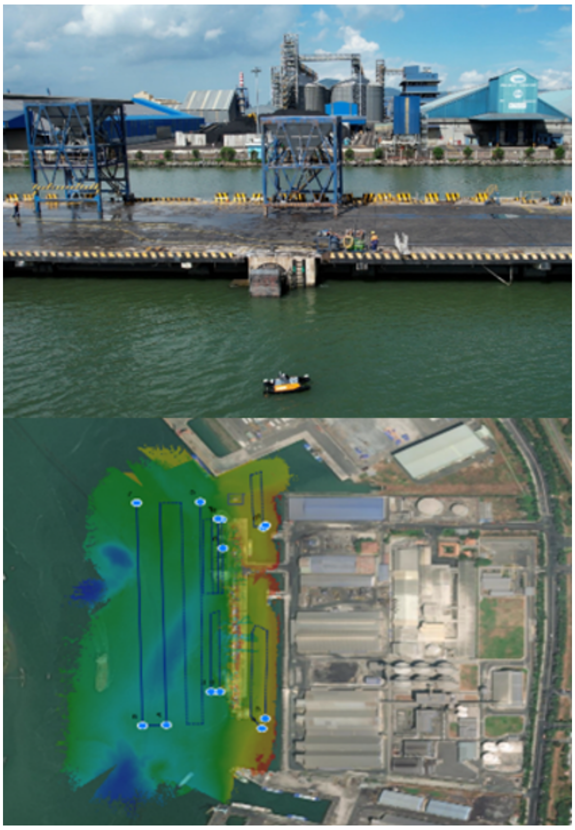

Figure 4. USV Otter in front of the port (top) and its planned routes (bottom) for bathymetric surveying

Geological data from each borehole and the stratigraphy of the port area were surveyed using a traditional method of geotechnical drilling combined with field and laboratory testing (Figure 5). The data was then used to create a 3D digital representation of the boreholes and stratigraphy of the area on a GIS platform [6].

In unison, these diverse data acquisition methodologies coalesce within ArcGIS Online, forming a comprehensive repository of spatial information that embodies the port's multifaceted landscape. The integration of terrestrial, aerial, and aquatic data streams establishes a robust foundation for subsequent phases, ensuring that the GIS becomes an invaluable tool for decision-making, planning, and ongoing management within the dynamic ecosystem of the port.

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Figure 5. Drilling at site

- Scan to BIM

The progression from Scan to Building Information Modeling (BIM) marks a transformative leap in the digitalization journey of port projects, heralding a paradigm shift from conventional two-dimensional representations to immersive, three-dimensional models that encapsulate the port's intricate infrastructure in unprecedented detail. At the crux of this evolution lies the conversion process, transitioning from static 2D drawings to dynamic, information-rich 3D models [7].

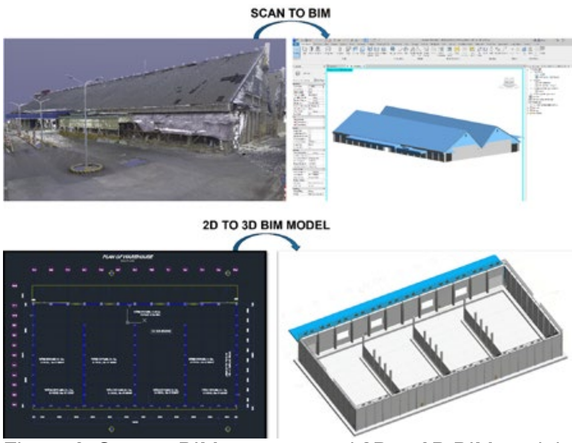

Figure 6. Scan to BIM progress and 2D to 3D BIM model

Scan to BIM utilizes 3D laser scanning technology to create digital representations of buildings or infrastructure. This involves key steps like data acquisition, processing, model creation, quality control, and integration. Its advantages over traditional methods include enhanced accuracy, time and cost savings, improved collaboration, data-driven decision-making, clash detection, and detailed as-built documentation.

Initial stages involve consolidating data from diverse scanning methods into a unified digital canvas. Indoor scanning captures detailed interior features, while outdoor scanning captures overall building shape and its environment. The combination provides a comprehensive view used for various purposes like documentation, design, construction, and maintenance.

Using specialized BIM software, scanned data undergoes meticulous processing. Advanced algorithms and point cloud processing transform this data into spatially accurate 3D representations (Figure 6 top). Simultaneously, BIM integration enriches these models with material specs, structural details, spatial relationships, and operational parameters, empowering stakeholders with a comprehensive understanding for analysis, simulation, and decision-making.

In the Baria Serece project, besides the status quo 3D scanning described above, existing historical documentation and 2D drawings necessitate digitization and conversion into 3D BIM models (Figure 6 bottom). This transition bridges the gap between historical documentation and digital innovation, preserving knowledge while embracing transformative potential.

In essence, the Scan to BIM conversion transcends the mere translation of visual data; it encapsulates the evolution toward a comprehensive, intelligent, and data-enriched representation of the port. This transition empowers stakeholders with an immersive, information-rich digital environment, fostering enhanced collaboration, informed decision-making, and optimized management within the evolving landscape of port infrastructure development.

- BIM-GIS integration

The integration of Building Information Modeling (BIM) with Geographic Information Systems (GIS) within the ArcGIS platform represents a transformative convergence, melding the spatial intelligence of GIS with the detailed structural and operational insights offered by BIM. This union empowers stakeholders within port projects to harness the synergistic potential of these distinct yet complementary technologies, fostering a holistic understanding and management of the port infrastructure [8].

At the heart of this integration lies the seamless interoperability between BIM and GIS datasets within the ArcGIS environment. This synergy allows for the amalgamation of spatially rich information from GIS, encompassing topographical, environmental, and infrastructural data, with the detailed, information-rich 3D models generated through BIM methodologies. The ArcGIS platform serves as a central hub, facilitating the fusion of these datasets and enabling stakeholders to visualize, analyze, and derive insights from the integrated information. Through this integration, spatially referenced BIM

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data is overlaid onto GIS layers, creating a comprehensive, multidimensional representation of the port's infrastructure. This confluence offers a nuanced perspective that incorporates both the physical spatial context from GIS and the detailed structural, material, and operational information from BIM.

Furthermore, the integration within ArcGIS transcends visualization; it enables advanced spatial analysis and decision-making. Stakeholders can perform complex geospatial analyses leveraging BIM attributes, allowing for scenario simulations, clash detection, risk assessments, and optimized resource allocation within the geographical context provided by GIS.

Moreover, this integrated platform fosters collaboration and communication among multidisciplinary teams involved in port development. It provides a common framework for stakeholders, including planners, engineers, architects, environmentalists, and managers, to work cohesively, share insights, and make informed decisions based on a comprehensive understanding of both spatial and structural aspects.

The ArcGIS-enabled BIM-GIS integration not only enhances project planning and execution but also facilitates ongoing operational management of the port. Real-time data updates, maintenance information, and asset management within the GIS environment can be seamlessly integrated with BIM, ensuring that the digital twin created through BIM remains reflective of the dynamic, evolving nature of the port.

Digitizing an entire port project is a complex undertaking that necessitates the integration of various modern tools and different software. It also requires specific skills and appropriate processing workflows, which cannot be exhaustively described within the scope of this article. Figure 5 provides an overview of the key steps and equipment used in the digitization process of the Baria Serece port in Vietnam.

Results

The process of digitizing the Baria Serece port involves a series of steps, as outlined in Figure 7. These steps include creating a 3D point cloud model, followed by a 3D photogrammetry model, then a 3D BIM model, and finally, a multi-layer representation on a web-based platform.

Various scanning devices like Terrestrial Laser Scanning (TLS), LiDAR on Unmanned Aerial Vehicles (UAVs) and Unmanned Surface Vehicles (USVs), and multibeam echo sounders on USVs, along with compatible software, generate dense point cloud datasets. These datasets consist of millions of 3D spatially coordinated points, forming a recognizable 3D model as seen in Figure 8 (top). Ensuring data alignment across devices relies on control points, overlap coverage, and meticulous data processing for accuracy.

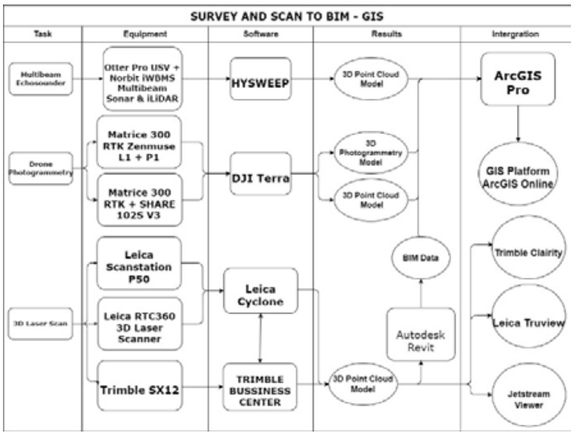

Figure 7. The summary of equipment, software and process using in Baria Serece port digitalization project

For higher-resolution imagery, UAV-captured aerial photos undergo photogrammetry. Processing these images, taken from various angles, alongside evenly distributed Ground Control Points (GCPs), produces an accurate 3D photogrammetry model, depicted in Figure 8 (middle). This serves as the foundational dataset for display on the ArcGIS online platform. At this stage, the ability to zoom in to see details clearly is possible, as illustrated in Figure 8 (bottom).

Building the BIM model involves detailed processes from creating an object library to executing object recognition post-scan. It includes managing attribute information, converting pre-existing 2D design drawings, especially for underground structures. Figure 9 illustrates the 3D BIM model of the entire Baria Serece port (top) and highlights geological borehole details (bottom). The complete BIM model aids in information retrieval and clash detection if any before construction, as seen in Figure 9 (middle). In addition, some specialized models can be built and integrated directly on the ArcGIS Pro platform, such as the voxel-based model that represents geological layers and boreholes in Figure 9 (bottom).

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Figure 8. 3D point cloud model (top), 3D photogrammetry model (middle) of Baria Serece port, and zoom in a part of 3D photogrammetry model (bottom)

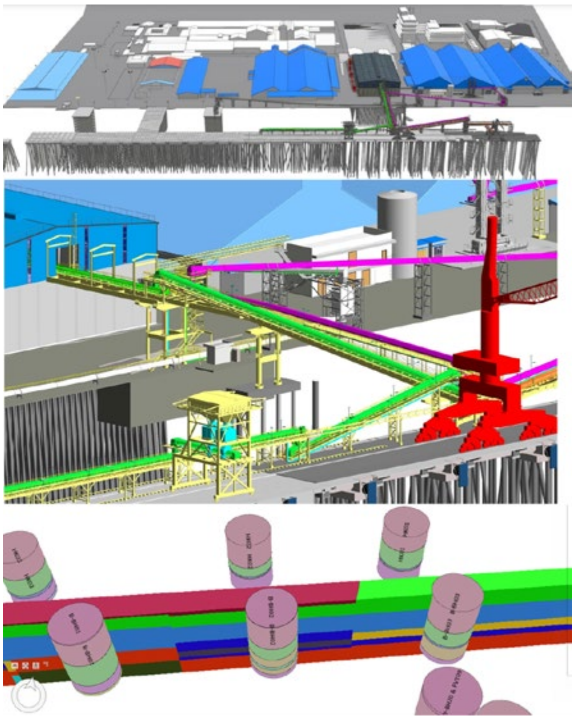

Figure 9. 3D BIM model of Baria Serece port (top), a zoom-in part of 3D BIM model (middle), and model of geological borehole (bottom)

The integrated BIM-GIS product on the ArcGIS online platform is shown in Figure 10, displaying different layers that can be viewed separately or stacked. Figure 10, top reveals any conflicts by overlaying existing condition BIM data with designed BIM data if any. Figure 10, bottom additionally displays dense point cloud data with color-coded height/depth indications.

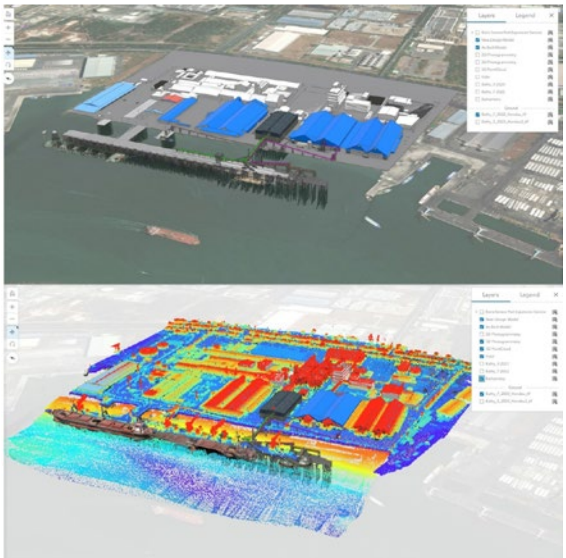

Figure 10. BIM-GIS integration for multi-layer presentation

This integrated model allows measurements and calculations, as depicted in Figure 11, where distance and slope are accurately depicted (top), or in selected cross-sections (bottom). These functionalities simplify measurement and calculation tasks within this integrated model.

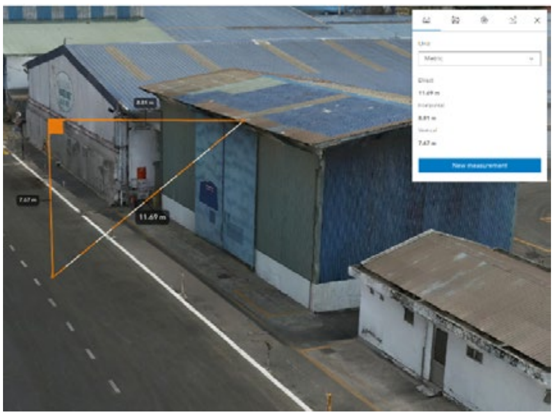

Figure 11. Measure directly on web- based platform: Distance (left) and Cross-section (right)

Discussion and Conclusions

Within the sphere of digitalizing port facilities, various fundamental facets contribute significantly to enhancing operational efficiency and managerial capabilities. Based on the ongoing digitization project of Baria Serece port facilities (since 2023) in Vietnam, the discussion encompasses the advantages and necessity of integrating 3D models, the potential implications for real time management post-digitalization, the evolving trends and benefits concerning the adoption of cloud-based systems, and the strategic importance of embracing mobility-centric approaches, notably through devices like the iPad, in the application of BIM-GIS systems.

The implementation of 3D models presents several key advantages. These models offer a comprehensive and detailed depiction of port landscapes, thereby fostering improved comprehension and informed decision-making among stakeholders. Furthermore, they enable efficient clash detection, allowing for the pre-emptive identification and resolution of discrepancies within designs, ultimately optimizing construction processes. Additionally, the intuitive nature of 3D models facilitates clearer and more effective communication among stakeholders, which is vital for comprehensive project understanding and collaboration.

In the post-digitalization landscape, the capability for near-real-time management becomes crucial. Real-time data accessibility ensures prompt insights into alterations or advancements, enabling swift decision-making. This dynamism allows for streamlined resource allocation and management, optimizing operational efficiency. Moreover, the immediate detection and resolution of issues minimizes potential operational disruptions, contributing to sustained smooth operations.

The adoption of cloud-based systems brings forth manifold benefits. These systems enable enhanced accessibility to data, fostering collaboration and supporting remote work functionalities. Their scalability feature allows for flexible resource scaling without substantial initial investments. Furthermore, advanced security measures offered by evolving cloud security protocols assure robust data protection, ensuring the confidentiality and integrity of information.

In line with technological advancements, mobility-oriented approaches, particularly leveraging devices such as the iPad, present significant advantages. On-site accessibility to data enables prompt decision-making within the port environment. Mobility facilitates improved collaboration among stakeholders, allowing them to interact with models and data during on-site visits or collaborative sessions. This mobility also ensures real-time updates, enabling informed decisions based on the latest available information. As trends continue to evolve, augmented reality (AR) integration and ongoing enhancements in user interfaces tailored for mobile devices further amplify the potential of these mobility-oriented approaches within the BIM-GIS system application.

Collectively, these aspects underscore the transformative potential of digitalization within port facilities. They showcase how technological integration can optimize operations, facilitate informed decision-making, and enhance overall efficiency in managing complex maritime infrastructures.

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