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GIS-BASED CONSTRUCTION GROUND LEVEL MANAGEMENT IN URBAN PLANNING: A CASE STUDY IN HANOI, VIETNAM

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ABSTRACT: The management of construction ground levels must be carried out synchronously within a unified coordinate system across all sectors to ensure effective implementation and to minimize the risk of flooding across entire regions. In Vietnam, construction ground-level data in urban planning projects are typically managed by various agencies using different formats. This fragmentation causes significant difficulties in updating, adjusting, and sharing data across agencies. This study proposes the application of Geographic Information Systems (GIS) in developing a construction ground-level database in the Hanoi Software Technology Park Urban Area Project in Phuc Loi ward, Long Bien district - an innercity district of Hanoi. The input data were gathered from the officially approved planning drawing files at a scale of 1:500, dated 2013, and stored in *.dwg format of AutoCad software, including: topographic map; current land use map; detail planning map; technical infrastructure system drawing; communication system layout; and power supply system. A synchronous construction ground-level database was developed within the GIS environment, serving both management and decision-making functions. Moreover, this database is proposed to be publicly and transparently shared among inter-sectoral agencies and local communities, ensuring data accuracy and supporting digital transformation in the management of construction ground levels in particular and urban planning management in general. By visualizing and providing construction ground-level elevation, this result also enables identifying low-lying, flood-prone areas, and analyzing the impact of floods on infrastructure, thereby contributing to more effective flood risk reduction.

Keywords: Geographic Information System, Construction ground level database, Urban planning projects, Digital transformation, Hanoi city, Vietnam.

1. INTRODUCTION

The “*construction ground level*” term is widely used in various fields, including construction, irrigation, environment, transportation, and others, especially in the field of urban planning [1]. The construction ground level is understood as the minimum elevation that must be complied with to ensure conformity with the planned height of the entire foundation system, thereby maximizing rainwater drainage capacity [2]. Based on this, the construction ground level will help buildings avoid flooding, especially in urban areas and large cities. In general, architects will rely on the average water level in each region to calculate the value of the construction ground level to avoid flooding and drain water more effectively [3]. Therefore, the construction ground level plays a significant role in the planning and design of buildings, road networks, and urban landscapes [4].

Nowadays, Geographic Information System (GIS) is considered an optimal and effective solution for managing urban planning projects in the context of rapid urbanization. GIS provides a powerful tool in building and storing databases synchronously and effectively, from land use planning information, construction ground-level planning, existing infrastructure, and current land use information [3]. Moreover, advanced GIS functionalities, such as spatial interpolation, data classification, and quantitative measurement, contribute significantly to essential planning and analytical tasks [5]. GIS allows users to easily look up, extract, update, and edit information, perform spatial analysis to make smarter and more effective decisions in managing and monitoring construction ground-level in urban areas [6]. In general, building a construction ground-level database to serve planning projects in GIS makes urban planning easier and more effective [3].

In recent decades, GIS has been applied extensively in the urban planning field, like preconstruction planning [3], development of a building construction information system [7], development of a 4D view for buildings [8], evaluation of urban construction land and geological environment [9], and management of assets in buildings [6].

The building construction should not be planned in isolation but in reference to its locality, existing facilities/utilities, topography, land use,… Thus, GIS technology is proposed as an effective tool in the preconstruction planning stage as it can combine both knowledge-based systems and computer graphics [3]. In another study, GIS was employed to create a building construction information system by integrating 2D drawings and 3D models with the activities database in the GIS model [7]. The other study of [8] applied ArcMap 10.2 for interlinking schedules from Primavera software and 2D drawings from AutoCAD, and ArcScene for developing 4D views. In [9], GIS was used to reveal the coupling and coordination relationship between urban construction land and geological environment to propose reasonable urban land use planning. In the latest study [6], a framework and model for a web-based building management platform were proposed. Accordingly, BIM data was transformed into a GIS workspace using the latest technology from ArcGIS. This platform facilitates data sharing and collaboration among stakeholders, leading to more effective building management and informed decision-making. Furthermore, stakeholders who do not need a BIM-GIS expert can virtually view reports and updates of the building model at any time.

In Vietnam, GIS technology has received much attention in recent decades due to its potential for enhancing spatial data management and decision-making processes. In the urban planning field, GIS is applied in a variety of ways. Initially, GIS was tested to build 3D models for urban planning in the Hai Chau district, Da Nang city [10], to evaluate the possibility of building a detailed Cyber city for the Manor building, Nam Tu Liem district, Hanoi [11] and Kien Thuy Industrial Zone, Hai Phong [12]. In recent years, GIS has been applied in site clearance for the second ring road in Hanoi [13], or appraising and selecting district-level land use planning options [14, 15], identifying the proper planning locations [16, 17]. The construction ground level plays a fundamental role in all urban planning projects; however, up to now, this term has not been mentioned in any research related to GIS application in urban planning in Vietnam.

In the current practical urban planning field in Vietnam, construction ground-level data is often stored in various departments and agencies, with multiple versions of planning adjustment information, which leads to significant difficulties in utilizing data, providing information when requested, or updating these changes regularly and continuously. In addition, most completed urban planning projects have a higher construction ground level than the surrounding existing ground level, leading to widespread flooding. These issues pose significant challenges to urban management in large cities such as Hanoi [18]. Therefore, this study proposes the application of GIS in managing construction ground levels for an urban planning project in the Long Bien District, Hanoi, Vietnam. The proposed database will integrate multiple data layers, including construction ground levels information, current land use status, land use planning, and technical infrastructure (e.g., water supply and drainage systems, telecommunications, and power supply systems) in the area. The integration of these information layers will facilitate faster and more effective management, retrieval, updating, editing, and sharing of construction ground-level data among management units.

The content of this study consists of the following main parts: the first part presents the data sources and methodology used to build the GIS-based database; the second part describes the database design and implementation process; the third part illustrates how the system supports spatial queries and practical applications in urban planning; and the final part discusses limitations and future directions.

2. RESEARCH SIGNIFICANCE

Construction ground-level data plays a significant role in infrastructure, architecture, land, and urban planning. However, it is often overlooked in urban planning studies. This study proposes applying GIS to integrate and manage construction ground-level data with other urban planning datasets, to meet the management and digital transformation requirements in urban planning in big cities in Vietnam. This approach enables the creation of a synchronous database, enhancing interoperability and cross-sectoral data sharing. In addition, this study also promotes the need to establish legal documents suitable for the complex urbanization process and limit overlaps between departments in Vietnam.

3. A CASE STUDY AREA

The Hanoi Software Technology Park Urban Area Project is located within the administrative boundaries of several wards, namely Phuc Loi, Phuc Dong, Viet Hung, and Gia Thuy, in Long Bien District, Hanoi City, Vietnam (Fig.1).

Fig. 1 Case study area boundary (Source: Google Earth)

The total area designated for planning and research encompasses approximately 4,132.29

hectares, with an estimated population of 39,500 people. According to the detailed planning at a scale of 1:500, this project will combine the urban area with a modern software technology park, featuring synchronous architecture, technical infrastructure, and an environment suitable for the Northeast area of Hanoi and the area between the Red River and the Duong River.

4. METHODOLOGY

4.1 Research Methods

- Synthesis method: This method involves the collection, investigation, analysis, and synthesis of various data formats related to construction ground levels that are commonly employed in urban planning projects.
- Expert consultation method: Consultation with state management agencies was conducted to assess the current status of construction ground-level management in the pilot area. Additionally, expert opinions were solicited to identify the requirements for establishing a construction ground-level database that aligns with management needs.
- Experimental method: GIS technology was applied to develop a construction ground-level database for the pilot area, allowing for a practical demonstration of the proposed methodology.

4.2 Data Collection

In this study, the selection of input data was based on the following criteria: 1) Direct relevance to construction ground-level information in urban planning; 2) Official approval and issuance by a state management agency; 3) A level of detail appropriate to the scale of the research area. Based on that, the input data were collected from the approved planning drawing files at a scale of 1:500, dated 2013, and provided by the People's Committee of Long Bien district.

These datasets were stored in the *.dwg format of AutoCAD software and included the following components: current land use map, topographic map, detail planning map, technical infrastructure system drawings, communication system drawings, and power supply system drawings.

These data are verified and reconciled regarding spatial and geometric relationships within the GIS environment and are reviewed by experts to ensure accuracy. The main software used in the data construction ground-level checking process is ArcGIS 10.5.

The steps for data validation are as follows:

- Check geometric relationships of objects: Detect and eliminate errors such as overlaps and non-closed boundaries between spatial object layers.
- Coordinate system reconciliation: All input data layers must be standardized to the same coordinate system to ensure consistency for serving analysis and visualization procedures.
- Verify attribute information among different layers, such as planning boundaries, construction elevations, and topographic maps, to ensure there are no conflicts or missing information.
- Expert consultation: After technical checks, the data are reviewed by experts in urban planning, land administration, and technical infrastructure to ensure accuracy and reliability before integration into the official database in GIS.

4.3 Building A Construction Ground-Level Database In GIS

All input data is edited and standardized in GIS (Fig. 2). Based on the collected data and experts' opinions, the database is organized into three main groups for managing construction ground level in the study area: 1) Urban base data group; 2) Urban planning data group; 3) Construction ground level group (Fig.3).

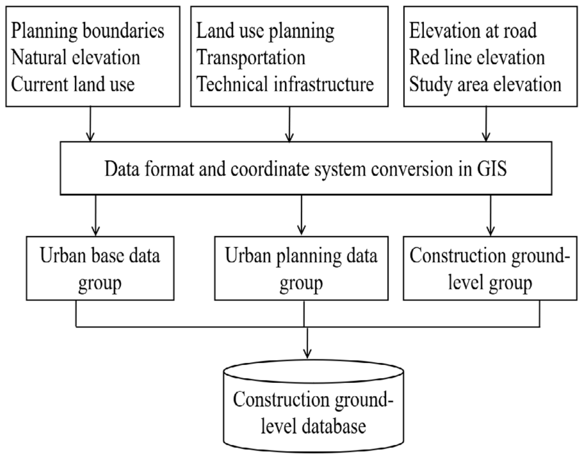


Fig. 2 GIS-based procedure for construction ground-level database

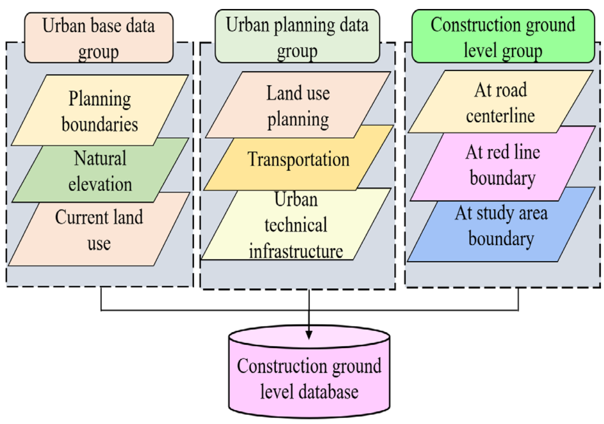


Fig. 3 Layers of construction ground-level database in GIS

4.3.1 Data format conversion

Because the collected data is stored in the *.dwg format of AutoCAD software, it is necessary to convert the data format and edit it to match the database format in the GIS environment. When adding these data sources to the GIS workspace, many different information layers will appear, in which, the popular formats are Annotation (usually corresponding to text symbols in Autocad software), Point (corresponding to point symbols), Polyline (corresponding to line symbols), and Polygon (corresponding to polygon symbols). After selecting the object to be converted, use the Feature Class to Feature Class tool in GIS to convert it into the shapefile format (*.shp).

Preliminary editing was performed on the newly converted *.shp file using ArcGIS software. This involved removing frames, redundant features, and overlapping objects by initiating the Start Editing mode in GIS. After deleting unnecessary and duplicate features and correcting topology errors such as overlaps and gaps, the edits were saved using the Save Edits function in GIS.

4.3.2 Coordinate system conversion

After being converted into shapefile format (*.shp) in the GIS workspace, the data layers were not assigned to any specific coordinate system. Therefore, the Project tool in GIS was used to assign an appropriate coordinate system to all data files. The database of the construction ground level for the Hanoi Software Technology Park Urban Area Project, located in Long Bien District, Hanoi City, needs to be established using the VN-2000 National Coordinate System.

This system applies the map projection of UTM, projection zone 3°, a central meridian (Lo) of 105°00', and a distortion coefficient (k_o) of 0.9999. The WGS-84 ellipsoid is used and positioned appropriately for the territory of Vietnam within the GIS environment (Fig.4).

4.3.3 Attribute information import

Based on attribute information stored separately by location, in note tables, or by symbols in AutoCAD software, attribute data for each corresponding layer can be entered into GIS. This information can be input directly using the Start Editing tool in GIS. Alternatively, it can be linked to an external attribute table from other GIS-compatible software to complete the construction ground level database in GIS using the Join tool in the object's attribute table (Table 1).

According to that, the construction ground level database is built completely in GIS with the corresponding attribute information, as shown below:

Table 1. Construction ground-level database in GIS

Groups	Layers	Format	Attribute information
Urban base data group	Planning boundaries	Polyline	ID; Line style; Length
	Natural elevation	Point	ID; X (m); Y (m); H (m)
	Current land use	Polygon	ID; Land use type; Area (m^2)
Urban planning data group	Land use planning	Polygon	ID; Land use type; Area (m^2)
	Transportation	Polyline	ID; Line style; Length
	Urban technical infrastructure	Polyline	ID; Line style; Length (m)
Construction ground-level group	Elevation at road centerline	Point	Name; X (m); Y (m); H (m)
	Elevation at the red line boundary	Point	Name; X (m); Y (m); H (m)
	Elevation at the study area boundary	Point	Name; X (m); Y (m); H (m)

5. RESULTS AND DISCUSSION

In this study, the construction ground-level database is created and developed in the ArcGIS 10.5 software. The construction ground-level database for the study area is structured into three main groups, including the urban base data group, the urban planning data group, and the construction ground-level data group. The urban base data group serves as the geographic base data layer in this study region, and includes the following three main layers: current land use, planning boundary, and natural elevation (Figs. 4 and 5).

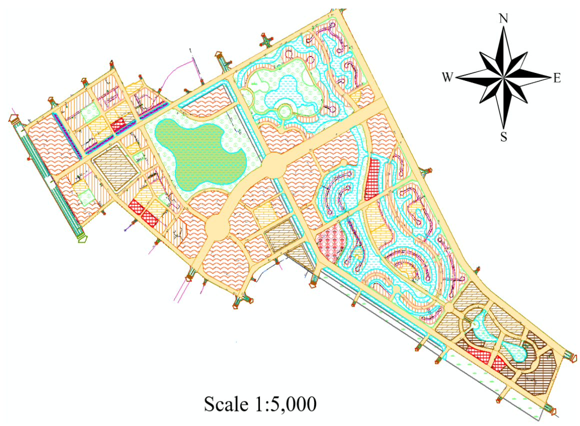


Fig. 4 Data layers were converted into GIS environment (Source: Authors' work)

The urban planning data group contains information related to land use planning and urban technical infrastructure in the study area, including the following data layers: land use planning, transportation, water supply pipeline, and lighting electricity (Figs. 4 and 6).

The construction ground-level group consists of information related to construction ground-level at different locations in the research area, namely at the road centerline, the red line boundary, and the study area boundary (Figs. 4 and 7).

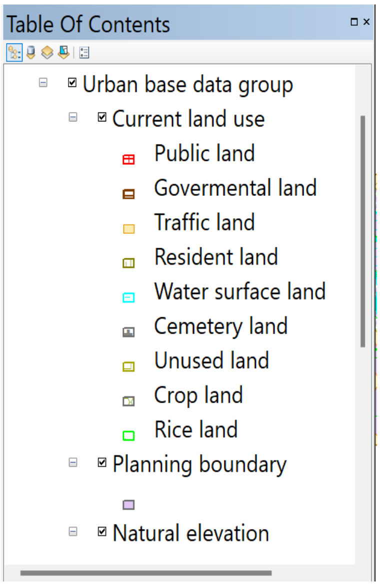


Fig. 5 Data layers of the urban base data group were managed and displayed in detail in GIS (Source: Authors' work)

The obtained results indicate that construction ground-level management becomes simpler and easier; specifically, data layers are stored synchronously in a unified coordinate system, information lookup related to natural height, construction ground-level, and types of land use planning according to spatial location is continuous, connecting both spatial information and attribute information.

In addition, the use of ArcGIS 10.5 software to search and retrieve information related to construction ground levels, urban planning, and urban technical infrastructure systems within the Hanoi Software Technology Park Urban Area Project enhances the ability of managers to visualize spatial data and efficiently update attribute tables associated with spatial features. These advantages within the GIS environment significantly reduce the likelihood of errors resulting from manual data entry, while ensuring connectivity and synchronization in the management and operational processes.

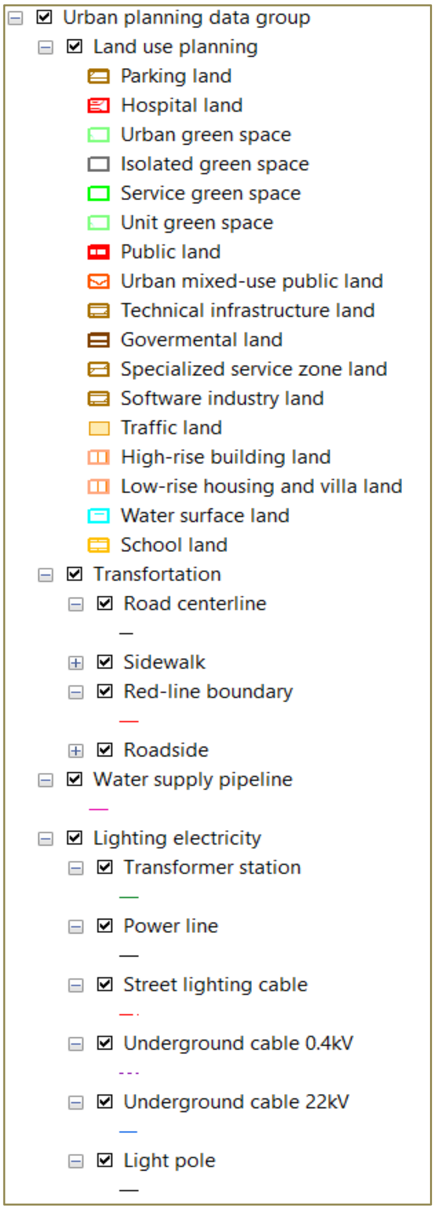


Fig. 6 Data layers of the urban planning data group were managed and displayed in detail in GIS (Source: Authors' work)

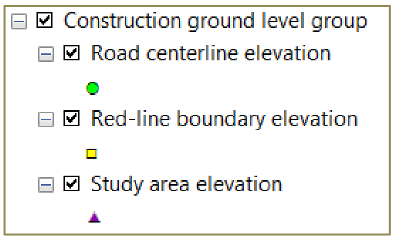
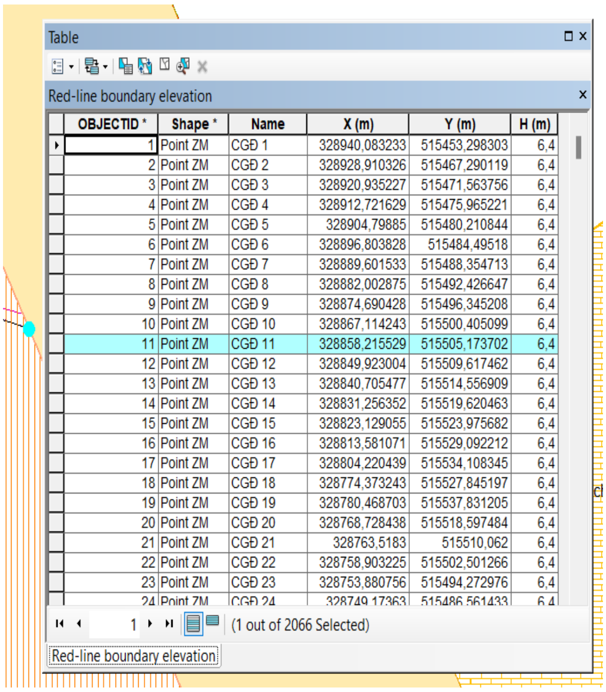


Fig. 7 Data layers of the construction ground-level group were managed and displayed in detail in GIS (Source: Authors' work)

5.1 Querying Construction Ground Level At The Red-Line Boundary

Parking lots, hospitals, green spaces, public facilities, government offices, residential areas, villas, hydrological zones, and educational institutions within the urban planning layer are delineated using red-line boundaries. The elevation of these functional areas is managed through a system of boundary markers that are integrated with approved elevation data. The extracted information from this system includes a unique identifier (ID), spatial coordinates (X and Y), and the designated design elevation (H), as illustrated in Fig.8.



Table

Red-line boundary elevation

OBJECTID *	Shape *	Name	X (m)	Y (m)	H (m)
1	Point ZM	CGĐ 1	328940,083233	515453,298303	6,4
2	Point ZM	CGĐ 2	328928,910326	515467,290119	6,4
3	Point ZM	CGĐ 3	328920,935227	515471,563756	6,4
4	Point ZM	CGĐ 4	328912,721629	515475,965221	6,4
5	Point ZM	CGĐ 5	328904,79885	515480,210844	6,4
6	Point ZM	CGĐ 6	328896,803828	515484,49518	6,4
7	Point ZM	CGĐ 7	328889,601533	515488,354713	6,4
8	Point ZM	CGĐ 8	328882,002875	515492,426647	6,4
9	Point ZM	CGĐ 9	328874,690428	515496,345208	6,4
10	Point ZM	CGĐ 10	328867,114243	515500,405099	6,4
11	Point ZM	CGĐ 11	328858,215529	515505,173702	6,4
12	Point ZM	CGĐ 12	328849,923004	515509,617462	6,4
13	Point ZM	CGĐ 13	328840,705477	515514,556909	6,4
14	Point ZM	CGĐ 14	328831,256352	515519,620463	6,4
15	Point ZM	CGĐ 15	328823,129055	515523,975682	6,4
16	Point ZM	CGĐ 16	328813,581071	515529,092212	6,4
17	Point ZM	CGĐ 17	328804,220439	515534,108345	6,4
18	Point ZM	CGĐ 18	328774,373243	515527,845197	6,4
19	Point ZM	CGĐ 19	328780,468703	515537,831205	6,4
20	Point ZM	CGĐ 20	328768,728438	515518,597484	6,4
21	Point ZM	CGĐ 21	328763,5183	515510,062	6,4
22	Point ZM	CGĐ 22	328758,903225	515502,501266	6,4
23	Point ZM	CGĐ 23	328753,880756	515494,272976	6,4
24	Point ZM	CGĐ 24	328749,17363	515486,561433	6,4

(1 out of 2066 Selected)

Red-line boundary elevation

Fig. 8 Querying construction ground level based on the red-line boundary (Source: Authors' work)

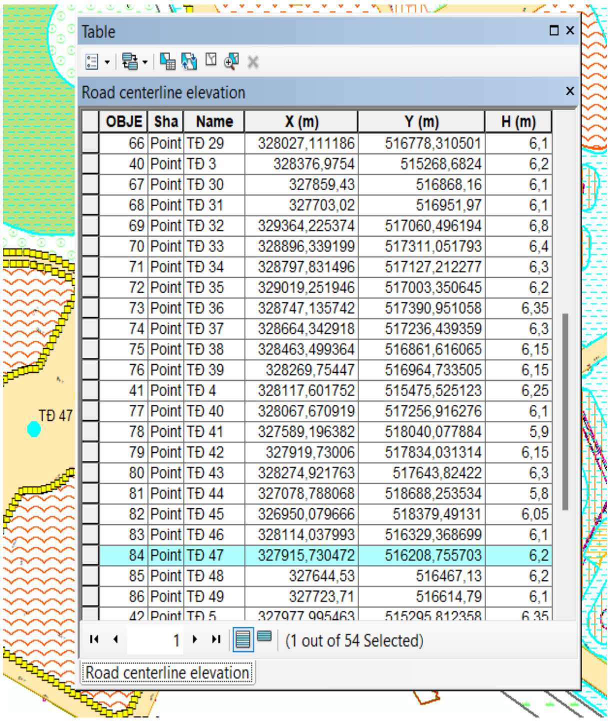
The boundary marker system, deployed in the field and linked with attribute data stored in a GIS environment, enables management agencies to efficiently manage, query, and retrieve data as needed. In addition, the management of the construction ground-level elevation at red-line boundaries helps ensure consistent elevation transitions, improves surface drainage, and reduces the risk of localized flooding, especially in areas with uneven terrain or fragmented development [18].

5.2 Querying Construction Ground Level At The Road Centerline

The internal road network within the study area is located on the road centerline system. The management of road centerline elevation is integrated with approved base elevation information in the GIS environment.

The information extracted from the system includes an ID, X and Y coordinates, and the planned elevation values (H), as illustrated in Fig.9.

Elevation management based on the road centerline contributes to the consistency of the urban road network's vertical profile, ensures compliance with designated slope directions and gradients, meets urban drainage requirements, and facilitates future road maintenance and rehabilitation operations.



Table

Road centerline elevation

OBJE	Sha	Name	X (m)	Y (m)	H (m)
66	Point	TĐ 29	328027,111186	516778,310501	6,1
40	Point	TĐ 3	328376,9754	515268,6824	6,2
67	Point	TĐ 30	327859,43	516868,16	6,1
68	Point	TĐ 31	327703,02	516951,97	6,1
69	Point	TĐ 32	329364,225374	517060,496194	6,8
70	Point	TĐ 33	328896,339199	517311,051793	6,4
71	Point	TĐ 34	328797,831496	517127,212277	6,3
72	Point	TĐ 35	329019,251946	517003,350645	6,2
73	Point	TĐ 36	328747,135742	517390,951058	6,35
74	Point	TĐ 37	328664,342918	517236,439359	6,3
75	Point	TĐ 38	328463,499364	516861,616065	6,15
76	Point	TĐ 39	328269,75447	516964,733505	6,15
41	Point	TĐ 4	328117,601752	515475,525123	6,25
77	Point	TĐ 40	328067,670919	517256,916276	6,1
78	Point	TĐ 41	327589,196382	518040,077884	5,9
79	Point	TĐ 42	327919,73006	517834,031314	6,15
80	Point	TĐ 43	328274,921763	517643,82422	6,3
81	Point	TĐ 44	327078,788068	518688,253534	5,8
82	Point	TĐ 45	326950,079666	518379,49131	6,05
83	Point	TĐ 46	328114,037993	516329,368699	6,1
84	Point	TĐ 47	327915,730472	516208,755703	6,2
85	Point	TĐ 48	327644,53	516467,13	6,2
86	Point	TĐ 49	327723,71	516614,79	6,1
42	Point	TĐ 5	327977,995463	515295,812358	6,35

(1 out of 54 Selected)

Road centerline elevation

Fig. 9 Querying construction ground level based on the road centerline (Source: Authors' work)

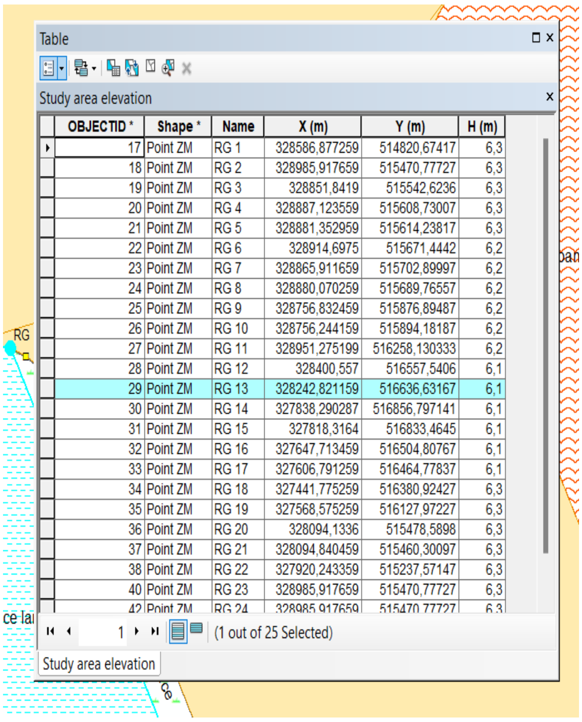
The management of the construction ground level elevation at the road centerline ensures a consistent vertical alignment across the urban road network. This approach guarantees adherence to prescribed slope directions and gradients, satisfies drainage design requirements, and supports future maintenance and rehabilitation efforts.

5.3 Querying Construction Ground Level At The Study Area Boundary

The typical locations of the study area are determined by the boundary marker system. The management of construction ground-level at these typical locations can identify the area permitted for construction following the granted license, as well as manage the approved construction ground-level.

The information extracted from the system includes an ID, X and Y coordinates, and the planned elevation values (H), as illustrated in Fig.10.

The management of the construction ground level elevation at the boundary of the study area helps control the elevation transition between the planned area and adjacent regions, thereby minimizing the risk of creating topographic barriers or causing water accumulation within the planned area.



OBJECTID *	Shape *	Name	X (m)	Y (m)	H (m)
17	Point ZM	RG 1	328586,877259	514820,67417	6,3
18	Point ZM	RG 2	328985,917659	515470,77727	6,3
19	Point ZM	RG 3	328851,8419	515542,6236	6,3
20	Point ZM	RG 4	328887,123559	515608,73007	6,3
21	Point ZM	RG 5	328881,352959	515614,23817	6,3
22	Point ZM	RG 6	328914,6975	515671,4442	6,2
23	Point ZM	RG 7	328865,911659	515702,89997	6,2
24	Point ZM	RG 8	328880,070259	515689,76557	6,2
25	Point ZM	RG 9	328756,832459	515876,89487	6,2
26	Point ZM	RG 10	328756,244159	515894,18187	6,2
27	Point ZM	RG 11	328951,275199	516258,130333	6,2
28	Point ZM	RG 12	328400,557	516557,5406	6,1
29	Point ZM	RG 13	328242,821159	516636,63167	6,1
30	Point ZM	RG 14	327838,290287	516856,797141	6,1
31	Point ZM	RG 15	327818,3164	516833,4645	6,1
32	Point ZM	RG 16	327647,713459	516504,80767	6,1
33	Point ZM	RG 17	327606,791259	516464,77837	6,1
34	Point ZM	RG 18	327441,775259	516380,92427	6,3
35	Point ZM	RG 19	327568,575259	516127,97227	6,3
36	Point ZM	RG 20	328094,1336	515478,5898	6,3
37	Point ZM	RG 21	328094,840459	515460,30097	6,3
38	Point ZM	RG 22	327920,243359	515237,57147	6,3
40	Point ZM	RG 23	328985,917659	515470,77727	6,3
42	Point ZM	RG 24	328985,917659	515470,77727	6,3

Fig. 10 Querying construction ground level based on the study area boundary (Source: Authors' work)

In general, the developed database in this study will allow centralized and synchronized data management across agencies, reducing inconsistencies and delays in information exchange. It will also support more efficient decision-making by enabling quick spatial queries and visualization of construction ground level elevation among various urban regions. While real-time updates have not yet been fully implemented, the database structure is designed to accommodate future dynamic updates.

6. CONCLUSIONS

This study proposes the application of GIS technology in building a construction ground-level database to support the management of urban planning projects synchronously and effectively. Based on the collected datasets and expert consultations, the construction ground-level management database for the research area is organized into three key groups: the urban base data group, the urban planning data group, and the construction ground-level data group. Spatial data layers, along with their associated attribute information, are organized and managed within a unified coordinate system, enabling efficient information retrieval, updating, and editing. Additionally, the construction ground-level database for the Hanoi Software Technology Park Urban Area Project facilitates data sharing, object search, and report generation, thereby improving efficiency for management agencies compared to traditional management methods.

In summary, this study presents an experimental application of GIS technology in developing a construction ground-level database for the Hanoi Software Technology Park Urban Area Project in Hanoi, with the aim of evaluating and demonstrating the potential effectiveness of this approach. To establish a comprehensive and synchronized construction ground-level database for the entire city, it is essential to promote the adoption of GIS technology in urban planning management for other urban areas, contributing to city-wide planning consistency, improved flood risk management, and enhanced coordination across departments in the long term. Additionally, the formulation and issuance of legal and regulatory frameworks governing database standards and management practices across the urban area are required to ensure systematic implementation.

This study has some limitations, as it has not fully reflected the complexity and diversity of the construction ground-level for most urban areas in Hanoi. The GIS-based approach in this study has not currently effectively handled dynamic or time-series elevation changes, such as post-construction terrain settlement. In addition, the system has not yet been tested for integration with other data sources such as remote sensing imagery, UAVs, Building Information Modeling (BIM), real-time monitoring sensors, or other urban infrastructure management platforms like drainage simulation models to update the construction ground-level database. These technologies are becoming essential trends in smart urban management in the digital transformation. Therefore, future research directions will further explore the integration of data sources from these advanced technological platforms to enhance urban planning management in Hanoi.

7. ACKNOWLEDGMENTS

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8. REFERENCES

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