Building Smart Cities and Developing Public Transport – Oriented Development (TOD) – Key Strategies for Hanoi Capital

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Abstract

Sustainable smart cities are innovative urban areas that utilize information technology, communication, and other means to enhance the quality of life, optimize urban activities, services, and increase competitiveness. In the context of the Fourth Industrial Revolution, the development of smart cities, along with adopting the Transit-Oriented Development (TOD) model with a focus on extensive public transportation, is a suitable and effective direction for Hanoi's urban development. Smart cities are built on three pillars: intelligent social infrastructure, intelligent urban technical infrastructure, and digital infrastructure. The development of cities following the TOD model is closely related to smart cities and these three pillars. Research and evaluations have shown that TOD development is an intelligent solution for urban areas, effectively addressing various economic, social, and environmental challenges while preserving resources.

Key words: Smart cities, Transit-Oriented Development (TOD), Digital Transformation, TOD model

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1. Introduction

Resolution 15-NQ/TW dated May 5, 2022, by the Politburo on the orientation and tasks of developing Hanoi Capital, has set the goal of building Hanoi into a city that is "Civilized, Modern, and Sophisticated," becoming a center and driving force for the development of the Red River Delta region, the northern key economic zone, and the whole country. To achieve this desired goal, one of the requirements is to have appropriate solutions and directions from the planning stage. Hanoi is the capital of the country and, especially after the period of renovation, particularly since the administrative boundary expansion, the scale and pace of urban development have been rapid, resulting in significant achievements. The urban landscape has become more modern and splendid, gradually resembling major cities in the region. However, alongside these achievements, the city has also faced various challenges concerning the environment, socio-economic issues, such as traffic congestion, environmental pollution, and inadequate social infrastructure. Despite substantial investments in infrastructure development, particularly in the road traffic system, drainage systems, and other technical infrastructure, the speed has not kept up with the increasing demands, and significant breakthroughs have yet to be made.

Entering the 21st century, with the Fourth Industrial Revolution and the wave of digital transformation, many cities worldwide have transitioned to building smart cities, along with adopting the Transit-Oriented Development (TOD) model, using extensive public transportation as the main backbone for the transport network and urban development orientation. These solutions represent intelligent and effective ways to conserve resources and address the enormous challenges faced by cities, including those applicable to Hanoi.

2. Development of Smart Cities

2.1. The Concept of Digital Transformation, Smart Cities, and Characteristics of Smart Cities

*What is Digital Transformation?

Definition: Digital transformation is the process of self-changing to adapt to the digital future.

- Digital transformation of enterprises - Smart enterprises.

- Digital transformation of cities - Smart cities.

- Digital transformation of governments - Smart governments.

- Digital transformation of nations - Smart nations.

- Digital transformation of humanity - Smart world.

*The Concept of Smart Cities (SC)

Until now, there are still various interpretations of smart cities, and this concept is continually evolving.

ITU-T provides the definition: "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve the quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, and environmental aspects."

IEC believes: "A smart city is an effective, sustainable, and livable system of systems, designed for people and shaped by citizens, businesses, organizations, and technology developers with the purpose of creating added value."

In a relatively open interpretation, a smart city converges three elements: efficient infrastructure, sustainable development, and a friendly living environment. This is reflected through six categories: (1) Smart Economy, (2)

Smart Mobility, (3) Smart Citizens, (4) Smart Environment, (5) Smart Governance, and (6) Smart Living.

In Vietnam, the definition states: "Smart Sustainable City" is an innovative city that uses information and communication technology and other means to improve the quality of life, enhance the efficiency of urban activities and services, and increase competitiveness while still ensuring meeting the current and future needs in terms of economic, social, and environmental aspects.

*Characteristics of Smart Cities.

The attributes of smart cities are divided into three groups and are closely related to each other: (1) Environment and sustainable development; (2) Urban services; (3) Quality of life. Smart cities are not just a "product" to be built; they represent a method of development. It is crucial to understand that a city does not need to be wealthy to embark on smart city development. On the contrary, even in challenging economic conditions, there should be more efforts to construct smart cities. Essentially, a smart city represents the integration of digital technology into the urban development process, efficiently utilizing limited resources to best meet the needs of city residents.

According to the Decision No. 950/QD-TTg dated August 1, 2018, by the Prime Minister, and the Official Letter No. 4211/VPCP-QHQT dated May 8, 2018, by the Government Office, Hanoi is striving to become a leading city in the ASEAN Smart Cities Network and a pioneer in smart city development methods. This leadership should be prominently demonstrated in the city's plans. Incorporating general plans, sectoral plans, and detailed plans with a system of standards and criteria for smart urban space infrastructure will provide the foundation for Hanoi's smart city development in the upcoming phase.

Recently, Hanoi has made significant efforts to pilot some Smart City applications, yielding some initial achievements. However, complex issues concerning technical infrastructure, social infrastructure, and the environment still persist, demanding the city to further strengthen the construction of Smart City projects. Building Smart City projects should be seen as a method of comprehensive and modern urban planning and management, not just a collection of scattered and isolated smart applications.

2.2. Structure of Smart Urban Infrastructure

- Smart urban infrastructure is based on three foundational platforms:

+ Smart Social Infrastructure

+ Smart Technical Urban Infrastructure

+ Information (Digital) Infrastructure

Building upon these three foundational platforms, a smart city is characterized by pillars that encompass smart governance, smart citizens, smart environment, smart living, smart economy, and smart information.

* Smartification should start with urban planning: (1) It requires a combination of construction solutions + technological solutions + management solutions. (2) New technical infrastructure projects must be smart from the outset (starting from planning and investment stages). (3) Existing infrastructure projects need to be smartified simultaneously with upgrading and renovation efforts. (4) It is necessary to establish management regulations for smart technical infrastructure projects and issue standards and guidelines to ensure that smart components can interconnect.

a. Smart Social Infrastructure: A society where digital technology improves human happiness, economic power, and organizational efficiency is considered a smart society. The areas covered by smart social infrastructure include smart individuals, smart government, smart economy, and smart lifestyle.

b. Smart Technical Urban Infrastructure: Smart technical infrastructure plays a crucial role in creating smart cities. The areas covered by smart technical infrastructure include: (1) Smart environment (smart energy, smart waste and wastewater management, pollution control); (2) Smart mobility (public transportation, transportation, smart logistics); (3) Smart utilities (internet technology, Building Information Modeling (BIM) technology, and urban utilities services); (4) Smart living (electronic connectivity, housing, cultural platforms, safety, and security).

c. Information (Digital) Infrastructure

A smart city optimizes all parameters by creating intelligent connections among all relevant parties of the city and simultaneously controlling them, utilizing powerful tools for big data processing. Smart information infrastructure includes: smart network, smart data, smart sensors, smart communication.

2.3. Requirements and Steps to Build a Smart City

The implementation of sustainable smart urban development involves a combination of top-down and bottom-up approaches. The central government focuses on establishing a legal framework and supportive policies, while local authorities take an active role. Encouraging investment and promoting the socialization of smart urban development is crucial. The process should be organized and carried out gradually, ensuring both short-term and long-term investment efficiency, avoiding spontaneous and widespread development trends. Prioritize building fundamental contents, including Smart Urban Planning; Constructing and managing smart cities; Providing smart urban utilities for organizations and individuals with the fundamental basis being the Urban Technical Infrastructure System and the ICT infrastructure system, including the connected smart urban spatial database and the integrated system of both [5].

a. The tasks and requirements are as follows

In Decision No. 950/QD-TTg dated August 1, 2018, the Prime Minister outlined the key solutions and tasks for sustainable smart urban development as follows [1]:

Group 1: Review and complete the system of legal documents, policies, economic and technical norms, and issue guidelines for sustainable smart urban development.

Group 2: Gradually form and improve the system of national standards and standards for smart urban areas, promote basic scientific research and application research for sustainable smart urban development.

Group 3: Establish, connect, maintain, and operate the digital urban spatial data system and the national urban database.

Group 4: Strengthen the application of smart technologies in urban planning and management.

Group 5: Develop smart urban infrastructure.

Group 6: Develop smart utilities for urban residents.

Group 7: Build the capacity for sustainable smart urban development.

Group 8: Mobilize investment sources and provide

Table 1. Steps for Implementing Smart City Construction

TT	Content	Description
1	Assessment of the current situation	• Implementation of surveys to assess the current situation, challenges, difficulties, and needs of the city, residents, and businesses
2	Establishing a Vision	• Building a Comprehensive Vision and Concretizing the TOD Vision for the City in Each Area • Ensuring Consensus on the Vision among Government, Citizens, and Businesses.
3	Identifying the overall objectives; establishing guiding principles; specific objectives and measurement criteria for each area.	• Identifying the overall objectives and guiding principles to ensure that activities, solutions, and TOD construction projects always align with the established vision and general goals; • Determining specific objectives for each area and the role of ICT (Information &Communication Technologies) in realizing these objectives. Establishing milestones for each phase and evaluation criteria for each area.
4	Developing a Roadmap	• Developing a Comprehensive Reference Roadmap towards Public Transport-Oriented Development (TOD), which includes urban-level focused projects (related to multiple areas), key projects, hot areas, and fast-track projects that can be implemented quickly and deliver immediate results.
5	Flexible Implementation	• Prioritize the implementation of projects that can be quickly deployed and deliver immediate results, as well as key projects and hot areas. Subsequently, the remaining programs and projects will be defined in terms of scale and evaluation criteria in each implementation phase, ensuring adherence to guiding principles. • Additionally, corresponding to each phase, the city will research and implement supplementary solutions concerning organizational structures, policy mechanisms, financing, communication, etc., to support the implementation of ICT solutions.
6	Measurement, Evaluation, and Improvement	• Involving citizens throughout the implementation of programs/projects will help in measuring, evaluating, and determining the level of responsiveness to their needs, enabling continuous improvement of the solutions. • Annual reviews and updates will be conducted to adjust any outdated content, and multiple evaluation methods will be used, including internal assessments, feedback from citizens, or the possibility of hiring independent evaluation entities.

Source: Research Report by the Ministry [3]

technical support from both domestic and foreign resources.

b. Implementation steps for building a Smart City

It may not be necessary to wait for the completion of the entire smart urban development plan, but rather, general projects and small projects that have immediate impacts can be implemented first (followed by continuous upgrades and improvements). Depending on the level of priority, the city can gradually develop programs for each sector, allowing for flexibility in timing as long as the guiding principles are ensured.

There are 6 steps for Implementing Smart City Construction as following [3]:

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Establishing a Vision: Building a Comprehensive Vision and Concretizing the TOD Vision for the City in Each Area; Ensuring Consensus on the Vision among Government, Citizens, and Businesses;

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Developing a Roadmap: Developing a Comprehensive Reference Roadmap towards Public Transport-Oriented Development (TOD), which includes urban-level focused projects (related to multiple areas), key projects, hot areas, and fast-track projects that can be implemented quickly and deliver immediate results;

Flexible Implementation: Prioritize the implementation of projects that can be quickly deployed and deliver immediate results, as well as key projects and hot areas. Subsequently, the remaining programs and projects will be defined in terms of scale and evaluation criteria in each implementation phase, ensuring adherence to guiding principles; Additionally, corresponding to each phase, the city will research and implement supplementary solutions concerning organizational structures, policy mechanisms, financing, communication, etc., to support the implementation of ICT solutions;

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2.4. Standards and Criteria for Smart City Development

a. Standards

Standards are essential in connecting stakeholders,

components, and operations of a Smart City. Some groups like IEEE (Institute of Electrical and Electronics Engineers) focus on detailed technological aspects related to connectivity and transportation in Smart Cities, while others like ISO (International Organization for Standardization) concentrate on higher-level activities such as management strategies and authority in Smart Cities. These standardization activities can be categorized into three levels: strategic, procedural, and technical.

- Level 1: Strategic Standards. These standards provide guidance to city leadership and agencies. They include guidelines for identifying priorities, building implementation roadmaps, and monitoring and evaluating progress along the roadmap.

- Level 2: Procedural Standards. This level focuses on managing Smart City projects and provides best practices and integration guidance.

- Level 3: Technical Standards. This level includes technical specifications required to implement Smart City products to meet all objectives.

The Ministry of Science and Technology has issued 14 Vietnamese Standards on Smart Cities.

b. Criteria for Smart Urban Technical Infrastructure

According to a research project on smart urban technical infrastructure conducted by the Hanoi Institute of Planning and Architecture (HUPI), it has proposed 7 groups of criteria as follows [2]:

Smart Transport Infrastructure: Density of highways and interconnectivity between urban areas; Traffic information system; Traffic monitoring system; Smart public transportation system (buses, trains, etc.); Smart parking management system; Electronic payment system for public transport.

Smart Power Supply Infrastructure: Assessment factors include: Density and distribution of smart power stations; Smart power distribution system; Smart power management system; Renewable energy power system; Smart maintenance, repair, and inspection system; Smart electricity consumption measurement and monitoring system.

Smart Lighting Infrastructure: Assessment factors include: Smart urban lighting system with automatic brightness adjustment capability; Aesthetic design; Lighting system linked to security monitoring system; Integration with smart power grid.

Smart ICT (Information and Communication Technology) Infrastructure: Assessment factors include: Network coverage density; Network speed and bandwidth; Smart public access points; Sensor system; Urban information management system; Interconnected database system; Smart monitoring and control system; Smart applications; Information security and safety system.

Smart Water Supply System: Assessment factors include: Smart water distribution system; Centralized water supply system; Smart water monitoring and control system.

Smart Drainage System: (1) Rainwater drainage: Adaptability to natural disasters and climate change; Flood monitoring and warning system; Information system on drainage, data collection devices, geographic information system; (2) Wastewater drainage: Smart wastewater drainage system; Wastewater treatment system; Environmental technology system; Interconnected drainage system with other systems such as transportation, electricity, clean water, and ICT to support each other.

Smart Waste Management System: assessment factors include: Waste treatment technology; Convenience and meeting demands; Smart interaction capability; Space optimization; Ensuring safety and environmental protection.

3. Developing Smart Cities Using TOD Model in Hanoi

3.1. The Relationship Between Smart City Development and TOD

Smart city development is based on three platforms:

+ Smart social infrastructure

+ Smart urban technical infrastructure

+ Information infrastructure

Developing cities according to the Transit-Oriented Development (TOD) model is closely related to these three platforms. Regarding the smart social infrastructure aspect: TOD creates an efficient and convenient living, working, and recreational environment. Land use planning is linked to public transportation hubs, effectively meeting the needs of residential, working, entertainment, and commuting purposes. Residents enjoy a good living environment with well-developed public social infrastructure and ample green spaces in parks. Urban services, office spaces, and workplaces are arranged in integrated or interconnected settings. The development of public transportation is also closely linked to urban economic growth and the effectiveness of urban rail and public transportation systems.

Regarding the smart urban technical infrastructure aspect: A high-quality public transportation network, with urban rail as its backbone, ensures the highest efficiency in transportation, guaranteeing fast and convenient access to destinations. It adheres to the "From door to door" principle, making it easy and convenient for people to travel to their destinations through transit hubs, including bus stops, taxis, bicycles, pedestrian-friendly paths, etc. Smoke-free public transportation provides a good environmental quality, energy efficiency, and time savings.

Regarding the information infrastructure aspect: Developing TOD requires an efficient information network to connect public transportation systems effectively. This includes information and operation coordination between urban rail lines and other public transportation systems such as buses, taxis, parking lots, and ticketing systems, all interconnected seamlessly. For example, within an urban rail station and its surrounding TOD area, the information infrastructure must support guidance, ticket purchasing, operation monitoring, safety, and security. Predictions for TOD development trends in the 21st century emphasize the importance of network connectivity and the application of information technology, including the Internet of Things (IoT) in the industrial 4.0 era.

3.2. Developing TOD in the Context of Hanoi

3.2.1. Opportunities and Challenges in Implementing TOD Development in Hanoi

- Land, space, and infrastructure conditions: There are limited opportunities for new development in the inner city, requiring a focus on exploiting redevelopment and revitalization. New development areas, such as the Eastern Beltway 4 and the northern bank of the Red River, offer favorable conditions for TOD implementation. The urban technical infrastructure and social infrastructure, in general, are insufficiently developed. Public transportation, especially urban rail, has not been fully developed. The establishment
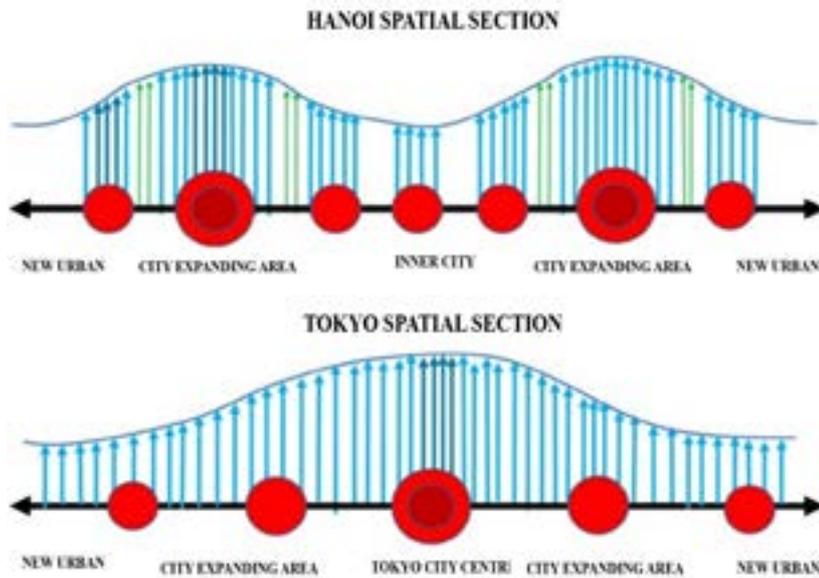
HANOI SPATIAL SECTION

TOKYO SPATIAL SECTION

Fig.1. Cross-section diagram of the central urban space in Hanoi[9]

of transportation connections, land use connections, and transportation connections has not been fully achieved. The unique characteristics of Hanoi's natural conditions include numerous rivers and lakes, a hot and humid climate with heavy rainfall, and cultural and lifestyle habits related to transportation.

- Preservation and development: Preserving historical and cultural values will contribute to creating a modern, refined, and distinctive urban Hanoi. When researching TOD, solutions should be closely tailored to the specific conditions of each region in Hanoi, especially within the historic inner city.

- Challenges to be addressed:

+ Increasing the ratio of public transportation usage: Solutions for funding mechanisms are needed to prioritize the development of the public transportation system. TOD projects should be linked to the development of land around transit hubs to offset construction costs. The government needs to have a comprehensive plan for investing in the underground public transportation system, while other investors should invest in station facilities, train equipment, and operations.

+ Institutional arrangements: Specific mechanisms for project implementation and coordination among relevant parties, including the government, residents, and investors, need to be established to ensure consensus and a balance of interests under the governance of the authorities.

+ Investment capital: The city's resources are limited, so there should be mechanisms to attract cooperation and investment. The availability of land funds to correspond with TOD projects should be preserved.

+ Urban restructuring: Urban restructuring will gradually transition as the TOD and public transportation systems are established along the roadmap. The implementation of the TOD model must be strategically planned and integrated with urban planning.

+ Establishing the urban image: TOD development should aim to create a distinct character for Hanoi, suitable for the cultural and lifestyle habits, without disrupting the landscape and preserving heritage and historical values.

+ Addressing the current land fund issue, especially in the restricted inner city: Appropriate evaluations should be made to determine the suitability of the TOD model for different regions in Hanoi. Solutions for completely new development areas, redevelopment, and revitalization should be provided based on the TOD development level.

3.2.2. Some Specificities and Development Potential for TOD Adaptation in Hanoi

- Developing TOD harmoniously with the conservation of historical and cultural spaces, monuments, and controlling high-rise development in the historic inner city. TOD characteristics are divided into three different regions: the historic inner city, the expanded inner city, and new development areas. Regarding space utilization: exploit the potential of lakes, water surfaces, connected open spaces, green spaces, and community spaces.

- Strengthening parking spaces for motorcycles, providing ride-hailing spaces, and expanding the TOD radius. To reduce access distance, implement crosswalk green spaces. Plant shade trees, rooftop trees, deploy shade structures, bridges, and pedestrian tunnels to create a comfortable environment for pedestrians.

- Developing housing in the form of shop-houses, utilizing "sidewalk economies" for services, tourism, etc., associated with walking. Organize spaces according to the urban form of each area.

- Applying high-density, compressed ratios, and increasing the proportion of residential areas in TOD (for new development areas) to create community spaces.

- Ensuring the allocation of public technical infrastructure: schools, kindergartens, cultural facilities according to the standards. Place local markets near the TOD area.

- For existing areas, some parts of the historic inner city without new development opportunities will improve accessibility and public transportation transfer to the urban rail station, utilizing underground space, and possibly forming incomplete TOD points.

- Applying information technology, the Internet of Things (IoT), and industry 4.0 in managing and operating the functions of the urban rail station area and the TOD area.

When the TOD model has not been implemented, many cities, including Hanoi, have been planned and constructed according to traditional models, including existing urban areas and new development areas. The thesis proposes a solution to transform from the traditional urban model and traditional unit model to the TOD unit model, aiming for sustainable and effective urban development.

Implementing the TOD model needs to be associated with the Urban development program, setting out plans for developing the urban rail system and TOD areas in the medium and long term to create a synchronized and mutually supportive operation.

Develop unified management principles for underground and surface spaces in areas with a transportation orientation. Establish urban design guidelines for TOD areas.

Propose policies to successfully develop the TOD model suitable for Hanoi's conditions. Address the spatial connection between existing areas and new development areas using the TOD model, developing TOD in the inner city through redevelopment and revitalization. Propose guidelines for the planning process for Hanoi, serving as the basis for the Urban development orientation.

3.2.4. The advantages of applying TOD in Hanoi

- TOD helps solve the traffic congestion problem in Hanoi, especially in the central urban areas. According to the Hanoi Capital Construction Master Plan, the population of the central urban areas will reach about 4.6-5.4 million people. According to the forecast of the Hanoi Master Plan Adjustment, the population size will be even higher. If relying only on expanding road infrastructure and continuing to increase private vehicles, the congestion problem cannot be solved. Currently, the bus system has developed quite well with improved service quality. However, it cannot continue to significantly increase the public transport proportion because it uses the road system, suffers from traffic congestion and takes time, which is less attractive to passengers. Urban railways with large transportation volume and high speed are the optimal means of public transportation. The development of urban railways and promoting walking and cycling will eliminate the need to invest more in road construction and urban expansion. This is also suitable for the current situation in Hanoi which lacks road area. By developing the TOD model, economic efficiency can be exploited from the land fund around metro stations to invest in building and maintaining the metro system. The problem of lack of capital and resources for metro construction will be solved. Developing the TOD model will also increase walking, cycling, limit private cars, and does not require too many additional roads, so the problem of lack of transportation area will also be solved. In summary, the development of TODs, metros, and public transportation will increase transportation capacity, fight congestion, while reducing costs for road construction, urban expansion, and can make up for resource imbalances from land funds, commercial services at TOD points. Hanoi is a developing and expanding city, with a lot of new development areas outside still having a lot of undeveloped land funds, with many favorable conditions for implementing the TOD model.

- The implementation of the TOD model will contribute to building sustainable, green, civilized, smart and modern urban development, as stated by Hanoi's goals. TOD brings economic, social and environmental efficiency. TOD optimizes the organization of land use functions, including mixed-use functions that help reduce distance and travel time for 3 needs: Living - Working - Services & Entertainment; increasing land use efficiency with height to save land, allocating space for green spaces, without having to invest too much in urban expansion infrastructure. The application of information technology, IoT, the operation of the metro system, multimodal interchange hubs, information and data connectivity, combined with underground transportation infrastructure and other technical infrastructure are favorable conditions for developing smart cities.

- Economic efficiency: the development of commercial services, offices at TOD hubs associated with transportation needs will increase efficiency, customer utility and business efficiency, creating connections in the urban commercial and financial system. With the habit of trading and sidewalk economy of people, developing shops, commercial streets within TOD areas, within walking distance of stations suits the lifestyle of Hanoi people as well as Vietnamese.

- Public spaces, open spaces, street services will help create highlights and preserve cultural values and identities of the city.

- TOD development will guide urban development. TOD is the driving force for developing different areas of the city according to the urban development program. Hanoi's goal is to reduce the population in the inner city, expanding urban development outward. The metro network and TOD system in new urban areas will attract people concentrated in the old inner city as well as promote the development of satellite towns as desired.

- The development of TOD brings economic, social and environmental benefits, creates modern and civilized cities, reduces investment costs for technical and social infrastructure, suitable to the ability of resources. Balancing
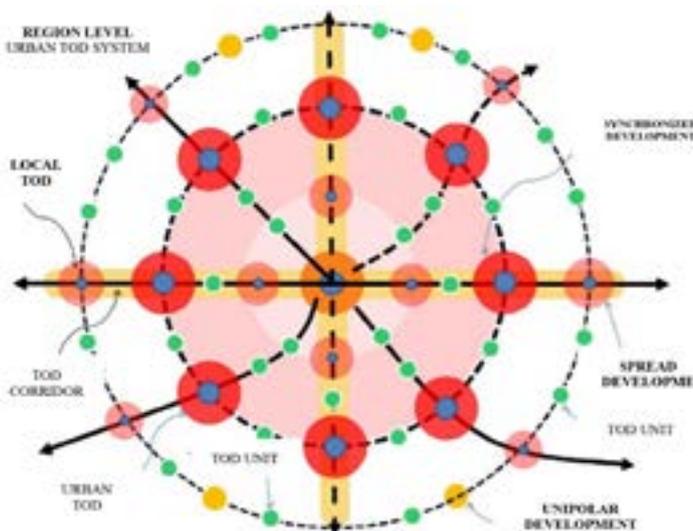

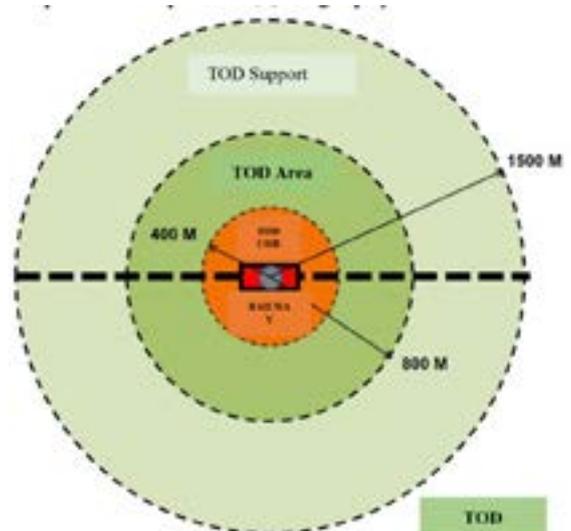**Fig. 2. The TOD System Organization Model for the entire central urban area of Hanoi[9]**

Fig.3. The TOD Point Organization Model[9]

the exploitation of land value towards "using the city to feed the city" will be a necessary solution for large and crowded cities like Hanoi.

3.2.4. Orientations for TOD Development in Central Hanoi

a. TOD in Restricted Development Areas and Historic Inner City

These areas are already developed with high population density, representing the central part of the city (Fig 1).

- Develop TOD with a focus on commercial and service functions to serve the dense population, improve transportation infrastructure, and develop commercial and tourism services. Avoid developing TOD areas primarily for residential purposes.

- Limit high-rise development to preserve the characteristic landscape, prioritize the development and utilization of underground space.

- Develop TOD with office functions in a limited capacity to reduce commuting pressure and focus on commercial TOD.

- Organize small TOD points based on redevelopment criteria, aiming to improve landscape conditions, spaces, the environment, enhance pedestrian access, and connect the transportation network.

- Develop TOD in areas with available land funds, such as some redeveloped residential areas, industrial areas, and hospitals.

b. TOD in Expanded Inner City

- These areas have already been developed to a relatively high density, but there is uneven development among different regions. The public transportation network and rail stations are well-established [4].

- The planned urban rail lines (MRT lines 1, 2, 3, 4, 5, 6, 8) will facilitate the development of TOD in these areas. Some central and beltway-oriented lines will form chains of TOD points.

- Develop large-scale urban TOD areas with varying density and height depending on the location and characteristics. Maximize the utilization of public transportation capacity. The characteristics of TOD will be based on the area's functions, population distribution, and the capacity to meet social needs.

- Organize modern TOD spaces that are associated with sustainable development, address transit transfer methods, and promote compressed development.

c. TOD in New Development Areas Eastern Beltway 4 and Northern Bank of the Red River

- These are newly developing areas with relatively low population and building density. Developing TOD in these areas will stimulate the creation of centers and urban development areas.

- These areas have the potential for large-scale TOD development with a goal of modern and synchronized development, reducing population pressure on the inner city [4].

- Develop TOD systems at different levels, including urban-level, area-level, and unit-level TOD. They have the potential to form large TOD centers with strategic significance and drive new developments. These areas have the potential for residential development, accompanied by synchronized technical and social infrastructure due to the availability of large land funds.

- Strongly develop TOD at the unit-level, associated with the development of new urban areas.

- Develop based on the MRT network: lines 1, 2, 3, 4, 5, 6, 7, 8, and connections to national railway lines, LRT lines, and BRT lines.

3.2.6. TOD Spatial Organization.

a. General Principles (fig.3)

TOD is developed following the 8D principles, which can be specified through the following elements: (1) Transport capacity; (2) Intermodal transportation conversion; (3) Mixed-use function; (4) Economic development; (5) Land reserves, development potential; (6) Compact development; (7) High population density, labor; (8) Pedestrian and bicycle accessibility. TOD points are developed around a "transit hub" such as urban railway stations for MRT, LRT, etc. To ensure an appropriate walking distance within 10 minutes, the TOD radius is 800 - 1000 meters. TOD consists of two zones: a core zone with a radius of 400 meters and an outer zone with a radius of 800 meters. The core TOD zone concentrates on commercial, office, and partially residential functions. [6], [7], [8]

*Commercial Core: Each TOD must have a mixed-use commercial area adjacent to the transit hub. This core area includes convenience stores, professional offices, restaurants, commercial and entertainment services.

*Surrounding Area: Within a radius of 400-800 meters, walking distances are ensured. This area serves mixed functions: commercial, office, residential, and public services such as social housing, green spaces.

*TOD Support Area: The surrounding area with a radius of 1500 meters is influenced by TOD and is automatically oriented. It includes residential functions (with lower density), green spaces, and other services such as schools. The support area is connected to the transit hub via a convenient transportation network, suitable for bicycles or bus services.

b. Some specific models for TOD spatial organization

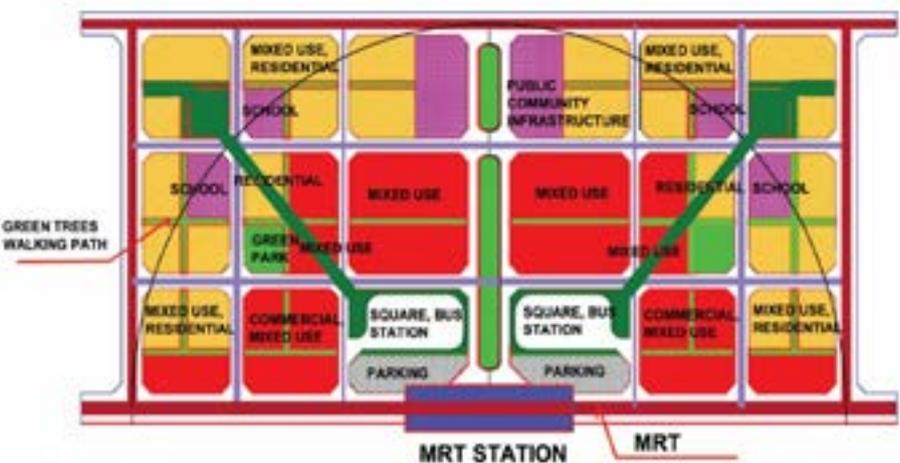*TOD spatial organization for new development areas (fig.4)

Fig. 4. TOD Point Spatial Organization following the Grid Road Network with Green Spaces and Central Pedestrian Walkways[9]

Fig.5. Addressing the Development of Connectivity Space between Old and New Areas through the TOD Model[9]

For inner-city expansion and new development areas with available construction land, planning can adhere to theoretical models. In this model, the transportation network is organized in a grid pattern with smaller road distances to enhance land accessibility. The TOD transit station is located at the center, adjacent to the station square, bus terminal, taxi stand, transfer point, green spaces, and public spaces. Highlighted space axes are created. From the core zone around the transit station, there will be functions like commercial, office, mixed-use, residential, social housing, with decreasing land utilization ratios and density. In the case of underground transit stations, underground space is maximally utilized for parking and commercial purposes, while the surface is dedicated to green spaces, squares, and bus transfer terminals. Pedestrian walkways and central pedestrian routes are organized to reduce travel distances and times.

*TOD spatial organization for renovation, integration, and transition between existing and new areas (fig.5)

For renovation and reconstruction areas based on the current reality of Hanoi, the TOD model is organized to integrate new and existing areas. Existing residential areas and villages will retain their characteristic structures, undergo expansion and improved transportation connections to the transit hub, including enhancements to pedestrian and bicycle traffic. Unused land areas will be used to build public facilities, social housing, and green spaces. Unused land areas will be prioritized for mixed-use functions, commercial services, public spaces, open spaces, and public transit transfer points around the transit hub, while also organizing transportation and pedestrian pathways connecting to existing areas.

*TOD spatial organization for underground areas

For historical, restricted development areas in the inner city where main urban railway lines will primarily run underground, due to the lack of surface land and to avoid affecting the urban landscape, the TOD development approach for these areas focuses on exploiting underground spaces. In this approach, the underground station will be arranged to include commercial floors, parking spaces, and underground intermodal transport centers around the station, combined with underground levels of high-rise buildings. The entire underground space will be interconnected through pedestrian tunnels, while also linking the open green spaces on the surface.

4. Conclusion

In the context of Industry 4.0 and the current digital transformation trends, building smart cities has become an essential requirement for urban areas. It also presents an opportunity for outstanding development, allowing cities to catch up with developed countries in the region in terms of economic, social, and environmental aspects.

For major and mega cities like Hanoi, adopting the TOD model is a comprehensive approach towards constructing a smart city. Developing TOD brings numerous benefits in terms of economic and social efficiency, resource conservation, land utilization, and protection of the natural environment. It is a necessary solution for densely populated urban areas.

Research and development of TOD will be integrated into urban development programs, wherein priority projects will be identified, and a roadmap for developing public transportation systems and TOD will be established based on short-term, medium-term, and long-term plans. This will create mutual supportive linkages within the system, enhancing operational efficiency.

Building a smart city while implementing the Public transport - TOD development model will contribute to the development of our Hanoi city, making it green, civilized, intelligent, and modern, in line with the set objectives./.

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