Issues to note in managing and exploiting underground space in the context of Hanoi urban area

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Abstract

With the increase in urban population and rapid development of large cities, underground space has been increasingly emphasized as a solution to address the pressure on land use on the surface. Through reviewing international experiences from cities such as Tokyo, Helsinki, Singapore, and London, key factors for improving underground space development practices are discussed. Issues such as effective identification of co-location opportunities, successful integration of underground and surface developments, and the need for data availability are highlighted, and their implications for underground space planning are clarified. When these factors are understood and integrated into the process, the management of underground space exploitation in Hanoi can be improved and implemented in an efficient and sustainable manner.

Key words: Urban management, planning, underground space, subway

1. Introduction

The value of underground space for urban development is increasingly acknowledged, particularly in cities where the demand for additional space continuously escalates. Historically, underground spaces have been utilized on a first-come, first-served basis, which has necessitated more comprehensive planning. Nevertheless, successful projects have demonstrated the significant benefits underground development can offer to urban communities (Smith,2023).

Major historical underground projects, such as the London Underground, which was initially developed in the 1850s and has been in operation since then and continues to expand to this day, were developed to solve a specific problem, such as the need for transport. However, little consideration has been given to the impact on the future use of underground space.

Many developments in the second half of the 20th century, such as Montréal's RÉSO, recognized the specific significance of underground space and undertook detailed planning and policy changes to capitalize on this. In Montréal, the opportunity to develop an underground pedestrian network was recognized and seized during the development of major public and private projects alongside the rail transit system. Since the original network planning, RÉSO has evolved through opportunistic expansion as new buildings were developed and connected to the network at basement levels. However, there have been criticisms of this opportunistic approach and the potential unintended impacts of the development. For example, negative impacts on street life have been reported due to the over-expansion of the underground network (Doe,2022)

Nowadays, many countries have recognized the limitations of unplanned underground space development and its implications for the future. Helsinki has implemented comprehensive planning measures to optimize underground space development and control underground construction activities. Similarly, Hong Kong has actively developed its approach to underground space use through projects

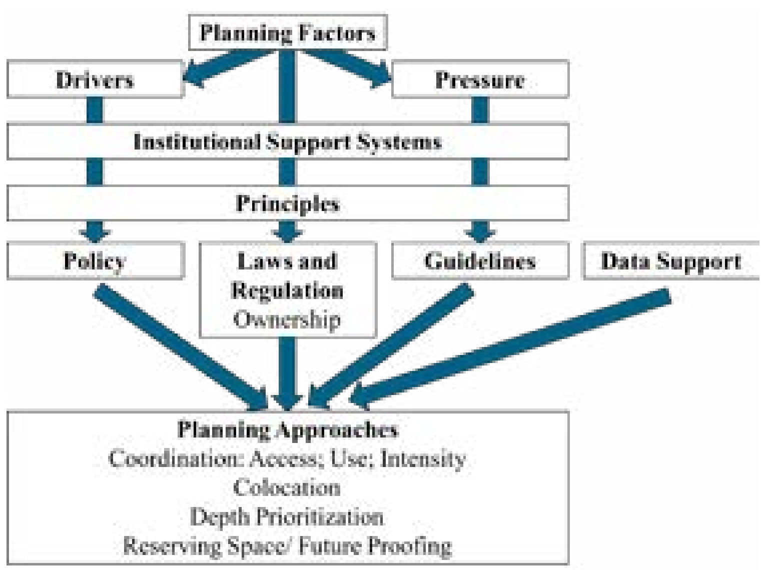

Figure 1. Aspects affecting underground space planning

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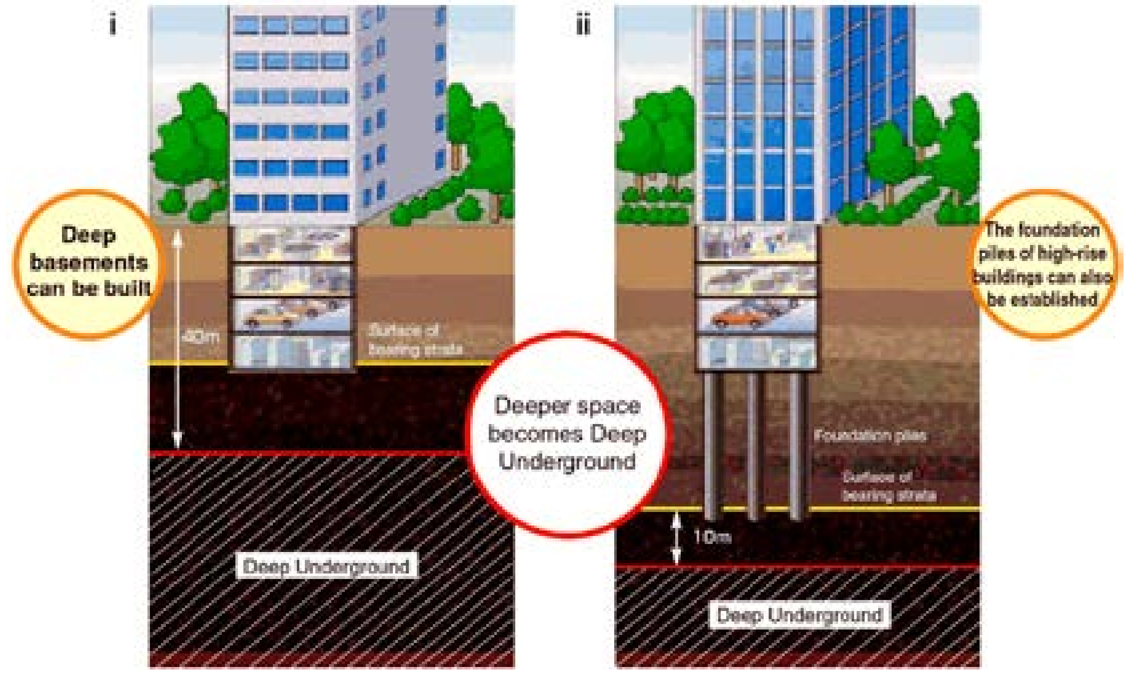


Figure 2. Utilization of underground space in Japan

such as the Underground Space Potential Utilization Study, which promotes the greater use of rock caves as part of Hong Kong's sustainable development goals. Since this message was conveyed, Hong Kong has also conducted the Hong Kong Underground Space Greater Utilization Study. Through this work, Hong Kong is proactively inventorying its assets, identifying potential resources, and planning the use of this underground space (Lee & Nguyen, 2023).

The transition from a first-come, first-served planning approach to a more thoughtful approach to optimal, strategic underground space development is ongoing. There are many different approaches and factors that influence underground space planning. These include the principles applied to underground space planning, existing policies, institutional support systems, laws and regulations that govern underground space development, and existing guidelines to shape underground space development (Figure 1).

In light of the foregoing discussion, this paper aims to synthesize experiences from cities that have demonstrated advanced underground space planning capacities. It will specifically focus on the legal aspects, planning processes, and data requirements for improving underground space planning in Hanoi. Key topics include the methods for effectively integrating underground and surface spaces, identifying connectivity opportunities and implementing depth zoning for underground space, and clarifying ownership and usage rights to maximize the underground space exploitation.

2. Urban underground space development: Drivers, Pressures and Legal issues

When developing underground space planning, urban planners need to consider the driving forces and pressures influencing the use of this space. Driving forces include goals such as economic and population growth, improvement of living conditions, preserving heritage and surface features, and enhancment of connectivity between areas (Nguyen & Tran, 2023). Pressures primarily stem from land scarcity, increasing urbanization, high land costs, and harsh climatic conditions. In Hanoi, rapid population growth and high land costs are driving the development of underground space solutions to meet infrastructure needs and support economic growth, such as the construction of underground facilities for transportation and technical infrastructure.

In addition to driving forces and pressures, another critical factor that cannot be overlooked in developing underground space is the legal issues related to ownership and usage rights. Different countries have varying legal regulations regarding underground space ownership and use, which affect the ability to develop underground space projects. In many countries, underground space ownership and usage rights are typically tied to surface land ownership and usage rights. However, this right may be separated in some countries, creating disputes and complications during development. For example, in London, land ownership is understood according to the ancient principle: "The owner of the surface also owns the sky and the earth." However, there are exceptions for minerals and underground resources. In countries like Japan and Singapore, underground space ownership is regulated more flexibly. For instance, Japan passed the Deep Underground Space Usage Law in 2001, allowing developers to use deep underground space without needing permission from the surface landowner. This promotes the development of underground structures such as transportation systems, pipelines, and public services without facing complex legal barriers (Figure 2). Similarly, Singapore has established regulations that limit underground space ownership to a certain depth, allowing developers to use underground space below this depth without concerns about land ownership issues. FIgure 3 below presents the underground space ownership in London, Helsinki, Tokyo/Osaka and Singapore.

Clarifying ownership and usage of underground space is crucial to promoting the use of this space. Unclear ownership can be as disruptive as cumbersome ownership. Uncertainty about this issue blurs the boundaries and scope of work for planners and developers. This can create a risky climate, making investment difficult and further restricting underground space use.

Hanoi's underground space can be effectively exploited in three layers: the shallow layer (0-5m) for technical infrastructure, medium layer (5-15m) for public works and parking, and the deep layer (15-30m) for underground transportation. Groundwater exploitation and geothermal energy also depend on the depth.

3. Considerations for Approaching underground space planning

3.1. Coordination between surface and underground use

Underground space planning must be based on a comprehensive understanding of current and future surface uses to ensure harmony and avoid negative impacts. Underground development can place pressure on the surface, such as an increased infrastructure demand, changes in pedestrian flow, or the need for additional space for entrances and ventilation. Coordination between underground and surface spaces is essential, encompassing the following factors:

3.1.1. Intensity

Underground development should be planned in alignment with the intensity of surface use to avoid imbalances. Excessive underground intensity, such as high population density or dense floor areas, can adversely affect the surface environment. This might manifest as increased traffic or infrastructure shortages. Conversely, excessively low underground intensity can lead to the squandering of resources and missed development opportunities (Smith,2023)

3.1.2. Entrances

The location, size, and aesthetics of underground space entrances must be carefully planned to balance functionality and visual impact. These entrances, including pedestrian access, vehicular access, emergency routes, and ventilation shafts, should be strategically placed and scaled to ensure convenience for users while maintaining a positive perception. Proper planning should designate specific surface areas for these entrances and incorporate design adjustments to minimize disruption to the surrounding environment and surface aesthetics (Smith & Johnson, 2020).

3.1.3. Purpose of Uuse

Coordination of uses is a key factor in the success of underground space projects. One of the significant benefits of using underground space is that very different uses can be placed nearby. However, the compatibility between these uses needs to be carefully considered.

Like above-ground planning, the compatibility between above-ground and underground uses should be assessed based on the impact of the proposed use (in this case, underground space) on existing uses and the environment. Impacts may include implications for traffic (e.g., foot traffic), noise (e.g., noise/vibration), air quality (e.g., odor/vapor), health (e.g., disease transmission), security (e.g., high-security use), safety (e.g., explosion/poisoning risk) and operational requirements (e.g., maintenance requirements). The following principles may apply:

If the uses are functionally and environmentally compatible, they should be considered compatible. In some cases, planning conditions or guidelines may be imposed, such as:

i) volume conditions to clearly define primary versus secondary or auxiliary uses;

ii) allowing only specific uses within a general category;

iii) location requirements, e.g., commercial activities may be limited to the first basement level.

Different uses may be located close together only if appropriate mitigation measures, such as soundproofing, nuisance abatement, or safety and security measures are in place. These are considered compatible.

Uses should not be located close together if they would cause environmental or other adverse impacts. These are considered incompatible.

In conclusion, ensuring the compatibility of uses in underground space projects is essential for their success. By carefully assessing the functional and environmental impacts of proposed uses, planners can mitigate potential conflicts and enhance the integration of underground and above-ground spaces. Applying principles such as compatibility assessments, mitigation measures, and planning guidelines provides a structured approach to managing these complexities. Ultimately, a well-designed compatibility matrix, combined with case-by-case evaluations, can serve as a valuable tool for sustainable and efficient underground space planning.

3.2. Opportunities for colocation

As discussed above, the drivers, opportunities, and constraints of underground space must be understood. In many cases, underground space development is more expensive than above-ground development. Therefore,

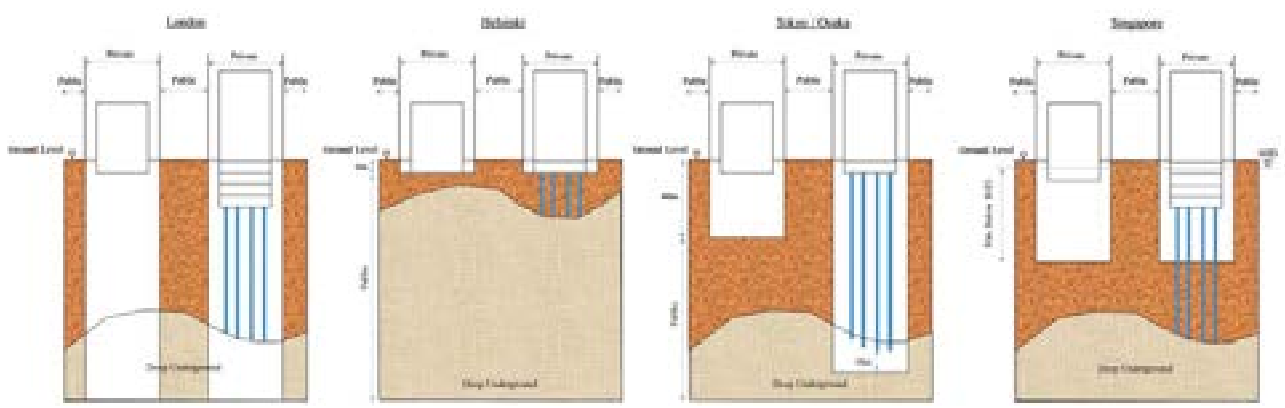


Figure 3. Underground space ownership in London, Helsinki, Tokyo/Osaka and Singapore

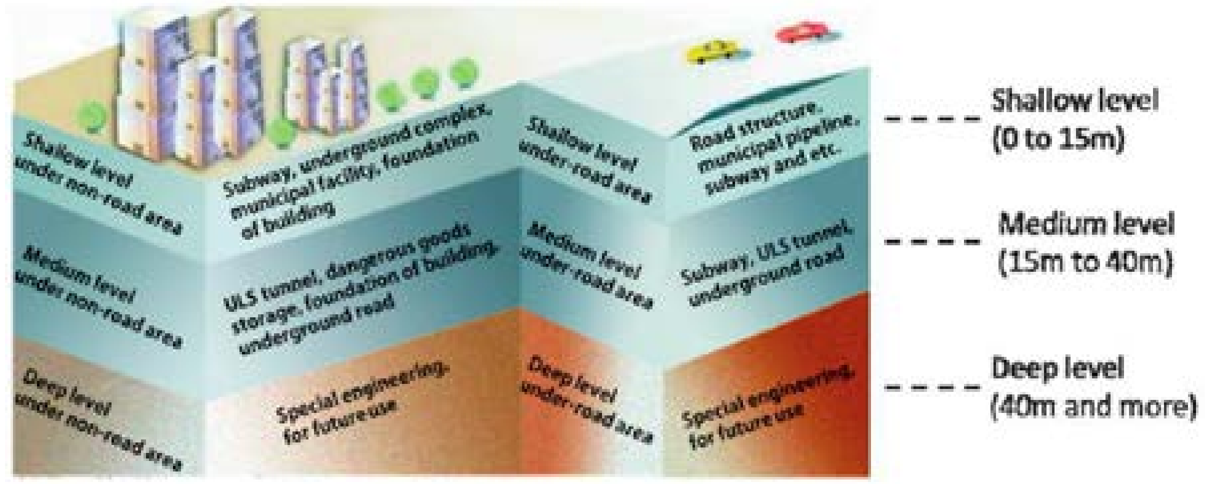


Figure 4. Underground stratification principles applied in Shanghai

the chance to diversify the uses of underground space is attractive, maximizing the value of the project. Mixed-use is one way to achieve this. More, specifically, mixed-use refers to integrating different but complementary land uses, buildings, services, businesses, and amenities into a single project. This optimizes land area, serves multiple uses, and can be reserved for future purposes while maximizing the opportunity to share infrastructure (e.g., access, ventilation, exits, etc.) to save on the cost of underground space development.

In underground space planning, coordination of uses can occur in two basic cases (1) Clustering of compatible uses/functions; (2) Linear coordination of infrastructure and utilities. Compatible use clustering arranges two or more compatible uses or functions. These spaces can be placed horizontally, stacked vertically, or in a typical underground facility. Linear coordination refers to the arrangement of linear infrastructure such as tunnels, railway tunnels, utilities, and/or underground walking/biking networks in the same corridor or intersecting to form a network of underground spaces and utilities. In Helsinki, linear coordination has been widely applied to efficiently use space, especially for utility tunnels that contain multiple services within a deep tunnel with shared access, ventilation, and fire protection systems. The benefits of this approach are cost reduction by sharing expenses between developers and increased space efficiency. The principle of shared use of utilities is integral to underground space planning in Helsinki.

However, the factors driving use coordination need to be clearly defined. In areas with limited space, the motivation may be to improve space efficiency, while in other regions, cost-sharing may be the primary motivation. For example, the rationale for locating utilities in a Combined Utility Tunnel may be to reduce the impact of excavation for utilities on the road surface and to optimize underground space use in dense areas. However, if the primary motivation is on cost savings, an alternative could be to locate the utilities in a separate corridor without the Combined Utility Tunnel, dedicating the corridor to utilities and accepting a reduction in space efficiency. The overall objective will impact the project's implementation model and economic viability.

The mixing of uses should be seriously considered whenever there are barriers to development, such as water bodies, existing developments, or topography, which are simply development activities. Mixing multiple uses requires consideration of the compatibility between them. In addition, projects should also seek to take advantage of cost, space, time, or resource savings opportunities that a mix of uses provides.

3.3. Depth-based prioritization

The depth of underground development is a critical factor influencing costs and technical requirements, including access, ventilation, and fire safety. In Tokyo, the Tokyo Station Area Underground Space Use Guidelines (1997) provide a stratified system for allocating underground functions. Utilities such as supply and disposal services and communication networks are placed at the shallowest layer beneath the street, ranging from 0 to 3 meters deep. Pedestrian networks, automotive networks, and underground parking are positioned at depths ranging from 3 to 5 meters, while subway networks, additional underground parking, and underground roads are located at depths of 6 to 10 meters. Deeper layers, such as those exceeding 30 meters, accommodate subway networks and underground rivers.

Similarly, in Shanghai, the allocation of underground functions follows a strategic depth hierarchy. Functions closely connected to the surface, such as pedestrian mobility, are placed at shallower depths, while utility infrastructure, which is less reliant on surface connectivity, is located at greater depths. (Figure 4)

These approaches are essential for planning underground space at the regional scale. Ensuring continuity within an area regarding pedestrian connections, utility corridors, transport corridors, and other uses should be a priority for planners.

Developing and applying stratification principles provides a holistic approach and allows planners to navigate the 3D complexity of underground space planning. The consensus among advanced underground space development areas suggests that uses requiring frequent surface connections should be located at shallower depths. This is a typical casewhere population density is high, or there is a significant movement of people to the surface. Uses that require less connectivity can be located at greater depths. Reducing the human presence can reduce ventilation and fire safety requirements, allowing infrastructure to be located at deeper depths.

3.4. Value of reserving for future

Reserving underground space is a critical component of long-term urban planning, ensuring efficient use of resources and future development potential.

In Helsinki, over 200 underground areas have been reserved for development, with surface space strategically planned to create vertical connections. Similarly, in Hong Kong, underground space has been reserved for undefined purposes, with specific access routes from the surface carefully planned.

For Hanoi, space reservation should prioritize:

3D Connectivity: Incorporating entrances, emergency exits, ventilation, and surface areas to support underground development.

Resource Utilization: Avoiding the waste of valuable land and rock resources while creating a foundation for future development.

To ensure the success of the underground space reservation process in Hanoi, it is essential to appropriately plan and reserve all above-ground interfaces alongside vertical connections. Encouraging three-dimensional space reservation will help integrate above- and below-ground systems effectively. Above-ground connections should include entrances, exits, emergency access and exits, ventilation systems, asset protection, provisions for daylight, and support for above-ground development (Figure 5).

4. Data considerations

Effective underground space planning relies heavily on the availability and quality of data. A critical factor for success is ensuring accurate, up-to-date data is accessible in a format suitable for planning purposes.

Traditionally, planning data focused on demographic information such as population size, density, age, and gender distribution, alongside geographic data like topography, zoning plans, and infrastructure details such as roads and blocks. Additional datasets, such as environmental factors and growth projections, were also included. While these elements remain relevant in underground planning, the process introduces unique challenges and data requirements.

Unlike above-ground environments, underground spaces are largely invisible and poorly understood. This makes acquiring comprehensive and precise data for underground environments more challenging. Among the various datasets, geological and geotechnical data are particularly critical in underground space planning. Identifying areas with stable soil suitable for development or weak soils where construction may pose significant challenges, greatly enhances the effectiveness of planning efforts. Geological and geotechnical data come in various forms, including borehole logs, test pit records, geophysical survey data, and geological maps. Collecting, organizing, and sharing this data is complex and requires collaboration across multiple sources. These sources may include academic research, private sector projects (e.g., construction, mining, tunneling), and targeted investigations initiated by planners.

Cities like Helsinki and Hong Kong demonstrate successful approaches for managing geotechnical data. On the one hand, Helsinki uses a geotechnical database to store and distribute data, including reports, regional maps, 3D models, and links to other databases. Hong Kong, on the other hand, has established a geological library to provide planners with geological and geotechnical resources. Planners should recognize the various types of geological and geotechnical data and their applications. While creating highly accurate 3D geological models may seem ideal, it is not always practical or necessary. Data of known accuracy can still play a vital role in planning by informing studies and enabling plans to account for identified risks. Even less accurate data can contribute meaningfully by guiding future research and helping develop plans with an awareness of associated uncertainties. In other words, understanding and leveraging geological and geotechnical data is indispensable for successful underground space planning

In Hanoi, the author relied on geological data collected over 17 years from 1990 to 2007, including 135 volumes of geological survey reports with 917 boreholes. Geological

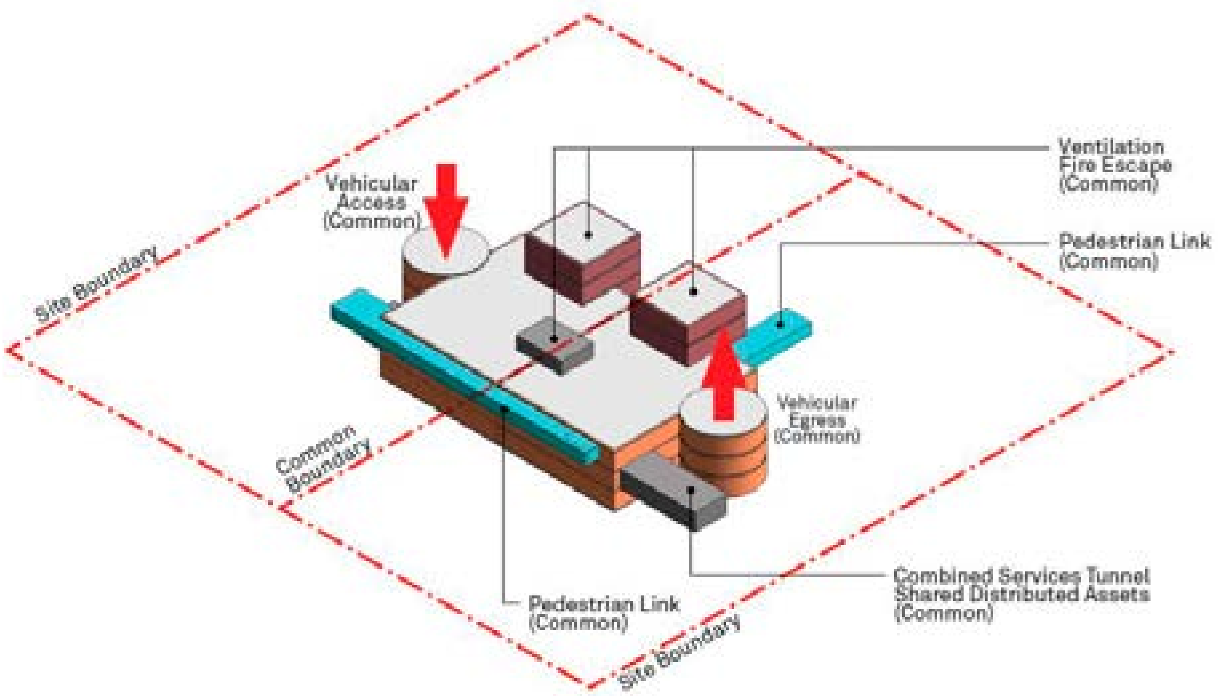
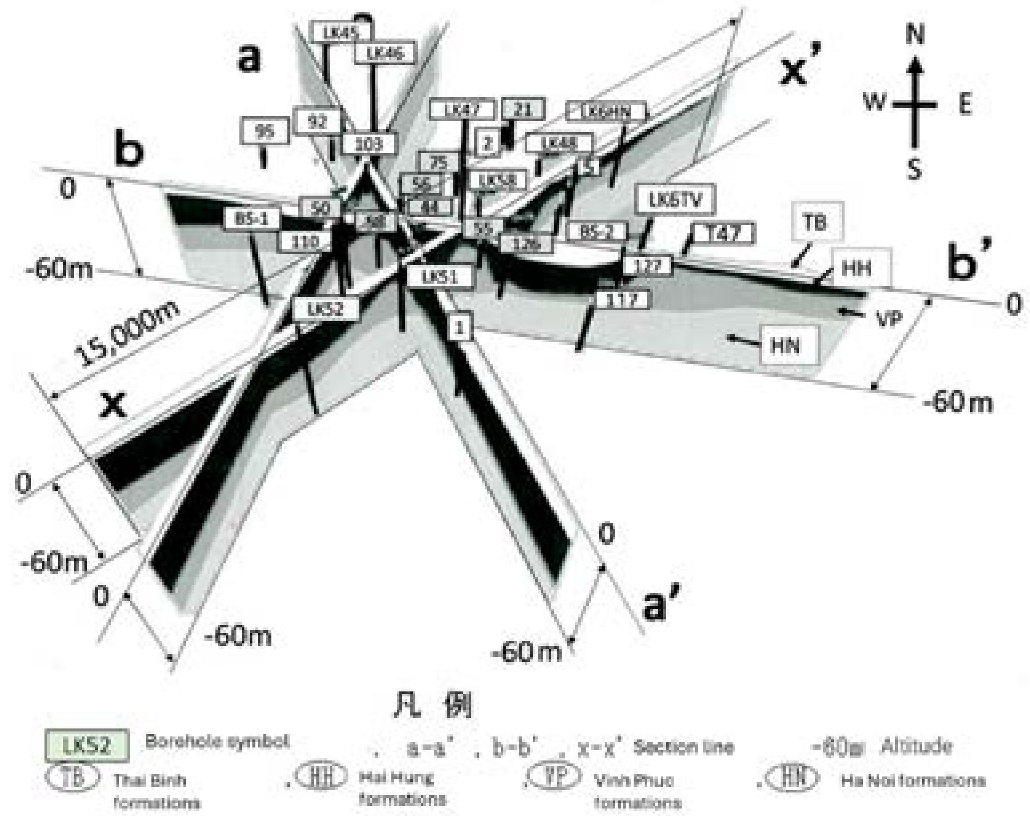
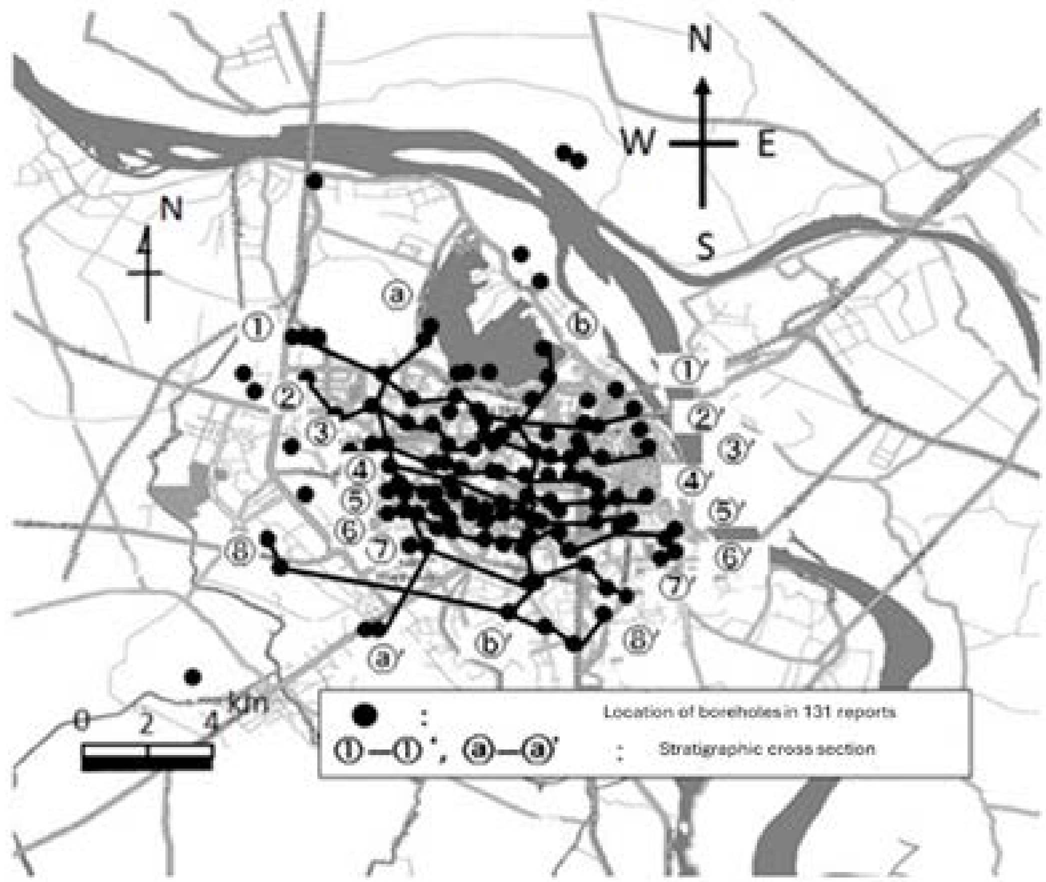


Figure 5. Illustration of at-grade and underground space reservation



Hình 6. Location of boreholes in 131 reports



Hình 7. 3D map of Hanoi's stratigraphy

Table 1. Classification table of 26 types of geological strata in Hanoi City from a geotechnical perspective

		Stratigraphic name	Stratigraphic classification						
Holocene	Topsoil		1: Topsoil						
	Upper part	Thai Binh	Top	2: Lake bottom mud		3: Brown sandy clay		4: Gray loose sand	
			Bottom	5: Brown clay	6: Brown to yellow clay	7: Grey organic clay	8: Gray sandy loam	9: Gray medium dense fine sand	10: Dark gray clay and sand
	Middle and bottom part	Hai Hung	Top	11: Black soft organic mud					
			Middle	12: Blue gray clay					
			Bottom	13: Black organic mud					
Pleistonce	Upper part	Vinh Phuc		14: Grayish white to grayish black clay, plastic to semi-hard	15: Reddish brown clay	16: Dark gray soft organic clay	17: Clay mixed with sand	18: Brown fine sand	19: Gray gravel, sand and gravel
	Upper and middle part	Ha Noi		20: Gray clay mixed with sand and organic matter		21: Gravel, sand and gravel		22: Gravel and brown sand	
	Bottom part	Le Chi		23: Gray to brown sand mixed with gravel			24: Gray gravel mixed with sand		
Quaternary unclassified				25: Semi-hard brown clay			26: Weathered clay		

surveys were also conducted at two boreholes inside Hanoi to supplement the existing geological survey data. From this, it can be seen that the geology of Hanoi is formed from bottom to top, including the Tam Diep system, the Neogene system, the Quaternary system, the maximum depth of the Tam Diep system is about 200m, and that of the Neogene system is about 100m. The stratigraphy of the Quaternary system irregularly covers the Neogene system, with its main components consisting of sand, gravel, and mixtures of dust and clay. In the Quaternary system, the strata since the last ice age are divided from bottom to top into Vinh Phuc strata, Hai Hung strata, and Thai Binh strata. Tanabe et al. (2006) divided the strata of the Red River Delta from Pleistocene to Holocene into Unit 0 (Pleistocene marine sediments), Unit 1 (flood sediments), Unit 2 (fluvial sediments), and Unit 3 (delta sediments). They also mentioned the underground valley extending in a north-south direction along the Day River. Funabiki et al. (2007) reported a geological survey in the suburbs of Hanoi showing that at a depth of 4m, there are flood sediments, below that are tidal river sediments, and below 10m are marine sediments (7,500 - 8,700 years ago). Nguyen (2004) studied the stratigraphy up to 50m, dividing Hanoi's soil into 26 categories based on color, elasticity, and organic content.

The geotechnical properties of Hanoi differ significantly from north to south. The clay layer beneath the Holocene water fill is found in Soc Son and Dong Anh. The clay layer is thicker in the south but has fewer clay particles, gradually changing to clay loam, sand loam, and plant remains. Below the clay layer are layers of sand silt, clay silt, and organic silt. The northern clay layer has better construction properties than the southern one.

The geological data collected by the author, when combined with approved planning documents, can help urban planners and underground space planners choose the depth of underground construction, the underground construction's location, and the underground building's outline.

Another critical data set, especially related to urban underground development, is the historical development, which includes buildings and utility systems. Building data may consist of several structures such as buildings, basements, underground pedestrian networks, traffic tunnels, and underground cavities. Utility data may comprise water, sewerage, sanitation, electricity and gas networks, and telecommunications systems.

Building data is typically collected through design or as-built records from building owners and planning or approval departments. The data is generally stored in hard copy forms, such as paper or soft copy, as in digital scans of these hard copies. More recently, building records may be stored in soft copy form, such as 2D PDFs or 2D CAD drawings. Additionally, records may be produced as 3D PDFs, 3D CAD drawings, or 3D BIM files. Records are generally more accurate for above-ground developments, especially regarding as-built records. As-built records are often tricky for underground developments, where post-development surveys are often not feasible. Whenever possible, planners should utilize existing building records to avoid proposals impacting existing structures. This can be done in several ways, such as creating sufficient distances between proposals and known existing structures, aligning floor levels appropriately to seamlessly link developments, or ensuring that proposals connect to existing structures at appropriate points

Utility data are often less accurate than building records. Common problems include utility records frequently being at the schematic level, not being linked to general spatial data, inconsistent quality, incomplete content, and

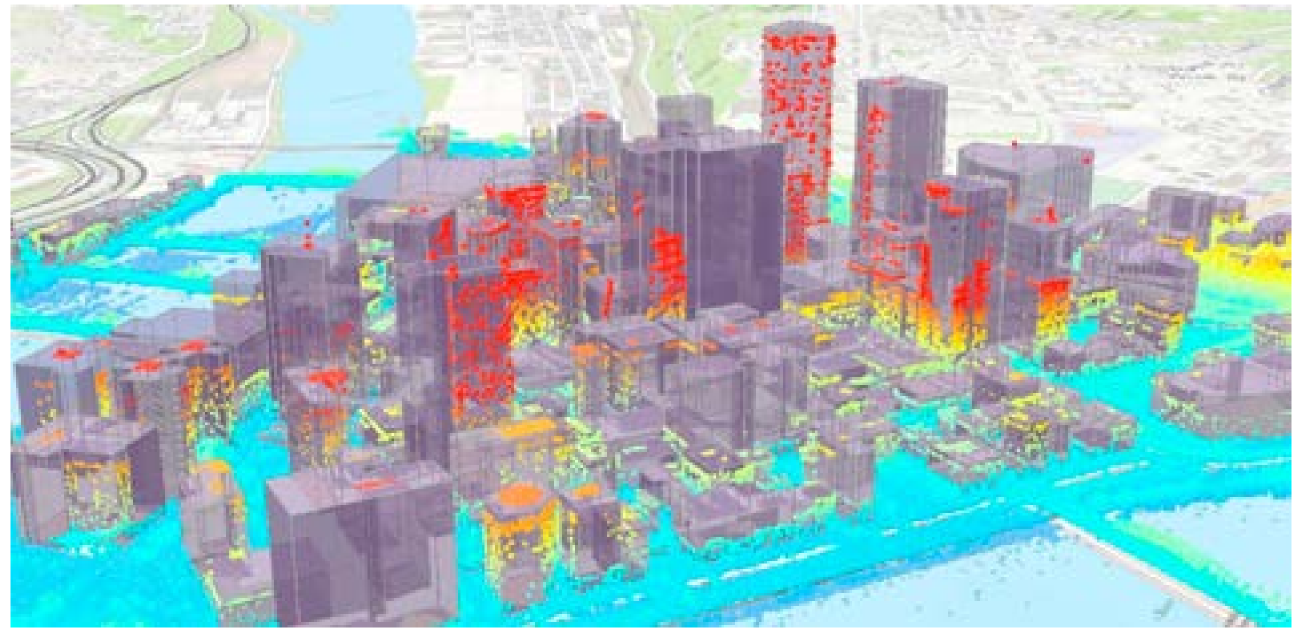


Figure 9. Illustration of 3D data visualization

incompatible formats. As a result, many utilities may be unrecorded, abandoned, or unused, or utilities that are often installed in different paths than those recorded during design development.

It is recommended that an accuracy assessment system be developed to understand the accuracy of the information for the wording quality data. Australia, through the Australian Standard: Classification of Underground Utility Information (AS 5488—2013), has established a method for all utilities to be given an accuracy assessment. This system informs planners of the likelihood that the record is accurate and the factors designers should consider in their planning. Accurate, up-to-date as-built records for buildings, particularly new buildings, are feasible and should be a focus for improving underground space planning. Historical underground development records should be digitized and updated as additional data becomes available. However, the issue with utility records is more complex, and targeted approaches are needed to improve them. Developing an accuracy assessment system and establishing good record-keeping practices for developers and utility contractors are among these.

With the continued advancement of technology, it is becoming easier and easier to record relevant planning data and use and manage it to support planning. This visualization has been visualized using many advanced technologies, including 2D and 3D GIS, 3D AUTOCAD and BIM Systems, 3D Imaging, and 3D Printing. These systems enable planners to visualize the opportunities and constraints of underground space development, allowing for more effective planning for future developments. As an example of the capabilities of 3D Visualization is shown in Figure 9.

Data management is also a key element of effective underground space planning. Successful data management practices should simplify the collection and distribution of data to the necessary stakeholders. The respective data distributors should be responsible for the aggregation, verification (if required), and distribution of their data. A centralized data system, such as the one in Helsinki, can serve as an adequate method for data distribution. Therefore, in such a system, the respective data managers can upload their data, allowing necessary data users to access it on demand. Particular care should be taken with sensitive data, which may require a method of restricting distribution.

5. Conclude

This paper presents potential learning points from major cities worldwide that have adopted advanced underground space planning practices, focusing on key elements for improving underground space planning with implications for Hanoi.

A comprehensive policy framework that supports underground space development is essential. The first step to achieving this is to clarify ownership and use rights of underground space. Clearly defining boundaries and scope of work for planners and developers helps avoid creating a climate of risk, which can discourage investment and reduce underground space use.

At the core of all planning work is a clear understanding of the drivers and pressures behind these works. All planners should be equipped with this knowledge before they begin developing plans.

During the planning process, the importance of coordination between above-ground and below-ground developments, opportunities for co-location, and depth considerations should be emphasized. Planning tools and methods should be deployed to take advantage of these considerations when developing underground space plans. As a plan is being developed, space should be reserved to ensure the appropriate use of underground and above-ground space assets.

Last but not least, accurate data must be available for planning to be meaningful and actionable. This should include general planning and underground space-specific data such as geology. This issue is evolving with the continued development of data collection and visualization systems. Leveraging the latest technology has enabled planners to plan in a data-rich 3D environment, improving planning accuracy and resolution./.

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Real estate improvement at the area in-between the new urban...

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cohesive space is a new point. In application, the solution was flexible when affecting each area in order to bring a unique aesthetic, bringing identity value to the area. The synchronous application of this solution contributes to the current urban design research of the street in Hanoi.

- Proposal to establish diversity and share space. The proposed solution has partially solved the problem of limited land fund and is consistent with current manifestations. Shared spaces are established not only for bonding and cultural exchange between communities, but also as physical spaces for establishing transport connections between regions and between means of transport.

The proposed solutions are applicable in deployment in specific cohesive spaces in Hanoi. Creating a friendly space, improving economic performance, minimizing potential risks of social unrest, contributing to improving the quality of life and real estate. As stated initially, these spaces always appear at the same time as urban expansion and have an increasing number. Therefore, the proposed solution contributes to ensure the sustainable urban development of Hanoi city. On the other hand, with its role as the capital - a large economic center with a high rate of urbanization, the study in Hanoi brings many lessons learned, and it is possible to apply in other cities across the country.

Base on this results, the specific following diagram is shown to synchronize the multi purposes of residents with the aim of improving quality of life./.

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Architectural characteristics of Thai den ethnic houses in Tram Tau, Yen Bai province

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Abstract

Under the influence of socio-cultural factors and the environment, the housing of the Thai Den ethnic group in Tram Tau, Yen Bai province, has become a symbol of cultural diversity and architecture in the northern mountainous region of Vietnam. Up to now, although architectural features have undergone modifications to adapt to modern life, these structures still reflect the inheritance of long-standing traditional values through identifiable images and spaces serving the daily lives of the Thai Den people. It can be seen that with contributions to the architectural and cultural history treasure of Tram Tau, specifically, and the Northwest region in general, the stilt houses of the Thai Den people play an important role in sustainable development and the continuation of traditional architecture in the area. The article employs investigative methods, current situation surveys, historical investigations, and comparative methods to identify architectural characteristics of Thai Den ethnic houses in Tram Tau in relation to Thai ethnic houses in the Northwest region in general.

Key words: Thai Den ethnic houses, Yen Bai, ethnic architecture, ethnic cuture, stilt house

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1. Introduction

Tram Tau, a district nestled in the Northwestern region of Vietnam, amidst towering mountain ranges, creates a majestic and distinctive natural landscape. It not only bears witness to numerous significant historical events but also holds a treasure trove of Vietnam's cultural heritage. With a diverse population comprising various ethnic groups such as the Hmong, Thai, Khơ Mú, Tay, Muong, and Kinh, it paints a vibrant picture of ethnic cultural and architectural diversity. Among these, the Thai Den ethnic group constitutes a significant proportion, and their houses still retain deep-rooted traditional architectural characteristics, becoming emblematic of this region.

Until now, there have been limited studies on the architectural aspects of Thai ethnic houses, primarily conducted by ethnographers such as Nguyen Khac Tung, Vuong Trung, Cam Trong, Lo Cao Nhum, and Tong Van Han. Vuong Trung's book "Traditional Stilt Houses of the Vietnamese Thai" contextualizes the Thai Den stilt houses in Thuan Chau, Son La, describing the rituals, customs, traditions, and activities related to the houses (for both Thai Den and Thai Trang), focusing more on ethnographic aspects while briefly covering architectural content. Cam Trong's book "Understanding the Thai People in Vietnam" also mainly describes the layout and activities inside the stilt houses of Thai Den in Thuan Chau, Son La, and Thai Trang in Ky Son, Nghe An. Meanwhile, Tong Van Han's "Construction Process of Ancient Stilt Houses of the Thai Den People in Muong Thanh, Dien Bien Province" primarily discusses the construction steps and rituals related to the building process and completion of the houses. Nguyen Khac Tung's "Traditional Housing of Vietnamese Ethnic Groups" provides more detailed information on the architecture of Thai ethnic houses (including both stilt houses and ground houses), distinguishing between Thai Den and Thai Trang, but is limited to a few houses in Muong La, Son La, Muong Lay, Lai Chau, and Con Cuong, Nghe An. In the architectural community, the Vietnam Association of Architects' book "Folk Housing in Vietnamese Rural Areas" presents architectural drawings of some stilt houses of Thai Den in Son La, including floor plans, sections, and elevations, but lacks in-depth analysis and interpretation of their architectural characteristics [1-7]

Overall, these studies provide a general overview of the traditional architectural aspects of the Thai people in Vietnam. However, empirical surveys reveal that while there are similarities in the architecture of Thai Den and Thai Trang houses, there are also significant differences alongside these similarities. Even within each branch of the Thai ethnic group, there are many variations in different regions (potentially influenced by natural conditions, cultural interactions with other ethnic groups, or adaptation to societal changes and new needs). These differences contribute to the diversity within the unity of traditional Thai ethnic architecture—a topic that requires further exploration. Therefore, in-depth research on the architectural characteristics of Thai houses in different locations/regions is essential and meaningful, as it can help identify local specificities and contribute to completing the unified picture of Thai architecture in Vietnam.

To systematically fill in the gaps regarding the architecture of Thai houses, this article aims to delve deeply into the architectural characteristics of Thai Den houses in one of the regions with a significant Thai Den population that has received limited research attention: Tram Tau, Yen Bai.

2. Research methodology

To achieve the stated objectives, the research team conducted multidimensional research methods, including investigation and current situation surveys, historical