ISSN 2029-6991 / eISSN 2029-7009

GEODESY and CARTOGRAPHY

2025
Volume 51
Issue 4
Pages 216–226
https://doi.org/10.3846/gac.2025.21985

UDC 528.94

WEBGIS AND LAND PLANNING DATA MANAGEMENT: A STUDY OF HANOI UNIVERSITY OF CIVIL ENGINEERING'S CAMPUS 2

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Article History:
- received 07 August 2024
- accepted 29 November 2025

Abstract. The use of WebGIS in urban land planning and management has become a global trend. A WebGIS system was developed specifically for planning management at HUCE's Campus 2. While not yet fully complete, the findings indicate that this system has provided substantial support to stakeholders, including local authorities, planners, and the broader community. Through efficient data management and analysis, the WebGIS system has facilitated timely monitoring and adjustments during the construction process, while also enabling comprehensive modifications to land planning. Additionally, its field interaction function gathers valuable information for detecting damages requiring repair and maintenance, along with updates on the status of areas where land use rights have not yet been transferred. Despite certain limitations, such as challenges in integrating 3D model data and enhancing public consultation methods, the incorporation of these research findings offers significant potential to improve the effectiveness of urban land planning and management in the future.

Keywords: GIScience, WebGIS (Geoweb), land planning, geospatial data management, geospatial analytics, public participation.

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1. Introduction

Urbanization in developing countries or low-income areas is undergoing rapid expansion, accompanied by pervasive changes in land use. This trajectory imposes significant urban planning imperatives on state and governmental entities, necessitating the provision of accessible services and the preservation of a good quality of life (Sejati et al., 2020). Urban and regional planning is inherently strategic, demanding transparency, openness, and efficient information dissemination from local authorities to various stakeholders (Mougiakou et al., 2020). Thus, the meaningful implementation of participatory planning hinges on the active engagement of local authorities. Furthermore, the analysis of participant perspectives offers valuable insights into the constraints associated with planning projects. These complexities present challenges in the cartographic and visual representation of geographic data, compounded by the intricacies of sharing planning information from administrators and managers. Additionally, understanding how to solicit and process public feedback is pivotal for ensuring the ongoing viability and enhancement of urban planning initiatives. At present, the integration of Geographic Information Systems (GIS) and web technology platforms has been determined to be the optimal approach for addressing these issues (Kurniawan et al., 2023).

Information, with an emphasis on geospatial data, assumes a pivotal role in the methodologies employed in urban planning and management. The predominant use of geographic information by planners is manifest in its reliance on topographic maps or its association with a specific geographic location through coordinate references and attribute data. GIS serves as information systems renowned for their capacity to integrate, analyze, share, and visualize spatial data or geographic information. In the last decade, the utilization of GIS in information management represents an efficacious solution for urban planning and construction planning, as highlighted by Van Maarseveen et al. (2018). GIS facilitates a comprehensive understanding of patterns, relationships, and the geographic context, affording benefits such as enhanced communication, heightened management efficiency, and improved decision-making processes. Moreover, GIS technology has been substantiated as yielding scientifically reliable outcomes and policy recommendations. This substantiation, as asserted by (Addo, 2010; Wang et al., 2020), underscores its instrumental role in supporting decision-makers and planners in advancing sustainable development initiatives, particularly in the context of swiftly expanding urban areas. Furthermore, WebGIS has been assessed as a viable alternative to desktop GIS for improving the dissemination of results and facilitating international collaboration among experts (Grecea et al., 2016).

Urban planning is intricately related to various dimensions of socio-economic life. In the review of urban planning by (Haklay et al., 2018), the authors mentioned technical facets, socio-economic dynamics, healthcare, transportation, land use, heritage preservation, and air quality as well as pertinent policies within the urban environment. Delving into the specifics of individual components within urban planning, Rigolon and Németh employed the QUINPY tool (QUality INdex of Park for Youth) to scrutinize the domain of park planning, assessing the quality of parks with a focus on the youth demographic (Rigolon & Németh, 2018). Within the QUINPY, there are GIS shapefiles, geodatabases, and spreadsheets that can be connected to geospatial data through unique identifiers, addresses, or geographic coordinates. This functionality empowers to swiftly and precisely derive comprehensive and accurate information by using geospatial data. However, these GIS systems have also identified significant limitations in accessing, collecting field data and exchanging data across various spatial contexts and. In the realm of urban planning infrastructure and traffic systems, the authors' research highlights the essential role of GIS in analyzing and visually representing cycle routes in urban over spaces and time (Butler et al., 2018). The study underscores the importance of providing cycle route designers with access to quantitative spatial assessments for enhanced preparedness. The authors simultaneously recognized the importance of fostering community interaction through websites to enhance data collection efforts. On the other hand, the study conducted by Lepetiuk et al. (2023) emphasize the effectiveness of GIS in spatially analyzing transportation systems. Furthermore, the author advocates for the establishment of a website or web application by travel agencies to efficiently manage and disseminate supplementary travel information. Thus, the ubiquity of Geo-information applications in various facets within the municipality is evident. Nonetheless, Morales contends that while GIS is predominantly used for spatial data visualization, there is a lack of applications that offer tools for spatial analysis and facilitate a data-sharing environment (Morales et al., 2018).

The utility of WebGIS lies in the digitalization of information and the facilitation of collaboration within a unified data milieu. This data environment serves as a GeoPackage, enabling the perpetuation of project-related information for subsequent reuse. Effective and seamless sharing of the planning data environment among stakeholders contributes to the optimization and ongoing improvement of the whole life of planning projects. In the context of university planning, several studies have been undertaken to address internal utilization requirements. For example, Al-Rawabdeh et al. (2014) developed a 3D offline GIS solution to enhance data management related to the usage of facilities and services on campus. Furthermore, an ordinary WebGIS system was integrated household data with spatial imagery from Google Earth, facilitating improved access to information for rural residents interested in higher education institutions (Pavan Kumar & Venkata Reddy, 2020). Similarly, Papua et al. (2020) developed a WebGIS system based on an open-source platform to provide essential information, including location coordinates, building names, and navigation tools for users within the university campus. Recognizing that these are fundamental WebGIS systems with limited functionalities, they have not fully leveraged the benefits of integrating and unifying multiple data layers simultaneously. This integration is crucial for providing planners with a comprehensive view of the study area, thereby facilitating the development of effective planning options (Dai et al., 2020), overseeing construction activities (Li et al., 2023), and updating data for more nuanced interpretations (Ratti Guzman, 2022). Concurrently, these systems have not adequately satisfied the demands for effective management strategies and stakeholder engagement techniques (Cureton & Hartley, 2023). Furthermore, they have fallen short in facilitating community participation in the urban planning process (The National Assembly of Vietnam, 2009).

HUCE's Campus 2, newly established and located a considerable distance from the urban center, provides an ideal setting for initiating the planning process and enhancing asset and facility management. This context highlights the need for effective solutions that a WebGIS system can address. This study showcases the WebGIS application designed to support sustainable land planning at HUCE's Campus 2. The system enhances the management of land planning data through advanced editing, analysis, and evaluation of land use changes, while also fostering community interaction, thereby facilitating informed decision-making in planning and asset management.

2. Study area and data collection

2.1. Study area

The study area pertains to Campus 2 of Hanoi University of Civil Engineering (HUCE's Campus 2), situated within Namcao University Area in Hanam province at coordinates 20°36′00″ north latitude and 105°56′00″ east longitude. This campus has been strategically developed to accommodate the growing scale of educational programs as outlined in the HUCE's Development Strategy. Additionally, it plays a pivotal role in advancing the network planning initiatives for Vietnamese Universities and Colleges.

The planning area of HUCE's Campus 2 encompasses approximately 24 hectares designated for academic and research purposes (denoted as planning box symbol TH-15), along with an additional 2 hectares allocated for official and staff residences, as illustrated in Figure 1.

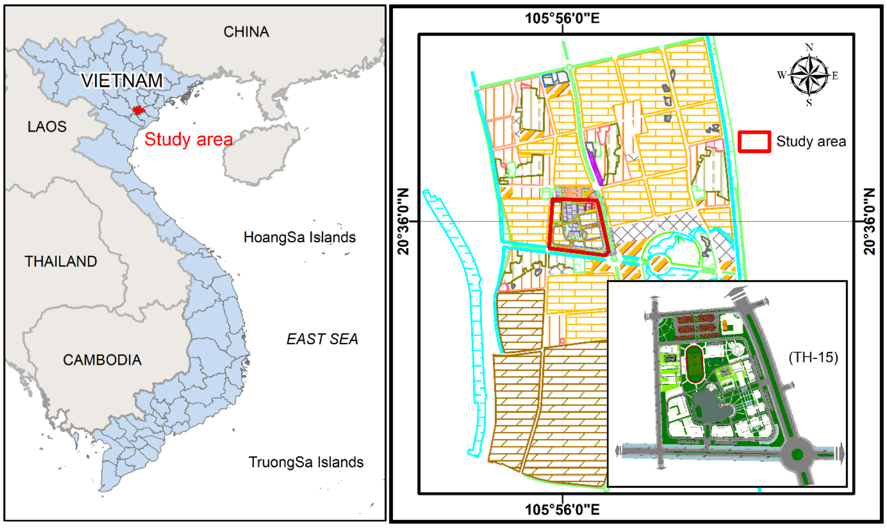


Figure 1. Positioning of study area in the Namcao university area

2.2. Collection data

The planning project at HUCE's Campus 2 aims to facilitate organized spatial development, enhance key functional areas, establish robust technical infrastructure, and implement effective land use planning. Aligned with contemporary science park trends, the project is designed to maintain a construction density of approximately 20–25%, while ensuring that at least 40% of the land area is dedicated to green spaces. Data for this initiative is sourced from the HUCE data center, which primarily provides spatial data in various formats, such as .dng, .dwg, and .skp files, along with attribute data comprising project explanatory reports available in .docx and .xlsx formats. Additionally, supplementary data is gathered from the field using technologies such as UAVs, GNSS, and total stations, as well as through direct surveys.

Due to the presence of data pertaining to each object in various formats and styles, it is essential to implement a data standardization process. This process ensures consistency, allowing each piece of information to be stored in a single location, thereby facilitating effective management and updates. Additionally, it establishes a foundation for a standardized database that can be easily expanded and integrated with other systems. Specifically, spatial data includes current base maps at a scale of 1:500, as well as cadastral maps, regional planning maps, and zoning plans at a scale of 1:2000. These data sets are uniformly converted to Shapefile format within the ArcGIS Pro environment to ensure accurate spatial coordinates and compatible data structures.

The standardization of spatial data and construction planning attributes in this study is conducted in accordance with (Circular No. 04/2022/TT-BXD, 2022). This adherence ensures the proper storage, utilization, and sharing of data, thereby providing a robust technical and legal foundation. Additionally, the data must be structured to facilitate the creation of interactive maps, enable queries, support analysis, and aid decision-making within the WebGIS environment. Consequently, the data has been optimized to enhance the speed of display and retrieval on the web, while also ensuring ease of data sharing through web services.

3. Methodology

3.1. Platform and operation structure of WebGIS

WebGIS serves as a solution for the publication, access, and querying of geospatial information within open environments, such as the Internet. The adoption of open standards is gaining prominence due to the necessity for uniformity and globalization in the communication and sharing of GIS data across various systems. The integration of WebGIS with OpenGIS standards invigorates planning and management applications, particularly within the contemporary landscape of digital transformation. A typical structure of WebGIS platform comprises three primary layers: the Client layer, the Component layer, and the Data layer, Figure 2.

At each phase of urban planning, WebGIS offers numerous advantages. In the initial phase, which involves establishing project objectives, WebGIS plays a critical role in the synthesis and analysis of spatial data. The system facilitates the integration and simultaneous processing of various geographic information layers, such as topography, geology, land use, technical infrastructure, and socio-economic indicators. This capability enables planners to gain a comprehensive understanding of the study area, leading to the formulation of scientifically grounded and efficient planning options. Furthermore, WebGIS's 3D simulation features enhance urban space design by enabling the assessment of the landscape impacts of different planning scenarios. In terms of strategic environmental assessment, WebGIS provides spatial analysis tools that can predict and evaluate the environmental consequences of planning decisions. For example, the system can simulate

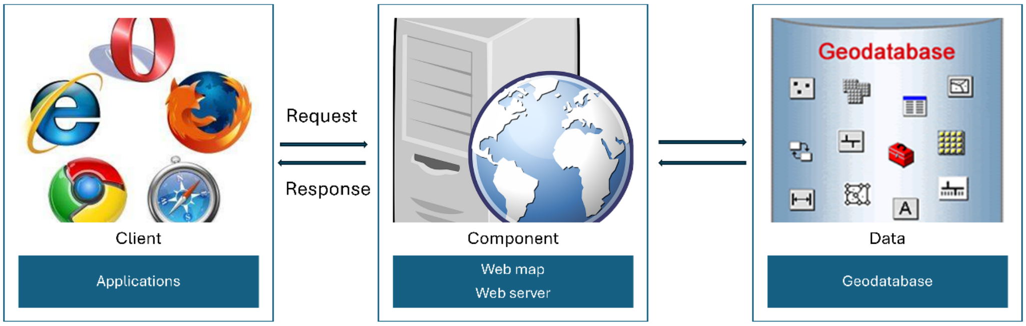


Figure 2. Typical structure of WebGIS

the spread of air and water pollution or assess impacts on ecosystems, aiding in the development of more effective strategies to mitigate negative environmental effects.

Additionally, during the stages of public consultation and the announcement of urban planning initiatives, WebGIS serves as an efficient online interactive platform. Through geographic information portals, the public can easily access planning documents, retrieve detailed information for specific locations, and provide feedback. This approach not only enhances transparency but also fosters community engagement in the planning process, aligning with the requirements of the Law on Urban Planning, which emphasizes the rights and responsibilities of organizations and individuals in contributing their opinions. In the execution of planning management and task implementation, WebGIS provides significant support for boundary marker placement, architectural landscape space management, and construction oversight. The system facilitates the precise determination of boundary marker coordinates, management of boundary marker databases, and monitoring of adherence to construction boundaries. Additionally, the integration of a 3D urban model within WebGIS allows for the assessment of the impact of new developments on the urban landscape, ensuring coherence and balance in architectural design.

Moreover, during the process of planning review and adjustment, WebGIS serves as an effective tool for monitoring and evaluating urban changes over time. By comparing spatial data across different phases, discrepancies between planned and actual development can be easily identified, enabling the proposal of timely and appropriate adjustments. However, implementing a comprehensive WebGIS system to support these tasks presents considerable challenges. In the planning project for HUCE's Campus 2, efforts have been made to develop a WebGIS system that addresses some of the practical issues specific to the project.

The workflow depicted in Figure 3 follows a structured approach to data management and processing. It begins with data collection, which involves collecting various types of data, including vector, UAV, planning, raster, attribute, current state data, and field data synchronization. These data sources are then processed in the data ingestion phase, where they are uploaded via an API, synchronized through a dedicated module, and stored in a central data storage system while maintaining their original formats. Next, the data moves into the data processing phase, where raster and vector data are processed separately, and attribute data is linked. The processed data is stored in a database management system, which supports further

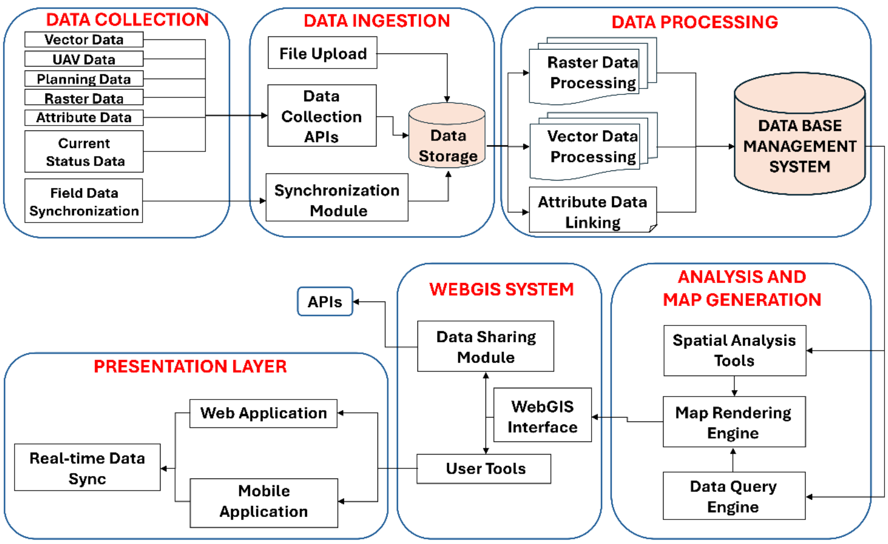


Figure 3. Workflow diagram for data management and processing

analysis. This step involves using ArcGIS Pro to perform spatial analysis tasks and generate various maps. The map rendering engine then transforms the processed data into visual representations. In the WebGIS system phase, maps and rendered data are integrated into a WebGIS interface that includes data lookup, data-sharing, and data update functionalities, along with user tools for interaction. Finally, the workflow reaches the Presentation Layer, where the data is made accessible via web and mobile applications. These applications provide real-time data synchronization, ensuring that users receive seamless updates across multiple devices.

3.2. WebGIS design

A WebGIS system has been developed specifically for managing planning information related to HUCE's Campus 2. This system is equipped with functionalities for system administration, data retrieval, display, and data updating, along with additional support functions. It processes current status data and planning information to generate the required results. Figure 4 outlines the specific operations and outputs associated with each function. In comparison to traditional planning methods, our WebGIS system offers substantial advantages, particularly in terms of data integration, interoperability, and the ability for project participants to update and access information anytime and anywhere. However, there are still certain limitations that need to be addressed, such as the integration of 3D model data and the enhancement of interaction between users and administrators.

The management functionality of the WebGIS system enables access rights to database resources based on user roles. Simultaneously, it manages system logs and user authentication processes. The application functionality allows users to visualize and explore various types of map

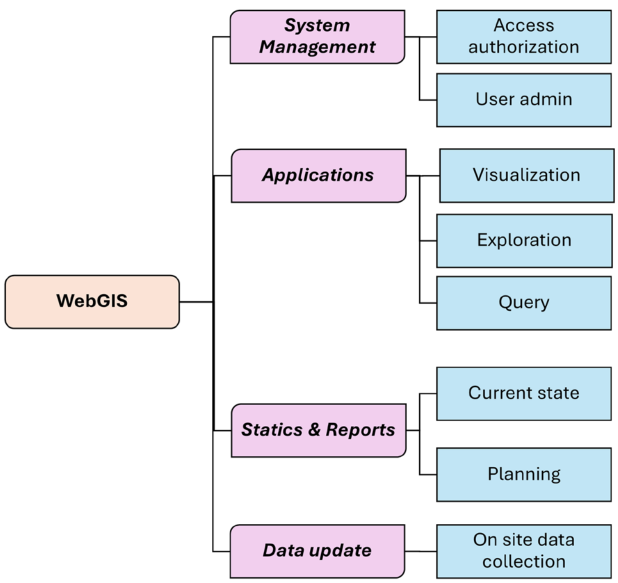


Figure 4. Functional structure of WebGIS for planning information management at HUCE's Campus 2

data, conduct queries, and generate statistics or reports on current and planned land information.

With the support function subsystem, users can utilize a variety of utilities beyond fundamental services like Zoom and Pan. These include capabilities such as measuring objects on dynamic maps, determining optimal routes with the aid of the platform's base maps, and updating field data.

a. Measure and draw tools

This function enables users to execute several fundamental utilities, including measuring and delineating objects (points, lines, and areas), toggling the visibility of basemap and thematic map layers, presenting map layers or pop-ups of map data, querying attribute information of geospatial data, and managing the export/import of geospatial data (e.g., orthomosaic and digital elevation models). It also provides tools for measuring and analyzing specific objects or locations of interest within the university area planning context, taking into account factors such as proximity to existing facilities and accessibility of infrastructure.

b. Determining optimal routes

Through the integration of geographic data into an interactive map interface, users can effectively visualize and analyze optimal routes for various purposes, including travel, emergency response, and infrastructure planning. The tool offers intuitive features such as search functionalities, layer conversion, and customizable route options. Leveraging sophisticated spatial analysis techniques, it evaluates diverse criteria such as accessibility, proximity to amenities, and existing infrastructure. A critical component of this approach involves employing multi-criteria decision analysis to systematically assess and prioritize factors that impact route optimization.

Users can take into account specific parameters relevant to the planning objectives of the university area, such as minimizing travel time, enhancing access to key facilities, or optimizing land utilization. The tool generates visual outputs, including interactive maps and suggested routes, allowing decision-makers to evaluate and compare different scenarios. Field data were collected to validate the tool's accuracy and effectiveness by comparing predicted optimal routes with actual observations in the real-world context.

c. Update data from the field

Field surveys are integral to the university planning process, involving physical inspections to document and verify the current state of the campus and its surroundings. This method ensures the inclusion of real-time information and a firsthand understanding of the natural landscape, including recent changes or developments. Integration of real-time data feeds ensures that information on the WebGIS platform remains current and accurately reflects the evolving campus environment. Furthermore, stakeholder engagement through user feedback sessions validates data accuracy and incorporates valuable insights from individuals involved in university planning. As a result, the on-site data collection function has been specifically developed for this WebGIS application. It facilitates greater transparency of information, enables real-time information sharing and feedback, and broadens the scope of stakeholder participation.

4. Results and discussion

To access the WebGIS platform, users can utilize web browsers via https://igeo.edu.vn/ or scan the QR code displayed in Figure 5 within the WebGIS interface. User login credentials are created by the system administrator and assigned based on specific usage permissions (For accessing our WebGIS application, temporary access credentials are provided as follows: username: **igeo**, password: **huce**). Decentralization of access rights facilitates efficient database management, ensuring appropriate access across all user groups and mitigating risks associated with unauthorized data intervention. For instance, community members are empowered to report data changes, whereas specialized units possess editing rights subsequent to data verification and processing.

Figure 5 also presents various utility tools integrated into the system. These tools facilitate the straightforward determination of point coordinates, object dimensions (length and area), and provide drawing capabilities essential for localizing and identifying objects of interest on the map. Additionally, they support the editing and updating of objects to accommodate changes over time. Objects drawn directly on the map can be exported in KML or JSON formats, allowing for seamless integration into the system's data center or easy sharing for use on widely accessible platforms such as Google Earth.

The incorporation of map data layers, encompassing base maps, thematic maps (such as cadastral, topographic, and planning maps), and regularly updated current status data (including ortho images obtained via UAV), facilitates comprehensive information management across the project lifecycle. Within the map layer management feature, custom settings allow for selective object blurring, facilitating easy comparison and tracking of changes while assessing progress in implementing project plans (Figure 6). By overlaying these diverse map data layers, it becomes feasible to pinpoint areas of conflict and optimize the arrangement of functional zones within the planning process.

As previously discussed, in addition to the capability of downloading map data, this WebGIS system facilitates the uploading of various geospatial data types. Orthomosaic data obtained from UAVs, Figure 7 has proven instrumental in assessing construction plans and monitoring their implementation progress. Notably, the construction of infrastructure within HUCE's Campus 2, specifically a lecture hall and a student residence building, has been completed following approved planning strategies. In addition, with

Figure 5. Interface and QR code of WebGIS for HUCE's Campus 2

Figure 6. Management of map layers and selective blurring function

real-time status data continuously updated by UAVs, the site grading process has been closely monitored in terms of material volume, ensuring adherence to the scheduled construction timeline.

Effective project planning management necessitates a thorough grasp of essential information. Land management databases encompass various datasets such as cadastral information, statistics, land inventory, planning data, land use plans, and land prices. Cadastral data layers are particularly critical, detailing each land plot and organized according to commune-level administrative units (the most detailed administrative level). Statistical and inventory data provide insights into land types, land use patterns, and asset quantities on land. Information on land use planning outlines purposes and zoning of land functions (e.g., agricultural, educational, medical, and public uses) as planned by governmental and local authorities. Figure 8 illustrates typical data layers associated with land plots, including sheet numbers, plot identifiers, areas, land types, ownership details, and license numbers. Additionally, land prices are crucial information of significant value to both parties involved in compensation and land recovery processes during site clearance.

We can also find the zoning planning information of HUCE's Campus 2 shown in Figure 9, which highlights the allocated proportions for different types of land use. This depiction provides clear insights into the specific planning details for lecture halls, dormitories, and sports areas, as well as the infrastructure and public spaces within the campus. Planning data is regularly reassessed and compared with actual developments at other construction sites. Specifically, delays in implementing the internal traffic infrastructure packages at the Nam Cao University Area led to adjustments in the entrance gate layout for HUCE Campus 2. Instead of constructing the originally planned gates to the east and south, a temporary gate was opened to the west to connect with the existing road infrastructure.

This WebGIS application has been developed to accommodate diverse data queries, ensuring comprehensive satisfaction for users at all levels. As illustrated in Figure 10, users can effortlessly query information based on coordinates, land type, or planned land function. This functionality supports various stakeholders, including administrative agencies, investors, and the general public, promoting a transparent information environment. It fosters improved access to information, enhances management efficiency, and encourages community involvement in the planning process.

The determination of optimal routes, as illustrated in Figure 11, is a key feature integrated within this WebGIS application. This functionality facilitates the analysis and evaluation of the road network's effectiveness, particularly

Figure 7. Direct importation of orthomosaic data devired from UAV data into the WebGIS system

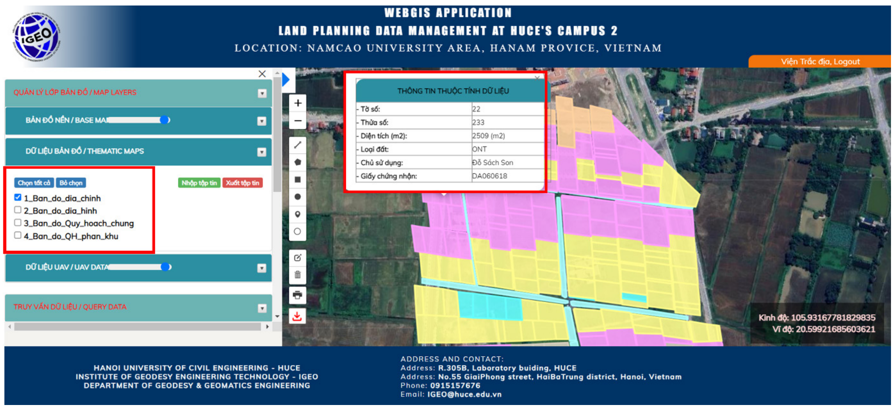


Figure 8. Visualization of thematic map layers and attribute querying for individual land plots

concerning the accessibility of public facilities and services in connection with the proposed location of HUCE's Campus 2. This aligns with findings from previous research conducted by Soltani et al. (2019) and Huang et al. (2020), which highlight the importance of such analyses in urban planning. This feature proves valuable for planning purposes by enabling the rapid identification of safe evacuation routes from hazardous areas during natural disasters. Moreover, it provides insights into favorable conditions for the effective deployment of emergency response teams to disaster-stricken areas for timely rescue and relief efforts. This function enables users to select multiple locations simultaneously either by specifying geographic coordinates or through direct interaction with the map interface. By selecting multiple interconnected locations, a transportation network is formed, facilitating planning tasks such as analysis and the identification of optimal solutions.

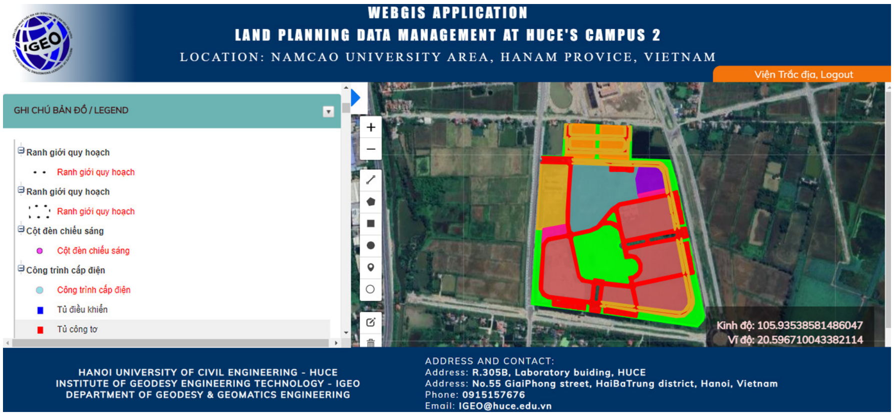


Figure 9. Management and querying of planning data for HUCE's Campus 2

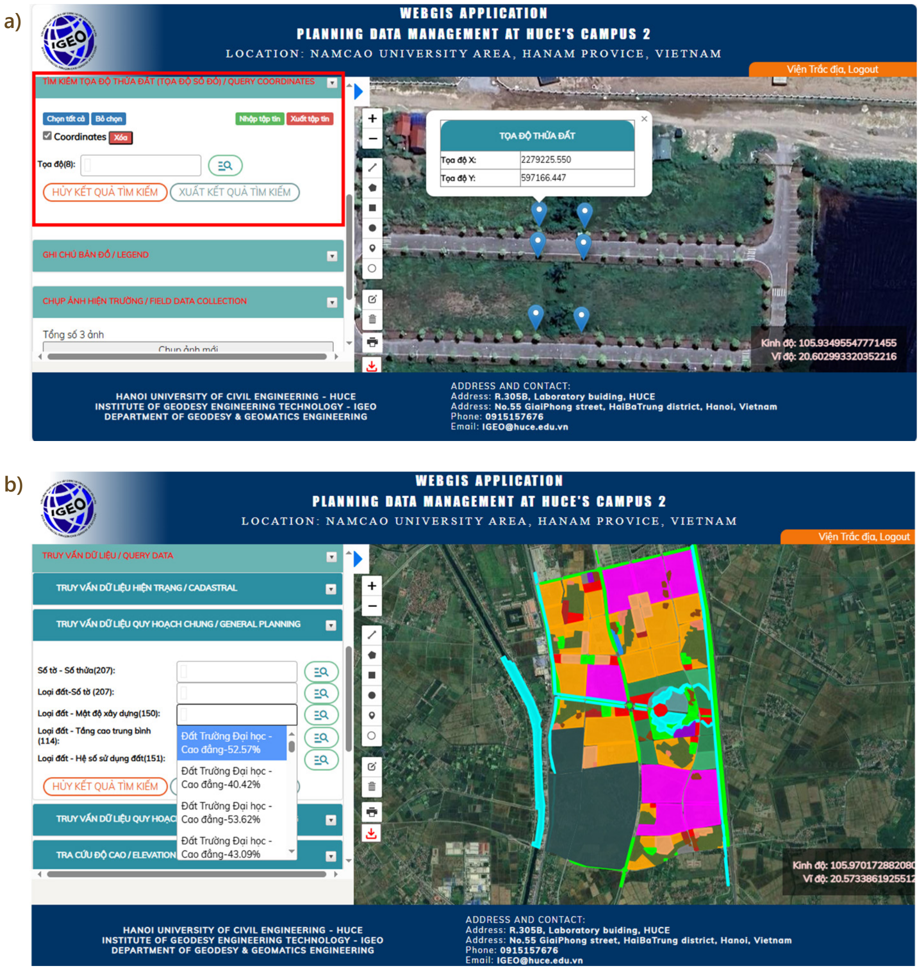


Figure 10. Querying land data using: a) coordinates; b) land type or land use function

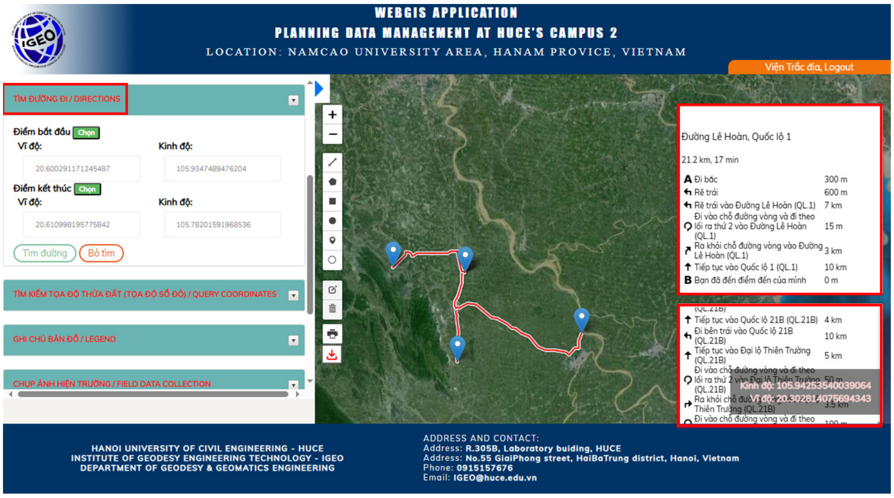


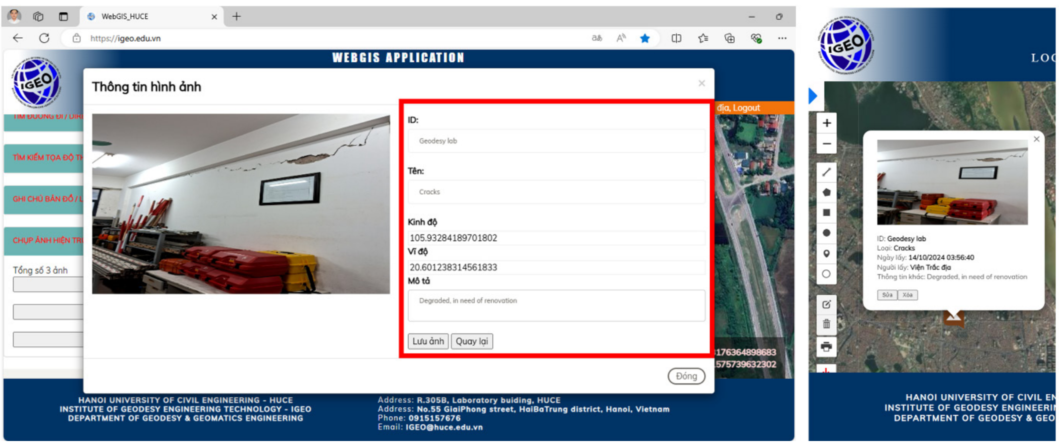
Figure 11. Determination of optimal routes: Functionality Overview

Community engagement and consultation are essential data sources in the planning process. Haklay et al. (2018) review the types of information highlighted in the research by Pánek et al. (2014), which include: evaluating the comfort and safety of public spaces, identifying those that are unattractive or unsafe and require improvement; exploring enhancements in public transportation and walkability; and identifying areas within planning that warrant further development. These insights are critical for informing and refining urban planning processes.

In response to the limitations of traditional community consultation methods, such as printed maps, geo-questionnaires, and geo-discussions, as reviewed by Haklay et al. (2018), we have developed an on-site data collection feature within our WebGIS application. This functionality allows users to report current issues and upload relevant images and descriptive data directly through the web interface. The immediate availability of this spatial information facilitates timely updates and enables planning stakeholders to better understand and address current challenges. Moreover, the descriptive feedback provides insights into the community's actual needs, offering critical insights for the development and refinement of public service planning.

As depicted in Figure 12a, a photograph of a crack inside the Geodetic Laboratory is taken using a laptop camera. Along with the image, coordinates and descriptive details of the event are directly uploaded to the WebGIS system. Figure 12b illustrates how this information is displayed on the WebGIS interface. This functionality enhances the management of issues and supports effective planning for maintenance and repair tasks.

Although the community consultation interaction within the WebGIS system necessitates further improvement, the on-site data collection feature has enabled the regular dissemination of updated information regarding land use rights transfer records in the areas designated for official and staff residences. This functionality assists property owners in understanding their rights and obligations, while also providing investors and local authorities with timely insights into community concerns. As a result, this approach enhances information transparency and reinforces the rights of the community.



a) b)

Figure 12. Field data collection procedures: a) recording cracks in a Geodetic laboratory room; b) visualization of data on the WebGIS interface

5. Conclusions

Geographic Information Systems have been shown to be highly effective in managing spatial data and conducting detailed geospatial analysis, while web technologies offer a robust platform for data sharing. Accordingly, the WebGIS application was employed to construct and monitor geospatial data for the planning of HUCE Campus 2.

The findings reveal that this method benefits multiple stakeholders, including policymakers, planners, investors, and the wider community. Key features of the WebGIS application support decentralized management, providing easy access to planning data and enabling continuous monitoring of the HUCE Campus 2 project. During construction, the WebGIS system allowed for real-time monitoring and timely adjustments to the campus entrance gate and site grading process, based on updated status data. Additionally, the online provision of field data facilitated the identification of damages requiring repair and maintenance. Improved public consultation, enabled by accurate real-time information, ensured that planning issues were promptly identified and resolved. This integration of individual land planning projects adds substantial value to the sustainable design and development of urban areas. However, several challenges persist with the WebGIS system, including the integration of 3D model data and the need to improve interactions between users and administrators.

Data availability statements

The datasets generated during and/or analyzed during the current study are available in the "Code & data" at https://drive.google.com/drive/folders/1A_OVScXoEeCR2Q4mjP-9Jvk01FgSteJh-?usp=sharing.

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