35th PIANC World Congress, 29 April – 23 May 2024, Cape Town, South Africa
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BIM-GIS Integration for Ha Nam Channel Upgrade Project

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Abstract: Given the demand to accommodate a fleet of 30,000 DWT vessels, the current Ha Nam channel, a segment of Hai Phong navigational channel, located in Northern Vietnam, requires deepening. This paper describes the field survey processes, as well as the hydrodynamic study conducted to evaluate the feasibility of the upgrade work. The hydrological and bathymetric survey are carried out by combining traditional multibeam equipment with advanced Unmanned Surface Vehicles (USVs) in the initial step to collect data on the current condition of the channel, providing input for the numerical model. The Unmanned Aerial Vehicles (UAVs) equipped with advanced sensors are used to capture and create a detailed 3D representation of the channel's surrounding area above the water surface. Finally, a cloud-based project management technique related to this channel upgrade is also proposed.

Keywords: Channel, dredging, hydrodynamic, digital model, BIM-GIS

Introduction

Recently, the construction industry in the world is undergoing a digital revolution, with Building Information Modeling (BIM) emerging as a transformative force. Vietnam's embrace of BIM is evident in the Decision 258/QĐ-TTg, issued in 2023 by the Prime Minister, outlining a strategic plan for its implementation in construction projects. While BIM has seen widespread adoption in various projects across Vietnam, its application in complex infrastructure projects like navigational channels remain largely unexplored territory. However, given that these structures often involve high complexity and significant costs, the adoption of BIM could be particularly beneficial. This paper concentrates on developing the pioneering application of BIM model in upgrading the Ha Nam channel, a crucial segment of the Hai Phong navigational channel in Northern Vietnam (Figure1).

The Ha Nam channel plays a pivotal role for accessing the Nam Dinh Vu port cluster, a key hub for both domestic and international commercial transport in the region. Located at the mouth of the Bach Dang River, the industrial zone thrives on efficient maritime access. To accommodate larger vessels with capacities exceeding 30,000 DWT and drafts of 8.5 meters, deepening the channel from its current 7.0 meters is paramount.

This paper transcends mere channel deepening, venturing into the realm of cutting-edge technology. By employing BIM technology, a comprehensive and informative 3D digital model of the Ha Nam channel has been established. Additionally, a comprehensive hydrodynamic study leverages the collected data to evaluate the feasibility of deepening the channel, specifically considering the impact of increased yearly dredging volume and its potential effects on the existing revetments.

Figure 1 The project area overview

Furthermore, recognizing the growing need for intelligent and sustainable project management, a cloud-based approach was proposed. This aligns with the concept of BIM-GIS integration, as outlined by Hajji and Oulidi [1], emphasizing the necessity of considering two distinct scales for intelligent and sustainable building management. While BIM provides the core data including detailed models of the channel and surrounding infrastructure form the foundation of the system, GIS adds spatial context in which geospatial data enhances the model with real-world references, enabling insightful analysis and informed decision-making [2,3]. This concept of integration adheres to international standards like GeoBIM [4,5]. The primary advantage of GeoBIM is its capacity to conduct spatiotemporal analysis where all changes in the channel over time at various scales were studied, providing valuable insights for long-term maintenance and development [6]. Such integration holds immense potential for applications in smart cities, integrating navigational channel data with broader urban infrastructure projects [7], environmental sustainability [8], and the construction industry [9], among others.

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Looking ahead, the development of digital twins, integrating extended reality technologies, is gaining momentum which involves the fusion of BIM modeling technology with GIS map data, terrain, images, and realistic 3D models. This combination of technologies is used to visualize complex data with graphic and information displays, transforming abstract information into readily understandable visual representations [10]. In this study, the authors discuss the benefits of this integrated model, specifically applied for managing project quality of the Ha Nam navigational channel.

Methodology
Navigational channels like the Ha Nam Channel face complex challenges in data acquisition and model development, often leading to fragmented information and not aligned processes. To address these challenges, this research explores the innovative integration of Building Information Modeling (BIM) and Geographic Information Systems (GIS) in the Ha Nam Channel upgrade project. The paper details the comprehensive methodology employed, from cutting-edge data collection techniques to the development of a validated numerical model and an integrated BIM-GIS platform.

Data collection

Figure 2 Recorded data in the project area

A numerous dataset of historical parameters, including wave patterns (C4 station), current flows (S1 and S2 stations), water levels (WL and T2 station), and suspended sediment concentrations (S1, S2, and C4 stations) as shown in Figure 2, serves as a valuable foundation for model calibration and validation. This dataset, spanning back to 2011, provides a comprehensive understanding of the channel's long-term behavior.

Additional field survey
The initial phase of the study involves conducting addition hydrological and bathymetric surveys to gather data on the current state of the channel, thereby ensuring the most accurate and up-to-date information including wave parameters, water levels, current speeds, and suspended sediment concentrations for numerical model development. Traditional bathymetric data collection is performed using a multibeam echosounder mounted on a boat. However, this technique proves less effective in shallow regions. One reason for this is the higher cost and complexity of mapping in shallow areas (near the revetment), which arises mainly from depth limitations.

To address these challenges, this study employs the innovative use of Norbit's iWBMS Multibeam mounted on Otter Unmanned Surface Vehicles (USVs). USVs are particularly effective in shallow areas due to their low draft and enhanced maneuverability enabling more efficient and accurate bathymetric data collection in environments where traditional methods fall short (Figure 3).

Figure 3 USVs Otter

Numerical models
DHI MIKE21 software was employed for hydrodynamic analysis (wave, current, and sediment transportation), with model calibration and validation performed using the combined historical and field survey data (Figure 4). Using this validated model, the hydrodynamic factors of deepened channel and annual sediment volume are accurately estimated. Furthermore, the study extracts simulated data on wave height and current speed at the revetment location, ensuring informed assessments of structural integrity under the upgraded conditions of the channel.

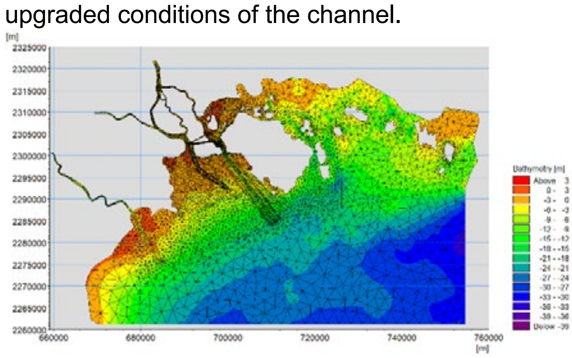

Figure 4 Computational area and mesh

Dredging the Ha Nam Channel will allow for the passage of larger vessels, potentially increasing their impact on the revetments due to wave generation. This study focuses on accurately assessing the real impact of vessel-induced waves on these crucial structures. Fortunately, during trial runs of several large vessels through the existing channel (Figure 5), the authors had the opportunity to collect supplemental wave measurements using Nortek AWAC equipment (Figure 6). This valuable data offers crucial insights into the interaction between large vessels and the channel's infrastructure. However, limitations in equipment deployment depth prevented us from directly measuring wave heights at the revetment base.

To address this limitation, we employed estimated values derived from the well-established empirical formula provided by PIANC InCom WG4 (1987) [11]. This formula allows to accurately calculate the propagation of wave heights from the vessel's location to the areas of interest, including the revetments.

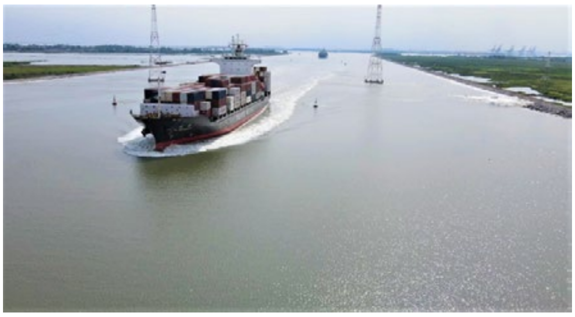

Figure 5 Big vessel YM INTERACTION maneuver through the Ha Nam channel

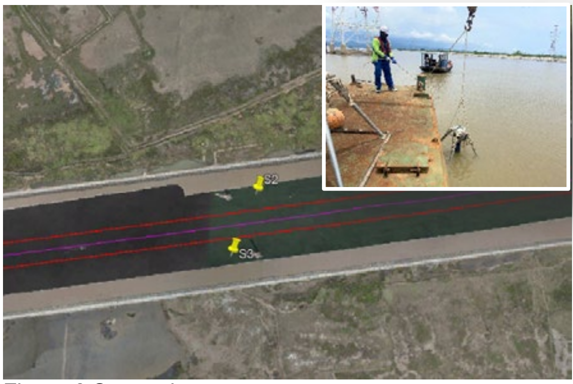

Figure 6 Set up the wave measurement

BIM model

The Ha Nam Channel's BIM model was built using two field survey methods: aerial photogrammetry and LiDAR, both deployed on Unmanned Aerial Vehicles (UAVs). LiDAR sensors offer exceptional accuracy (up to millimeters) and versatility, while UAV cameras capture hundreds or thousands of color photographs, subsequently converted into 3D point clouds and assembled into maps or models.
In this study, DJI Matrice RTK300 UAVs equipped with advanced L1 (LiDAR) and Zenmuse P1 (photogrammetry) sensors to generate detailed 3D point clouds of the channel's above-water area and surroundings were utilized (Figure 7). This data was then processed using professional software to create a precise 3D representation of the entire project area. The complete workflow, from field survey to the development of the BIM model based on the 3D data, is referred to as "*survey to BIM*."

Figure 7 UAVs DJI Matrice RTK300 with Zenmuse P1 (upper right picture) and L1 (lower right picture)

Integrating of the navigational channel BIM-model into GIS-based environment

While BIM concentrates on individual buildings and their detailed components, GIS encompasses broader geographic landscapes, including multiple project elements within a geographic coordinate system. Both technologies, including the advancement of 3D GIS, facilitate comprehensive modeling of built environments, encompassing both interior and exterior elements. They offer powerful tools for documenting, editing, managing, and visualizing spatial and non-spatial data across various scales and detail levels.

Recently, the Architecture, Engineering, and Construction (AEC) sector is undergoing a crucial digital transformation, necessitating the seamless integration of geospatial (GIS) and design data (BIM). Recognizing this demand, industry leaders like Esri and Autodesk have partnered to prioritize GIS-BIM integration in construction projects. This collaboration paves the way for a future characterized by improved sustainability and resilience.

A key factor in linking GIS with BIM is the effective exchange of data between BIM, CAD, and geospatial information. The fusion of design and geospatial data is rapidly becoming a standard expectation in the AEC industry worldwide. ArcGIS, a leading GIS platform, continue to adopt common BIM and CAD formats to facilitate diverse workflows across project stages, including planning, construction, operations, inspections, and maintenance.

This study showcases the integration of the Ha Nam Channel BIM model into a GIS-based environment. The model incorporates various data types crucial to the project, enriched with high-precision point cloud data from Unmanned Surface Vehicles (USVs) and Unmanned Aerial Vehicles (UAVs), which are then integrated into the ArcGIS Web-GIS platform, creating a comprehensive BIM-GIS model.

Within the Ha Nam channel model, each object is parameterized and organized into specific layers within Esri ArcScene. This approach enables a thorough characterization of each element, encompassing on-site survey results (hydrological and geotechnical data), design details (channel cross-section and navigational aids system) as well as the current physical state represented through 3D point cloud data and photogrammetry. The resulting online platform offers not only user-friendly visualization of the channel model but also efficient strategies for smooth project execution and management. The workflow the whole digitalization process is illustrated in Figure 8.

Figure 8 Workflow of Ha Nam channel digitalization process

Results

Numerical models results

The outcome of the hydrodynamic analysis indicated that dredging the Ha Nam Channel had a minimal impact on the hydrodynamic regime, with current velocities remaining below 1.0 m/s (Figure 9). The projected accretion thickness after one year also showed no significant change, exceeding 0.3 m (Figure 10) and aligning with the expectations of both the port authority and the investor. This stable hydrodynamic regime paves the way for further analysis of vessel-induced impacts on the channel infrastructure.

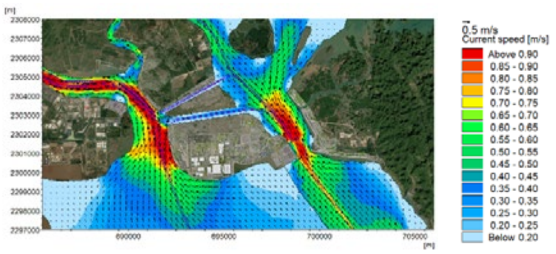

Figure 9 The current field after channel upgrade

Figure 10 The 1-year accretion of the deepen channel

Ship-induced wave checking

Figure 11 shows the water level measurements taken during the passage of a vessel through the channel. This wave calculation is implemented considering both the condition of the actual water level at +3.5mCD, and hypothetical scenarios at a lower water level of +2.0mCD. The estimated wave heights, using an established empirical formula, closely matched the measured data created by three ships as shown in Figure 12 (the FAREAST HAMORNY - 43,756 DWT, CONSERO - 13.684 DWT, and PEARL RIVER BRIDGE - 21.976 DWT), validating the basis for further calculations. This confirms the accuracy of our approach for predicting wave heights under various conditions. Notably, the calculated wave height for a 10-knot vessel is under 0.4m, well within the revetment's design limits of 1.08m, indicating its sufficient stability for handling larger vessels.

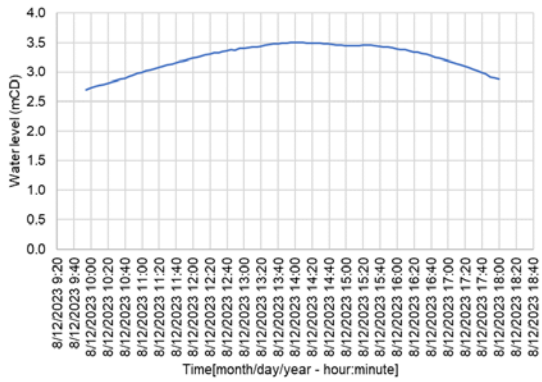

Figure 11 Water level during the observation period

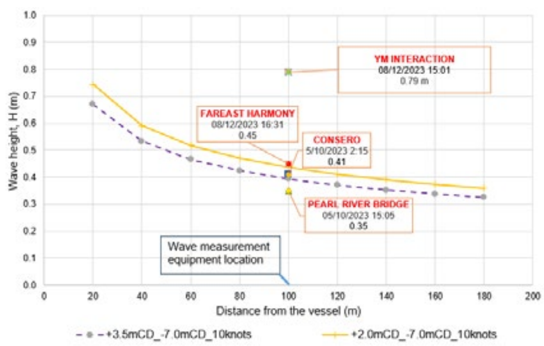

Figure 12 The vessel-induced wave calculation

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BIM-GIS model of the Ha Nam navigational channel
The integrated BIM-GIS model (Figure 13) seamlessly combines data from both underwater and land-based surveys. Bathymetric data from underwater surveys and boat surveys of the channel are merged with the data collected using USVs at the shallow area, while point cloud data captured by UAVs creates a 3D model of the surrounding land, including buildings and infrastructure. Every element within the channel is precisely geo-referenced within the GIS environment, enabling accurate visualization and analysis.

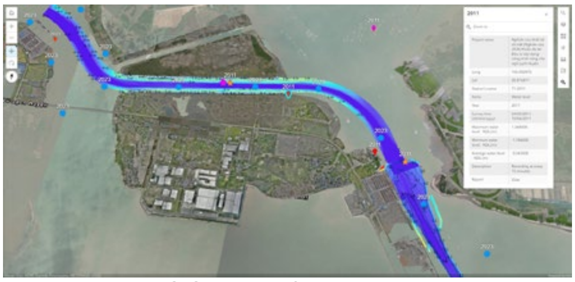

Figure 13 BIM-GIS model of Ha Nam channel

Discussion
What the is the benefit of the BIM-GIS model.
Integrating BIM with Web-GIS unlocks powerful benefits. The resulting model can be directly visualized and interacted with in a web browser, eliminating software hurdles and enabling collaborative exploration. BIM focuses on designing physical structures at an object level, such as slopes and cross-sections of the revetment, but falls short in capturing the broader context. Additionally, the GIS component empowers spatial data analysis, offering valuable insights beyond the individual object level. By combining these technologies, we gain a richer understanding of how infrastructure integrates with its surroundings, allowing us to manage structures within a holistic spatial framework that encompasses land, features, and infrastructure networks.

This integrated environment transforms user experience in 3D and access additional parametric information about objects. For instance, Figure 14 showcases a prime example – a 3D revetment model replacing traditional site photos. Users can directly view the model, access detailed parameter information about objects, and conduct virtual assessments. Remote engineers can measure bank slopes, assess rock diameters (Figure 15), and even perform ship-induced wave checks – all within the virtual model.

Furthermore, the online platform elevates data accessibility and collaboration. Sharing the model becomes as simple as sharing a link, fostering seamless collaboration between stakeholders regardless of location. This "one-click" access to all necessary information streamlines workflows and enhances efficiency in building and infrastructure management.

Figure 14 The measurable model of the channel and surrounding area

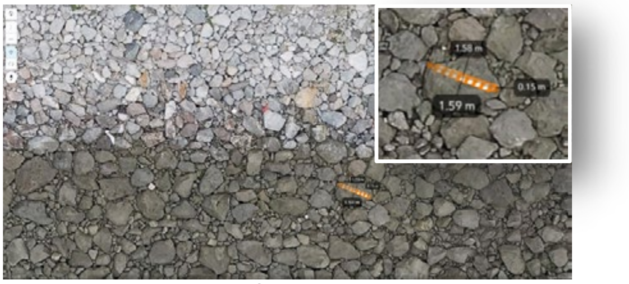

Figure 15 Digital model of the revetment

What type of database can be integrated into BIM-GIS model
Our experience demonstrates the remarkable versatility of BIM-GIS models, capable of seamlessly integrating virtually any form of data. This comprehensive integration proves particularly beneficial for navigational purposes, as exemplified by the meticulous monitoring of navigational buoy systems with precise coordinates on interactive map.

Additionally, the BIM-GIS model serves as a flexible information hub, extending beyond spatial representation to encompass a wealth of supplementary details. These include technical drawings, maintenance history, and real-time operational status of each navigational buoy. This ability to incorporate and update detailed information on-demand enhances the system's functionality and utility, providing a comprehensive and dynamic overview of navigational aids and their conditions (Figure 16). This real-time intelligence not only aids in safer and more efficient maneuvering but also empowers proactive maintenance and informed decision-making.

Figure 16 The informative model of the navigational buoy system

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The BIM-GIS model transcends static visuals by seamlessly integrating a dedicated hydrological survey layer. This layer doesn't merely mark station locations; it unlocks a wealth of vital data, enriching the user experience and empowering informed decision-making. Each station becomes a data hub, revealing not just its spatial coordinates but also a temporal dimension. Survey dates, alongside critical data points like maximum and minimum values, are readily accessible. This historical knowledge provides invaluable context for model calibration and validation, optimizing accuracy and reliability (Figure 17). These reports can provide in-depth information about each survey, which is valuable for model engineers. They can utilize this data to calibrate and validate their models, ensuring accuracy and reliability more effectively.

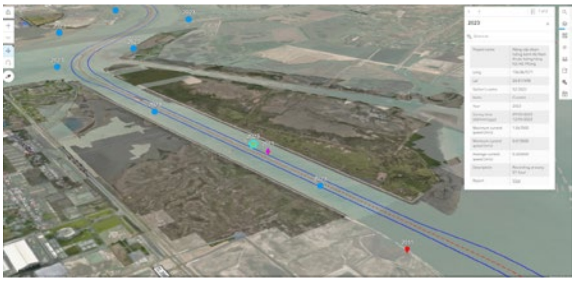


Figure 17 The locations of surveyed stations

Moreover, the platform's capabilities extend to integrating the results derived from numerical models. This fusion transforms the BIM-GIS model into a holistic and dynamic tool. Not only does it aid in planning and analysis, but it also tracks the impact and effectiveness of various hydrological interventions. This predictive capability empowers researchers and managers to make data-driven decisions, optimizing interventions and ensuring project success.

The integration of point cloud data from aerial LiDAR and underwater multibeam survey into a Web-GIS model significantly enhances its capabilities, transforming it into a robust 3D data powerhouses, revolutionizing waterway management. LiDAR technology facilitates the extraction of various geographical features, such as terrain contours, discrete points, and linear elements. This ability to capture detailed spatial information enables the creation of a more comprehensive and accurate model of existing conditions.

For design purposes, this feature is particularly valuable. Engineers can now precisely examine the real cross-section of any channel segment, which is a notable advancement offered by Esri. This update allows for the creation of detailed profiles based on the values obtained from the multibeam survey, as exemplified in Figure 18.

One of the critical applications of this feature is in the evaluation of water channels. By comparing multibeam-derived cross-sections with existing designs (Figure 19), engineers can pinpoint changes like sediment accumulation (accretion) that require dredging or erosion hotspots. This knowledge unlocks efficient management strategies, from targeted dredging to improved sustainability practices. This approach not only improves accuracy in design and maintenance but also contributes to more sustainable management of aquatic environments.

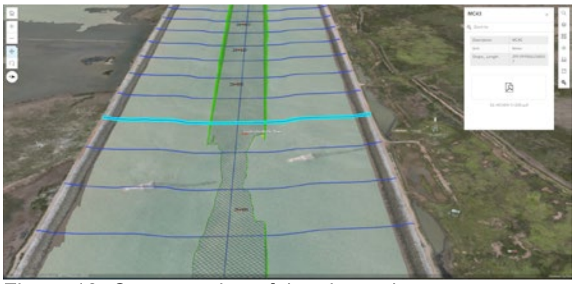
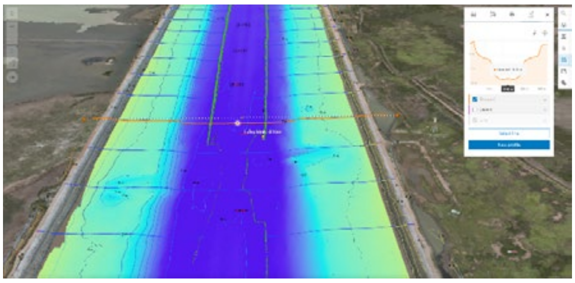


Figure 18. Cross-section of the channel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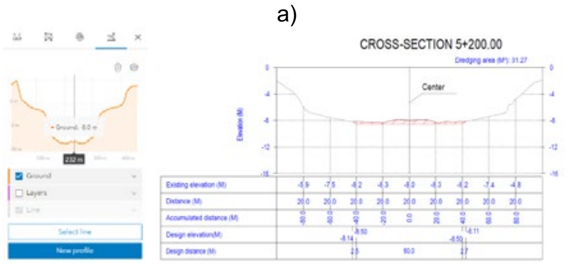

b)

Figure 19 Existing and design cross-section

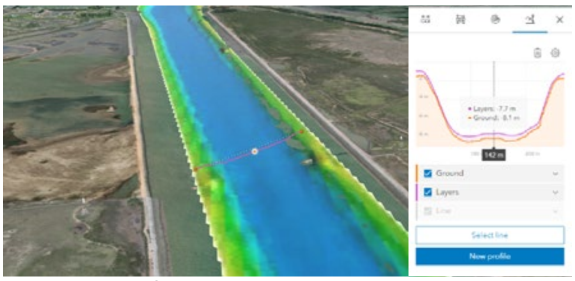

Figure 20 Bed form change between two periods

By integrating Building Information Modeling (BIM) and Geographic Information System (GIS) data, the platform ensures that all stakeholders, including planners, engineers, and even external partners, have instant access to the latest data information directly through a web browser at anytime, anywhere. This access eliminates the need for additional software installations and streamlining information flow across the project.

This integration is especially advantageous for project managers and planners. It enables them to easily access, understand, and interact with the project data due to the unified and connected nature of the data and the live models. The platform significantly improves the ability to locate and interact with various types of information, some of which were previously inaccessible in such an integrated manner.

Conclusions

This paper has unveiled a leap forward in navigational infrastructure management – an advanced BIM-GIS model for the Ha Nam channel. The study demonstrates the benefits of using advanced equipment to create a 3D digital model of the navigational channel. The BIM-GIS integration approach offers a user-friendly interface for stakeholders to engage with up-to-date project information online without additional software. This integrated model significantly advances project oversight and the ability to manage complex information systems in the context of transport infrastructure development. In conclusion, the Ha Nam channel stands as a testament to the transformative power of BIM-GIS integration. This digital bridge between physical infrastructure and real-time data unlocks an unprecedented level of control, paving the way for a future where navigational infrastructure is not just managed, but optimized.

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